A Proposal to the
State Energy Conservation Office
on behalf of the
Texas Sustainable Energy Council

POTENTIAL ENERGY AND COST SAVINGS IN THE TRANSPORTATION SECTOR OF THE STATE OF TEXAS

TEXAS MULTIMODAL TRANSPORTATION EFFICIENCY STUDY

Submitted by:

Center for Transportation Research
University of Texas at Austin
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Austin, Texas 78705-2650
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and

Tellus Institute
11 Arlington Street
Boston, Massachusetts 02116
(617) 266-5400

EXECUTIVE VICE PRESIDENT AND PROVOST
THE UNIVERSITY OF TEXAS AT AUSTIN

Main Building 201 • Austin, Texas 78712-1111 • (512) 471-4363 • FAX (512) 471-0577

April 28, 1994

Ms. Grace Rios
State Energy Conservation Office
221 East 11th St., Room 200
Austin, TX 78711

Dear Ms. Rios:

We are pleased to transmit a proposal prepared by Mark Euritt of our Center for Transportation Research. This proposal has the approval of cognizant officials of The University.

Further information relating to the technical portions of this proposal may be obtained from Mr. Mark Euritt, Center for Transportation Research, The University of Texas at Austin. Contractual matters should be referred to the Office of Sponsored Projects, The University of Texas at Austin, Post Office Box 7726, Austin, TX 78713-7726 (Phone: 512/471-6424).

Sincerely,

Stephen A. Monti
Vice Provost

SAM:mo

Enclosures

xc: Mr. Mark Euritt

COLLEGE OF ENGINEERING
THE UNIVERSITY OF TEXAS AT AUSTIN

Center for Transportation Research · Suite 200
3208 Red River · Austin, Texas 78705-2650 · (512) 472-8875 · FAX (512) 480-0235

April 28, 1994

Ms. Grace Rios
State Energy Conservation Office
P.O. Box 13047
Austin, Texas 78711-3047

Dear Ms. Rios:

The Center for Transportation Research (CTR) in concert with the Tellus Institute is pleased to submit this proposal as requested by the State Energy Conservation Office (SECO) on behalf of the Sustainable Energy Development Council. The proposal lays out a description of the two institutions, professional personnel, work plan, and supporting budget "to develop a realistic and reliable estimate of the technical and economic potential for energy and energy cost savings in the Texas transportation sector from a multimodal perspective."

The enclosed proposal brings together two outstanding institutions with impeccable credentials. The Tellus Institute's work on energy issues is internationally recognized and respected. CTR is one of the nation's leading university transportation research centers. Tellus Institute's strong energy background and modeling capabilities and CTR's knowledge base of state and national transportation issues and operations provide a basis for addressing the objectives of the SECO request for proposal (RFP) in a timely and cost effective manner. Both institutions are actively engaged in research activities that directly relate to the objectives of this study.

Mr. Mark Euritt, Associate Director for Alternative Transportation Fuels, and Dr. Angela Weissmann will co-direct the research activities for the Center for Transportation Research and serve as Principal Investigators. Dr. Stephen Bernow, Manager of Tellus' Energy and Environment Program, will serve as Project Manager and Principal Investigator for Tellus. All three individuals have extensive research and policy development experience. They are assisted by a cadre of professionals with a rich diversity of experiences. Details for all individuals working on the project are contained in the proposal.

We trust that you will find our proposal in compliance with the guidelines set forth in the RFP. If you need additional information or clarification regarding any aspect of this proposal, we can be reached at 512-472-8875 or by fax 512-480-0235.

Sincerely,

Frank McCullough

Dr. B. Frank McCullough
Director

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INTRODUCTION

The Texas State Energy Conservation Office (SECO) on behalf of the Sustainable Energy Development Council has issued a Request For Proposals in order "**to develop a realistic and reliable estimate of the technical and economic potential for energy and energy cost savings in the Texas transportation sector from a multimodal perspective.**" The study aims to meet the following primary objectives:

1) To conduct and assessment of near-term options for increasing energy efficiency in the transportation sector, including technology improvements, mode-shifting and incentive programs.

2) To develop and apply a computer model to examine transportation in Texas from a multimodal perspective, incorporating all costs components, including infrastructure, operations and social costs.

3) To prepare a realistic and reliable estimate of the technical and economic potential for energy savings and energy cost savings in the Texas transportation sector.

4) To prepare a final report of recommendations for increasing energy efficiency in the Texas transportation sector.

The Center for Transportation Research and Tellus Institute are pleased to respond to the Texas State Energy Conservation Office's RFP with this proposal.

Because of previous work, such as the Tellus Institute's multimodal analysis of transportation energy efficiency, mode-shifting, fuel choice and social costs embodied in *America's Energy Choices* (see **Attachment** E), and CTR's multimodal analysis for the Texas Department of Transportation and evaluation of transportation energy impacts for the Southwest Region University Transportation Center, we believe that we are uniquely qualified to carry out this project.

WHY THE CTR/TELLUS TEAM?

CENTER FOR TRANSPORTATION RESEARCH

- Over the last 31 years, the CTR has been one the leading university transportation research centers in the State of Texas and the U.S. It has completed more than 500 technical and professional reports and published more than 2,000 research papers on all aspects of transportation. CTR is one of the Texas Department of Transportation's two major sponsored research programs, having conducted more than 400 studies on the Texas transportation system.

- The CTR staff for this project have directed and participated in several transportation energy and multimodal transportation projects. In addition, they have presented papers to professional societies and transportation conferences throughout the world.

- The CTR co-director for this project served on the State of Texas Energy Policy Partnership, Committee for Alternative Transportation Fuels. He was a major author of the full-committee report. In addition, he developed a policy paper for the committee on the social costs of motor vehicle transportation.

- The CTR co-director for this project was a contributing author for the University of Texas at Austin Committee to Assess the National Energy Strategy. In particular, he was responsible for coordinating the evaluation of transportation energy efficiency impacts for the state of Texas. This Committee was developed at the request of Governor Richards.

- CTR is completing a major study for the Texas Department of Transportation evaluating the impact of multimodal transportation strategies on the Texas transportation system. As a part of this study, CTR developed a comprehensive social cost framework for evaluating investment alternatives from a multimodal transportation perspective.

- CTR recently completed a major study examining Texas and Mexico multimodal transportation. The data base developed during this study was used to evaluate multimodal transportation impacts as a result of adoption of the North American Free Trade Agreement (NAFTA). Three members of the CTR team were involved with this study.

- CTR is currently studying the energy and environmental tradeoffs for truck freight and rail freight transportation on the Interstate 35 corridor. This multimodal evaluation examines both the infrastructure costs, user costs, and costs of externalities. The social cost methodology used in this analysis is directly related to the objectives of this RFP.

- Two members of the CTR project team were involved as consultants for evaluating the multimodal transportation system costs of the Pennsylvania Interstate 80 corridor. This multimodal evaluation included an analysis of externalities, user costs, and facility costs. Subsequent to this work, the state of Pennsylvania began transferring state highway funds for intermodal rail improvements as part of its state transportation system.

- The CTR Economic Advisor has worked extensively abroad for the World Bank and was involved in the internationally acclaimed Brazilian vehicle operating cost study. This study led to the development of the World Bank's Highway Design and Maintenance Model (HDM) which is the world's leading model guiding transportation investment in developing countries. The CTR participant was a major co-author of the vehicle operating cost sub-model. This sub-model evaluates pavement surface conditions on vehicle fuel economy and other vehicle maintenance factors.

- Project team members for CTR have recently completed a sectoral model for evaluating trade flows and transportation impacts between Texas and Mexico. This model is being utilized by the Texas Department of Transportation to guide transportation infrastructure development and maintenance along Texas' largest trade corridor.

- CTR is currently conducting a study identifying the social costs of urban transportation in Texas. This study is developing a framework for analyzing multimodal transportation alternatives in Texas metropolitan areas. The study is completing its first year and the material and information gained in this Texas Department of Transportation study is available for use by project team members.

- CTR has developed a model for analyzing motor vehicle tax revenues based on vehicle travel patterns and fuel consumption. This model is part of the Texas Highway Cost Allocation model.

- CTR recently completed a report evaluating the energy and environmental tradeoffs of congestion mitigation strategies. This report contains a basic framework for evaluating impact of transportation alternatives on mobility, energy conservation, and tailpipe emissions. This paper was presented at the 1994 Transportation Research Board annual meeting and accepted for publication in the *Transportation Research Record.*

- CTR has been actively engaged in the evaluation of alternative transportation fuels technology for the state of Texas. CTR has developed a model for evaluating the economics of fleet conversion on a life-cycle basis. The model has been used to evaluate more than 400 different fleet scenarios. CTR has also been at the forefront in modeling all possible aspects of Texas transportation systems, from rail to airport to highways, and as such it possesses the relevant background and first hand knowledge of Texas transportation status and needs.

TELLUS INSTITUTE

- Tellus has worked on more than 1500 studies on energy, technology, environment and related economic and policy issues for government and the private sector for seventeen years. Tellus has worked throughout the world, for organizations including the US DOE and EPA, EPRI, World Bank, United Nations, OECD, and numerous regional, national and state regulatory, environmental and planning agencies. (see Attachment B for list of Tellus clients)

- The Tellus staff for this project have undertaken studies and presented papers on vehicle efficiency fuels and emissions invited and accepted for publication at transportation conferences by the U.S. Department of Transportation, U.S. DOE, U.S. EPA, and the European Council for an Energy Efficient Economy. It is now developing national energy/environment scenarios for vehicle technologies and fuels, as part of a project with World Resources Institute.

- The Tellus project manager for this project was invited by the DOE to participate in the transportation working group for the Administration's Climate Change Action Plan, by the New York State Energy Office to its transportation focus group for the State Energy Plan, and is a reviewer for the U.S. DOE's electric vehicle fuel cycle emissions program.

- Tellus has expertise in the detailed technical, economic, financial, regulatory, policy, and environmental aspects of the electric and gas sectors at the utility, power pool, state and national levels throughout the U.S., and in Texas in particular. It has recently completed a draft report for the U.S. EPA, evaluating potential resource plans for a large Texas utility, taking account of efficiency and renewable resources in the context of SO_2 compliance and potential national CO_2 policy.

- Tellus has been in the forefront in the U.S. and abroad in work related to incorporation of environmental impacts, social costs and externalities in technology assessment, resource planning and system operation in energy, solid waste and industrial production. Among the organizations that have recognized these efforts are the U.S. EPA and DOE, the World Bank, the Organization for Economic Cooperation and Development (OECD), the Office of Technology Assessment of the U.S. Congress, and many others.

- Tellus has developed and applied many computer models and data bases that are used in the U.S. and abroad -- on energy and environment, greenhouse gases, solid waste, water, DSM -- that use up-to-date software and approaches chosen and designed to meet user needs. Among the sponsors of this work are World Bank, United Nations, Organization of Economic Cooperation and Development, and NYSERDA (for the ESEERCO externalities model.)

- Tellus has extensively studied the potential for energy from renewable resources including wind energy, wood energy, small-scale hydropower, solid waste and other sources. Sponsors of this work currently include the U.S. DOE and U.S. EPA, and in the past have included the General Accounting Office of the U.S Congress, Massachusetts Division of Energy Resources, Brookhaven National Laboratory, Stanford Research Institute, the Coalition of Northeastern Governors, New York State Research and Development Authority, the Union of Concerned Scientists, the Swedish International Development Agency, and the United Nations Food and Agricultural Organization.

- Tellus is currently working on several projects, including studies for the U.S. DOE and EPA, to review methodologies for including the full range of non-price factors -- environmental, economic development, uncertainty and risk, and social costs generally -- into the evaluation of energy efficiency and integrated resource plans in the electric and gas sector.

- Tellus has also been in the forefront in assessing how to integrate environmental consideration into energy planning processes. Tellus has reviewed environmental laws and regulations governing electricity generation on federal, state and local levels, has actively contributed to state regulatory efforts to address environmental externalities, and is regarded as one of the leading organizations to explore externalities and recommend practical alternatives to recognize and incorporate environmental and economic externalities (such as job impacts) in energy decisions. Tellus has also performed several job impact studies for energy scenarios using input/output and other types of economic models.

- Tellus Institute has developed and applied a wide range of analytical tools in designing and evaluating DSM programs in the context of least-cost energy planning. Members of the staff have helped to pioneer nationally accepted methodologies for end-use forecasting and avoided cost calculations, which are essential to DSM planning, and state-of-the-art methods for quantifying the environmental costs and benefits of electric and gas supply alternatives.

- Tellus has been at the forefront in developing Integrated Resource Planning (IRP) rules and in performing IRP analyses and reviews continually from the late 1970s to the present. IRP is the current term for comprehensive electric resource planning, including the impacts of "cradle-to-grave" social costs. Recently, Tellus developed for NARUC a white paper on electric IRP and rate design, and advised on a gas IRP Guidebook. Since 1991 Tellus has been proposing and reviewing Clean Air Act compliance methodologies plans.

SECTION 1
PROPOSER'S ABILITY TO ASSIGN QUALIFIED PERSONNEL TO THE PROJECT

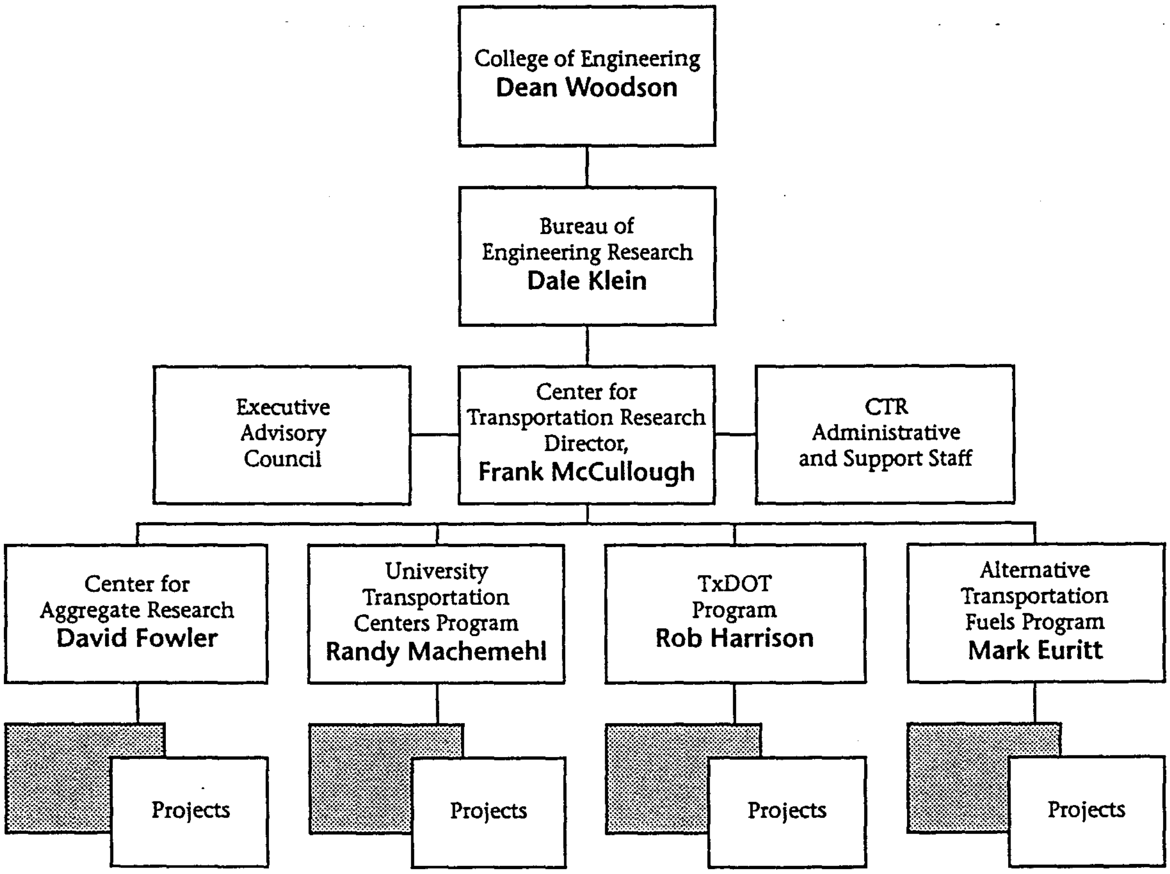
A. BUSINESS ORGANIZATION

Center for Transportation Research
3208 Red River, Suite 200
Austin, TX 78705-2650
512-472-8875

Established in 1963, the Center for Transportation Research is a multidisciplinary transportation research and educational unit of the Bureau of Engineering Research of the College of Engineering, The University of Texas at Austin (see Figure 1-1). With its focus on local, state, and national transportation issues, the Center coordinates and administers a comprehensive research program aimed at both improving transportation and, at the same time, developing professional careers in the field. The central goal of this 30-year-old research institution is to expand fundamental knowledge on a broad spectrum of transportation problems and issues: urban policy studies, energy and environmental impacts, transportation management systems, traffic operations, fuel savings, pavement and soil research, and transportation tends into the next century — all such issues represent a typical cross-section of ongoing Center research. And preeminent among the newer concepts is the idea of multimodal transportation, the interest in which anticipated the multimodal approach now embraced by the Texas Department of Transportation, one of the Center's major sponsors.

Assisting the Center in these research efforts are two noteworthy supporting programs—the Southwest Region University Transportation Center (SWUTC) and the Advanced Institute for Transportation Infrastructure Engineering and Management. The SWUTC is one of ten competitively selected centers established in 1987 by the U.S. Department of Transportation's University Transportation Centers Program. This program is a major national initiative designed to foster university-based, long-term applied research that encompasses all transportation modes. The Advanced Institute for Transportation Infrastructure Engineering and Management, established in 1990 through U.S. Department of Transportation funding, recognizes that the planning, design, and management of the transportation infrastructure represent considerable challenges that cut across traditional civil engineering disciplines. Moreover, professionals involved in the engineering and management of infrastructure systems must consider the complex interactions among the engineering, financial, economic, environmental, energy, and social aspects of the problem. The Institute's educational program is multimodal in scope and cross-disciplinary in perspective.

Figure 1-1
CTR Organization Chart



The Center is perhaps unique in its pursuit of transportation solutions. Unlike other such transportation research centers in the state, the Center promotes an interdependent relationship with its professional research staff, its faculty, its students, its sponsors, and its governing institution. That governing institution — The University of Texas at Austin — is, of course, an internationally recognized research institution and the largest educational facility in the Southwest. The high caliber of the research undertaken campus-wide is reflected in the Center.

Yet much of the success of the Center has been the result of the high level of student involvement that, again, makes the Center distinctive among transportation centers. While the Center's projects are supervised by full-time University faculty members or research scientists, much of the actual hands-on research is undertaken by dedicated graduate students seeking either masters or doctoral degrees. With 99 graduate students appointed to half-time research assistants for the current year, and with 72 students supported by scholarships and tuition assistance, the Center fulfills its objective of linking meaningful research to University academic programs. (Approximately 27 masters students and 19 doctoral students graduate each year.) One result of this unique research program — one which benefits the state directly — is that many students find employment within Texas agencies and research centers upon graduation. Over the years, their efforts have helped to make the Texas transportation system one of the nation's finest.

The Center for Transportation Research uses on- and off-campus facilities of The University which includes over 35,000 square feet of space and a variety of modern laboratory testing equipment and instruments. The administrative offices of the Center are located at 3208 Red River and in the ECJ Building. Research studies which require large testing equipment or land areas are conducted off the main campus at Balcones Research Center, which has the Phil M. Ferguson Structural Research Laboratory, The Asphalt Research Laboratory, and a full-scale pavement testing laboratory among its facilities.

The Center utilizes the mainframe computer facilities of The University which represents one of the most powerful systems (including a CRAY super-computer) available to U.S. universities. The Center maintains its own terminals for direct access to these campus facilities, as well as off-campus facilities available through networking agreements. Advances in microcomputer technology, network applications, and graphics have created a need for access to microcomputers. To address this need, the Center, together with the Civil Engineering Department, established a Microcomputer Resource Laboratory for faculty, staff, and student use. These microcomputers provide a variety of operating systems and hardware/software capabilities to include word processing, graphics, spreadsheets, communications, and numerous programming languages. The microcomputer lab represents a powerful, state-of-the-art, programming development tool for the research and teaching needs of the Center. Overall, the wide range of mainframe and microcomputer facilities provide all the necessary computer capabilities to carry out the theoretical and empirical investigations conducted through the Center.

Tellus Institute
11 Arlington Street
Boston, MA 02116
617-266-5400

Tellus Institute is a team of scientists, planners and policy analysts organized into a not-for-profit (501C-3) research and consulting organization. The Institute, with over 17 years of experience, applies the best available scientific methods, technical data, and policy analysis to address resource management and environmental issues. The Tellus mission is to design rational and equitable resource and environmental strategies for the public good. They conduct policy research on specific problems and issues with a keen awareness of the larger issues of our time—the linked problems of economic development, social equity, and environmental sustainability.

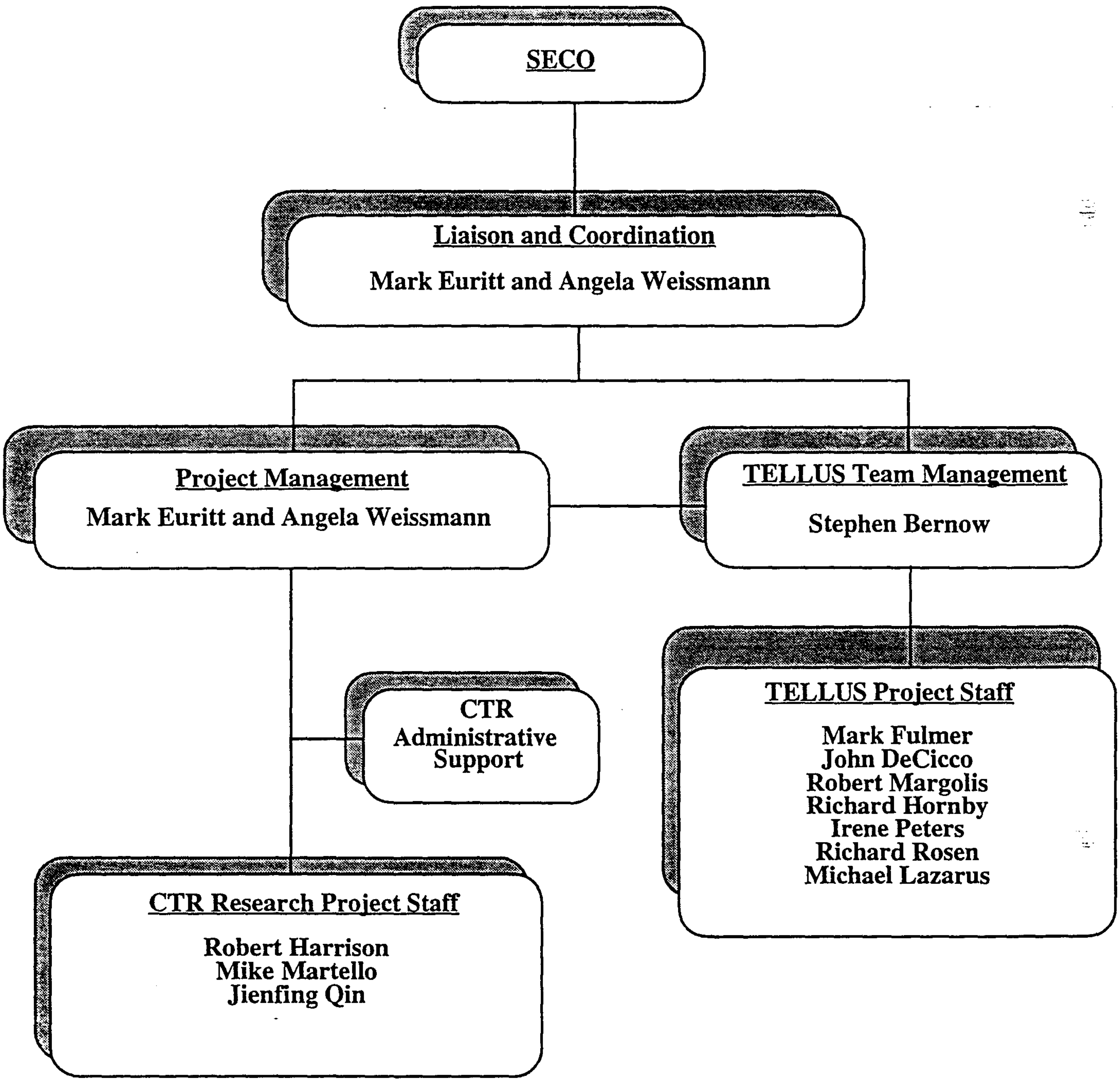
Tellus Institute was founded in 1976. Tellus work includes over 1,500 research reports, policy papers, and monographs. Senior staff have testified widely before regulatory and policy-making bodies. Tellus projects are sponsored by foundations, state and federal agencies, international bodies, public interest groups, and private organizations. The research program is divided into four groups (see Figure 1-2):

1) Energy
2) Solid Waste
3) Risk Analysis
4) Stockholm Environment Institute—Boston Center

The Energy Group provides expertise on the technical, economic, environmental, regulatory, and policy aspects of energy. The group is comprised of five programs—Energy and Environment, Electricity, Natural Gas, Demand-Side Management, and Finance and Regulation. The Solid Waste Group performs research, planning studies, and computer modeling on issues of waste management, materials use, and related economic and environmental impacts. These activities promote the efficient management of natural resources through appropriate solid waste programs and materials policies. The Risk Analysis Group evaluates the environmental, public health, and financial risks of projects and provides policy, regulatory and technical analysis. The group develops analytical methods, conducts policy studies and technical training, and provides expert testimony in a variety of areas including pollution prevention, environmental accounting, life-cycle assessment, corporate environmental practices. Tellus conducts an extensive international program as host to the Stockholm Environment Institute—Boston Center (SEI-B). SEI-B performs research, policy evaluations, and field applications concerned with environmentally sound development.

Figure 1-2

Texas Multimodal Transportation Efficiency Study
Organization Chart



The Tellus staff of approximately 50 professionals are drawn from a variety of scientific, social science, and engineering backgrounds. Tellus Institute's offices, library and research facilities are located in Boston, Massachusetts. Tellus maintains close contact with other research institutions in the Boston area and elsewhere and collaborates with specialist consultants as needed.

B. PROJECT MANAGEMENT STRUCTURE

Overview

The successful conduct of any study requires effective organization and management. This project amplifies these needs because of three unique aspects:

1) Significant time constraints—the study must be substantially completed by December 1994 in order to provide SECO with necessary information for input into the legislative process.

2) Breadth of coverage—the study encompasses a wide and complex range of energy and transportation issues.

3) Interdisciplinary approach—as a result of the RFP's objectives and our own approach the study will involve the disciplines of energy policy analysis, transportation engineering, statistical and computer modeling, economics, and environmental analysis.

Our strategy for meeting these needs relies primarily on choosing experienced staff, highly qualified across the necessary disciplines and content areas, and on organizing the study under the leadership of experienced principal investigators. Additionally, we have given careful attention to deploying staff to tasks and activities appropriate to their expertise. This part of the proposal elaborates on the details of project management.

Center for Transportation Research

As a major University research center, CTR is in a unique position to network with other organizations that can provide expertise directly applicable to the problem at hand. In order to do this, CTR has subcontracted with the Tellus Institute, a team of scientists, planners and policy analysts organized into a non-profit research and consulting organization. Tellus specializes in resource management and environmental issues, as well as design of rational and equitable resource and environmental strategies for the public well-being. Tellus Institute already has some models for integrated planning of energy resources that place equal emphasis on energy demand, energy supply, and environmental effects.

This unique combination of technical expertise is organized as indicated in figure 1-2. The organization warrants maximum efficiency of the team members, since an Austin-based research center will manage the project and serve as liaison with SECO, thus minimizing travel budget. In addition, project managers will not restrict their role to project supervision; rather, they will actively participate in the development and completion of the research work.

The project coordination and technical management will be shared between Mr. Mark Euritt, policy analyst, and Dr. Angela Jannini Weissmann, engineer. CTR believes that a shared technical coordination approach between an engineer and a policy analyst will provide the appropriate combination of skills necessary to ensure timely completion of this project.

Dr. Weissmann is immediately available to work on this project according to the budgeted time. Dr. Weissmann has 17 years of international experience in the transportation engineering area, nine in Brazil and eight in Texas. She has a very thorough knowledge of statistical methods and model development methods, as well as a strong computer background. In addition to the technical skills in the transportation engineering area, Dr. Weissmann has been working with Texas transportation projects for the past eight years, and is familiar with all state, federal and local level transportation programs and organizations in Texas. She is currently finalizing a project that provides the Texas Department of Transportation and the Texas Turnpike Authority with guidelines for transportation planning at the Texas-Mexico border area, and has traveled extensively throughout the state, having firsthand knowledge of Texas' peculiarities and transportation needs. Dr. Weissmann's managerial and technical skills will be supplemented by Mr. Euritt's strong policy and economics background and international expertise as a transportation policy analyst. He is available according to the budgeted time. Mr. Euritt has directed more than 20 studies in the last 7 years and authored or co-authored more than 50 reports and technical papers. He is completing a major multimodal transportation analysis study for the Texas Department of Transportation. Within this study, a major transportation data base was compiled on modal operations, as well as a framework for analyzing the system, or social, costs of multimodal transportation alternatives. His current involvement in two studies—"Development of an Urban Transportation Investment Model" and "I-35 Multimodal Corridor Analysis"—provide the CTR team with a head start on the objectives of this study.

Dr. Angela J. Weissmann and Mr. Euritt will work closely with CTR and Tellus staffs, and will coordinate and oversee the efficient use of resources, the management of schedules and budgets, and interaction with SECO. The Center for Transportation has a qualified administrative staff that work closely with research supervisors. The Center staff are on-line with the University Accounting Office permitting on-line access for reviewing the financial status of research projects. The Project Managers for this study, Mr. Mark Euritt and Dr. Angela Weissmann, have demonstrated experience in completing projects within the scheduled time and budget. They will track the project on a weekly basis to ensure the project is proceeding according to the planned budget and time schedule. Weekly project meetings will be held with all participating staff to ensure project integrity is maintained.

In addition, Mr. Euritt and Dr. Weissmann will provide technical guidance and supervision to the project staff in their respective areas of expertise. Dr. Weissmann and Mr. Euritt will assign a substantial amount of their time to actively supervise and directly work on all project tasks. The engineering and modeling tasks will be undertaken by Mr. Martello and Mr. Qin, civil engineers with strong transportation and computer backgrounds, and supervised by Dr. Weissmann, an engineer with 17 years of experience and a strong theoretical background in computer and statistical models. The CTR team will work closely with Tellus, and will analyze and adapt their energy analysis model to the Texas case. CTR will also count on the expertise of Mr. Rob Harrison, a transportation economist with 25 years of international experience. Mr. Harrison was co-author of the World Bank's Vehicle Operating Cost Model for evaluating transportation improvements. His expertise in this area strengthens the analytical capability of the project research team. Mr. Harrison is currently CTR's Associate Director for TxDOT Research. His expertise with Texas Department of Transportation policies and operations will lend valuable guidance to the project. All CTR staff responsibilities are shown in Table 1-1.

Table 1-1
CTR Project Staff Roles

Staff	Role in Project
Mark Euritt	Co-Project Manager, and Co-Principal Investigator
Angela Weissmann	Co-Project Manager, and Co-Principal Investigator
Robert Harrison	Transport Economist, vehicle operating costs, fuel efficiency
Mike Martello	Transportation Analyst, multimodal transportation engineering
Jiefeng Qin	Computer Analyst, transportation modeling

Tellus Institute

For this project, we propose Dr. Stephen Bernow of Tellus as Project Manager and Principal Investigator for the Tellus contributions to the joint efforts of the project team. He will work over the lifetime of the project, with responsibilities for overall direction, analysis, management, planning, scheduling and budgeting. Dr. Bernow will hold a project start-up meeting with all Tellus staff to discuss the workplan and tasks in detail, make work assignments, outline schedules, appropriate budgets for tasks, and answer any questions. He will also hold on-going meetings during the project, to ensure that the tasks and analyses are completed on time and within budget. He will be responsible for on-going client liaison and monthly progress reports to the project staff and the Council. Dr. Richard Rosen will perform a thorough technical review of the Tellus contribution to the report, and will also edit it.

Other staff on the Tellus team include Mark Fulmer (engineering; vehicle efficiency and fuels), Dr. John DeCicco (engineering; vehicle efficiency and policies); Richard Hornby (engineering; fuels), Robert Margolis (engineering; modeling), Dr. Irene Peters (economics; social costing), and Michael Lazarus (engineering; energy demand). All staff responsibilities are highlighted in Table 1-2.

All staff time at Tellus is tracked (budgeted and accounted for) via Tellus' computerized accounting and time sheet systems. Information on person-days per project task is incorporated into accounting, planning, and invoicing systems. Dr. Bernow will track the project and the task budgets via weekly accounting and project planning reports which are generated from this information. He will use the reports to continually guide and plan the project, to ensure that it is completed on time, within budget, and in the most professional and cost-effective manner possible.

Table 1-2
Tellus Project Staff Roles

Staff	Role in Project
Stephen Bernow	Project Manager and Principal Investigator
Mark Fulmer	Research and Analysis; Vehicle Fuels and Efficiency
John DeCicco	Research and Analysis; Vehicle Efficiency and Policies
Robert Margolis	Modeling; Transportation Intermodal Energy and Environment
Richard Hornby	Research and Analysis; Fuel Availability and Cost
Irene Peters	Research and Analysis; Economic Behavior
Michael Lazarus	Research and Analysis; Demand Analysis
Richard Rosen	Technical Reviewer and Editor

If required, other staff experienced in energy and environment research and modeling can be assigned to the project with little advanced notice required. Sub-contractors for Tellus include a woman-owned word processing business (HUBS).

C. AUTHORIZED NEGOTIATOR

The authorized CTR negotiator for all contractual terms of this proposal is:

Mr. Wayne Kuenstler, Director
Office of Sponsored Projects
Main 303
The University of Texas at Austin
Austin, TX 78712
512-471-6424

For technical work within the proposal, Mr. Mark Euritt is the contact person. He can be reached at the following address:

Mr. Mark A. Euritt
Center for Transportation Research
3208 Red River, Suite 200
Austin, TX 78705-2650
512-472-8875

Tellus is a subcontractor with the University of Texas at Austin for this project. Their authorized negotiator for this subcontract is:

Dr. Stephen Bernow
Manager, Energy and Environment Program
Tellus Institute
11 Arlington Street
Boston, MA 02116
617-266-5400

SECTION 2
RELEVANT BACKGROUND OF ASSIGNED PERSONNEL AND FAMILIARITY WITH SIMILAR WORK

A. PRIOR EXPERIENCE

The Center for Transportation Research (CTR) and the Tellus Institute have organized a highly professional cadre of researchers to address the objectives of the RFP. CTR is nationally known for its transportation research on national, state, and local issues. Tellus brings over 17 years of experience in energy and environmental planning, management, and regulation. Together, the assigned research staff have ample experience in multimodal transportation and energy efficiency to address the needs of this project in a timely manner.

1. Center for Transportation Research

The Center for Transportation Research is the University of Texas at Austin department where all transportation-related research takes place. The University of Texas at Austin's graduate program in Civil Engineering is the fourth best in the U.S., due primarily to the highly qualified faculty and research body, which in turn attract top-notch students.

CTR's expertise includes all transportation engineering areas, and involves a considerable amount of research for state agencies such as the Texas Department of Transportation and the Texas Turnpike Authority. CTR has recently opened an Alternative Fuels Program, to respond to the increasing need for exploring and evaluating the impact of alternative fuels on the transportation sector. This program is headed by Mr. Euritt, co-principal investigator in this project.

Transportation Cost and Investment Analysis

CTR has a multitude of studies in this area, most of them developed for Texas conditions. Currently, Mr. Euritt serves as the Co-Principal Investigator in the **"Development of an Urban Transportation Investment Model,"** for Texas Department of Transportation, (Karen Dunlap, TxDOT Coordinator, 512-483-3663), September 1993 - August 1995. Mr., Qin is the research assistant, and the overall goal of this study is to provide TxDOT, and other policy-makers, with an efficient method for investing public transportation dollars. Specifically, the project is addressing the following three objectives: 1) Identify the systems costs of public transportation; 2) Develop a working model for analyzing transportation investment from a systems cost perspective; and 3) Support the development of an ISTEA mandated Public Transit Management System. The tasks are geared around an analysis of previous multimodal comparison studies, development and refinement of a multimodal systems investment model, collection of relevant data to test the model, and demonstration of the model in selected areas.

Another important study is the "**Multimodal Investment Analysis: A Corridor Study of Energy Efficiency and Cost Effectiveness,**" for Southwest Region University Transportation Center, Texas Oil Overcharge Funds, (Dock Burke, SWUTC Director, 409-845-5815), 1993-1994. Mr. Euritt and Mr. Harrison are the Co-Principal Investigators for this research project. In addition, Mr. Qin serves as the primary research assistant. The Texas transportation system has evolved into a complex multimodal network. The new multimodal environment requires a more thorough examination of public transportation investment, particularly in light of the Intermodal Surface Transportation Efficiency Act and other federal enactment's. Currently, policy makers have insufficient information to develop energy efficient and cost effective procedures for investing public dollars. Traditionally, transportation investment has been along modal lines. This "modally oriented planning and investment," as noted by the Transportation Research Board in a 1992 NCHRP problem statement, "have been shown to be economically inefficient and generate fewer social benefits than might be achieved under a multimodal approach." Since transportation investment is now effected by the new Energy Policy Act and the Clean Air Act Amendments, new multimodal comparisons are needed. This project is examining a key inter-city surface corridor in Texas and comparing the system costs of moving freight by the different modes. The systems cost include infrastructure or facility costs, vehicle operating costs, congestion costs, and externalities (property and physical damage for accidents, user delay costs, and environmental costs.) The major goal of this project is to conduct a multimodal corridor analysis of freight transportation in Texas. Specifically, the project is addressing the following objectives:

1. Identify the energy consumption differences for freight transportation along an inter-city corridor by transportation mode.

2. Identify the systems cost of moving freight along an inter-city corridor by transportation mode.

3. Identify the most cost-effective transportation investment strategy for moving freight along an inter-city corridor.

Energy and Impacts in Transportation

Among the several studies CTR is undertaking, the "**Energy Impacts of Natural Gas Vehicle Operations for Transit,**" for Southwest Region University Transportation Center, Texas Oil Overcharge Funds, (Dock Burke, SWUTC Director, 409-845-5815), 1992-1994 is an important example of a case in which energy and air quality concerns have forced cities to reevaluate their strategies for addressing urban mobility issues. The diesel bus, for example, is no longer a viable mass-transit vehicle in non-attainment areas. The city of Austin is currently in attainment; however, continued growth may push the city into the moderate level of non-attainment. Mass transit will have to play a more important role in the city's transportation system. Early research suggests that natural gas may be a viable alternative fuel for transit fleet operations. This project evaluates and compared an optimized CNG-bus developed for the University of Texas with their current fleet of diesel buses. A number of comparative tests were conducted including fuel economy, engine performance, maintenance and service, and passenger satisfaction. It was found that the fuel cost per mile for operating the natural gas bus is the same as the diesel bus. The lower fuel cost of natural gas was offset by the poorer fuel economy. Mr. Euritt served as the Co-Principal Investigator of this study.

Another important study is "**Energy Impacts of Electric Vehicle Operations for Capital Metro,**" for Southwest Region University Transportation Center, Texas Oil Overcharge Funds, (Dock Burke, SWUTC Director, 409-845-5815), 1992-1994. Mr. Euritt is the Project Supervisor for this project which has as its principal objective is attempting to identify opportunities for the use of battery-powered electric transit vehicles in the Capital Metropolitan Transportation Authority service area. This objective will be accomplished by completing the tasks identified in the work plan. Existing electric vehicle technology was researched to determine their operating characteristics. These characteristics are then compared to the various Capital Metro services routes to find possible applications. Feasibility is dependent on vehicle range, vehicle capacity, and operating costs. Full fuel cycle analysis is used to measure the energy gains from electric vehicles as well as emissions benefits.

Mr. Mark Euritt also served as the Principal Investigator for a study entitled "**Energy Savings from an Urban CNG-Operated Taxi Company,**" for Texas Department of Transportation, (James Zach, TxDOT Coordinator, 512-465-7437), 1992 - 1993. A life-cycle economic evaluation model was developed to determine the cost-effectiveness and energy savings of urban taxis fueled by compressed natural gas. This project was part of the TxDOT Planning and Feasibility Program funded by Texas Oil Overcharge Funds. The model allows for economic analysis according to a variety of scenarios accounting for fuel price changes, changes in mile of travel, maintenance savings, etc. Analysis was also done on the availability of public refueling infrastructure versus fleet operated fueling stations.

"**Truck to Rail Freight Diversion in Pennsylvania,**" for Conrail, (Steve Sullivan, Project Director, 215-977-5659), April 1992 - August 1992, was a study conducted by Mr. Euritt and Mr. Harrison as a follow-up to the Pennsylvania I-80 study examining truck freight operations. This study found that existing infrastructure subsidies resulting from the failure to analyze highway operations on a system or social cost basis resulted in significant diversions from rail to highway. This resulted in significant increases in energy consumption and emissions.

"Evaluation of LP-Gas Regulations for Texas," for Texas LP-Gas Association, (John Danks, Executive Director, 512-836-8620), February - March 1992, was conducted by Mr. Euritt and Mr. Harrison. The study examined Railroad Commission regulatory policy on pressurized vessels for propane. The study found that Railroad Commission rules for propane pressure vessels and equipment resulted in unnecessary time delays and costs. Additionally, the study found that existing rules are not based on documented engineering principles. It was recommended that Texas adopt National Fire Protection Association rules which would provide a more competitive, cost-effective, and safe environment for Texans. This report led to major changes in rules for the Texas Railroad Commission.

"Impact of Alternative Fuels on State Highway Financing," for Southwest Region University Transportation Center, U.S.D.O.T. Funds, (Dock Burke, SWUTC Director, 409-845-5815), June 1991 - August 1992. Implementation of alternative transportation fuels policies at the state and national level can have a dramatic effect on state highway funding. Texas, for example, relies heavily on fuel taxes to fund its highway infrastructure needs. Many alternative fuels receive exemptions or reductions on fuel tax rates. Moreover, failure to account for the energy content of fuels results in distorted rates. This study examined several alternative fuel growth scenarios using existing tax policies to determine their impact on state highway transportation funds. Mark Euritt served as the Principal Investigator for this study.

"Transportation Energy Impacts of Clean Air Legislation," for Southwest Region University Transportation Center, Texas Oil Overcharge Funds, (Dock Burke, SWUTC Director, 409-845-5815), June 1990 - August 1991. The successful implementation of a transportation control measure (TCM) and, in particular appropriate combinations of measures may provide significant benefits to urban areas in the form of congestion reduction, improvements in air quality, and fuel savings. The effectiveness of TCMs in accomplishing these goals will most often be determined by the specific characteristics of the urban environment in which they are implemented. This study develops a macro-analysis model -- a unified framework that links the transportation planning and air quality analysis models. The framework can be used to evaluate the impact of a transportation control measure on mobility, transportation-related emissions, and energy consumption. The results from two sample transportation networks show that the effectiveness of a TCM depends on the characteristics of the networks. The evaluated TCMs are limited to those that affect travel time or travel costs. Mark Euritt served as the Project Supervisor and Mr. Qin served as the Principal Analyst for this study.

"**Transit Station Energy Savings,**" for Southwest Region University Transportation Center, Texas Oil Overcharge Funds, (Dock Burke, SWUTC Director, 409-845-5815), June 1990 - August 1991. Mr. Euritt served as the Co-Principal Investigator on this research study. Transit trip—when compared with automobile travel—not only relieve congestion, but also offer considerable energy savings per person. Transit trips also affect land use and development patterns that surround a transit station. This study addresses the energy effects of development in transit station areas; that is, development that occurs within a certain radius of a transit station (approximately a quarter-mile) is considered "transit-sensitive" development. This "transit-sensitive" development would, by design and density, encourage trip ends to and from land uses in the transit beltway. Since infrastructure serving high-density development is more efficient that infrastructure serving low-density, typically suburban, land uses, the potential exists to conserve energy that is used in everyday trips. In this study, a methodology is developed to estimate the energy savings associated with land use changes in the station areas. Since changes in land use and development in a station area are partially dependent on the type of service offered (rail versus bus rapid, for example) a classification system is developed for different types of transit stations, a system based on the land use and development changes that occur within the station's zone of influence.

Cost Allocation and Revenue Analysis

Mr. Mark Euritt is Co-Principal Investigator in the "**Cost Allocation Procedure Enhancement - Revenue Analysis,**" for Texas Department of Transportation, (Alvin Luedecke, Director of Planning, 512-465-7346) 1992-1994. This study is a continuation of the Texas Highway Cost Allocation Study. The models for estimating and forecasting vehicle tax revenues based on fuel economy and traffic growth were refined to incorporate more recent energy consumption data. This model is used to predict vehicular cost recovery shortfalls for the Texas Department of Transportation.

Mr. Harrison is co-principal investigator, Dr. Weissmann is technical coordinator, and Mr. Martello is researcher in the "**Texas-Mexico Toll Bridge Study**", for Texas Department of Transportation (Alvin Luedecke, Director of Planning, 512-465-7346) and Texas Turnpike Authority (1993-1994)., which, among other deliverables, estimated the potential revenues of additional toll bridges along the Texas-Mexico border.

"**System Cost Analysis of Truck Freight on Interstate 80 in Pennsylvania,**" for Conrail, (Steve Sullivan, Project Director, 215-977-5659), September 1990 - August 1991. Mr. Euritt served as the Revenue consultant and Mr. Harrison served as the Vehicle Operating Cost consultant for this research effort through the Texas Research and Development Foundation. This study was one of the nation's first multimodal system cost studies for freight transportation. The study found that the operating cost per ton-mile of freight is significantly higher for truck-highway than for rail. This emphasis on truck-highway results in significant losses in energy and reduced transportation efficiency. The results of this study were used by decision makers to transfer resources from the highway fund for use on railroad enhancements for intermodal operations. This was the first time that this kind of transferred was used in Pennsylvania.

"Comparison of Cost Responsibility Studies," for Texas State Department of Highways and Public Transportation, (Alvin Luedecke, Director of Planning, 512-465-7346), June 1988 - August 1991. The Texas Cost Responsibility Study for Texas has shown that heavy trucks receive significant subsidies by not paying an equitable share of the highway infrastructure costs. These subsidies promotes a more rapid deterioration of the road system and causes higher maintenance and rehabilitation costs, resulting in significant losses in energy. Moreover, the subsidies divert freight transportation from the more energy efficient rail system. Mr. Euritt serves as the Co-Principal Investigator for this continuing study.

"Conversion of the SDHPT Automotive Fleet to Alternative Fuels," for Texas State Department of Highways and Public Transportation, (Don Lewis, Project Liaison, 512-416-2085), June 1990 - August 1992. This study resulted in the development of a comprehensive fleet evaluation model for use of compressed natural gas or propane. The model requires inputs as to the number and type of vehicles, current fuel economy, and annual miles traveled. The model then estimates the refueling infrastructure requirements and examines the net present value of the fleet on a life-cycle basis. The primary savings is for reductions in the fuel price and maintenance savings. The model was used to evaluate over 300 public fleets in the Texas Department of Transportation. Mr. Euritt served as the Project's Co-Principal Investigator. The model has been demonstrated at several national transportation conferences.

Multimodalism

"Increasing Mobility and Economic Development through Multimodal Centers," for Texas State Department of Highways and Public Transportation, (Alvin Luedecke, Director of Planning, 512-465-7346), September 1991 - August 1993. Mr. Euritt and Mr. Harrison directed this 2.5 year study for TxDOT. Following a first year analysis of multimodal transportation centers, the study scope was modified to study modal trends and develop a comprehensive framework for evaluating transportation on a social cost basis. The information collected in this study is directly related to data necessary to complete the SECO study.

"Improved Energy Efficiency Through Better Urban Intermodal Coordination," for Southwest Region University Transportation Center, Texas Oil Overcharge Funds, (Dock Burke, SWUTC Director, 409-845-5815), June 1990 - August 1991. During the late 1980s, transportation analysts began to explore the benefits of intermodal transportation operations. This study examines port operations to determine optimal strategies for storage and movement of containers. The objective is to minimize cost and promote greater efficiency in the transportation system. Intermodal connectivity is critical in this process. Significant delays occur in urban transportation networks, resulting in wasted energy, when links are missing in the intermodal system. Mr. Euritt served as the Co-Principal Investigator for this study.

"Evaluating the Coordination of Intermodal Transportation Policies and Programs to Promote Economic Growth," for Southwest Region University Transportation Center, U.S.D.O.T. Funds, (Dock Burke, SWUTC Director, 409-845-5815), September 1988 - August 1992. There were, and continue to be, serious deficiencies in intermodal transport policies. This study examined existing policies for promoting and hindering multimodal transportation policies. The major obstacle blocking the development of more effective intermodal transportation systems is the lack of decision tools to examine transportation from a multimodal perspective. This study set in motion a number of studies examining and developing new approaches to evaluating transportation alternatives. Mr. Euritt served as the Co-Principal Investigator for this study.

Alternative Fuels

Alternative Fuels Laboratory Advisory Council, (Craig Biddle, Coordinator, 512-452-1776), Austin Texas, 1994. Mr. Euritt serves on this Advisory Council which is charged with the technical review of the Texas Project for evaluating the fuel efficiency and emissions of about 100 natural gas and propane powered motor vehicles.

Program Committee of the International Dedicated Conference on Electric, Hybrid and Alternative Fuel Vehicles, Aachen Germany, 1993-1994. Mr. Euritt serves on this Committee and is charged with soliciting and reviewing professional papers on alternative fueled vehicles.

Alternative Transportation Fuels Committee of the Transportation Research Board, National Research Council, Washington, D.C., 1993 (Friend of the Committee). As a Friend of this Committee, Mr. Euritt reviews numerous papers submitted to the Transportation Research Board for presentation at its annual meeting and publication in the *Transportation Research Record.*

State of Texas Energy Policy Partnership, Committee on Alternative Transportation Fuels, Texas Railroad Commission, 1992. Mr. Euritt served on this committee that assisted in developing a state energy policy for consideration by the Texas legislature. As part of his committee work, Mr. Euritt developed a Social Cost Index for incorporating social costs into current vehicle taxing mechanisms. This paper has been presented at several national and international conferences.

UT Austin Committee to Assess the National Energy Strategy, 1991 (Contributing author). Mr. Euritt was a contributing author to the report submitted to the Texas Governor. He was in charge of coordinated the effort to evaluate the transportation efficiency impacts on the state of Texas.

"Fuel and Time Savings through Expediting Pavement Construction," for Southwest Region University Transportation Center, (Dock Burke, SWUTC Director, 409-845-5815), 1992-1993. Pavement construction on existing highways creates problems for state agency staffs, vehicle owners, and commercial businesses. In addition, such activities can have substantial financial impacts on motorists in terms of time delays and wasted fuel. If expediting techniques are used to get the pavement back into service faster, then significant energy savings are possible. This study identifies procedures and guidelines for transportation planners to estimate fuel and time impacts when using various expediting techniques. This project was directed by Mr. Robert Harrison

"Alternative-fueled Bus Impacts on Transit Networks and City Streets," for Southwest Region University Transportation Center, (Dock Burke, SWUTC Director, 409-845-5815), 1992-1993. Alternative fuel use mandated by the Texas Legislature for mass transit vehicles has resulted in heavier mass transit vehicles. The additional weight of fuel storage tanks causes accelerated wear on specific transit routes, a fact that is not currently considered into the economic evaluation of alternative and conventional fuels. This project identifies these related costs so that a total system cost can be used for comparing various alternative fueled vehicles. This project is directed by Mr. Harrison.

2. Tellus Institute

Tellus Institute is a nonprofit research and consulting organization with over seventeen years of experience in energy and environmental planning, management and regulation. With a team of over 50 scientists, economists, engineers and policy analysts, Tellus has the wide scope of technical, regulatory and policy expertise needed to fulfill our mission of designing equitable resource and environmental strategies for the public good.

Our expertise in resource planning stems from having completed over 1,500 studies of energy and the environment, assisting a range of regulatory and public agencies, as well as utilities, regional energy agencies, industry associations, and other groups throughout the U.S. and abroad.

Tellus Institute's research program covers four specific areas: energy, solid waste, risk analysis, and international energy and environmental studies addressed by the Stockholm Environment Institute - Boston Center (located at Tellus Institute).

The Energy Group at Tellus focuses on energy resource planning, management, regulation and policy development on the national, regional, state and local levels for all types of resources, across all sectors. The Group conducts its work for public utility commissions, federal, regional and state energy offices, consumer advocates and counsels, utilities, foundations, international organizations, and others. The Group's expertise includes a seventeen-year history on issues of supply planning, energy efficiency, demand forecasting, environmental externalities, financial analysis, and related topics. Within the group there are five distinct programs -- Energy & Environment, Electricity, Natural Gas, Demand-Side Management, and Rates, Regulation & Finance -- and over twenty professional staff make up the Energy Group, many with over fifteen years of experience in their field of expertise.

The group's Energy & Environment Program, headed by Dr. Bernow, focuses on broad areas of energy, economic and environmental planning and policy (versus that of utility-specific rate case proceedings), in state, regional, national and international contexts. It provides policy-makers and the public with information, analyses and recommendations on energy supply and demand, technology choice, economic impacts and environmental consequences of policies and strategies across all sectors of the economy and all fuels.

The research projects described below only include those projects in which the key staff assigned to this project actively participated. Those staff are shared within the Energy Group at Tellus between the Energy and Environment Program and the Electricity Program.

Transportation Energy and Environment

Increasing energy efficiency in transportation is crucial for checking growth in oil imports, alleviating air pollution, and cutting greenhouse gas emissions. Tellus has assembled a team that can help the Texas SEDC address these critical issues so that it may better plan for a economical and environmentally sustainable transportation future.

The transportation sector consumes about one-fourth of all primary energy and emits more than one-third of the carbon dioxide in the U.S., as well as significantly contributing to urban congestion and pollution. Tellus has provided an interdisciplinary approach to transportation policy and planning -- linking fuel choice, vehicle efficiency and design, emissions and their controls, consumer purchase and driving patterns, and alternative transportation modes -- to meet transportation needs. In developing transportation policy, Tellus considers instruments such as efficiency standards, pollution taxes, demand management, market mechanisms, restrictions, and programmatic/investment initiatives in developing policy to address transportation. We perform data development, cost/benefit analysis, and scenario design/analysis at different geographic levels and in different market segments.

Transportation and Greenhouse Gases. Dr. Bernow has contributed the recent ACEEE book *Transportation and Global Climate Change,* co-authoring the last chapter entitled "Transportation on an Greenhouse Planet: A Least-Cost Transportation Scenario for the U.S."

Natural Gas Vehicles. Mr. Fulmer analyzed the natural gas vehicle program of consumers Gas (Toronto, Ontario, Canada) in the context of the Company's preliminary integrated resource planning activities.

Alternative Vehicle Fuels. Dr. Bernow and Mark Fulmer presented *A Social Cost Analysis of Alternative Fuels for Light Vehicles*, presented at Transportation and Energy Strategies for a Sustainable Transportation System, Pacific Grove, California. To be published by he Transportation Research Board.

Integrated Energy/Environmental Planning for Transportation. "Applying an Integrated Energy/Environmental Framework to the Analysis of Alternative Transportation Fuels," presented at: European Council for an Energy Efficient Economy, 1993 Summer Study, Rungstedgaard, Denmark. June 1-5. Stephen Bernow and Mark Fulmer.

National Transportation Energy/Environment Analysis. Tellus collaborated with Union of Concerned Scientists and American Council for an Energy-Efficient Economy to produce the personal transportation and freight transportation chapter of *America's Energy Choices.*

Global Transportation Scenarios. Working collaboratively with World Resources Institute and the Brookings Institution on the **2050 Project**, in which scenarios for sustainable futures in transportation energy and environment and other energy/environment interactions is being modelled.

The DOE Transportation Working Group for the Administration's Climate Change Action Plan. Dr. Bernow invited to contribute to the working group's deliberations and recommendations.

New York State Energy Office. Dr. Bernow was invited to the Transportation Experts Focus Group for the State's 1994 Energy Plan.

U.S. DOE's Electric Vehicle Fuel Cycle Emissions Program (EVTECA). Dr. Bernow selected as a reviewer of work done under this program.

John DeCicco of American Council for an Energy-Efficient Economy (ACEEE) has agreed to join the Tellus team. Mr. DeCicco has worked closely with Tellus on past projects including the multi-modal transportation sector analyses of efficiency, fuel choice, mode-shifting, costs and emissions in *America's Energy Choices.* Mr DeCicco takes a comprehensive approach to the issue by working to help enact a complementary set of federal, state, and local policies to increase vehicle efficiency and reduce vehicle miles of travel.

Mr. DeCicco is in the forefront of efforts to improve the fuel economy of cars and light trucks. He has examined the technological and economic aspects of vehicle efficiency improvements. He analyzes and advocates a balanced array of policies on this issue, including stronger fuel economy standards, financial incentives such as fees and rebates linked to efficiency, research and development programs, and market-pull concepts such as a "Green Machine Challenge." He also investigate how vehicle efficiency relates to emissions control, safety, and alternative fuels.

Another key component of Mr. DeCicco's work is developing and advocating strategies to reduce travel demand and encourage more efficient modes of travel. He is evaluating reform of parking subsidies and equitable changes in taxation that can dampen travel demand and help pay for more efficient infrastructure. He is also exploring new approaches to vehicle insurance and other user fees, and sustainable approaches to land use, such as transit-oriented and infill development.

Selected publications:

> **Transportation Modelling for Policy Analysis.** Dr. DeCicco is a reviewer for the U.S. DOE Energy Information Administration, of its recently completed National Energy Modelling System Transportation Model.
>
> *Transportation and Global Climate Change*
>
> *An Updated Assessment of the Near-term Potential for Improving Automotive Fuel Economy*
>
> *Feebates for Fuel Economy: Market Incentives for Encouraging Production and Sales of Efficient Vehicles*

Renewable Energy

In undertaking energy/environmental analyses, Tellus has assessed the availability, costs and technical and environmental characteristics of alternative primary energy resources for electric generation, transportation, industrial processes, and heating. Among these electric generation technologies are renewables resources including solar, wind, geothermal and biomass, and their associated technologies, which offer potential environmental advantages at costs that are becoming competitive. Thus Tellus has extensive experience in quantifying in detail how each type of operating characteristic of new technologies like renewables or DSM must be taken into account to perform the proper cost/benefit analyses. At the same time, Tellus evaluates economic and environmental costs and impacts of conventional fossil-fuel resources, along with new conversion and pollution reduction technologies, as part of integrated energy systems.

Tellus has evaluated renewable energy opportunities, from a technical and social cost perspective for transportation as well as for the electric and industrial sectors.

The following studies include assessments of renewable resources for the various sectors:

Renewable Vehicle Fuels. Dr. Bernow and Mark Fulmer presented *A Social Cost Analysis of Alternative Fuels for Light Vehicles*, presented at Transportation and Energy Strategies for a Sustainable Transportation System, Pacific Grove, California. To be published by he Transportation Research Board.

Renewable Resources in the Midwest. As one of six organizations to be awarded the U.S. DOE's *Innovative IRP* Awards in 1992, Tellus is collaborating with the Union of Concerned Scientists to assess the integration of wind and biomass into the Northern States Power system vis-a-vis reliability, economic dispatch, and long-term economics. Building upon the ongoing work of the UCS's in their study *Renewables in the Midwest* by taking the economic and technical performance data generated by UCS, and using it to develop utility system reliability, and IRP dispatch scenarios for a case study of utility systems in the upper-midwest., Tellus is identifying and characterizing the most appropriate renewable technologies for the state; creating scenarios to analyze and model the chosen technologies within relevant utility systems; and analyzing economics and reliability sensitivity to such factors as resource diversity, scale and spatial dispersion.

Renewable Energy in State Energy Planning. On behalf of the Division of Energy Resources, Tellus helped formulate the renewable resource options contained in *Renewable Energy for Massachusetts: A Strategy for Energy, Environment and the Economy*, the recently-released state energy plan. A companion report, *Conservation Energy for Massachusetts,* was also completed for the DOER.

An Alternative National Energy Strategy. Tellus worked with the Union of Concerned Scientists in developing the renewable resources analyses for *America's Energy Choices: Investing in a Strong Economy and a Clean Environment*, . Using the *LEAP/EDB* energy/environment planning models, Tellus modelled the primary energy requirements, pollutant emissions, costs and benefits, and integration of electric supply and demand for major economic sectors. The four resulting scenarios demonstrated the feasibility of meeting energy needs through aggressive DSM, increased reliance on renewable resources, and a shift from old fossil-fuel technology to new fossil-fuel technology with lower emission rates.

Modelling Renewable Electric Resources. A Case Study of Wind Reliability. Dr. Bernow recently completed a renewables study for the U. S. Department of Energy's "Innovative IRP Program" in which he focused on the electric system reliability contribution of wind turbines.

Energy, Biomass and Emissions. In December 1991, Tellus staff completed a study of the energy systems and greenhouse emissions of eleven northeast states for the Northeast Regional Biomass Program of the Coalition of Northeastern Governors. Tellus examined the contribution of biomass to the energy systems in the Northeast and to the region's net releases of carbon dioxide and methane, and projected these releases over three decades, given a continuation of current trends and policies. This Reference Case was compared with three alternative scenarios, assuming successively more aggressive efforts to reduce greenhouse gas emissions through strategic implementation of energy efficiency and biomass resources. Tellus used *LEAP* to explore alternatives and assess policies for reducing future emissions.

Towards Global Energy Security: The Next Energy Transition. An Energy Scenario for a Fossil Free Future. Tellus completed the draft technical report of this study, which provided technical analysis and documentation as input to Greenpeace International's project *Towards Global Energy Security*. The report presents a main scenario and sensitivity analysis for reducing greenhouse gas emissions, as well as the technical methods and assumptions used to develop them. *LEAP/EDB* were used to develop the main scenario, with an end-use-oriented modelling approach that requires detailed energy consumption and production data for recent years, as well as supplemental forecasted data.

Energy Efficiency

Tellus staff have earned a reputation for working on energy efficiency and conservation issues for over seventeen years, involving both the electricity and natural gas industries. Tellus has been particularly involved in electric utility efficiency and conservation, but has greatly expanded its expertise to include numerous gas projects undertaken within the past few years. Our longevity in the field and experience in a wide variety of contexts has given us a strong background in the evolution of utility demand-side management (DSM). Our utility DSM work has been informed and strengthened by the depth of our knowledge of the range of energy resource issues.

In the electric sector, Tellus has researched and testified in over fifty studies of DSM for numerous state regulators in the U.S. and for agencies abroad. Tellus staff have written extensively on conservation and have actively participated in numerous industry association activities, such as NARUC's Energy Conservation Committee, for many years. In the natural gas industry, Tellus has completed gas conservation studies most recently for clients in California, Colorado, the District of Columbia, Hawaii, Maryland, New Mexico, New York, Pennsylvania, Rhode Island, Vermont, Wisconsin and Ontario.

New England: Oil Dependence and Employment. As part of an analysis of the extent to which New England's dependence on oil could be reduced through conservation and alternative energy sources, Tellus forecasted the regional employment effects of implementing a broad-based set of residential energy conservation measures. Sponsored by the U.S. General Accounting Office.

Efficiency and Conservation Program Planning, Design & Review. Tellus has focused a large portion of its energy efficiency and conservation practice on DSM program planning and design, including cost-benefit analysis of achievable DSM potential, critique/development of program designs, and participation in collaborative processes. Tellus worked with Wisconsin Gas on an RFP for large commercial customer DSM, as well as with DSM program design, avoided cost calculation, and DSM bid evaluation. Other recent projects include development of cost-effective gas and electric DSM programs as part of a DSM Action Plan for

Long Island (described below); collaborative review/critique of electric utility DSM plans in Pennsylvania; development of residential, commercial and industrial DSM programs for Consumers Gas in Ontario; and many others.

Conservation and its Environmental Benefits. Tellus developed a comprehensive set of gas and electric DSM programs for Long Island in a DSM Action Plan for the area. As part of this project, Tellus established societal avoided costs including the costs of energy production, distribution and consumption and the environmental costs of air pollution, and water and land use. This analysis established the avoided costs we used to design and evaluate the DSM programs in the resulting DSM Action Plan. Tellus also made recommendations in the state's building codes for improved efficiency, and designed a public facilities conservation proposal. And Tellus further assisted with an implementation plan for the DSM Action Plan. Sponsored by the Long Island Power Authority.

DSM Process and Impact Evaluation. Tellus has experience in both the qualitative (process) and quantitative (impact) aspects of DSM program evaluation, having performed evaluations for numerous utilities and in collaborative processes. Tellus staff are familiar with the methodologies and useful resources used in program evaluation, and focus their efforts on innovative approaches to evaluation design and practice.

An National Energy Efficiency Strategy. Tellus worked with the Union of Concerned Scientists in developing the renewable resources analyses for *America's Energy Choices: Investing in a Strong Economy and a Clean Environment.* Energy efficiency was evaluated against avoided fuel and technology costs for each major sector of the U.S. economy, taking account of the social cost of pollutant emissions and greenhouse gas reduction goals.

Environmental Impacts and Social Costs of Energy

Tellus has analyzed the environmental impacts of energy use at the various stages of the fuel cycle (extraction, processing, distribution, and conversion) as part of an overall assessment of alternative options, plans and scenarios. Tellus has estimated pollutant emissions and the costs and characteristics of emissions controls and take these into account in integrated energy/environment planning. Tellus applied a variety of approaches to address externalities, including social costing through taxation, shadow pricing for planning, social dispatch, and emission cap/trading systems. Our basis for externalities policy is sustainability, inter-generational equity, and public health and amenity. Particularly important to this work is climate stabilization analysis. Below we describe several recent projects of significance:

Maine's Energy Choices Revisited. Tellus collaborated with American Council for an Energy-Efficient Economy (ACEEE) and Economic Research Associates to evaluate impacts of the policies of the Maine Public Utility Commission during the 1980s on electric rates, customer bills, state employment and the environment. The study was sponsored by Mainewatch, an independent research and educational organization that analyzes issues affecting the environment, economy, and people of Maine.

New York: Externalities Modelling. Tellus is designing and implementing a model that will evaluate the environmental impacts and externalities costs of alternative resource facilities in New York state, based on specific emissions characteristics and the human and environmental aspects of the regions affected in a project sponsored by ESEERCO and other agencies in New York including NYSERDA, NYPP, EPRI and the NYPSC.

Environmental and Economic Externalities in Nevada. Tellus completed a two-part report profiling our approach on incorporating environmental and economic externalities in the resource planning practices of Nevada's regulated utilities. Our analysis expanded on a portfolio of environmental and economic concerns, including relationships between identification, quantification and valuation of environmental and economic externalities and the role of monetization; methods for implementation of these ideas; and examples of the magnitude of impacts that inclusion of monetized externalities would likely have on costs of energy resources. In a November 1990 Rule, the Nevada Commission adopted Tellus' approach and dollar values for monetizing emissions. Sponsored by the Nevada Office of Consumer Advocate. (July 1990)

CAAA Consensus. Tellus reviewed the implications of the Clean Air Act Amendments for CECA, the Consumers Energy Council of America, helping to bring together a variety of stakeholders including regulators, intervenors, energy and environmental organizations, utilities, and others.

CAAA Compliance Planning. Tellus has addressed the implications of the 1990 Clean Air Act Amendments for both individual utility compliance plans and regulatory procedures on cost recovery. This has included analysis of the Southern Company's (Georgia) fuel-switching-based compliance plans, the Allegheny Power System CAA compliance plan and APS's plan for SO_2 reductions and development of DSM programs, and the compliance plans of two Ohio utilities as part of a comprehensive review of their IRP plans.

Externalities in Electric System Planning. Tellus worked with the Colorado Office of Energy Conservation to develop an integrated resource planning rule for the state's electric utilities, discussing the need for emissions and other environmental data in a utility IRP, various methodologies for developing the costs of emissions, the issue of when best to quantify these costs, and a specific methodology for monetizing externalities.

IRP and Externalities. For the Kansas Corporation Commission, the New Mexico Attorney General, and the Colorado Office of Energy Conservation, Tellus developed comprehensive integrated resource planning rules, which are currently being adopted in each state. An externalities component to the rules proposed the consideration of quantifying environmental and other externalities relevant to the utility's resource portfolio into monetary terms.

Wisconsin Environmental Externalities. Tellus determined the environmental costs of several pollutants associated with Wisconsin's electric utility resources. Tellus identified key issues, explained externalities valuation methodology, presented monetary estimates for specific air emissions (fossil fuel combustion, EPA criteria pollutants and acid gases, greenhouse gases, air toxics), discussed rate impacts and implementation issues, examined water quality issues vis-a-vis valuation methodology, and explored the roles of the Commission the Department of Natural Resources in utility externalities. Sponsored by Wisconsin Citizens for a Better Environment. (Mid-1991 to 1992)

Pollutant Valuation in Massachusetts. In on-going work in Massachusetts, Tellus testified on the monetary values of specific environmental pollutants (the values were developed in a previous Tellus/DOER study and adopted in DPU Docket 89-239). The testimony explored Massachusetts Electric Company's analysis regarding CO_2 valuation, their "market-based" approach, and the Clean Air Act Amendments and SO_2 valuation. Sponsored by Massachusetts Division of Energy Resources.

Integrated Resource Planning

In the past several years, Tellus has placed electric and gas system integrated resource planning at the forefront of its research program. Staff have participated in most of the major IRP dockets in the U.S., and have been instrumental in helping jurisdictions shape the electric utility process and define the criteria for evaluating integrated resource plans. Tellus has been a leader in promoting the adoption of IRP by electric utilities, and is now applying the IRP planning technique to local gas distribution utilities, as promoted by the Energy Policy Act of 1992.

Tellus has developed and or critiqued numerous additional electric and gas IRP plans for regulatory and public-sector agencies throughout the U.S. In recent years, we have also worked directly for electric and gas utilities, developing IRPs and analyzing related issues of demand-side management (DSM), avoided cost calculation, and environmental externalities. We see this work as contributing significantly to our understanding of the intricacies and challenges of IRP, and heightening our ability to understand and critique supply planning from a least-cost perspective. Recent efforts have been completed or are underway in Hawaii, Ontario Canada, Ohio, District of Columbia, Vermont, Colorado, and Utah.

Tellus has further advanced the IRP debate by evaluating IRP regulatory reforms to facilitate electric resource planning and implementation such as incentive strategies to promote DSM, decoupling strategies to separate profits from sales, and recommending cost recovery treatments for utility DSM investments.

NARUC IRP and Rates White Paper. Dr. John Stutz, a ratemaking expert at Tellus, was chosen along with Dr. Rosen to write a white paper for NARUC on rate design and how to align it with IRP. This paper was completed in December 1993, and is available from NARUC to regulators and industry stakeholders throughout the U.S.

NARUC Gas IRP White Paper. Richard Hornby of Tellus was on the technical advisory committee to NARUC in its development of guidelines for IRP in the gas industry.

Kansas. In helping to define the IRP process and write the IRP rule, Tellus addressed cost recovery and financial incentive mechanisms in its preliminary drafts of Rules and process issues for each state agency.

B. PERSONNEL

1. CTR

We propose Mr. Mark A. Euritt and Dr. Angela J. Weissmann as principal and co-principal investigators in this project. They will devote respectively 30 and 38 percent of their time to this project. Other key investigators and researchers are Mr. Harrison (economics) Mr. Martello and Mr. Qin (engineering and computer analysis). Mr. Martello and Mr. Qin will allot 40 percent time each, while Mr. Harrison will allot 11 percent of his time to this project. Additional research assistance will be provided University of Texas' graduate and undergraduate students in the areas of Engineering, Economics, and Computer Science. Below are brief biographies of the proposed CTR team. Attachment A contains full resumes.

Mr. Mark A. Euritt

Mark A. Euritt received his B.S. in Political Science from Northwest Missouri State University (1980), his Master of Public Affairs (1985) from the Lyndon B. Johnson School of Public Affairs, University of Texas at Austin, and his Master of Business Administration (1985) from the University of Texas at Austin. He is currently the Center for Transportation Research's Associate Director for Alternative Transportation Fuels Research.

Mark's professional and educational background have focused on transportation policy issues. During the last eight years, his research has centered on three general themes: transportation finance, multimodal planning, and alternative fuels. With respect to transportation finance, he has served as the co-principal investigator on several studies relating to the Texas highway cost index, highway cost responsibility, and private sector participation in funding infrastructure improvements. In the area of multimodal planning he has served as the Co-principal investigator on studies relating to fixed-guideway decision processes, economic impacts of state-wide multimodal coordination, economic impacts of highway bypasses, implementation of multimodal centers, and mobility impacts on urban air quality. In the alternative fuels arena, he has led studies relating to the implementation of alternative fuels for the Texas Department of Transportation, use of natural gas and electric vehicles for transit, the impact of alternative fuels legislation on highway financing, and an evaluation of Texas rules and procedures for propane pressure vessels used on motor vehicles. His research in these three areas has resulted in the publication of more than 50 articles and reports.

In 1991 he served as a Economic Consultant to the World Bank sponsored Multi-State Roads Project in Nigeria, Africa. In 1992, he served on the State of Texas Energy Policy Partnership for the Texas Railroad Commission. Mark is a member of the Transportation Research Board (TRB) Committee on Taxation, Finance, and Pricing and the TRB Committee on Transportation Economics. He is a member of the Society of Automotive Engineers and serves on the Program Committee on Advanced Transport Telematics/IVHS of the International Symposium on Automotive Technology and Automation.

Dr. Angela Jannini Weissmann

Dr. Angela J. Weissmann received her B.S. and Master degrees from the University of São Paulo, acknowledged as a sister-University by The University of Texas. During nine years, she was a professor of the Brazilian Air Force Institute of Technology, where she was responsible for a multitude of transportation related studies, such as the design and environmental impacts of the Guarulhos International Airport, which serves the heaviest traffic demand in Latin America.

She received her Ph.D. in Civil Engineering from the University of Texas at Austin in 1990, where she developed and programmed a method for backcalculating reaction moduli of rigid pavements from deflections, and a reliability model for Texas pavements, as well as comprehensive data base for Texas highways. She traveled extensively through the state, and she is at the forefront in Texas transportation issues and infrastructure. Currently, she is about to complete a multimodal transportation planning project for the Texas-Mexico border area, which entails the development of guidelines for state transportation planning and transportation efficiency at the border region.

Dr. Weissmann has 17 years experience in Transportation Engineering. She has a deep and comprehensive knowledge of statistics, including sophisticated methods such as causal analysis, time series analysis and non-parametric inference, and she is an expert in model development and calibration. She is also proficient in both mainframe and microcomputer applications, having a deep knowledge of most programming languages, and most statistical and data base packages, for both mainframe and micro-computers.

She is the author of publications on several transportation engineering areas, such as airport design, air transport safety, pavement design and evaluation, and transportation planning and evaluation, in the United States and abroad. She is fluent in written and spoken Spanish, Portuguese and French.

Mr. Robert Harrison

Mr. Harrison is Associate Director of the Center for Transportation Research (CTR), at the University of Texas at Austin. He has worked with civil engineers in the United States and Europe for over 25 years, particularly in the areas of vehicle operating costs, life-cycle costing, user benefits, and transport planning. He co-authored a book on vehicle operating costs published by Johns Hopkins Press in 1988 and was, between 1976 and 1982, the economist on a UNDP/World Bank infrastructure project in Brazil where he was responsible for the collection, analysis and modeling of vehicle operating costs. Since joining CTR in 1987, he has contributed to several Texas Department of Transportation studies and is currently the co-Principal Investigator on four economic studies; one evaluating the economic impact of loops and by-passes on medium sized Texas cities, another evaluating the privatization of interstate rest areas, another determining the opportunities for highway privatization in Texas, and the fourth examining multi-modal terminals. He is also a principal investigator on a DOT regional research center project investigating the design and implementation of a high-speed ground corridor (where fuel costs are important) scheduled to begin operation early in the next century. In addition, he is the principal investigator on two state energy projects involving vehicle operating cost research. The first evaluates the impacts on users of expediting pavement construction, and the second examines operating large truck combinations on interstate bridges.

Mr. Jiefeng Qin

Mr. Jiefeng Qin holds a bachelor degree in Engineering by the Shanghai Jiao Tong University, Shanghai, P.R. China (1988), and a master degree from the Virginia Polytechnic Institute and State University, Blacksburg, VA, (1992). His educational background includes courses in the areas of traffic engineering, computer simulation models for traffic analysis, transportation's interrelationship with the urban environment, methodologies for planning multimodal transportation systems, operations research and systems analysis, systems and graphical simulation, and geographic information system. Mr. Qin is currently a research assistant at University of Texas at Austin, where he is seeking his doctoral degree in Transportation Engineering.

Mr. Qin is currently participating in a multimodal cost comparison analysis between truck and rail freight system in Texas. He is also developing a macro-analysis framework which links the transportation planning, evaluation of TCMs, and air quality analysis.

The framework consists of five models as well as cost-benefit analysis, e.g., mode choice model, traffic simulation model, emissions estimation model, fuel consumption model, and dispersion model. Because of his outstanding academic performance, Mr. Qin is a member of the Phi Kappa Phi Honor Society, . He is also a student member of ITE, ASCE, and ORSA.

While he was a research assistant at Virginia Tech, he used System dynamics and Catastrophe theory to develop transportation planning model, and he was in charge of the development of output part in the software package REDIM2,0.

In China, he was an assistant engineer with the Shanghai Ship Research & Design Institute, where he participated in a study of coal water-transportation system in north-east China, and in a feasibility analysis of passenger transportation system in southern China.

Mr. Qin has comprehensive and deep modeling and computer skills, and he has proven ability to use Turbo C++, QBasic, FORTRAN, as well as NETSIM, TEXAS, MOBILE4.1, HCM.

Mr. Michael Martello

Mr. Martello received his bachelor of Science degree in Civil Engineering from the University of Florida, Gainesville (1984), in his Master degree in Transportation Engineering from the University of California, Berkeley (1989). He is currently continuing his education at the University of Texas at Austin's Computer Science program, and he is also a part-time researcher at CTR, where he just finalized his participation in a study that prepared recommendations for transportation planning and transportation efficiency along the Texas-Mexico border. His responsibilities in this project included extensive travel throughout the border area, and a capacity assessment of the current infrastructure.

As a part of his seven-year career, Mr. Martello was involved in the Colorado River Regional Transportation Study at the Transportation Research Center of the University of Nevada in Las Vegas. His primary responsibility was to work with TIGER and DIME files in ARC/INFO GIS software in order to develop a TRANPLAN network. He also assisted in preparation of research paper for Clark County Department of Comprehensive Planning assessing various Transportation Control Measures as defined by the EPA

At the Institute of Transportation Studies of the University of California at Berkeley, he was involved in IVHS research project . Responsibilities included coordinating with LADOT traffic operations staff the simulation modeling of seventy five signalized intersections in the Los Angeles SMART corridor utilizing TRANSYT-7F software and assessing potential benefits of an in-vehicle information system.

As a traffic engineer with DKS Associates, in Oakland, California, his primary responsibilities were conducting traffic impact analyses, traffic operations studies and general civil design work. He also developed traffic signal timing plans for coordinated operation at 9 signals in Pittsburgh, CA, as part of a Fuel-Efficient Traffic Signal Management Program (FETSIM) project.

2. Tellus Institute

Tellus proposes Dr. Stephen Bernow and Dr. Richard Rosen of Tellus Institute as Project Manager/Principal Investigator and Technical Reviewer/Editor for the project, respectively. Other key investigators from Tellus will include Mark Fulmer (engineering), Dr. Irene Peters (economics), Robert Margolis (engineering; technology and policy), Richard Hornby (engineering; technology and policy), and Dr. John DeCicco of ACEEE (engineer). Additional staff will provide support and research assistance, if needed. Ms. Faye Camardo will provide word-processing services, as a women-owned business. Directly below we provide brief biographies for each proposed staff member. Attachment A contains full resumes for each.

Dr. Stephen Bernow

Dr. Stephen Bernow is a Tellus senior scientist and a nationally recognized expert in the area of energy/environmental planning and externalities analysis, including job impact studies. As a co-founder of Tellus and manager of its Energy & Environment Program, Dr. Bernow has over seventeen years of experience on energy/environment planning and policy issues.

The most prominent of his recent work includes *America's Energy Choices*, an all-sectors all-fuels projection of potential low pollution, low CO_2, low cost futures for the U.S. economy, and the policies to initiate such futures. Tellus evaluated the primary energy requirements, pollutant emissions, costs and benefits, and integration of electric supply and demand for each major sector. The study demonstrated the feasibility of meeting energy needs through energy efficiency, renewables, fuel switching, transportation mode shifting, and advanced electric generation technologies. Dr. Bernow also led a study for CONEG (Coalition of New England Governors) to evaluate the potential of biomass to mitigate greenhouse gas emissions in the Northeast. Alternative scenarios for the eleven-state CONEG region on energy, biomass and greenhouse gases were developed.

Dr. Bernow has authored papers on vehicle efficiency, fuel choice and emissions, accepted for presentation at transportation conferences by the U.S. Department of Transportation, U.S. DOE, U.S. EPA, and the European Council for an Energy Efficient Economy. He was invited by DOE to participate in the transportation working group for the Administration's Climate Change Action Plan, by the New York State Energy Office to its transportation focus group for the State Energy Plan, and is a reviewer for the U.S. DOE's electric vehicle fuel cycle emissions program.

Dr. Bernow has also recently focused on renewable energy resources. Two such projects include one for the *US DOE "Innovative IRP"* project in which Tellus is collaborating with the Union of Concerned Scientists to assess the integration of wind and biomass into the Northern States Power system vis-a-vis reliability, economic dispatch and long-term economics. Dr. Bernow also contributed renewable energy policy recommendations to the Massachusetts Division of Energy Resources, which was then used as input into the state's energy plan. He was also a participant in the recent *National Biofuels Roundtable*.

For the U.S. EPA, Dr. Bernow is completing a study of the role of cost-effective efficiency, renewables and fuel-switching in achieving joint S02/C02 reductions for a case-study utility system in Texas.

His work also includes numerous recent studies of the treatment of environmental and economic externalities, taking a "cradle-to-grave" approach. Over the past several years, Dr. Bernow has played a leading role nationally and in various states on environmental impacts (and externalities of energy options and plans). He is currently completing the design and development of a computer model to assess the environmental externalities of alternative energy resources in New York for several agencies in that state. He has analyzed electric utility environmental externalities quantification and valuation for public-sector agencies in Vermont, Nevada, Wisconsin, Kansas, Ohio, New Mexico, and Colorado, and has stimulated discussion on the exploration of full cost dispatch and other techniques to internalize environmental impacts, including the critical loads approach. He has been a leading voice nationally in energy and environmental impact issues, and has been invited to speak on that topic by NARUC, NECPUC, NASUCA, NRRI, and ACEEE, and other national and international organizations such as the World Bank, OECD, IPCC, UNEP, IEA, and others.

Dr. Bernow received a B.S. degree from Columbia University School of Engineering and Applied Science in 1963, and a Ph.D. in physics from Columbia University in 1970. Before joining Tellus Institute he taught at the university level for seven years.

Mr. Mark Fulmer

Mr. Fulmer is a research associate at Tellus where he focuses on alternative fuels analysis and natural gas integrated resource planning. He has performed nearly all of the fuel switching and gas heating/cooling technology analyses, and is involved in Tellus' work on alternative resource technologies.

Mr. Fulmer has been extensively involved in both the supply and the demand-side of fuel alternative studies. On the supply side, he has developed price and availability forecasts for the principal fossil fuels, as well as for alternative vehicle fuels. On the demand side, he has assessed the cost and performance characteristics of alternative technologies in both the building and the transportation sectors.

In the transportation fuels field, in 1991 Mr. Fulmer assessed the natural gas vehicle program of Consumers Gas of Toronto, Canada, within the framework of an integrated resource planning study Tellus was performing for the Company. Mr. Fulmer has performed social cost analysis for alternative vehicle fuels, including natural gas, propane, electricity and alcohol fuels. The results of these studies have been presented both in the US and in Europe.

Prior to joining Tellus, Mr. Fulmer was a research assistant at Princeton University's Center for Energy and Environmental Studies. His research focused on the application of advanced gas turbine cogeneration technologies in the cane sugar and alcohol industries, including considering the production of alcohol for a motor fuel.

Mr. Fulmer holds a Bachelor of Science in Mechanical Engineering from the University of California, Irvine and a Masters of Science in Engineering from Princeton University.

Dr. John DeCicco

Dr. DeCicco is a Senior Associate at ACEEE where he is responsible for research, technology assessment, policy analysis, and advocacy work regarding energy efficiency. His specialty focuses on transportation, including vehicle technologies, transportation systems, and integration of economic development and environmental protection in transportation energy planning.

Under the leadership of Dr. DeCicco, ACEEE has developed an extensive expertise as well as the leading information on transportation fuel-efficiency supply curves. This includes information on both the available technologies and those most likely to emerge during the study's period of analysis. The information has been synthesized into a database containing the latest technology characteristics and their respective costs and anticipated savings.

His other efforts at ACEEE include policy and program analysis on national energy strategies, energy efficiency in buildings, and environmental impacts of energy use.

Previous to ACEEE, Dr. DeCicco was a staff scientist and engineer at the National Audubon Society, where he performed research and policy analysis on environmental impacts of energy use such as greenhouse gas emission, nuclear accidents, emissions from coal power plants, impacts of electric power lines, and environmental protection through energy conservation. He wrote both for technical audiences, and for the general public.

Dr. DeCicco holds a Ph.D. in mechanical engineering from Princeton University.

Dr. Richard Rosen

Dr. Rosen is a senior scientist and Director of the Energy Group at Tellus Institute. As a co-founder of Tellus, he has over seventeen years of experience in utility resource planning and management.

Recently, Dr. Rosen has worked on issues involving the proper integration of supply-side and DSM options into integrated resource planning, including consideration of the costs of environmental externalities. Resource supply system modeling, economics, and pricing have also been a major focus of Dr. Rosen's activities at Tellus. This work has included economic and technical analyses of utility system supply options, including transmission construction and power plant operations using production costing, financial, and system reliability simulation models and statistical techniques.

He has performed detailed analysis of the cost and performance trends of electricity supply, the price and availability of purchased power, the reasonableness of generation planning, the correct methodologies for computing avoided costs, and the performance standards of power plants. His research has also emphasized the theoretical basis of the appropriate rate making treatment of new power plants, and appropriate pricing mechanisms for purchased power contracts.

Dr. Rosen has performed this research and has testified in regulatory proceedings before numerous state utility commissions, before the Federal Energy Regulatory Commission and the Atomic Safety and Licensing Board of the Nuclear Regulatory Commission.

Dr. Rosen received his Bachelor of Science degree from MIT in 1966 and his Masters and Ph.D. degrees in physics from Columbia University in 1970 and 1974, respectively. In 1991, Dr. Rosen ended his three-year appointed term on the Research Advisory Committee of the National Regulatory Research Institute.

Mr. Robert Margolis

Mr. Margolis is a Research Associate at Tellus Institute and the Stockholm Environment Institute - Boston, where he is primarily responsible for development, enhancement, and application of various energy and environmental planning tools, including the Long-range Energy Alternatives Planning System (LEAP) and PoleStar. Most of the work he has been involved with at Tellus has focused on issues related to environmental sustainability. Mr. Margolis has: conducted analyses of and developed national and global energy and greenhouse gas (GHG) emissions scenarios; analyzed and developed methods for valuing GHG environmental externalities in Canada and the United States; and developed data and techniques for use in fuel cycle analysis.

Before coming to Tellus, Mr. Margolis, was a Research Assistant at MIT s Center for Energy and Environmental Policy. At MIT he evaluated the modeling approach used of assessing policy options to stabilized global climate by the U.S. EPA and Intergovernmental Panel on Climate Change (IPCC). He studied how models were used in the policy formation process by interviewing participants in the IPCC process, and by using models to explore the relative effectiveness of various policy tools in the context of uncertainty. Mr. Margolis holds a M.S. in Technology and Policy from MIT, and a B.S. in Electrical Engineering from the University of Rochester.

Mr. Rick Hornby

Mr. Rick Hornby, a specialist in natural gas supply and demand issues, is a senior scientist and the manager of the Natural Gas Program at Tellus. He has expertise in industrial operations, energy policy and natural gas, and over 15 years of experience as a project manager, policy analyst, and consultant on issues of energy supply, demand, and pricing.

Mr. Hornby worked for several years as a project engineer in the manufacturing sector, both in England and Canada. He served for several years with the Department of Mines and Energy of the Province of Nova Scotia as Assistant Deputy Minister of Energy. Concurrently, he served for four years as a member of the Canada-Nova Scotia Offshore Oil and Gas Board, a five person Board responsible for regulating gas exploration and development offshore Nova Scotia. While in Nova Scotia, Mr. Hornby was responsible for policy analyses of natural gas exploration, development, production, processing, transmission, distribution and marketing.

At Tellus, Mr. Hornby specializes in the analysis of natural gas integrated resource planning, supply planning, cost allocation, rate design, and load forecasting. During the course of his work, Mr. Hornby has evaluated the outlook for fuel prices, assessed the factors affecting fuel choice of industrial customers, and has analyzed the importance of fuel availability/price, relative to other considerations, in the siting of new cogeneration facilities and independent power plants.

He has worked on such natural gas issues for clients in Arizona, Arkansas, California, Colorado, the District of Columbia, Florida, Hawaii, Maryland, Massachusetts, Michigan, Missouri, Montana, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, South Carolina, Utah, Vermont, West Virginia, Wisconsin, and Ontario.

His gas IRP work has been extensive over the past few years. He was project manager and a principal investigator for two comprehensive IRP projects: developing a preliminary IRP for Consumers Gas in Ontario and a similar IRP for The Gas Company in Hawaii. Furthermore, he has reviewed several states' IRP and DSM plans. He assisted the New Mexico Attorney General, the Pennsylvania Office of Consumer Advocate, the Kansas Corporation Commission, and the Colorado Office of Energy Conservation in developing those state's IRP rules for natural gas utilities. And he participated as a technical advisor on NARUC's Gas IRP Subcommittee which developed the *Primer on Gas Integrated Resource Planning*, just released by NARUC.

Mr. Hornby received a Master of Science degree in Energy Technology and Policy from the Massachusetts Institute of Technology in 1978 and a Bachelor of Industrial Engineering degree from the Nova Scotia Technical College in 1973.

Ms. Irene Peters

Ms. Peters is an economist at Tellus and has worked on a variety of energy, resource and environmental issues.

She was the principal author, with Dr. Bernow, of a recent Tellus study on the practicality of pollution taxes, which included a chapter on transportation taxes and other policy instruments. Ms. Peters co-authored a major study for the California Waste Management Board on virgin materials incentives and another study for the same agency on Advance Disposal Fees, for which she developed a methodology to value the environmental impacts of solid waste management.

Other activities include the review of the DOE's model to forecast the demand for transportation energy and the comparative review of macro-econometric growth models estimating the effect of carbon taxes on the economy. One focus of that work was on taxes and other instruments for reducing pollution from personal transportation. She has also worked on the theoretical and practical issues of pollution measurement for the state of Washington. Dr. Peters has contributed to work at Tellus on issues surrounding social costing and externalities and has written on socio-economic impacts effects and external costs.

A native of Germany, Ms. Peters is familiar with current European research and experience in eco-taxes. She holds an undergraduate degree from Trier University and an M.A. in Economics from Clark University.

Ms. Peters recently completed her Ph.D. with a concentration in Industrial Organization and Econometrics. In her thesis she developed an econometric model to estimate the use of packaging materials in consumer products.

Mr. Michael Lazarus

Mr. Lazarus manages energy and environmental planning projects and performs analyses of economic and technical issues affecting energy and resource policy decisions. He directs projects in collaboration with energy agencies and NGOs in Africa, Asia, and Latin America, including the Philippines, Senegal, Tanzania, and the SADC Energy

Sector in Angola. He organizes and conducts training workshops for energy planners, and has made presentations on energy and environment planning methods and studies at international workshops and seminars in Austria, China, Mali, Mozambique, Zimbabwe, the World Bank, and elsewhere. He directs the development, enhancement, and application of computer-based planning tools including the Long-range Energy Alternatives Planning (LEAP) System and the associated Environmental Data Base (EDB). He also conducts local, national, and global energy studies. He has testified before a US state regulatory commission on electric utility financial issues and has co-authored reports on demand forecasting, conservation, and power supply planning. He has published articles in both English and French.

3. Skill Matrix Summary

As shown in this section, CTR/Tellus have combined to create an expert team to address the issues and concerns of the RFP. Our staffing plan brings together 5 persons from the University of Texas Center for Transportation Research and 8 persons from the Tellus Institute. To orchestrate the functioning of this team requires careful attention to task assignments, role responsibilities and formal organiztional relationships. While we believe clear advantages accrue from a team that is diverse in substantive discipline and dispersed geographically, we are mindful of the need for strong management techniques and clear role assignments. These assignments are more clearly delineated in Section 3. Importantly, Dr. Bernow, Mr. Euritt, and Dr. Weissmann have demonstrated experience in project management and have worked in a variety of settings. Figure 2-1 provides an overview of the skills of the research team.

Figure 2.1

Areas Of Expertise Represented By The Project Team

	Mark Euritt, CTR	*Angela Weissmann, CTR*	*Robert Harrison, CTR*	*Mike Martello, CTR*	*Jiefeng Qin, CTR*	*Stephen Bernow, Tellus*	*Mark Fulmer, Tellus*	*John DeCicco, Tellus*	*Richard Rosen, Tellus*	*Robert Margolis, Tellus*	*Rick Hornby, Tellus*	*Irene Peters, Tellus*	*Micheal Lazarus, Tellus*
Fuel Cycle Analysis						●	●	●		●		●	●
Alternative Fuels	●		●			●	●						
Transportation Economics	●	●	●	●								●	
Environmental Impacts	●				●	●	●	●	●	●		●	●
Computer Modeling		●		●	●		●	●	●	●			●
Cost Analysis	●	●				●		●			●		
Vehicle Oper Costs			●					●					
Veh Fuel Efficiencies						●		●			●		
Transportation Policy Analysis	●	●				●							
Multimodal Transportation	●	●	●	●	●								
Texas Transportation Programs	●	●		●									
Statistics		●			●	●							
Energy Analysis						●	●	●	●	●	●	●	●

SECTION 3
PROPOSED WORK PLAN AND ABILITY TO COMPLETE TASKS IN A TIMELY MANNER

A. PROPOSED WORK PLAN

INTRODUCTION AND BACKGROUND

A new era has dawned on the transportation system. In the past, transportation primarily focused on providing accessibility for growing mobility demand. The transportation system was, and continues to be, vital to the economic growth of the State. During the last decade, the challenge was to address the dramatic growth in congestion with a resource base ill-equipped to keep pace. Numerous strategies and methods were enacted to address this challenge. For the future, transportation decision-makers will continue to battle this problem, but according to a new paradigm. Solutions to future transportation problems will not only address the State's mobility needs, but also sustainable energy and environmental needs. In addition to promoting economic growth, transportation also affects other State and national policy objectives. Before developing specific objectives and a work plan to address transportation efficiency objectives, it is necessary to elaborate on the context in which the State and national transportation system operate. Only then can meaningful objectives and an effective work plan be developed.

The Transportation Crisis

Texas and American motorists confront congestion on a regular and growing basis. It is estimated that congestion costs consumers between $30 billion and $100 billion annually. (*Ref. 1, 2*) This strain on the system coupled with the decay in the nation's infrastructure has created a crisis of near-epidemic proportions. The transportation challenge over the next few decades is reflected in the authorizing language of the federal government's Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). "The National Intermodal Transportation System shall consist of all forms of transportation in a unified, interconnected manner, including transportation systems of the future, to reduce energy consumption and air pollution while promoting economic development and supporting the Nation's preeminent position in international commerce." Accomplishment of this objective particularly as it relates to multimodal transportation is problematic. The Transportation Research Board (TRB) sponsored National Conference on ISTEA and Intermodal Planning Issues found that although much progress has occurred in the multimodal planning area "much remains to be done. Significant learning experiences need to be shared, and important analytical tools and evaluation methodologies need to be developed." (*Ref. 3*) Responding to the transportation challenge is inherently complex. In the past, consumer mobility demands have been addressed through expanded road systems without regard to the total social costs of this investment decision. Addressing transportation problems requires a comprehensive approach that includes multimodal analysis, public/private partnerships, demand management, and the impact of transportation investment on other state and national priorities, i.e., energy conservation and security, clean air, economic growth.

Multimodal system development has suffered because of the highway focus of transportation policy. Transportation problems are not viewed from a multimodal perspective. As shown in Figure 3-1, U.S. passenger travel is dependent on highway infrastructure serving private vehicle needs. This differs from most European countries (see Figure 3-2), where reliance on highway private vehicle transport is less significant. Inefficient transportation investment has resulted in a growing demand for highway infrastructure. As shown in Figure 3-3, U.S. per capita travel has increased from 3,171 miles per year in 1951 to 8,781 miles per year in 1992. In order to change this highway emphasis and develop an effective multimodal transportation system, a multi-dimensional framework must be developed to evaluate the economic consequences of various transportation alternatives. A systems perspective for addressing mobility problems focuses on the total social costs of transportation decisions. Social costs consist of infrastructure and related support costs, modal ownership and operating costs, and the costs of externalities. These costs are summarized in Figure 3-4. Investment of public dollars for transportation must be made to maximize public gain. This can be done only if overall system costs are minimized. Using a systems, or social, cost approach will change, fundamentally, the evaluation of transportation alternatives. If the sustainable energy policy is to be developed for the State, then its transportation system must be examined from a multimodal framework where the social costs are addressed. This becomes even more apparent when examining the relationship between transportation and energy.

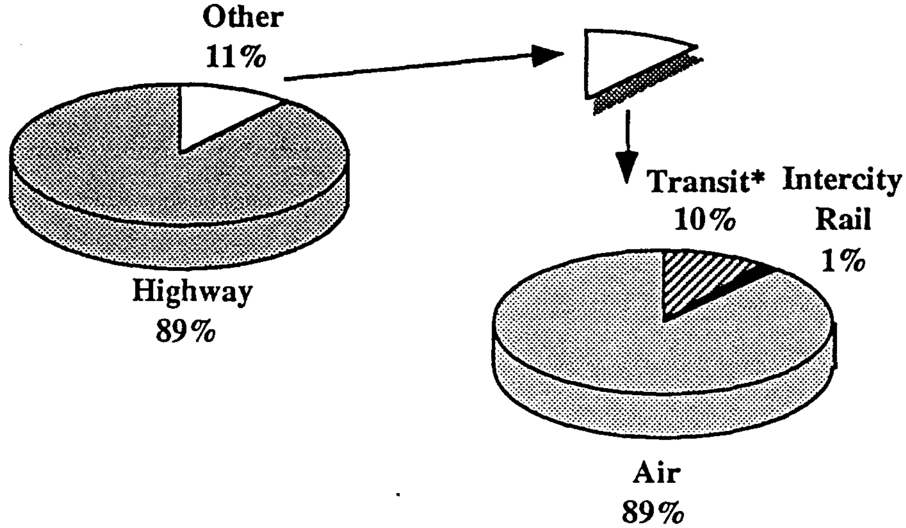
Transportation and Energy

The U.S. is a major energy consumer and the world's largest consumer of petroleum. The U.S. consumed nearly 33.5 quadrillion Btu's (quads) of petroleum in 1992. (*Ref. 4*) This dependence on petroleum has serious implications for national security. Most of the world's proven oil supplies are located in politically and socially unstable middle eastern and African regions -- over 70 percent in 1992. (*Ref. 4*) Coupled with the significantly higher costs of extracting petroleum reserves ($2 dollars per barrel for middle eastern countries versus $20 or more per barrel in the rest of the world), the U.S. is heavily impacted by the actions of these countries. This influence was demonstrated by the oil embargo of 1973-74, the 1978-79 Iranian revolution, the significant price cuts in 1985-86, and most recently the 1991 Persian Gulf War. In all, the petroleum-dependent countries are highly susceptible to unpredictable shifts in the world market. Consequently, many countries have explored alternative energy sources and petroleum conservation.

The vulnerability to unstable foreign petroleum sources has led to a reduction in petroleum use as a percentage of total U.S. energy consumption, as shown in Figure 3-5.

Despite this trend, total petroleum consumption has increased from 29.52 quads in 1970 to 33.47 quads in 1992. (*Ref. 4*) With the exception of natural gas, all sources have increased in use since 1970, as shown in Figure 3-6.

Figure 3-1
1990 Modal Distribution for Passenger Travel



* includes commuter rail and ferry boat passengers.

Figure 3-2
Percentage of Urban Trips by Private Highway Vehicle

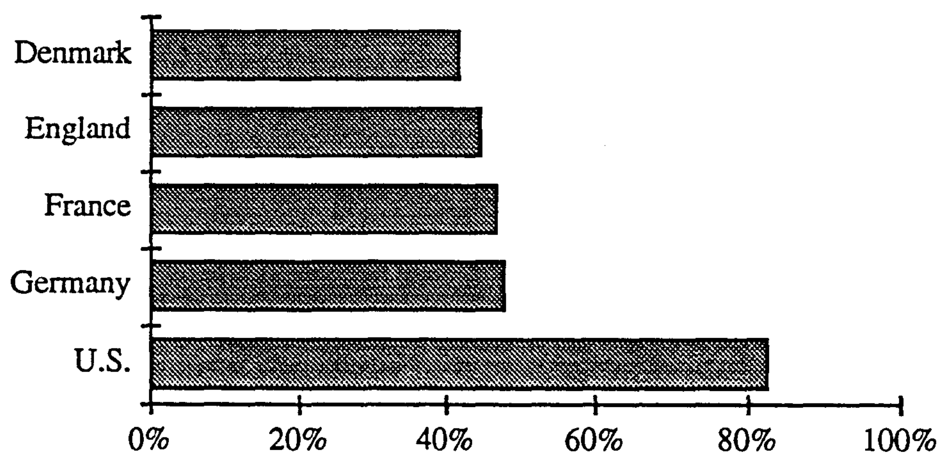


Figure 3-3
U.S. Per Capita Vehicle Miles of Travel (VMT)

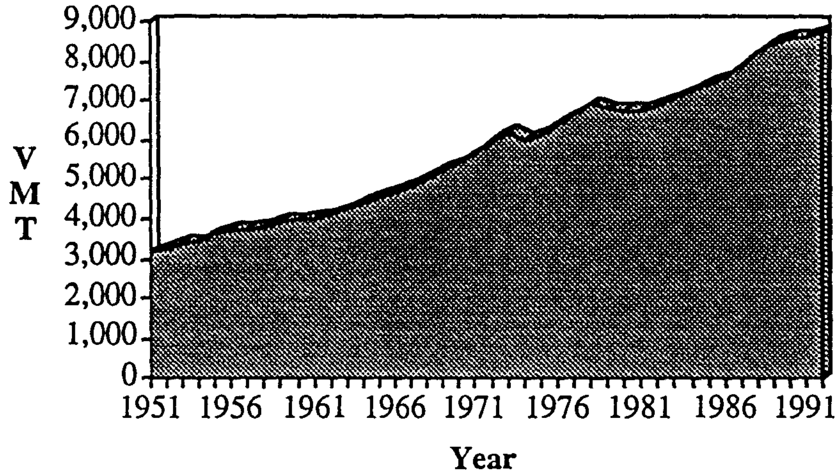
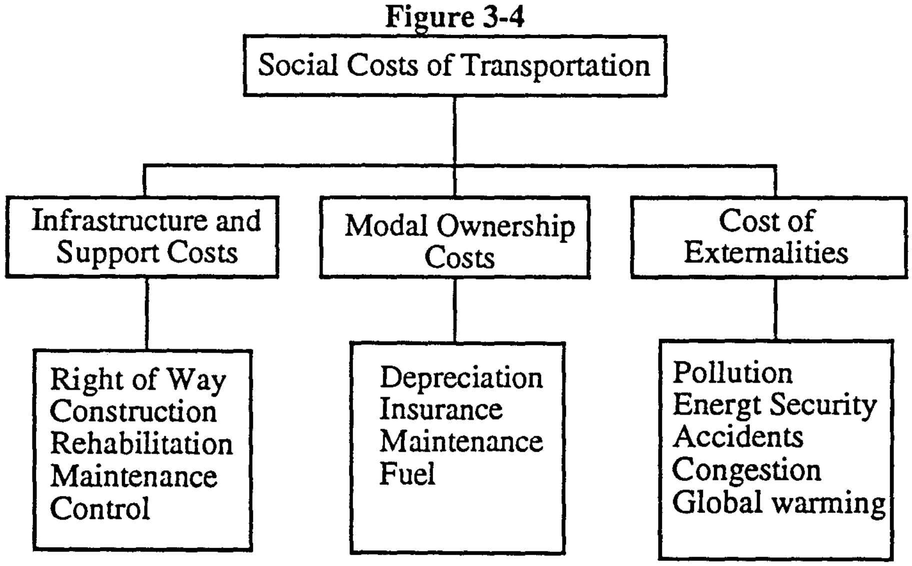


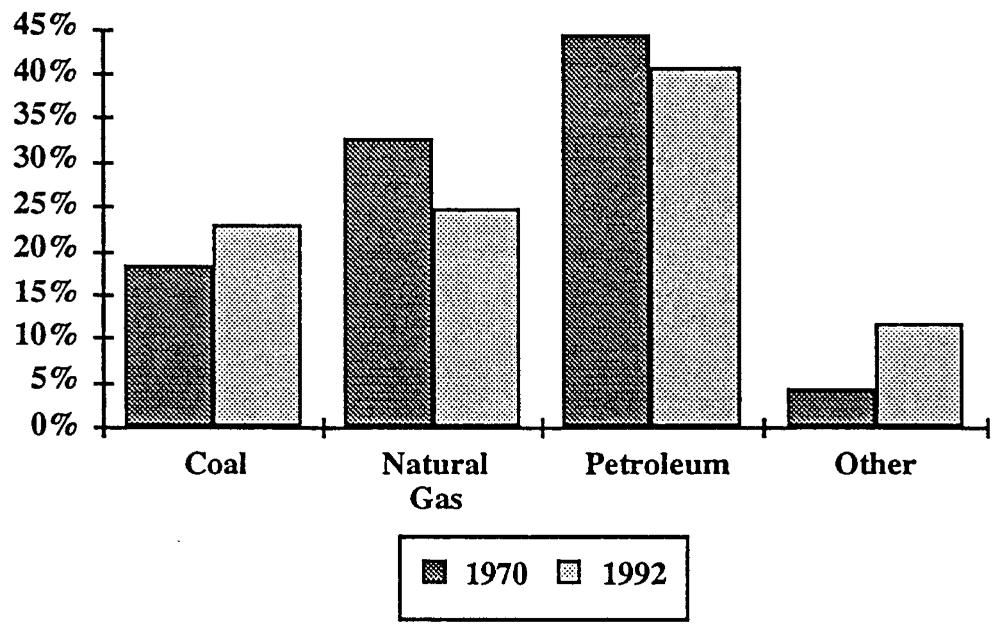
Figure 3-4



U.S. oil consumption comes into clearer focus when examining sector use. As illustrated in Figure 3-7, the residential, commercial, and electric utility sectors have reduced their consumption of petroleum since 1970, while the industrial sector has seen a small increase. On the other hand, the transportation sector's consumption of petroleum has risen dramatically from 7.78 million barrels/day in 1970 to 10.93 million barrels/day in 1993, a 40 percent increase. Within the transportation sector, petroleum accounts for 97 percent of total energy consumption. (*Ref. 4*). By mode, highways account for nearly 75 percent of total energy consumed in the transportation sector. (*Ref. 5*)

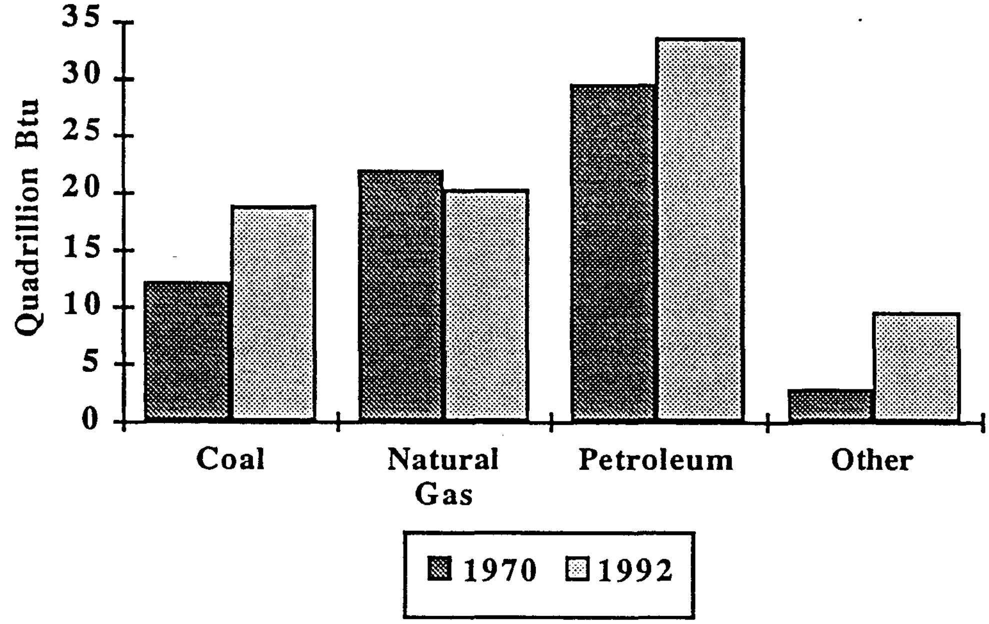
Figure 3-5

Distribution of U.S. Energy Consumption



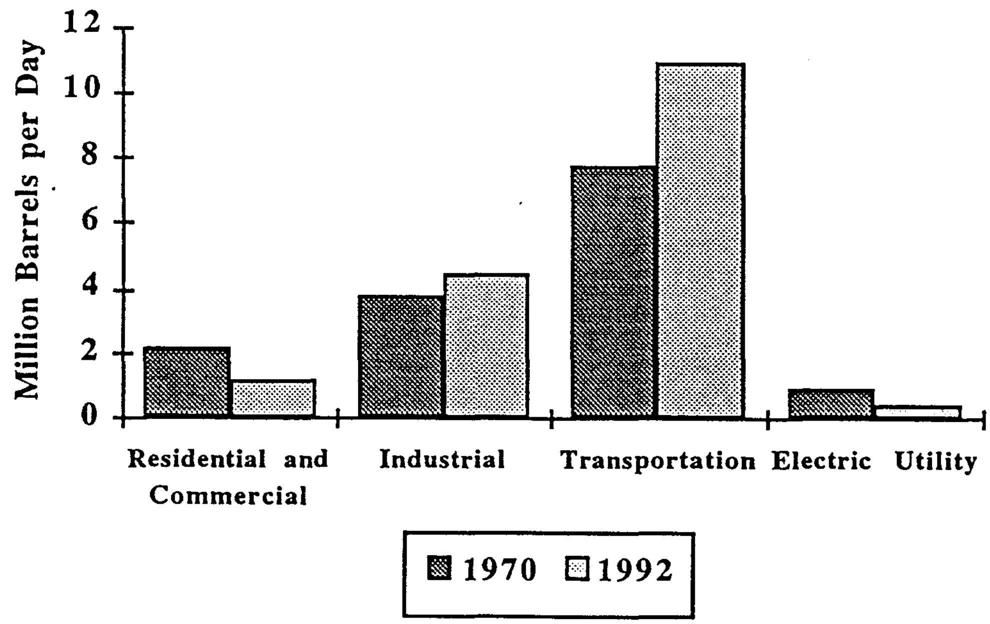
Source: Ref. 4.

Figure 3-6
U.S. Energy Consumption



Source: Ref. 4.

Figure 3-7
U.S. Petroleum Use by Sector



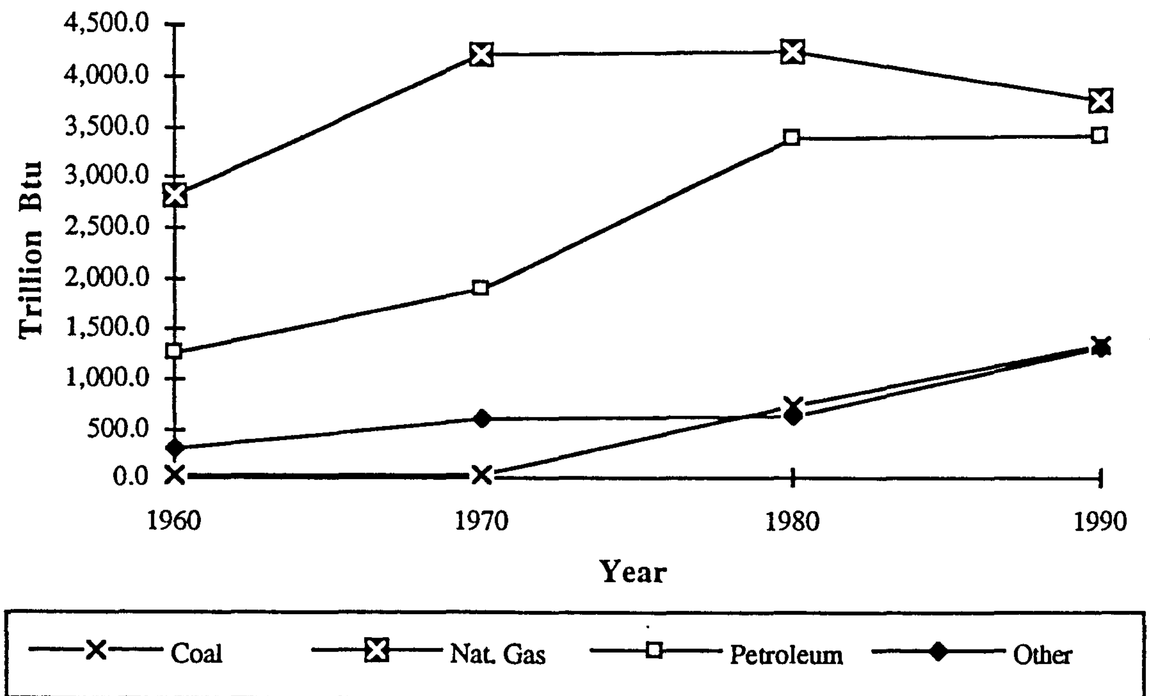
Source: Ref. 4.

Texas is the nation's major state consumer of energy. In 1990, Texas consumed 9,796.3 trillion British Thermal Units (BTUs) of energy, 25 percent more than California, the second largest state consumer. (*Ref. 6*) By energy source, Texas was the largest consumer of natural gas, petroleum, and electricity, and the fourth largest consumer of coal. Over the last 30 years, natural gas has served as the major source of energy for Texas. (See Figure 3-8.) However, as a percent of total energy consumption natural gas has declined steadily since 1960, as shown in Figure 3-9. The largest gains have occurred in the consumption of coal, primarily due to the increased used of coal by electric utilities. Liquefied petroleum gases (LPG) accounted for 6.7 percent of Texas energy consumption in 1960, compared to 10.7 percent in 1990.

The transportation sector in Texas is somewhat below the national average, primarily due to its large natural gas reserves. Petroleum, however, is still the principal energy source for transportation, supplying over 90 percent of its energy needs since 1960. Natural gas is the next major source of energy for transportation but declined from 6.8 percent in 1960 to 5.1 percent in 1990. LPG supplied less than one-hundredth of a percent in 1990, down from 1.0 percent in 1960.

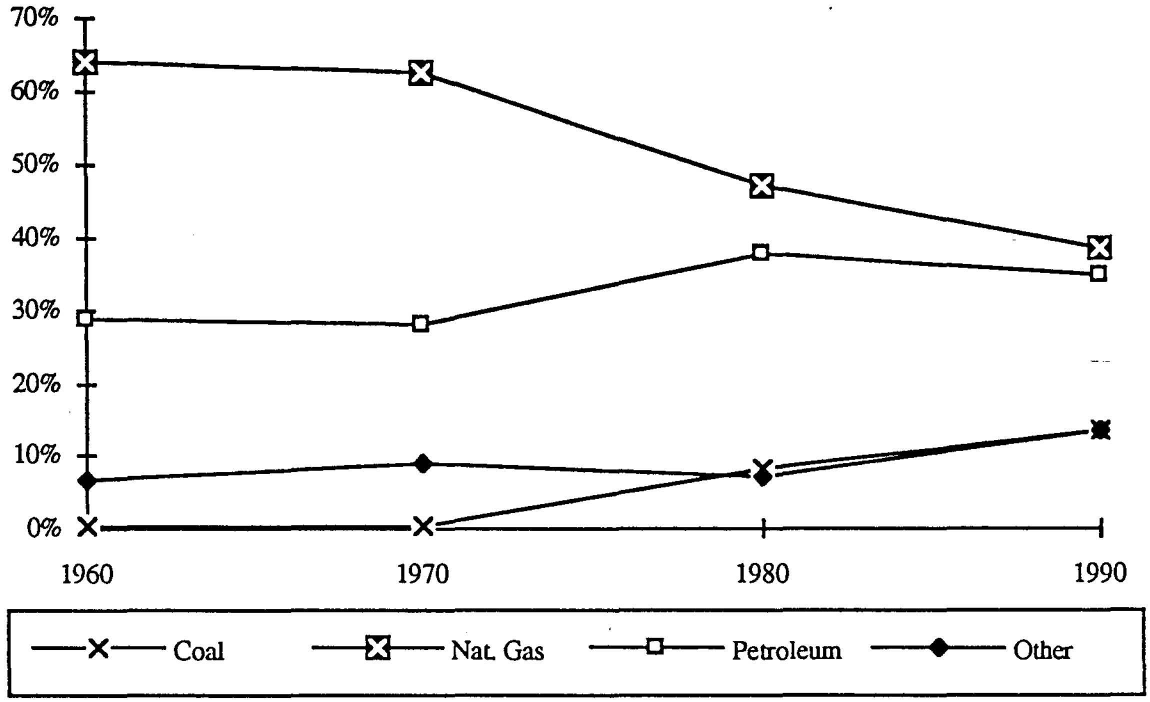
Figure 3-8

Texas Energy Consumption, 1960 - 1990



Source: Ref. 6.

Figure 3-9
Percent of Texas Energy Consumption by Source, 1960 - 1990



Source: Ref. 6.

Without a doubt, an effective state energy policy must include serious discussions about transportation. And within the transportation sector, policies affecting the provision of and the demand for highway infrastructure must be seriously examined.

Transportation and the Environment

One of the most pressing issues during the last decade has been concern over environmental degradation. Significant debate has taken place over procedures to improve air, water, land-use quality, and global warming. Within the area of air quality, the U.S. Environmental Protection Agency (EPA) has been charged with monitoring urban emissions through establishing National Ambient Air Quality Standards (NAAQS) for six criteria pollutants: carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), ozone (O_3)[1], particulate matter (PM-10), and sulfur dioxide (SO_2). All of these pollutants have deleterious effects on health. While the transportation sector has made significant progress in reducing emissions, the transportation sector remains a significant contributor to total emissions. As illustrated in Table 3-1, the transportation sector remains the primary source of CO emissions, and is the number two contributor for all other regulated emissions, except SO_2. Although not regulated, transportation accounts for between 70 and 90 percent of the U.S. CO_2 emissions, an important precursor to the development of

[1] Ozone formation is regulated through the control of volatile organic compound (VOC) emissions.

greenhouse gases. Future efforts to improve air quality must continue to include the transportation sector.

Table 3-1
Percentage of Regulated Emissions by Sector, 1992

Emission	Transportation	Fuel Combustion	Industrial Processes	Solid Waste & Other
CO	80.2	7.1	5.7	7.0
Pb	30.6	9.7	45.4	14.3
NO_x	44.6	50.7	3.8	0.9
VOCs	36.2	3.1	13.3	47.4
PM-10	30.9	18.5	32.7	17.9
SO_2	4.7	85.8	9.2	0.3

Source: Ref. 16.

The situation in Texas is even more critical. Almost 10 percent of U.S. carbon dioxide emissions, 10 percent of U.S. volatile organic compound (VOC) emissions, and 12 percent of U.S. nitrogen oxide emissions occur in Texas. The latter two are primarily of local and regional concern through direct human impacts (nitrogen oxides and VOC), the formation of tropospheric ozone (nitrogen oxides and VOC), and acid rain (nitrogen oxides). Carbon dioxide is of national and international concern with respect to the potential for climate change (greenhouse effect).

Transportation in Texas contributes about 22 percent of the State's CO_2 emissions, 33 percent of its VOCs, and 32 percent of its nitrogen oxides. The latter two ratios are somewhat lower than the national average for the transportation sector, while the CO_2 is comparable to the national average.

Federal and State Policy Initiatives

Because of the importance of transportation in developing sound policies for energy security and improved air quality, much attention has been directed to energy conservation and efficiency and non-petroleum based fuels. A number of Federal and Texas initiatives have been developed in response to these concerns.

Federal Initiatives

Alternative Motor Fuel Act of 1988. The major provision of this Act was the modification of the existing Corporate Average Fuel Efficiency (CAFE) program to include the building and selling of alternative fuel vehicles. The adjustment to the CAFE provided for fuel economy calculations based on the actual or assumed gasoline content of the fuel.[2] (*Ref. 7*) The Act was primarily aimed at alcohol fuels and natural gas. The Act also established a Alternative Fuels Advisory Council to report to the Interagency Commission on Alternative Motor Fuels and created the National Alternative Fuels Data Center at the National Renewable Energy Laboratory in Golden, Colorado. (*Ref. 8*) Finally, the law required that government-owned refueling stations for alternative fuels be opened to the general public. (*Ref. 7*)

Clean Air Act Amendments of 1990 (CAAA). Title II of this act establishes provisions for mobile sources. The Environmental Protection Agency (EPA) was mandated to issues regulations for clean fuels and vehicle emission standards. The alternative transportation fuels provisions of the CAAA are directed towards improving air quality. Alternative fuels include various low-emitting petroleum-based fuels, such as reformulated gasoline and oxygenated fuels. Strict tailpipe emissions standards were established for all vehicles. Additionally, the Act authorized the Clean Fleets Program. Automobile manufactures are required to produce 150,000 clean fuel vehicles by 1996 and 300,000 by 1999. Starting with model year 1998, fleets with 10 or more vehicles in the serious, severe, and extreme ozone non-attainment cities are required to begin purchasing these vehicles. It is optional for fleets in marginal and moderate ozone non-attainment cities.

Energy Policy Act of 1992 (EPACT). This Act uses mandates and incentives for domestically produced alternative fuels to reduce the nation's dependence on foreign oil. With respect to mandates, EPACT requires fleets for federal, state, and fuel providers to begin purchasing alternative fuel vehicles (restricted to non-petroleum-based fuels) over a period of time. In 1996, the alternative fuel vehicle requirements may be extended to private and municipal fleets.

In addition to a Local Bus Program, Electric Vehicle Demonstration Program, and an Alternative Fuel Research and Development Program, the Act provides incentives for purchasing alternative fuel vehicles and infrastructure development. The vehicle deductions are shown in Table 3-2. (*Ref. 9*) This deduction applies to both factory made vehicles and after-market conversions beginning June 30, 1993 during the year the vehicle is purchased or converted. This deduction is phased out between 2002 and 2004. The vehicle tax deduction is based on the incremental cost of the alternative fuel vehicles over its gasoline or diesel counterpart. Between June 30, 1993 and December 31, 2004, providers of clean-fuel refueling facilities are eligible for a tax deduction of up to $100,000 for the year facilities are placed into service. This deduction also will be phased out between 2002 and 2004.

[2] For compressed natural gas (CNG), the vehicle is assumed to burn 15 percent gasoline for the CAFE calculation.

Table 3-2
Alternative Fuel Vehicles Tax Incentives

Vehicle Class/Group	Maximum Tax Deduction
≥ 26,000 lbs	\$50,000
26 or more adult passengers	\$50,000
10,000 - 26,000 lbs	\$5,000
All other vehicles	\$2,000
	Tax Credit
Electric Vehicles	\$4,000

EPACT also amended the Renewable Energy and Efficiency Technology Competitiveness Act of 1989 to fund energy efficiency and renewable energy technology demonstrations. Moreover Tile XX includes funding authorization for reducing petroleum demand of motor vehicles. Other provisions of EPACT include an alcohol from biomass program, renewable hydrogen energy program, fuel cell technology development, and research and development for electric vehicles.

Texas Initiatives

Senate Bill 740. SB 740 is "an act relating to the purchasing, lease or conversion of motor vehicles by state agencies, school districts, and local transit authorities and districts to assure use of compressed natural gas or other alternative fuels." (*Ref. 10*) Alternative fuels in Texas currently include natural gas, propane, methanol, ethanol, and electricity. The law became effective September 1, 1991, for (1) school districts with more than 50 vehicles used for transporting children, (2) state agencies with more than 15 vehicles, excluding law enforcement and emergency vehicles, (3) all metropolitan transit authorities, and (4) all city transit departments. The law requires all new vehicle purchases for the above groups to be capable of operating on an alternative fuel. In addition, these organizations must meet the alternative fuel conversion requirements shown in Table 3-3. The conversion to 90 percent is contingent on a ruling by the Texas Air Control Board (TACB)[3] that the program has been effective in reducing total annual emissions. Compliance may be accomplished through the purchase of new vehicles, the conversion of existing vehicles, or by leasing the necessary vehicles.

[3] The TACB was consolidated with the Texas Water Commission to form the Texas Natural Resource Conservation Commission (TNRCC) in 1993.

Table 3-3
SB 740 Conversion Schedule

Date	Percent of Fleet
9/1/94	30%
9/1/96	50%
9/1/98	90%

An important component in the development and adoption of this legislation was the argument that utilization of alternative fuels would produce cost savings to state agencies. Accordingly, the legislation allows for a waiver if the affected agency can demonstrate that either (1) the effort for operating the alternate-fueled fleet is more expensive than a gasoline or diesel fleet over its useful life, (2) alternative fuels are not available in sufficient supply, or (3) it is unable to acquire alternative fuel vehicles or equipment necessary for their conversion. To date, no waivers have been granted by the Texas General Services Commission, although several studies have demonstrated that alternative fuel vehicles are not cost-effective for some public fleets. (*Ref. 11, 12*)

Senate Bill 769. This bill, which amends the Texas Clean Air Act, is an act relating to the adoption of certain regulations to encourage and require the use of natural gas and other alternative fuels in designated federal non-attainment regions, which currently includes the Houston, Dallas-Fort Worth, Beaumont-Port Arthur, and El Paso areas. (*Ref. 10*)

The organizations affected by this bill include (1) metropolitan and regional transit/transportation authorities, (2) city transportation departments, (3) local governments with 16 or more vehicles (excluding law enforcement and emergency vehicles), and (4) private fleets with 26 or more vehicles (excluding law enforcement and emergency vehicles). The implementation schedule and requirements for the first two groups are the same as SB 740 illustrated in Table 3-3. If the TACB (now TNRCC) determines that the alternative fuels program has been effective in reducing emissions, then groups 3 and 4 above will be required to convert to alternative fuels according to the schedule shown in Table 3-4. SB 769 became effective September 1, 1991.

Table 3-4
SB 769 Conversion Schedule
for Local Government and Private Fleets

Date	Percent of Fleet
9/1/98	30%
9/1/00	50%
9/1/02	90%

Senate Bill 737. SB 737 is an act relating to fuels and creation of an alternative fuels council and an alternative fuels loan program. SB 737 authorizes the creation of the Alternative Fuels Council (AFC) to oversee the Alternative Fuels Conversion Fund and promote the use of environmentally beneficial alternative fuels. The council consists of the General Land Office Commissioner, the three Railroad Commissioners, the Chairperson of the General Services Commission, and Chairperson of the TACB (now TNRCC) or designated representatives from these agencies.

The Alternative Fuels Conversion Fund is commissioned to make loans or grants for activities supporting or encouraging the use of alternative fuels. The fund is supported by designated oil overcharge funds, gifts, grants, payments made on fund loans, interest earned on the fund, and other government-approved money. The fund targets historically underutilized businesses, individuals with low incomes, institutions of higher learning, and health care facilities. In addition, government agencies, school districts, and transit authorities are automatically eligible. The loans can be for vehicle purchases, conversions, and construction of public refueling facilities. (*Ref. 13*)

Finally, SB 737 authorizes the Texas Public Finance Authority to issue bonds up to $50 million for:

- conversion of state vehicles to alternative fuels;
- construction of alternative fuel vehicle refueling stations;
- conversion of school buses;
- conversion of transit authority vehicles; and
- public-private joint ventures to develop alternative fuel infrastructure.

Bond issuance is contingent on the proposed project demonstrating energy and cost savings. (*Ref. 13*)

Senate Bill 7. This bill amends the requirements of SB 740 pertaining to school districts with more than 50 buses. SB 7 amends the implementation requirements according to the schedule shown in Table 3-5. Unlike SB 740, the 90 percent requirement in 2001 is not contingent on the TACB ruling. School districts are encouraged to meet the 30 percent requirement by 1994, although not required. As an incentive, SB 7 gives priority to appropriated funds for conversion for school districts meeting the 30 percent mix by 1994.

Table 3-5
SB 7 Conversion Schedule
for School District Fleets

Date	Percent of Fleet
9/1/97	50%
9/1/01	90%

SB 7 also provides for more lax waiver requirements. The burden of demonstrating economic feasibility shifts from the school district to the bidder.

Texas Sustainable Energy Development Council. This Council was established by Governor Richard's Executive Order on March 14, 1993. The Council is charged with developing a strategic plan for cost effective and efficient use of Texas' natural resource base. The Council's mission is to make recommendations that will assist Texas in developing and promoting a sustainable energy future. This Request for Proposal from the State Energy Conservation Office assists in this endeavor.

Summary

At the most basic level, reducing the dependence on oil for the transportation sector involves two elements 1) reducing actual energy consumption and 2) utilization of alternative fuels. The first area can include improvements in vehicle efficiency and use of advanced technologies, as well as strategies to curtail motor vehicle miles of travel. The second area examines the use of alternative fuels to displace petroleum. This includes a variety of feedstocks such as natural gas, coal, biomass, oil sands and shale, and water. Each of these feedstocks can be processed through one or more methods into motor vehicle fuels. For the short-term, it is unrealistic to expect that petroleum will be displaced by alternative fuels. This is stated rather succinctly by R. A. Corbett:

> The reality is that gasoline, albeit environmental formulations of it, will remain the dominant liquid fuel for most U.S. transportation needs through the 1990s and well into the next century. (*Ref. 14*)

Moreover, the U.S. national energy strategy also recognizes that even with large public and private investments into alternative fuels programs daily oil consumption will continue to rise through 2030, albeit at a slower rate. (*Ref. 15*).

Addressing the state's energy needs is a complex process. New methods and tools are needed to evaluate transportation investment in order to promote a more efficient multimodal transportation system. This section highlights the problems associated with transportation investment and the various federal and state policies that influence its development. With this information presented, it is easier to identify clear objectives and an appropriate work plan for addressing the fundamental concerns highlighted in the RFP.

The proposed study will integrate work already in progress in Texas, with experience and software tools available at Tellus and CTR, to create a model describing the present transport situation in the state, and several alternative ways of developing the state transportation system over the near-term, as well as the long-term. It is expected that this study will culminate in a report summarizing transport alternatives and their cost and environmental impacts, and will also yield a tool for quickly looking at the impacts of other transportation alternatives.

DESCRIPTION OF PROPOSED METHODOLOGIES

As discussed in the previous section, the state transportation system is inherently complex. However, there are important evaluations that can be accomplished to assist policy makers in addressing state problems of importance. The guiding objective of this study is the development of a new tool for evaluating transportation policy decisions. In particular, the project will accomplish the following objectives.

1. Estimate energy and cost savings potential of the transportation sector.
2. Develop a new multimodal framework for evaluating transportation alternatives from a social cost perspective.
3. Assist SECO in the development and implementation of guidelines for energy efficient transportation strategies.

The project objectives will be accomplished through completion of the six tasks discussed in this section. The tasks are sequential, and they represent major milestones to develop the study and arrive at the final report.

Task 1. Conduct an Assessment of Near-term Options for Increasing Energy Efficiency in the Texas Transportation Sector, Including Technology Improvements, Mode-shifting and Incentive Programs.

Cost-effective energy savings in transportation can come from two primary sources: increasing the efficiency of the vehicles being used, and/or more efficient use of the vehicles being used. As noted in the introductory section, the near-term options related to these sources can be categorized into technology-related and demand-related activities. Both costs and air pollutant emissions can be reduced by both of these approaches, as well as by control equipment and switching to less polluting fuels. Our three scenarios will embody assumptions and analyses of all these factors.

Significant opportunities exist in both categories. The US DOE projects average automobile fuel economy to increase only 11% from 1990 to 2010, or about 3.2 miles per gallon. (*Ref. 17*) Significant cost-effective fuel economy improvements beyond this are possible (50 mpg and beyond), much of which can be achieved without changing the basic "drivability" of the automobile that people have become accustomed to.

The transportation infrastructure can also be used more efficiently. Policies generically referred to as "transportation demand management," such car-pool lanes, improved mass transit, employer ride-share programs, cash-out parking, pay-as-you-drive insurance to name a few, can contribute to cost-effective energy savings. Mode shifting from less efficient to more efficient transportation technologies—such as rail freight transport rather than long-haul trucking, or medium distance rail rather than air—can also save energy and costs. Load factors—the average person-miles per vehicle-mile traveled—can be improved by both mode shifting and demand management.

Fuel switching to fuels other than gasoline may not necessarily effect the energy efficiency of a transportation system, but it will effect the air emissions generated by the vehicles. With both the Energy Policy Act and the Clean Air Act Amendments mandating alternative fuels for various categories of fleets, natural gas, methanol, ethanol and even electricity will pay some role in the transportation energy future of the region.

All of these alternatives have their own economic and environmental impacts; most can contribute to reduced CO and tropospheric ozone—smog. Others, such as natural gas and electricity, can reduce CO_2 emissions as well. Alcohol fuels have the possibility of being produced renewably from biomass resources, emitting negligible net CO_2. On the economic side, many of the alternative fuels (including natural gas, wind and gas based electricity, biomass), can be produced within the state. In the short term, natural gas could be used as the feedstock for methanol production, and in the longer term biomass could be added to produce methanol from an indigenous, renewable resource.

This task will categorize the various near-term options and evaluate their feasibility. Tellus will take the lead on analyzing the technology-related options, CTR will provide the leadership on the demand-related options. Feasibility will focus on cost and implementation issues.

Task 2 Develop and Apply a Computer Model to Examine Transportation—Energy Efficiency, Fuel Choice and Mode-shift—in Texas from a Multi-modal Perspective, Incorporating All Cost Components, Including Infrastructure, Operations and Social Costs.

CTR will provide the basic multimodal framework adapting it for use in the computer model and data base (LEAP/EDB) developed by Tellus. This model is an integrated tool for examining the full fuel consumption and cost aspects of various technology scenarios. The model will be calibrated to include assessment of demand-related transportation efficiency strategies.

2.1 Computer Framework for Integration of Transportation Energy and Environment in Texas

The team will utilize the *LEAP/EDB* computer model and database to integrate the energy, economic, and environmental analyses. *LEAP*, the Long-Range Energy Alternatives Planning system, and *EDB*, the Environmental Database, were developed by the Stockholm Environment Institute-Boston Center at Tellus Institute. The LEAP/EDB system was used as the data management system and scenario model to formulate *America's Energy Choices*, an alternative national energy strategy developed by Tellus Institute in consultation with ACEEE, Union of Concerned Scientists, Natural Resources Defense Council and Alliance to Save Energy. The project, funded by the Energy Foundation and completed in 1991, was a detailed and comprehensive energy, environment, and economic scenario analysis, which was followed by an employment impacts analysis. The analysis was performed on a regional basis, and the transportation sector—personal and freight—was represented in detail. Costs and emissions of alternative scenarios for efficiency, fuel choice, mode-shift were developed.

In this project, our scenarios using LEAP/EDB will consider an appropriate mix of efficiency gains, transportation demand management measures, and alternative fuels to meet the transportation requirements of the state. (See attachment C). We will use energy consumption data from E.I.A.'s National Energy Modeling Systems (NEMS) and/or its related models, synthesized for the state. These changes over time to the transportation sector in the state can result from both federal and state policies. We will highlight those to which state policies would best be addressed.

The energy efficiency technology and fuel switching options will be screened against avoided fuel and technology costs in each sector to identify those that will be cost-effective, and the results of these analyses will be incorporated into the LEAP/EDB system (in Task 2) to obtain the costs, electric system and fuel cycle impacts, and emissions.

The LEAP/EDB Model and Database System

LEAP/EDB is a computer model and data base system designed to provide information on the structure of an energy system and its costs and emissions characteristics, and to explore alternative energy futures along with their costs and principal environmental impacts. As a "bottom-up" model, its principal elements are the economic, energy, technology and emissions characteristics of end-use sectors and supply sources. It is ideally suited to create scenarios to guide policy development. (See attachment E).

The *LEAP* model has two important advantages. First, it allows very detailed specification for key physical parameters in each end-use sector. Thus, our scenarios will be able to embody the impacts of a variety of factors -- including energy prices, technological change, demographic variables, and structural shifts in the economy -- on energy use. Second, the accounting framework in LEAP enables it to take account of the full fuel cycle energy and emissions. For example, a reduction in petroleum use in the transport sector automatically leads to reductions in distribution losses and energy use for petroleum refining. LEAP/EDB can also keep track of the energy requirements for, and pollution resulting from, the extraction, processing, and distribution of fuels that provide the energy for each end-use.

LEAP (the Long-range Energy Alternatives Planning system), and EDB (the Environmental Data Base) are user-friendly, computer-based tools for integrated energy-environment planning, which was first developed in 1981 and has been used in many applications since. With the support of numerous international agencies, it has been continuously enhanced and updated to meet the needs of researchers and government agencies in both developing and industrialized countries.

In 1988, with support from the United Nations Environment Program (UNEP), the Stockholm Environment Institute - Boston (SEI-B) created the Environmental Data Base (EDB). EDB was designed to enable easy access to energy-related environmental loading data and to encourage the formulation of environmentally informed energy policy. Today, SEI-B and the UNEP Collaborating Centre on Energy and the Environment (UCC) are jointly engaged in the further development of LEAP and EDB to cover a broader range of fuel cycle issues.

LEAP Capabilities

LEAP is suitable for performing energy assessments of developing or industrialized countries, as well as of multi-country regions and local planning areas. Structured as a closely integrated family of computer programs, LEAP offers an accounting framework that can serve several purposes:

1. As a database it provides a comprehensive system for maintaining energy information;
2. As a forecasting tool, it enables the user to make integrated projections of energy supplies and demands over a medium or long-term planning horizon;
3. As a policy analysis tool, it simulates and assesses the physical, economic and environmental effects of alternative energy programs, investments and actions;
4. As a training and institution building tool, its simple structure, sample data sets, training notes and on-line help system make it a powerful educational resource.

The design of LEAP is guided by a number of methodological considerations. These include:

The Scenario Approach: Scenario analysis uses the computer to simulate alternative energy and economic futures under a range of different assumptions. A wide range of "what if" questions can be asked, such as: "what if all achievable cost-effective efficiency policies are pursued?", or "what if innovative patterns of industrialization and urban development are pursued?" Evaluations of the physical, economic and environmental impacts of alternative scenarios can help to guide the selection of appropriate energy policies.

Integrated Planning: LEAP stresses the importance of conducting energy analysis within a comprehensive planning framework that includes all fuels in the energy system (commercial fuels, biofuels, renewable energy); different stages of the fuel cycle (primary resource extraction, conversion, transmission, distribution, and final end-use consumption); separate geographical and demographic areas; and different sectors of the economy (households, industry, transport, agriculture, etc.).

End-Use, Needs-Driven Approach: In LEAP, resource requirements and supply-side projections are driven by an analysis of the energy services required by different economic sectors. This approach places development objectives, such as the provision of end-use goods and services, at the foundation of energy analysis.

Flexibility and User-Friendliness: For a software tool to be useful it needs to be flexible, expandable and comprehensive. LEAP is designed as a model building tool, not a rigidly structured model. Its expandable data structures can be adapted to diverse energy systems and analytical objectives. Its use of simple models whose structures (and hence results) are readily understandable, and its simple and intuitive menu-driven user-interface make LEAP usable by analysts and decision-makers with little computing experience.

Overcoming Data Constraints: Insufficient and unreliable quantitative data are a common obstacle to the use of models. LEAP is intended to be used in an iterative fashion to overcome this obstacle. An initial data set is gathered based on readily available sources for the first planning exercise. Initial runs produce preliminary outputs and energy policy analyses which help evaluate the status of existing data and identify areas where more or better information is required. Data can then be collected in a second iteration of the process.

LEAP/EDB Program Structures

LEAP consists of two blocks of programs: Energy Scenarios and Aggregation. The Energy Scenario programs address the main components of an integrated energy analysis. The Aggregation program can then be used to assemble these area level results into multi-area results. The Environmental Database (EDB), available separately or as part of the

LEAP system, provides a comprehensive summary of information linking energy production, conversion and consumption activities to air and water emissions, and other environmental and health consequences.

2.2 Representing the Texas Transportation System Energy, Cost and Environmental Characteristics and Evolution in LEAP/EDB for Multi-Modal Analysis.

Since LEAP/EDB has a great degree of flexibility in representing the details of energy systems it will be used here as our integrating framework for multi-modal analysis. This will allow ancillary analyses in this project and the relevant results of other studies, both current and to come, to be pulled together into a consistent representation.

Physical stock and demand, both current and forecast, available from National and State data and analyses, including work done under ISTEA in Texas, will be utilized as our point of departure. The multi-modal breakdown will be a matter for the project to determine in its early stages, based in large measure on the availability of reliable information and the most interesting technology and policy issues.

As example of what could be represented in LEAP/EDB is given in some detail in Appendices C and D of *America's Energy Choices*, (see Attachment D) which describe, respectively, our analyses of the personal and freight transportation sectors in detail. This can provide an idea of what we may undertake in this study. Personal transportation was broken out in LEAP into:

Private Transportation[4]

Light Truck/Van

With gasoline, diesel, cng, meth flex, meth neat, electric, fuel cell.
Each at several levels of efficiency.

Automobiles

With gasoline, diesel, cng, meth flex, meth neat, electric, fuel cell.
Each at several levels of efficiency.

Public Transportation

Bus

With gasoline, diesel, CNG, Electric.
Each at several levels of efficiency.

Rail

With diesel, electric.

[4] See Appendix C of America's Energy Choices in Attachment D for more detail.

Air
With jet fuel at different levels of efficiency (BTU/seat mi) depending on size and trip length.
Maglev; High Speed Rail

This representation took account of PMT, VMT, and load factor, as well as technologies, efficiencies and fuel mix, over time, in business-as-usual and policy scenarios. It also took account of mode shift opportunities between private and public modes of personal mobility.

Freight transport was broken down into twelve commodity groups, by ton-mile hauled, and a distinction was made between the portion that could and could not shift to rail. The LEAP analysis took account of improvements in fuel efficiency, mode shifts and shifts in the fuel mix.

Each vehicle, technology and fuel type is linked to its emissions factors in EDB, both directly through combustion and throughout the fuel cycle. Costs can be represented as well as energy use and emissions.

The foregoing discussion provided an example of how the LEAP/EDB structure permits detailed multi-modal representation of energy use (and emissions) for the transportation sectors. The options are by no means limited to those selected in that study. More detailed breakdown of technologies, efficiency improvements, and fuel choices can be utilized if desired and data permits. One can start with a relatively aggregated representation and move to increasing detail with a deepening of the study.

2.3 Characterizing the Texas Transportation System and Policies, and review the environmental issues for use in the LEAP/EDB Multi-Modal Analysis

A quantitative and qualitative assessment of the state transportation system, its physical characteristics, including energy use and pollutant emissions, will be prepared by CTR for use in the LEAP/EDB computer model. These inputs will serve as a basis for the analysis scenarios, together with a review of the environmental issues related to their direct and indirect effects of transportation systems on human health and on ecosystems. Additional impacts, as well as hidden subsidies may also warrant attention.

<u>Task 3 Develop Realistic and Reliable Estimates of the Economic and Technical Potential for Energy Savings and Energy Cost Savings in the Texas Transportation Sector.</u>

Once a fundamental data base has been compiled, LEAP and other software tools will be used to model the effects of alternative scenarios for Texas transportation, including energy consumption levels, equipment and fuel costs, and environmental emissions. This is the critical task for the study, and the scenarios examined will simulate and explore a range of different demographic, economic, regulatory and technological options. The LEAP model and other software as appropriate will be used to identify the most feasible alternatives for addressing transportation energy efficiency concerns in Texas.

The analysis will include the consequences of near-term and regulatory strategies that are already being considered in Texas and other states. These strategies include: drive-plus programs that discourage the purchase of autos with higher emissions and/or lower fuel efficiency; policies for procurement of public and private fleet vehicles; pay-as-you-drive insurance for autos; toll roads; pollution taxes, and others. Techniques to promote vehicle occupancy as well as mode shifting will also be represented and evaluated in light of existing and potential shifts in travel behavior and infrastructure. Results will be developed into a matrix comparing implementation complexity, political acceptability, costs, and energy benefits. The output will be a useful guide for policy makers in evaluating various energy efficiency strategies

<u>Task 4 Draft final report.</u>

As identified in the Project Management section, the research team will work closely with SECO. At the end of Tasks 1, 2, and 3, a draft report will be prepared and presented to SECO. This will give SECO the opportunity to provide additional comment and input. The report will document the development and results of tasks 1, 2 and 3, and it will provide guidelines for transportation policy and infrastructure improvements.

<u>Task 5 Provide Preliminary Briefings and Interim Reports to the Council.</u>

At the end of each task, the team will provide SECO with interim reports documenting the work progress and the task main conclusions, findings, and recommendations. Delivery of these interim reports will be scheduled simultaneously with preliminary briefings where the interim reports will be presented and discussed. These sessions will be completed in a single day in order to keep the project on schedule. A final briefing session will be conducted at the end of Task 6

Tasks 1, 2, and 3 will be completed prior to the convening of the state legislature, so the researchers will be available to provide a briefing for legislators and other entities as necessary. These briefings will be based on analyses, results, and policy recommendations developed in the project, and appropriately presented fro discussion at public forums. SECO and SEDC will be well situated to pursue an active and prominent role in public discussions, new legislation formulation, and development of administrative expenditures related to transportation efficiency, energy conservation, and transportation-related environmental issues.

Task 6 Release copies of the draft reports for public comment and incorporate comments received into the final report.

A final draft report will be prepared documenting all assumptions, findings and recommendations. This draft report will be submitted to SECO for assistance in gaining broader public input. Three weeks will be provided for public review. Based on a review of public comment with SECO, the final report will be prepared. All results will be documented thoroughly in this report. Recommendations with anticipated results will be summarized in a separate section of the report to assist policy makers in reviewing various transportation efficiency project alternatives. If necessary, the team will assist SECO with additional briefings to the legislature and other entities interested in discussing the final report. CTR's proximity to state offices will make it easy to accomodate the briefing needs of SECO.

B. SEQUENCE AND SCHEDULE OF ACTIVITIES

The tasks discussed in Section A consist of a sequence of acttivities tha have to be followed to carry out this project. CTR and Tellus will also provide preliminary briefings for Council staff at least once per month in person and via conference call, and will also send the Council written progress reports at the end of each task. If necessary, the team will also send brief progress reports at the end of each calendar month. Figure 3-10 depicts the schecule of activities. In this figure, the timeline represents each task's expected duration, and the double line represents a deliverable and a briefing.

This schedule can be modified via discussions with SECO staff as appropriate. In particular, since the RFP did not indicate how long a period must be allowed for public comment, we only allowed for about three weeks, since the schedule as a whole is very tight. More time may be required for public comment, and, therefore, for the schedule as a whole, particularly if the contract signing date is delayed significantly beyond June 7.

C. CURRENT WORKLOAD AND STAFFING LEVELS

This project requires a blend of technical, economical and managerial skills that can only be assembled by a combinaiton of teams of varied backgrounds. CTR and Tellus Institute have an ecletic staff of multiple backgrounds, and their level of participation in this study is presented in this section.

1. CTR

CTR is a not-for-profit research center of the University of Texas at Austin. Its current budget is over $8.7 million, and its staff includes 50 professors, engineers and economists, 45 technical and clerical staff, and 143 graduate students (Civil Engineering graduates). This project will not overburden CTR, and below is a list of CTR technical and managerial staff designated to this project.

Staff Member	Percent of Time
Mr. Euritt	30%
Dr. Jannini Weissman	38%
Mr. Harrison	11%
Mr. Qin	40%
Mr. Martello	38%

2. Tellus Institute

With a current staff of about 50, and a current annual budget of about $2 million, the addition of this project to the Energy Group's project list will not cause any problems with workload or staffing. Most Tellus projects last about 3 to 4 months and, therefore, the natural rate of projects beginning and ending allows for about 3 to 4 projects of this size to start-up each month.

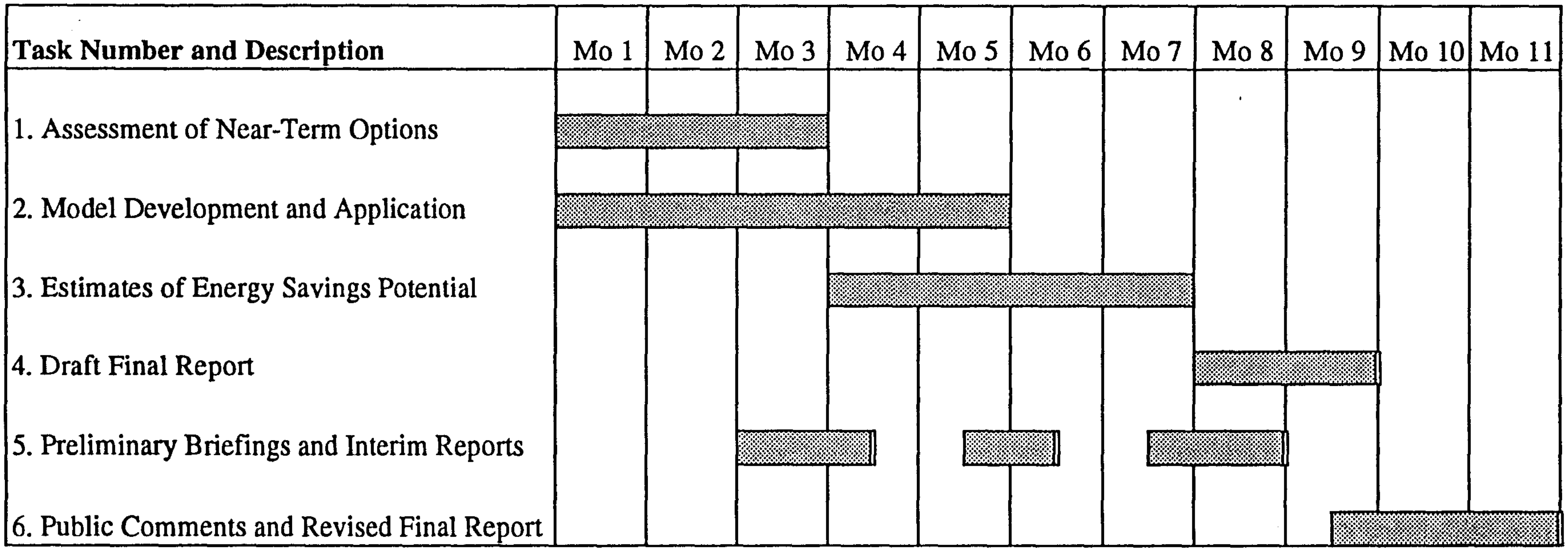
Below is a list of Tellus Institute's technical and managerial staff designated for this study, and their particiaption in this project in terms of percent of their total time.

Staff Member	Percent of Time
Mr. Fulmer	34%
Mr. Margolis	27%
Dr. Peters	15%
Dr. Bernow	14%
Mr. DeCicco	14%
Dr. Rosen	2%
Mr. Hornby	1%

Figure 3-10

Texas Multimodal Transportation Efficiency Study

Research Schedule



‖deliverable and briefing

D. REFERENCES

1. CTR

Mr. William Burnett, P.E.
Excutive Director
Texas Department of Transportation
125 East 11th Street
Austin, Texas 78701-2483
512-305-9501

Mr. James Griffin, P.E.
Deputy Director
Texas Turnpike Authority
P.O. Box 190369
Dallas, TX 75219
214-528-4826

Mr. Robert Cuellar, P.E.
Associate Executive Director
Texas Department of Transportation
125 East 11th Street
Austin, Texas 78701-2483
512305-9501

Mr. John Danks
Executive Director
Texas Propane Association
8408 North IH 35
P.O. Box 140735
Austin, TX 78714-0735
512-836-8620

Mr. Jacques Cellier
Senior Transportation Economist
World Bank
1818 H. Street, N.W.
Washington, D.C. 20433
202-473-9326

The Honorable Robert Early
Chairman, Committee on Energy Resources
Texas House of Representatives
P.O. Box 2910
Austin, TX 78768-2910
512-463-0512

Mr. Dock Burke
Director
Southwest Region University Transportation Center
Texas A&M University
College Station, TX 77843
409-845-5815

2. Tellus

Dr. Susan Tierney
Assistant Secretary
Policy, Planning and Program Evaluation
U.S. Department of Energy, PO1
1000 Independence Ave, SW
Washington, D.C. 20585

Larry De Witt
Director
Office of Energy Efficiency and Environment
New York State Public Service Commission
3 Empire State Plaza
Albany, New York 12223

Dr. Jack White
Senior Director
Energy Programs
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370 L'Enfant Promenade
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Rick Morgan
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Office of Air and Radiation
U.S. Environmental protection Agency
401 M Street SW, RM 3202
Washington, DC 20406

Eric Hirst
Oak Ridge National Laboratory
616-576-5454

Art Rosenfeld
Lawrence Berkeley Laboratory
Berkeley, California
202-785-2666

Hal Harvey
The Energy Foundation
San Francisco, CA
415-546-7400

Irwin (Sonny) Popowsky
Consumer Advocate of Pennsylvania
1425 Strawberry Square
Harrisburg, PA 17120
(717) 783-5048

Cheryl Harrington
Ex-Maine PUC Commissioner
Regulatory Assistance Project
Winthrop, Maine
(207) 582-1135

REFERENCES TO SECTION 3

(1) Delivering the Goods. Summary: Public Works Technologies, Management, and Financing, Report OTA-SET-478, Office of Technology Assessment, U.S. Congress, April 1991.

(2) James J. MacKenzie, Roger C. Dower, Donald D.T. Chen, The Going Rate: What it Really Costs to Drive, World Resource Institute, Washington, D.C., June 1992.

(3) Transportation Research Board, ISTEA and Intermodal Planning: Concept, Practice, Vision. Special Report 240, National Research Council, (National Academy Press: Washington, D.C.), 1993.

(4) Energy Information Administration, U.S. Department of Energy, Annual Energy Review 1992, Washington, D.C., June 1993.

(5) Stacy C. Davis and Sonja G. Strange. Transportation Energy Data Book: Edition 13, Oak Ridge National Laboratory, Oak Ridge, Tennessee, March 1993.

(6) Energy Information Administration, U.S. Department of Energy, State Energy Data Report: Consumption Estimates 1960-1990, Washington, D.C., May 1992.

(7) The Clean Fuels Report, Vol. 5, No. 4, J.E. Sinor Consultants, Inc., Niwot, Colorado, September 1993.

(8) DeShazo, Starek, & Tang, Inc. and Houston Advanced Research Center. "Alternative Fuels and Vehicles Workshop," February 2, 1993 (Notebook).

(9) Hitchcock, David. "The Energy Policy Act of 1992," Alternative Fuels Transportation Briefs, No. 1-6, Houston Advanced Research Center, July 1993.

(10) Hitchcock, David. "Texas Alternative Fuels Legislation -- SB 740 and SB 769," Alternative Fuels Transportation Briefs, No. 1-1, Houston Advanced Research Center, February 1991.

(11) Euritt, Mark A., Dean B. Taylor, and Hani Mahmassani. Cost Effectiveness Analysis of TxDOT CNG Fleet Conversion: Volume I, Research Report 983-2/1,

Center for Transportation Research, The University of Texas at Austin, August, 1992.

(12) Euritt, Mark A., Dean B. Taylor, and Hani Mahmassani. Cost Effectiveness Analysis of TxDOT LPG Fleet Conversion: Volume I, Research Report 983-4/1, Center for Transportation Research, The University of Texas at Austin, October, 1992.

(13) Hitchcock, David. "1993 Texas Alternative Fuels Legislation: Senate Bills 737 and Senate Bill 7," Alternative Fuels Transportation Briefs, No. 1-5, Houston Advanced Research Center, June 1993.

(14) Richard A. Corbett, Oil and Gas Journal, June 18, 1990.

(15) National Energy Strategy: Powerful Ideas for America, Washington, D.C., February 1991.

(16) Environmental Protection Agency, Office of Air Quality. National Air Quality and Emissions Trends Report, 1992, EPA 454/R-93-031, Research Triangle Park, North Carolina, October 1993.

(17) Energy Information Administration, U.S. Department of Energy, Annual Energy Outlook 1994, Washington, D.C., 1994.

SECTION 4
PROJECT BUDGET

The following budget will provide the necessary support to complete the work tasks defined in the previous section and accomplish the project objectives. CTR will subcontract with Tellus Institute to complete their portion of the study.

Budget Summary

PERSONNEL			
Salaries	$59,211		
Fringe Benefits	$15,395		
Subtotal		$74,606	
TRAVEL*			
Airfare, per diem, mileage, and other direct travel expenses		$ -0-	
OTHER DIRECT OPERATING EXPENSES			
Reproduction, printing, graphics, postage, shipping, communications, supplies		$3,121	
SUBCONTRACT - Tellus Institute*		$95,000	
TOTAL DIRECT COSTS			$172,727
INDIRECT COSTS (10% of Direct)			$17,273
TOTAL PROJECT COSTS			$190,000

* The subcontract with Tellus Institute includes $2,005 for travel.

In addition to this budget, Figure 4-1 provides a more detailed plan by Work Task. These hours can be adjusted to reflect changes in emphasis as desired by SECO. Following award of the contract, the project managers will consult with SECO staff to adjust these work task assignments, if necessary. The project managers will use this task effort to assist in monitoring study progress and budget.

Figure 4-1
Task Budget

PERSONNEL			Task 1		Task 2		Task 3		Task 4		Task 5		Task 6		Total	
CTR - Univ. Texas	**Project Role**	**Rate/Hr.**	Hours	Cost	Hours	Cost	Hours	Cost	Hours	Cost	Hours	Cost	Hours	Cost	Hours	Cost
Mr. Mark Euritt	Project Director, PI	$31.80	100	$3,180	120	$3,816	100	$3,180	75	$2,385	25	$795	25	$795	445	$14,151
Dr. Angela Weissmann	Project Manager, PI	$28.85	90	$2,597	150	$4,328	180	$5,193	80	$2,308	25	$721	25	$721	550	$15,868
Mr. Robert Harrison	Economist	$42.69	40	$1,708	80	$3,415	30	$1,281	20	$854	20	$854	20	$854	210	$8,965
Mr. Michael Martello	Research Analyst	$13.85	75	$1,039	250	$3,463	213	$2,950	50	$693	20	$277	20	$277	628	$8,698
Mr. Jiefing Qin	Computer Analyst	$13.85	75	$1,039	250	$3,463	305	$4,224	24	$332	20	$277	20	$277	694	$9,612
Staff	Support	$10.96	25	$274	25	$274	25	$274	60	$658	20	$219	20	$219	175	$1,918
Fringe Benefits	26.0% of Direct			$2,557		$4,877		$4,447		$1,880		$817		$817		$15,395
Subtotal CTR Personnel			405	$12,393	875	$23,635	853	$21,549	309	$9,109	130	$3,960	130	$3,960	2,702	$74,606
Tellus Institute																
Stephen Bernow	Project Manager, PI	$126.00 *	48	$6,048	40	$5,040	40	$5,040	16	$2,016	16	$2,016	16	$2,016	176	$22,176
Mark Fulmer	Research Analyst	$55.00 *	200	$11,000	64	$3,520	130	$7,150	32	$1,760	24	$1,320	0	$0	450	$24,750
John DeCicco	Research Analyst	$90.00 *	104	$9,360	24	$2,160	34	$3,060	0	$0	24	$2,160	0	$0	186	$16,740
Robert Margolis	Modeling Analyst	$47.00 *	32	$1,504	200	$9,400	64	$3,008	0	$0	24	$1,128	0	$0	320	$15,040
Irene Peters	Research Analyst	$55.00 *	40	$2,200	56	$3,080	63	$3,465	0	$0	32	$1,760	0	$0	191	$10,505
Richard Rosen	Technical Reviewer	$126.00 *	0	$0	0	$0	0	$0	0	$0	24	$3,024	0	$0	24	$3,024
Richard Hornby	Research Analyst	$95.00 *	0	$0	0	$0	8	$760	0	$0	0	$0	0	$0	8	$760
* includes fringe benefits																
Subtotal Tellus Institute Personnel			424	$30,112	384	$23,200	339	$22,483	48	$3,776	144	$11,408	16	$2,016	1,355	$92,995
Total Personnel (CTR and Tellus)			829	$42,505	1,259	$46,835	1,192	$44,032	357	$12,885	274	$15,368	146	$5,976	4,057	$167,601
TRAVEL - Tellus																
Boston-Austin				$1,000		$0		$0		$0		$1,005		$0		$2,005
Total Travel-Tellus				$1,000		$0		$0		$0		$1,005		$0		$2,005
OTHER DIRECT OPERATING EXPENSE																
Reproduction/Printing/Graphics				$175		$175		$175		$500		$500		$176		$1,701
Postage/Shipping				$100		$100		$100		$100		$100		$100		$600
Communications				$100		$100		$100		$100		$100		$100		$600
Other Misc. Supplies				$30		$30		$30		$30		$70		$30		$220
Total Other Direct Operating Expense				$405		$405		$405		$730		$770		$406		$3,121
TOTAL DIRECT COSTS				$43,910		$47,240		$44,437		$13,615		$17,143		$6,382		$172,727
Indirect Costs	10% of Direct			$4,391		$4,724		$4,444		$1,361		$1,714		$638		$17,273
TOTAL ESTIMATED COST				$48,301		$51,964		$48,880		$14,976		$18,858		$7,021		$190,000

SECTION 5
CONFLICTS OF INTEREST

The Center for Transportation Research has no conflict of interest whatsoever regarding the project proposed herein.

The Tellus Institute has no conflict of interest whatsoever regarding the project proposed herein.

ATTACHMENT A

RESUMES

Mark Allen Euritt

PROFESSIONAL EXPERIENCE

ASSOCIATE DIRECTOR FOR ALTERNATIVE TRANSPORTATION FUELS RESEARCH, Center for Transportation Research, The University of Texas at Austin, July 1993 to present.

PROJECT COORDINATOR/RESEARCH ASSOCIATE, Center for Transportation Research, The University of Texas at Austin, April 1990 to June 1993.

RESEARCH SCIENTIST ASSOCIATE II, Center for Transportation Research, The University of Texas at Austin, January 1986 to March 1990.

GRADUATE RESEARCH ASSISTANT, Center for Transportation Research, The University of Texas at Austin, August 1984 to December 1985.

RESEARCH ASSOCIATE, Policy Research Institute, The University of Texas at Austin, January 1984 to August 1984.

MANAGEMENT INTERN for the Assistant City Manager for Public Safety, Plano, Texas, June 1983 to August 1983.

ADJUNCT INSTRUCTOR, Washington International College, Washington, D.C., October 1981 to January 1982.

RESEARCH ASSISTANT, U.S. Department of Education, School Finance Project, Washington, D.C., January 1981 to July 1982.

RESEARCH INTERN, Education Policy Research Institute of the Educational Testing Service, Washington, D.C., August 1980 to December 1980.

Consulting for the following:

HIGHWAY FINANCE CONSULTANT, Ministry of Transportation and Communi-cations, Venezuela, through KEISAI Asociados, September 1993 to March 1994.

HIGHWAY FINANCE SPECIALIST, KEISAI Asociados, Caracas, Venezuela, March 1993.

COST ALLOCATION SPECIALIST, Conrail, Inc., Philadelphia, Pennsylvania, through the Texas Research and Development Foundation, 1991-1992.

POLICY CONSULTANT, Texas LP-Gas Association, Austin, Texas, February 1992 to May 1992.

TRANSPORT ECONOMIST, Federal Ministry of Works and Housing, Nigeria, Africa, through the Texas Research and Development Foundation, October 1991 to January 1992.

COST ALLOCATION SPECIALIST, Austin Research Engineers, Austin, Texas, 1989.

ANALYST, Rauh, Silard, and Lichtman, Washington, D.C., 1982.

EDUCATION

MASTER OF PUBLIC AFFAIRS - Lyndon B. Johnson School of Public Affairs, The University of Texas at Austin, 1985.

MASTER OF BUSINESS ADMINISTRATION - The University of Texas at Austin, 1985.

BACHELOR OF SCIENCE - Northwest Missouri State University, 1980. Major - Political Science; Minor - Humanities.

Professional Development

Certificate of Achievement in the Society of Automotive Engineers Professional Development Program, "Natural Gas Vehicles: Today and in the Future," March 1991.

Certificate of Achievement in the Society of Automotive Engineers Professional Development Program, "Alternative Fuels: Overview of Current and Future Technology," April 1991.

Certificate of Achievement in the Society of Automotive Engineers Professional Development Program, "Emissions from Alternative Fueled Engines," December 1991.

AWARDS AND HONORS

Lyndon B. Johnson Fellowship (1982-3)
Graduated with Highest Honors from Northwest Missouri State University (1980)
Pi Gamma Mu Social Science Honor Society (1979-80)
H.F. Holland Scholarship (1979-80)
Thomas E. Coleman Scholarship (1979-80)
Northwest Missouri State University Nominee for the Harry S. Truman National Fellowship (1979)
University Scholars Award (1978-80)
Regents Scholarship (1977-78)
Missouri State High School Activities Association Debate Champion (1977)

MEMBERSHIPS AND AFFILIATIONS

Alternative Fuels Laboratory Advisory Council, Austin Texas, 1994.

Program Committee of the International Dedicated Conference on Electric, Hybrid and Alternative Fuel Vehicles, Aachen Germany, 1993-1994.

Advisory Board, South Central Electric Vehicle Institute, 1993.

Transportation Economics Committee of the Transportation Research Board, National Research Council, Washington, D.C., 1993 (previously friend of Committee from 1986-1992).

Transportation and Air Quality Committee of the Transportation Research Board, National Research Council, Washington, D.C., 1993 (Associate Member).

Alternative Transportation Fuels Committee of the Transportation Research Board, National Research Council, Washington, D.C., 1993 (Friend of the Committee).

MEMBERSHIPS AND AFFILIATIONS, continued

Program Committee on Advanced Transport Telematics/Intelligent Vehicle Highway Systems of the International Symposium on Automotive Technology and Automation, 1993.

Society of Automotive Engineers, 1992-1993.

State of Texas Energy Policy Partnership, Committee on Alternative Transportation Fuels, Texas Railroad Commission, 1992.

UT Austin Committee to Assess the National Energy Strategy, 1991 (Contributing author).

Taxation, Finance, and Pricing Committee of the Transportation Research Board, National Research Council, Washington, D.C., 1990 - present .

Highway User Operational Information Study Advisory Group, Texas State Department of Highways and Public Transportation, 1988 - 1990.

Federal and State Programs for Special Purposes, American Educational Research Association, 1982 Annual Meeting, New York, NY, March 22, 1982.

Energy and Education Task Force of the Federal Inter-agency Committee on Education, Washington, D.C., 1981.

RESEARCH PROJECTS

"Impacts of Current Financing Methods on Transit Systems and Evaluation of Alternative Financing Schemes," for Texas Department of Transportation, September 1993 - August 1995, Co-Principal Investigator

"Estudio de Cargos A Los Usuarios De Las Vias Y Asignacion De Recursos A La Vialidad (Highway Cost Responsibility and User Cost Recovery Study)," for the Venezuelan Ministry of Transportation and Communications, September 1993 - February 1994, Consultant.

"Multimodal Investment Analysis: A Corridor Study of Energy Efficiency and Cost Effectiveness," for Southwest Region University Transportation Center, Texas Oil Overcharge Funds, 1993-1994, Research Supervisor.

"Energy Impacts of Natural Gas Vehicle Operations for Transit," for Southwest Region University Transportation Center, Texas Oil Overcharge Funds, 1992-1994, Research Supervisor.

"Energy Impacts of Electric Vehicle Operations for Capital Metro," for Southwest Region University Transportation Center, Texas Oil Overcharge Funds, 1992-1994, Research Supervisor.

"An Evaluation of the Status, Effectiveness, and Future of Toll Roads in Texas," for Texas Department of Transportation, begins September 1992 - December 1994, Co-Principal Investigator.

"Cost Allocation Procedure Enhancement - Revenue Analysis," for Texas Department of Transportation, 1992-1994, Co-Principal Investigator.

RESEARCH PROJECTS, continued

"Privatization of Fixed Route Bus Service: Evaluation and Cost Comparison," for Capital Metropolitan Transportation Authority, Austin, Texas, 1992-1994, Co-Principal Investigator.

"Energy Savings from an Urban CNG-Operated Taxi Company," for Texas Department of Transportation, 1992 - 1993, Principal Investigator.

"Truck to Rail Freight Diversion in Pennsylvania," for Conrail, April 1992 - August 1992, Consultant.

"Evaluation of LP-Gas Regulations for Texas," for Texas LP-Gas Association, February - March 1992, Consultant.

"Multi-State Roads Project for Nigeria," for Federal Ministry of Works and Housing, Government of Nigeria, October 1991 - January 1992, Transport Economist-Consultant.

"Highway Privatization in Texas," for Texas State Department of Highways and Public Transportation, September 1991 - August 1993, Co-Principal Investigator.

"Increasing Mobility and Economic Development through Multimodal Centers," for Texas State Department of Highways and Public Transportation, September 1991 - August 1993, Co-Principal Investigator.

"Impact of Alternative Fuels on State Highway Financing," for Southwest Region University Transportation Center, U.S.D.O.T. Funds, June 1991 - August 1992, Research Supervisor.

"Comprehensive Study Design for the 'Before' and 'After' Assessment of the Dallas Rail Transit Starter Line," for Southwest Region University Transportation Center, Texas Oil Overcharge Funds, September 1990 - August 1991, Co-Principal Investigator.

"Economic Impact of Highway Bypasses and Loops," for Texas State Department of Highways and Public Transportation, September 1990 - August 1992, Co-Principal Investigator.

"Transportation Energy Impacts of Clean Air Legislation," for Southwest Region University Transportation Center, Texas Oil Overcharge Funds, June 1990 - August 1991, Co-Principal Investigator.

"Transit Station Energy Savings," for Southwest Region University Transportation Center, Texas Oil Overcharge Funds, June 1990 - August 1991, Research Supervisor.

"Feasibility of Safety Rest Area Commercialization in Texas," for Texas State Department of Highways and Public Transportation, September 1990 - August 1992, Co-Principal Investigator.

"Evaluation of Transportation Corporations and Road Utility Districts," for Texas State Department of Highways and Public Transportation, September 1990 - August 1992, Co-Principal Investigator.

"System Cost Analysis of Truck Freight on Interstate 80 in Pennsylvania," for Conrail, September 1990 - August 1991, Consultant.

RESEARCH PROJECTS, continued

"Improved Energy Efficiency Through Better Urban Intermodal Coordination," for Southwest Region University Transportation Center, Texas Oil Overcharge Funds, June 1990 - August 1991, Co-Principal Investigator.

"Conversion of the SDHPT Automotive Fleet to Alternative Fuels," for Texas State Department of Highways and Public Transportation, June 1990 - August 1992, Co-Principal Investigator.

"Conversion of the SDHPT Six and Ten Yard Dump Truck Fleet from Standard to Automatic Transmissions," for Texas State Department of Highways and Public Transportation, November 1989 - August 1991, Co-Principal Investigator.

"Evaluating the Coordination of Intermodal Transportation Policies and Programs to Promote Economic Growth," for Southwest Region University Transportation Center, U.S.D.O.T. Funds, September 1988 - August 1992, Co-Principal Investigator.

"Comparison of Cost Responsibility Studies," for Texas State Department of Highways and Public Transportation, June 1988 - August 1991, Co-Principal Investigator.

"Highway User Operational Information," for Texas State Department of Highways and Public Transportation, September 1987 - August 1990, Co-Principal Investigator.

"Fixed-Guideway Evaluation Criteria Study," for Capital Metropolitan Transportation Authority, April 1988 - February 1989, Co-Principal Investigator.

"Long Range Railroad Management Alternatives," for Capital Metropolitan Transportation Authority and City of Austin, March 1988 - December 1988, Principal Investigator.

"Compilation of Texas Trucking Industry Statistics," for Texas Motor Transportation Association, February 1988 to August 1988, Principal Investigator.

"Extend and Improve the Texas Highway Cost Allocation Analysis," for Texas State Department of Highways and Public Transportation, September 1985 - November 1987, Co-Principal Investigator.

"Permit Fees for Overweight Vehicles," for Texas State Department of Highways and Public Transportation, September 1984 - December 1984, Research Staff.

"Texas Highway Cost Index Analysis," for the Texas Governor's Office, 1984, Research Staff.

"Analysis of Truck Use and Highway Cost Allocation in Texas," for Texas State Department of Highways and Public Transportation, September 1982 - August 1985, Research Staff.

"Alternative Service Delivery Methods," Lyndon B. Johnson School of Public Affairs Policy Research Project for the City of Austin," September 1982 - May 1983, Research Staff.

PUBLISHED PAPERS AND REPORTS

"A Highway Maintenance Cost Recovery Program for Venezuela," Paper prepared for presentation to the International Road Federation Conference, Calgary, Alberta, Canada, July 5, 1994 (with R. Harrison, M. Orellana, and N. Reines).

An Overview of Highway Privatization, Report 1281-1, Center for Transportation Research, The University of Texas at Austin, March 1994 (with R. Machemehl, R. Harrison, and J. Jarrett).

Strategic and Implementation Issues in Texas' Public-Private Transportation Projects, Research Report 1281-3F, Center for Transportation Research, The University of Texas at Austin, February 1994 (with J. Jarrett, R. Machemehl, and R. Harrison).

"A Framework for Evaluating TCMs: Mobility, Air Quality, and Energy Consumption Tradeoffs," Paper prepared for presentation to the 73rd Annual Meeting of the Transportation Research Board, National Research Council, Washington, D.C., January 1994 (with J. Qin, J. Meesomboon, and C. Walton).

"Cost Effectiveness Analysis of Texas Department of Transportation Compressed Natural Gas Fleet Conversion," in Transportation Research Record 1416 - Environmental Analysis, Air Quality, Noise, Energy, and Alternative Fuels, Transportation Research Board, National Research Council, Washington, D.C., 1993 (with D. Taylor and H. Mahmassani).

Estudio De Cargos A Los Usuarios De Las Vias Y Asignacion De Recursos A La Vialidad: Volumen I - Documento Principal, Venezuelan Ministry of Transportation and Communications, Caracas, Venezulea, December 1993 (with R. Harrison, N. Reines, M. Orellana, J. Weissmann, J. Sabal).

Estudio De Cargos A Los Usuarios De Las Vias Y Asignacion De Recursos A La Vialidad: Volumen II-1 - Anexos sobre la Vialidad, Costos y Clasificacion, Venezuelan Ministry of Transportation and Communications, Caracas, Venezulea, December 1993 (with R. Harrison, N. Reines, M. Orellana, J. Weissmann, J. Sabal).

Estudio De Cargos A Los Usuarios De Las Vias Y Asignacion De Recursos A La Vialidad: Volumen II-2 - Anexos sobre los Ingresos, Venezuelan Ministry of Transportation and Communications, Caracas, Venezulea, December 1993 (with R. Harrison, N. Reines, M. Orellana, J. Weissmann, J. Sabal).

Estudio De Cargos A Los Usuarios De Las Vias Y Asignacion De Recursos A La Vialidad: Volumen III - Presentacion a los Comites Directivo y Tecnico, Venezuelan Ministry of Transportation and Communications, Caracas, Venezulea, December 1993 (with R. Harrison, N. Reines, M. Orellana, J. Weissmann, J. Sabal).

Texas Highway Cost Allocation Analysis and Estimates, 1992-1994, Research Report 1919-2, Center for Transportation Research, The University of Texas at Austin, and the Texas Transportation Institute, Texas A&M University, November 1993 (with C. Walton, Z. Goff, and D. Burke).

Cost-Effectiveness Analysis of CNG Urban Taxi Operations, Research Report 3003-1F, Center for Transportation Research, The University of Texas at Austin, October 1993.

"Framework for Evaluation of TCM Effectiveness," in Transportation Planning Methods Applications: Volume I, Transportation Research Board, 4th National Conference on Transportation Planning Methods Applications, Daytona Beach, Florida, September 1993 (with J. Qin, J. Meesomboon, and C. Walton).

PUBLISHED PAPERS AND REPORTS, continued

Reliability of Toll Road Revenue Forecasts for Selected Toll Roads in the United States, Research Report 1281-2, Center for Transportation Research, The University of Texas at Austin, July 1993 (with B. Dedeitch, R. Machemehl, R. Harrison, and C. M. Walton).

Dallas Area Rapid Transit Impact Study: A Framework for Assessing Land Use and Development Impacts, Research Report SWUTC/92/60024-1, Southwest Region University Transportation Center, University of Texas at Austin, May 1993 (with P. Coleman and C. M. Walton).

State of Texas Energy Policy Partnership, Volume I, Report to the Governor, The Legislature, and The Citizens of Texas, March 1993, Austin, Texas (member of STEPP).

State of Texas Energy Policy Partnership, Volume II, Committee Reports, March 1993, Austin, Texas, (member of STEPP).

"Economic Impact of Highway Bypasses," in Transportation Research Record 1395 - Finance, Taxation, Pricing, Economic Analysis, Socioeconomics, Education, and Management, Transportation Research Board, National Research Council, Washington, D. C., 1993 (with J. Andersen, H. Mahmassani, R. Helaakoski, C. Walton, and R. Harrison).

"Determining Truck System Costs for the Pennsylvania Interstate 80 Corridor," in Transportation Research Record 1359 - Economics, Finance, and Administration, Transportation Research Board, National Research Council, Washington, D. C., 1992 (with M. McNerney and R. Harrison).

"Economic Evaluation of Compressed Natural Gas Fleet Conversion and Operation," in Transportation Research Record 1366 - Air Quality, Environment, and Energy, Transportation Research Board, National Research Council, Washington, D. C., 1992 (with D. Taylor and H. Mahmassani).

Transit Station Energy Impacts, Research Report SWUTC/92/60033-1, Southwest Region University Transportation Center, University of Texas at Austin, December 1992, (with P. Coleman, C. M. Walton).

"A Social Cost Index for Motor Vehicles: Concept Paper," in Memorias: Sistevu II, Segundo Seminario Internacional de Sistemas de Transporte y Vialidad Urbana, Puerto Vallarta, Jalisco, Mexico, Dec. 10-12, 1992.

1990 Texas Highway Cost Responsibility Revenue and Equity Analysis, Briefing Report 1919-1, Center for Transportation Research, The University of Texas at Austin, November 1992 (with C. Walton).

Economic Effects of Highway Bypasses on Business Activities in Small Cities: Final Report, Research Report 1247-3F, Center for Transportation Research, The University of Texas at Austin, November 1992 (with J. Andersen, R. Harrison, H. Mahmassani, and C. Walton).

Multimodal Planning and Transportation Centers: Interim Report, Research Report 1282-1, Center for Transportation Research, The University of Texas at Austin, November 1992 (with D. Noble, R. Harrison, and C. Walton).

PUBLISHED PAPERS AND REPORTS, continued

Feasibility of Safety Rest Area Commercialization in Texas, Research Report 1269-1F, Center for Transportation Research, The University of Texas at Austin, November 1992 (with R. Harrison and S. Grant).

Transportation Corporations and Road Utility Districts: The Texas Experience, Research Report 1270-1F, Center for Transportation Research, The University of Texas at Austin, November 1992 (with A. Almquist and C. Walton).

Vehicular Fleet Operation on Natural Gas and Propane: An Overview, Research Report 983-5F, Center for Transportation Research, The University of Texas at Austin, November 1992 (with D. Taylor and H. Mahmassani).

Truck to Rail Diversion Over the Conrail Network Using Pennsylvania I-80 Corridor Data, Texas Research and Development Foundation, Austin, Texas, October 1, 1992 (with R. Harrison).

Cost Effectiveness Analysis of TxDOT LPG Fleet Conversion, Research Report 983-4, Volume 1, Center for Transportation Research, The University of Texas at Austin, October 1992 (with D. Taylor and H. Mahmassani).

Cost Effectiveness Analysis of TxDOT LPG Fleet Conversion, Research Report 983-4, Volume 2, Center for Transportation Research, The University of Texas at Austin, October 1992 (with D. Taylor and H. Mahmassani).

Traffic and Spatial Impacts and the Classification of Small Bypassed Cities, Research Report 1247-2, Center for Transportation Research, The University of Texas at Austin, October 1992 (with J. Andersen, H. Mahmassani, C. Walton, and R. Harrison).

Economic Effects of Highway Bypasses on Business Activities in Small Cities, Research Report 1247-1, Center for Transportation Research, The University of Texas at Austin, October 1992 (with R. Helaakoski, H. Mahmassani, C. Walton, and R. Harrison).

Documentation for Propane Fleet Conversion Cost-Effectiveness Model, Research Report 983-3, Center for Transportation Research, The University of Texas at Austin, August 1992 (with D. Taylor and H. Mahmassani).

Cost Effectiveness Analysis of TxDOT CNG Fleet Conversion, Research Report 983-2, Volume 1, Center for Transportation Research, The University of Texas at Austin, August 1992 (with D. Taylor and H. Mahmassani).

Cost Effectiveness Analysis of TxDOT CNG Fleet Conversion, Research Report 983-2, Volume 2, Center for Transportation Research, The University of Texas at Austin, August 1992 (with D. Taylor and H. Mahmassani).

LPG Pressure Vessel Regulation: Safety and Economic Issues for Texas, Consultant Report for the Texas LP-Gas Association, April 27, 1992.

"Rest Area Privatization," in Memorias de los Temas Presentados, Fourth Annual International Conference for Transportation Engineers, Asociacion Regional de Caminos de Nuevo Leon, A.C., Monterrey, Mexico, February 13-14, 1992.

PUBLISHED PAPERS AND REPORTS, continued

"A Flexible Framework for Assessing Land Use and Development Impacts: An Approach for Dallas Area Rapid Transit," Paper prepared for presentation at the 71st Annual Meeting of the Transportation Research Board, National Research Council, Washington, D.C., January 1992 (with P. Coleman and C. Walton).

Documentation for CNG Fleet Conversion Cost-Effectiveness Model, Research Report 983-1, Center for Transportation Research, The University of Texas at Austin, December 1991 (with D. Taylor and H. Mahmassani).

UT Austin Committee to Assess the National Energy Strategy: Final Report, White Paper, November 1991 (with other committee members).

UT Austin Committee to Assess the National Energy Strategy: Final Report, Vol. I, Summary of Committee Analysis, November 1991 (with other committee members).

UT Austin Committee to Assess the National Energy Strategy: Final Report, Vol. II, Committee Analysis, November 1991 (with other committee members).

Conversion of the Texas Department of Transportation 6- and 10-Yard Dump Truck Fleet From Standard to Automatic Transmissions, Research Report 979-1F, Center for Transportation Research, The University of Texas at Austin, November 1991 (with J. Weissmann and R. Harrison).

Analysis of Texas Highway Cost Responsibility, Research Report 1937-1F, Center for Transportation Research, The University of Texas at Austin, October 1991 (with C. Walton).

Truck Versus Rail Freight System Cost Comparison: Conrail and I-80 Pennsylvania Corridors, Texas Research and Development Foundation, Austin, Texas, September 30, 1991 (with R. Harrison, M. McNerney, W. Hudson).

"Alternative Roadway Financing Methods," in 20th Seminario De Ingenieria De Transito, Asociacion Mexicana De Caminos, Mexico City, Mexico, September 27, 1991.

"Advanced Communication and Information Technologies in Intermodal Transportation," Paper prepared for presentation at the 70th Annual Meeting of the Transportation Research Board, National Research Council, Washington, D.C., January 1991 (with E. Jones, K. Young, and C. Walton).

"The Coordination of Container Weight Limits Between Ocean Carriers and Truckers," Paper prepared for presentation at the 70th Annual Meeting of the Transportation Research Board, National Research Council, Washington, D.C., January 1991 (with M. Kiesling and C. Walton).

An Analysis of Roadway User Information Systems, Research Report 957-2F, Center for Transportation Research, The University of Texas at Austin, November 1990 (with K. Emhjellen, S. Govind, C. Walton, and W. Ward).

"Highway Finance and the Private Sector: Issues and Alternatives," in Transportation Research: An International Journal: Special Issue - Financing Transportation Infrastructure, Vol. 24A, No. 4, July 1990 (with C. Walton).

PUBLISHED PAPERS AND REPORTS, continued

"Conceptual Model of the Fixed-Guideway Decision Process," in Transportation Research Record 1266 - Urban Public Transportation Research, Transportation Research Board, National Research Council, Washington, D. C., 1990 (with M. Hoffman and C. Walton).

Railroad Right-of-Way Management: Issues and Strategies, Center for Transportation Research, The University of Texas at Austin, July 1989.

The Decision Process for Implementing Fixed-Guideway Systems, Center for Transportation Research, The University of Texas at Austin, March 1989 (with M. Hoffman and C. Walton).

"Transportation Finance in Medium and Small Cities," Paper presented to the National Conference on Effective Planning Techniques for Small and Medium-Sized Urban Areas, Phoenix, Arizona, December 6-8, 1988 (with C. Walton).

The Texas Motor Carrier Industry: Statistics and Sources of Information, Center for Transportation Research, The University of Texas at Austin, August 1988 (with D. Eugene).

The Texas Highway Cost Allocation Study, Research Report 390-1F, Center for Transportation Research, The University of Texas at Austin, and the Texas Transportation Institute, Texas A&M University, December 1987 (with A. Villarreal, D. Burke, and C. Walton).

"Economic Factors of Developing Fine Schedules for Overweight Vehicles in Texas," in Transportation Research Record 1116 - Transportation Economics: Issues and Impacts, Transportation Research Board, National Research Council, Washington, D. C., 1987.

"Load Studies in Texas," in Annual Report 1987: Center for Transportation Research, The University of Texas at Austin, 1987 (with J. Lundy).

"Private Participation in Financing Highway Projects and Providing Property for Highway Improvements," in Understanding the Highway Finance Evolution/Revolution, American Association of State Highway and Transportation Officials, January 1987 (with C. Walton and R. Souleyrette II).

"Alternative Roadway Financing Methods: National Examples and Recent Experiences in Texas," in Transportation Research Record 1077 - Highway Finance and Management Issues, Transportation Research Board, National Research Council, Washington, D. C., 1986 (with C. Walton).

"Innovative Roadway Financing in Texas," in Technical Quarterly, Texas State Department of Highways and Public Transportation, Summer/Fall 1986, Vol. 2, Issue 2 (with C. Walton).

"Private Participation in Financing Highway Projects and Providing Property for Highway Improvements," Paper prepared for the National Conference on Highway Finance, American Association of State Highway and Transportation Officials, Smuggler's Notch, Vermont, August 16-19, 1986 (with C. Walton and R. Souleyrette II).

"Overweight Truck Operations in Texas: Developing Effective Fines and Penalties to Deter Violations." Master's Professional Report, The University of Texas at Austin, December 1985.

PUBLISHED PAPERS AND REPORTS, continued

Texas Highway Cost Allocation, Research Report 332/362-2F, Center for Transportation Research, The University of Texas at Austin, and the Texas Transportation Institute, Texas A&M University, November 1985 (with A. Garcia-Diaz, A. Villarreal, D. Burke, C. Walton, and K. Cervenka).

"Texas Highway Finance: The Highway Cost Index," in Transportation Research Record 1009 - Financing State and Local Transportation, Transportation Research Board, National Research Council, Washington, D.C., July 1985 (with L. Boske, W. Grubb, C. Walton and K. Cervenka).

An Overweight Fine Structure for Texas, Research Report 919-1F, Center for Transportation Research, The University of Texas at Austin, November 1984 (with C. Walton and K. Cervenka).

The Texas Highway Cost Index: An Assessment, No. 1, Policy Research Institute, The University of Texas at Austin, August 1984 (with L. Boske, W. Grubb, C. Walton and K. Cervenka).

Analysis of Plano's Future Public Safety Needs: A Cross-City Comparison, Plano, Texas, August 1983.

RESEARCH PRESENTATIONS AND LECTURES

"Alternative Transportation Fuels," Session Moderator, Texas Public Transportation Conference, College Station, Texas, April 26, 1994.

"New Paradigm for Transportation Investment," Texas' 5th Annual Alternative Vehicle Fuels Market Fair and Symposium, Austin, Texas, April 19, 1994.

"Electric Veicle Applications for Transit," Southwest Region University Transportation Center Review, College Station, Texas, April 7, 1994.

"Texas Highway Cost Allocation," Presentation to the Texas Transportation Commission, February 24, 1994.

"Economic Impact of Bypasses on Cities," Presentation to the XXI Seminario de Ingenieria de Transito, Puebla, Mexico, February 18, 1994.

"Overview of the Southwest Region University Transportation Centers Program," for the Public Transportation Advisory Committee of the Texas Transportation Commission, November 29, 1993.

"Alternative Transportation Fuels," Civil Engineering Graduate Student Seminar on Current Transportation Issues, University of Texas, November 22, 1993.

"Economic Impact of Highway Bypasses," Rockport-Fulton, Texas, Chamber of Commerce, August 10, 1993.

"Transportation and Social Costs," University of Texas Advanced Institute for Engineering Management, Austin Texas, June 24, 1993.

RESEARCH PRESENTATIONS AND LECTURES, continued

"Alternative Fuels," 13th Annual Transportation Symposium, Center for Transportation Research, University of Texas at Austin, Austin, Texas, July 15, 1993.

"Issues in Highway Privatization," Texas Department of Transportation, Area I Research Meeting, Wichita Falls, Texas, May 6, 1993.

"Multimodal Transportation Centers," Texas Department of Transportation, Area I Research Meeting, Wichita Falls, Texas, May 6, 1993.

"Framework for Evaluation of TCM Effectiveness," 4th National Conference on Transportation Planning Methods Applications, Daytona Beach, Florida, May 4, 1993.

"Exploring the Impact of Changing Policies on Urban Transportation Systems," Session Moderator, Public Transit Issues Workshop, Austin, Texas, April 29, 1993.

"Policies for Promoting Alternative Transportation Fuels," Civil Engineering Graduate Student Seminar on Contemporary Transportation Issues, University of Texas, March 22, 1993.

"Cost-Effectiveness Analysis of Texas Department of Transportation CNG Fleet Conversion," 72nd Annual Meeting of the Transportation Research Board, Washington, D.C., January 12, 1993.

"Transportation Policy and Social Costs: Looking to the Future," Presentation to the Segundo Seminario Internacional de Sistemas de Transporte y Vialidad Urbana, Puerto Vallarta, Jalisco, Mexico, December 11, 1992.

"Incorporating Social Factors into the Costs of Transportation," Presentation to the Conference on Energy Efficiency as a Transportation Objective: Traditional and Non-traditional Approaches to Conservation, Houston, Texas, November 5, 1992.

"Transportation and Energy: Looking Ahead," Presentation to Civil Engineering Graduate Student Seminar on Transportation, University of Texas, October 13, 1992.

"Cost-Effectiveness of Natural Gas for TxDOT," Texas Department of Transportation, Area I Research Meeting, Arlington, Texas, September 22, 1992.

"Cost-Revenue Implications of Commercialized Rest Areas in Texas," Texas Department of Transportation, Area II Research Meeting, Texarkana, Texas, September 10, 1992.

"Privatization - A Future Funding Source," 12th Annual Symposium of the Center for Transportation Research, Austin, Texas, July 14, 1992.

"Economic Impacts of Highway Bypasses," Texas Transportation Planning Conference, Texas Department of Transportation, Brownsville, Texas, June 12, 1992.

"Rest Area Privatization," Fourth Annual International Conference for Transportation Engineers, Asociacion Regional de Caminos de Nuevo Leon, A.C., Monterrey, Mexico, February 13-14, 1992.

"Highway Privatization in Texas" Texas Department of Transportation, Area I Research Committee Meeting, San Angelo, Texas, January 29, 1992.

"Multimodal Transportation Centers in Texas," Texas Department of Transportation, Area I Research Committee Meeting, San Angelo, Texas, January 29, 1992.

"Determining the Truck System Costs for the Pennsylvania Interstate 80 Corridor," 71st Annual Meeting of the Transportation Research Board, Washington, D.C., January 1992.

"Alternative Transportation Financing Methods," 20th Seminario De Ingenieria De Transito, Asociacion Mexicana De Caminos, Mexico City, Mexico, September 27, 1991.

"Transportation Privatization: Issues and Strategies," 11th Annual Symposium of the Center for Transportation Research, Austin, Texas, July 8, 1991.

"Land-Use Impacts for the DART Rail Starter Line," Southwestern University Transportation Center, College Station, Texas, May 14, 1990.

"Capital Metro Research Studies," Southwestern University Transportation Center, College Station, Texas, May 14, 1990.

"Rest Area Privatization," Texas State Department of Highways and Public Transportation, Area II Research Committee Meeting, Beaumont, Texas, May 1, 1991.

"Transportation Corporations, Road Utility Districts, and County Road Districts: Alternative Strategies for Expediting Highway Development," Third National Conference on Transportation Planning Methods Applications, Dallas Texas, April 23, 1991.

"Economic Impact of Highway Bypasses and Loops," Texas State Department of Highways and Public Transportation, Area I Research Committee Meeting, Nacogdoches, Texas, March 20, 1991.

"Evaluation of Transportation Corporations and Road Utility Districts," Texas State Department of Highways and Public Transportation, Area I Research Committee Meeting, Nacogdoches, Texas, March 20, 1991.

"Issues in Transportation Finance," Civil Engineering Graduate Student Seminar on Transportation Planning, University of Texas, November 20, 1990.

"Texas Roadway Signing: Issues and Alternatives," Texas Transportation Short Course, College Station, Texas, October 18, 1990.

"The Decision Process for Development of Fixed-Guideway Systems," Civil Engineering Graduate Student Seminar on Transportation Planning, University of Texas, October 18, 1990.

"Issues In Intermodal Transportation," Southwestern University Transportation Center, College Station, Texas, May 7, 1990.

"A Conceptual Model of the Fixed-Guideway Decision Process," Presentation to Civil Engineering Graduate Student Seminar on Transportation, University of Texas, January 29, 1990.

"A Conceptual Model of the Fixed-Guideway Decision Process," Best Papers in Urban Public Transportation, 69th Transportation Research Board Annual Meeting, Session 87, January 9, 1990.

RESEARCH PRESENTATIONS AND LECTURES, continued

"Comparison of Cost Responsibility Studies," Texas State Department of Highways and Public Transportation, Area III Research Committee Meeting, Marshall, Texas, May 2, 1989.

"Highway User Operational Information," Texas State Department of Highways and Public Transportation, Area I Research Committee Meeting, Brownsville, Texas, April 7, 1989.

"Highway Cost Allocation for Texas," Texas Commission for Highways and Public Transportation, Austin, Texas, March 28, 1989.

"Highway Cost Allocation for Texas," Texas Motor Carrier Advisory Committee, Austin, Texas, March 10, 1989.

"Texas Highway Cost Allocation -- Preliminary Findings," Texas State Department of Highways and Public Transportation, Area III Research Committee Meeting, Lubbock, Texas, October 1, 1987.

"Revenue Analysis for Texas Highway Cost Allocation," Texas State Department of Highways and Public Transportation, Area A Research Committee Meeting, Austin, Texas, April 28, 1987.

"A Review of Highway Cost Allocation Methodologies and Results," Texas State Department of Highways and Public Transportation, Area A Research Committee Meeting, November 5, 1986.

"Revenue Procedures and Issues for the Updated Texas Highway Cost Allocation Study," Texas State Department of Highways and Public Transportation, Area A Research Committee Meeting, Austin, Texas, June 17, 1986.

"Texas Highway Cost Allocation - Methods and Results," Truck Research Symposium II, Austin, Texas, June 16, 1986.

"Alternative Roadway Financing Methods: National Examples and Recent Experiences in Texas," Financing Major Highways, Session 165, 65th Transportation Research Board Annual Meeting, Washington, D.C., January 15, 1986.

"Analysis of Truck Use and Highway Cost Allocation in Texas," Texas State Department of Highways and Public Transportation, Area I Research Committee Meeting, El Paso, Texas, September 4-5, 1985.

"Texas Highway Finance: The Highway Cost Index," Transportation Finance, Session 180, 64th Transportation Research Board Annual Meeting, Washington, D.C., January 16, 1985.

April 26, 1994

Angela Jannini Weissmann
Co-Principal Investigator and Project Manager
Center for Transportation Research

EDUCATION

Ph.D. in Civil Engineering, Transportation; The University of Texas at Austin, spring 1990. Dissertation subject: Development of Procedures for Monitoring and Predicting the Long Term Performance of Continuously Reinforced Concrete Pavements.
Overall GPA=3.9

M.S. in Civil Engineering, Transportation; Escola Politécnica da Universidade de São Paulo (Polytechnic College of University of São Paulo), Brazil, December 1983. Thesis subject: Influence of Aircraft Wander in the Characteristics of Runways and Runway Strips.
Graduate courses in Pavements, Transportation, Bituminous and Concrete Materials, and Economics.
Overall GPA=4.0
Master Thesis approved with honors.

B.S. in Civil Engineering, Escola Politécnica da Universidade de São Paulo, Brazil, December 1976.

WORK EXPERIENCE

Research Engineer, The University of Texas at Austin, Center for Transportation. December 1992 to present. Technical coordinator of the "Texas-Mexico Toll Bridge Study", which investigates the economic feasibility of new toll bridges along the Texas-Mexico border and studies many aspects of the NAFTA impacts on transportation. Developed a binational data base with transportation-related data for the entire Texas-Mexico border. Developed recommendations for border transportation planning along the border.

Consultant Engineer, Texas Research and Development Foundation, Summer 1992. Developed models and statistical analyses for traffic and pavement condition data for the Strategic Highway Research Program (SHRP).

Consultant Engineer, The University of Texas at Austin, Spring 1990. Analyzed the implications of a recently issued study that re-evaluated the AASHO Road Test Data using Reliability Analysis techniques. Replicated the study models and developed a working paper with technical discussions about the issue.

Graduate Research Assistant, The University of Texas at Austin, September 1986 to December 1989. Developed and implemented procedures to monitor and predict the long-term performance of continuously reinforced concrete pavements (CRCP) in Texas. Surveyed over 200 sections of CRCP highways statewide, using the procedures developed in the first phase of the project. Used the new data in conjunction with historical data from previous projects to develop a computerized data base management system for Texas CRCP, and to model the reliability and performance of this type of pavement under Texas conditions, pioneering the application of Reliability Analysis techniques for this type of pavement.

Professor of Civil Engineering, Instituto Tecnológico de Aeronáutica, (Air Force Institute of Technology) São José dos Campos, SP, Brazil, February 1977 - August 1986. The Brazilian Air Force Institute of Technology is one of the best Engineering Colleges in Latin America, attracting students from all over the continent. Its areas of activity are civil, aeronautical, electrical and mechanical engineering, and it was responsible for the development of Brazil's aeronautical industry, which has clients worldwide. Academic responsibilities: Developed, organized and taught undergraduate courses in the areas of Pavements, Construction Materials, and Surveying, as well as continuing education courses of pavement design, evaluation, and management for the Air Force Corps of Engineers. Advised thesis and provided student counseling. Wrote comprehensive syllabuses for each of the courses taught. Research responsibilities: Projects sponsored by the Ministry of Aeronautics, related to its responsibility of constructing, maintaining and managing all civil and military airports in Brazil. Administrative responsibilities: Installed, supervised and operated the Pavements and Materials Laboratory. Organized budgets and developed cost allocations. Supervised technical and administrative staff. Coordinated and supervised student research and engineering work in sponsored projects.

Consultant Engineer, May 1982 - December 1982. Served as a consultant for the firm ENGEVIX, (São Paulo, SP, Brazil) on the design of the Guarulhos International Airport, in Guarulhos, SP, Brazil.

SELECTED PUBLICATIONS

Weissmann, Angela J., and N.D.F. Gualda. "Análise e Proposição de Critérios para Dimensionamento de Pistas e Faixas de Pouso" (Analysis and Proposal of Criteria for Designing Airport Runways and Runway Strips), Paper published in 1984 at the journal "ITA-Engenharia", vol. 6, Dec/85. "ITA-Engenharia" specializes in aircraft and airport engineering.

Weissmann, Angela J., and N.D.F. Gualda. "Novos Critérios para Dimensionamento de Pistas e Faixas de Pouso" (New Criteria for Designing Airport Runways and Runway Strips), Paper published and presented at the 2nd Biannual Meeting of Aeronautical Engineering, São José dos Campos, SP, Brazil, 1985.

Weissmann, Angela J., and K. Hankins. "Development of Procedures for a Statewide CRCP Diagnostic Survey", Research Report 472-4, Center for Transportation Research, The University of Texas at Austin, September 1989.

Weissmann, Angela J., and K. Hankins, "A Statewide Diagnostic Survey on Continuously Reinforced Concrete Pavements". Research Report 472-5, Center for Transportation Research, The University of Texas at Austin, October 1989.

Weissmann, Angela J., B. F. McCullough and W. R. Hudson, "Development of Procedures for Monitoring and Predicting the Long Term Performance of Continuously Reinforced Concrete Pavements". Research Report 472-6, Center for Transportation Research, The University of Texas at Austin, 1990.

Weissmann, Angela .J. "Assessment of Survival Probabilities for Continuously Reinforced Concrete Pavements". 6th International Symposium on Concrete Roads, European Association of Cement - CEMBUREAU, October 1990.

Weissmann, Angela J., Martello, M., et al. "Texas-Mexico Toll Bridge Study". Paper presented at the August 1993 meeting of the Society of Photo-Optical Engineers, special section on NAFTA impact and border issues.

Weissmann, Angela J., B.F. McCullough, and W. R. Hudson. "Reliability Analysis of Continuously Reinforced Concrete Pavements in Texas". American Society of Civil Engineers Transportation Journal, March 1994.

Weissmann, Angela J., Shamieh, M. et al. "A Comprehensive Overview of the Texas-Mexico Border: Assessment of Traffic Flow Patterns". Research Report 1976-3, Center for Transportation Research, The University of Texas at Austin, February 1994.

Weissmann, Angela J., Martello, M. et al. "A Comprehensive Overview of the Texas-Mexico Border: Demand and Revenue Analyses (Gulf to Laredo)". Research Report 1976-4, Center for Transportation Research, The University of Texas at Austin, March 1994.

Weissmann, Angela J., Martello, M. et al. "A Comprehensive Overview of the Texas-Mexico Border: Demand and Revenue Analyses (Eagle Pass to El Paso)". Research Report 1976-5, Center for Transportation Research, The University of Texas at Austin, April 1994.

Weissmann, Angela J., Harrison, R. and B.F. McCullough. "Texas-Mexico Toll Bridge Study: Summary Report". Research Report 1976-6F, Center for Transportation Research, The University of Texas at Austin, April 1994.

SELECTED PRESENTATIONS AND LECTURES

Undergraduate Course of "Pavements" (one semester). Instituto Tecnológico de Aeronáutica, (Air Force Institute of Technology) São José dos Campos, SP, Brazil, February 1977 through August 1986.

Undergraduate Course of "Materials Science" (one semester). Instituto Tecnológico de Aeronáutica, (Air Force Institute of Technology) São José dos Campos, SP, Brazil, February 1977 through August 1986.

Undergraduate Course of "Surveying" (one semester). Instituto Tecnológico de Aeronáutica, (Air Force Institute of Technology) São José dos Campos, SP, Brazil, February 1977 through August 1986.

Continuing Education Course of "Pavement Design and Evaluation" (two weeks). Commission for the Amazonian Region Airports, Air Force Corps of Engineers, Belém. PA, Brazil, February 1981 and 1982.

"New Criteria for Designing Airport Runways and Runway Strips", Paper presented at the 2nd Biannual Meeting of Aeronautical Engineering, São José dos Campos, SP, Brazil, 1985.

"Back-calculated Material Properties of Continuously Reinforced Concrete Pavements: A Comparison Between Two Approaches". Paper presented at the 69th Annual Meeting of the Transportation Research Board, January 1990.

"Texas-Mexico Toll Bridge Study". Paper presented at the August 1993 meeting of the Society of Photo-Optical Engineers, special section on NAFTA impact and border issues.

"Texas-Mexico Toll Bridge Study Overview". Briefing for the 1993 Meeting of the International Committee for Coordination of Communications and Transportation between Texas and Nuevo Leon. Monterrey, Mexico, December 1993.

"Texas-Mexico Toll Bridge Study Overview and Data Base". Briefing for the 1994 Meeting of the International Committee for Coordination of Communications and Transportation between Texas and Nuevo Leon. Laredo, Texas, July 1994.

"Recommendations for Transportation Planning at the Texas-Mexico Border". Briefing for the 1994 Texas Turnpike Authority Board of Directors Meeting. Austin, Texas, April 1994.

DETAILED RESUME

ROBERT HARRISON
ASSOCIATE DIRECTOR
RESEARCH SCIENTIST
CENTER FOR TRANSPORTATION RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

SUMMARY

Mr. Harrison holds a B.A. degree in economics and political science from the University of Durham, England. After completing a period of research with Gilbert Walker (a noted European Transport Economist), Michael Beesley and Sir Alan Walters, he held tenured teaching positions at the University of Birmingham and the University of Aston in Birmingham, from 1969 to 1976. In addition, he subsequently held honorary research fellowships at the Universities of Birmingham and Bristol, England. He co-authored a World Bank publication on vehicle operating costs (Johns Hopkins Press: 1988) and was, between 1976 and 1982, the economist on a UNDP/World Bank $15 million infrastructural research project in Brazil. He has worked with civil engineers for over 20 years and is particularly interested in user costs, life-cycle costing and optimization, privatization, and transport sector planning. In 1987, he joined the Pavement and Materials group at the Center for Transportation Research at The University of Texas at Austin as a research associate, responsible for economics and program planning. In 1991, he was promoted to Research Scientist and made Associate Director of the Center for Transportation Research which currently has a $10 million annual research budget. In 1992, he was made Principal Investigator of a FHWA research study (DTFH61-92-C-00099) entitled "Impacts of Heavy Trucks on Bridge Investment" which is still in progress. In addition, he maintains an interest in vehicle operating costs and is examining different methods of estimating vehicle spare parts consumption for highway evaluation models. He has worked closely with Professors W. R. Hudson and B. F. McCullough and has taken on several administrative duties in his research programs. He has served as a co-Principal Investigator and, more recently, as Principal Investigator on several state and federally sponsored projects whose combined funding exceeds $1.3 million. As Principal Investigator, his work has included an evaluation of pavement smoothness specifications, evaluation of FHWA requirements for the calibration of pavement roughness instrumentation, determining the economic impact of loops and by-passes, and the privatization of interstate rest areas. He is also a Principal Investigator on a Southwest Region University Transportation Center project investigating the design and implementation of a high-speed ground corridor which would begin operation early in the next century. In addition, he is the Principal Investigator on two Texas state energy projects involving vehicle operating cost research. The first evaluates the impacts on users of expediting pavement construction, and the second examines the consequences of new truck size and weight regulations. He is a member of the Transportation Research Board (TRB) Motor Vehicle Size and Weight Committee and recently organized and chaired a special session at the TRB 72nd Annual Meeting on the North American Free Trade Agreement (NAFTA) and truck size and weight legislation in Mexico, Canada and the United States.

ROBERT HARRISON
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I. PERSONAL

Citizenship and U.S. Status
British
Permanent Resident, Alien Worker Permit

Date and Place of Birth
12 May 1942, Birmingham England

Address:
Center for Transportation Research
The University of Texas at Austin
3208 Red River, Ste. 200
Austin, Texas 78705
Phone: 512-472-8875, Fax: 512-480-0235

Degree
Durham University, England: B.A. Politics and Economics (Hons.) 1965

Academic Honors

Participating Faculty Member:	Lyndon Baines Johnson School of Public Affairs, The University of Texas at Austin (1992 - 1993)
Honorary Research Fellow:	University of Birmingham, England (1982-1984) University of Bristol, England (1984-1986)

Languages
Portuguese, some Spanish

Professional Associations
Transportation Research Board member
Transportation Research Forum member
Transportation Research Board Motor Vehicle Size and Weight Committee (A1B04) member

II. PROFESSIONAL EXPERIENCE

1992 - 1993	Academic year, concurrently: Participating Faculty Member of the Lyndon B. Johnson School of Public Affairs, The University of Texas at Austin.
1991	Associate Director and Research Scientist: Center for Transportation Research, The University of Texas at Austin.
1987- May 1991	Research Associate: Center for Transportation Research, The University of Texas at Austin.
1982-87	World Bank Consultant: developing transport sector reviews and specific evaluations for pavement management systems, and life-cycle costing. Mission Reports prepared for Tunisia, Brazil, Cape Verde Islands, Mozambique, and Angola. Additional responsibilities included the preparation of a technical report for the UK Transport and Road Research Laboratory (TRRL) on vehicle costs in Botswana.
1976-82	United Nations Development Project/World Bank Economist to the Brazil/UNDP-funded project studying the interrelationships between highway construction, maintenance, and utilization.
1972-76	Associate Professor* (tenured) in marketing at the Management Center of the University of Aston in Birmingham, England.
1970-72	Associate Professor* (tenured) at the Graduate Center for Management Studies, University of Birmingham and University of Aston, England.
1968-70	Research Fellow at the Graduate Center for Management Studies, University of Birmingham, England.
1968-69	Transport Economist with Professor Sir A. A. Walters with Howard Humphreys, Keeble & Partners, Consulting Engineers. On temporary leave from the University of Birmingham while on assignment in the Republic of Honduras.
1966-67	Research Officer, to Professor G.J. Walker and sponsored by the Ministry of Transport at the University of Birmingham, England.
1965-66	Research Assistant to Dr. D. E. C. Eversley, West Midlands Social and Political Research Unit, University of Birmingham, England.

*American equivalent titles

III. CTR RESEARCH PROGRAMS

A. Texas Department of Transportation Projects

Principal Investigator or Co-Principal Investigator

Conversion of the State Department of Highways and Public Transportation 6- and 10-Yard Dump Truck Fleet From Standard to Automatic Transmissions (Project 979)
Development of Rigid and Flexible End-Product Smoothness Specifications (Project 1167)
Mitigating Adverse Effects of Urban Highway Construction (Project 1227)
Economic Impact of Highway Loops and Bypasses (Project 1247)
Privatization of Rest Areas (Project 1269)
Highway Privatization in Texas (Project 1281)
Increasing Mobility and Economic Development through Multi-modal Centers (Project 1282)
Truck Traffic in Laredo, Texas - A Case Study of Issues and Remedies (Project 1312)
Multi-Modal Planning and the U.S. - Mexico Free Trade Agreement (Project 1319)
An Evaluation of the Status, Effectiveness, and Future of Toll Roads in Texas (Project 1322)
Value of Access Rights (Project 1325)
Texas - Mexico Toll Bridge Study (Project 1976)

Technical Advisor

Strategies for Bridge Replacement (Project 439)
Tire Contact Pressure Distributions (Project 1190)
Evaluation of the International Roughness Index (Project 969)
Evaluation and Implementation of the ARAN Unit (Project 1223)

Reports

Report 1281-1, "An Overview of Highway Privatization" (with M.A. Euritt, R. Machemehl and J.E. Jarrett).

Report 1281-2, "Reliability of Toll Road Revenue Forecasts for Selected Toll Roads in the United States" (with B.P. Dedeitch, R. Machemehl, M.A. Euritt and C.M. Walton).

Report 1281-3F, "Strategic and Implementation Issues in Texas" (with J.E. Jarrett, M.A. Euritt and R. Machemehl).

Report 1281-3F, "Strategic and Implementation Issues in Texas' Public-Private Transportation Projects" (with J.E. Jarrett, M.A. Euritt and R. Machemehl).

Report 1312-1, "Transborder Traffic and Infrastructure Impacts on the City of Laredo, Texas" (with C. Said and W.R. Hudson).

Report 1312-2, "Effect of the North American Free Trade Agreement on the Transportation Infrastructure in the Laredo-Nuevo Laredo Area" (with J.C. Espinosa Rescala and B.F. McCullough).

Report 1312-3F, "Executive Summary - Truck Traffic in Laredo, Texas: A Case Study of Issues and Remedies."

Policy Research Project Report/Research Project 1319, "Texas-Mexico Multi-Modal Transportation," published with the Lyndon B. Johnson School of Public Affairs, August 1993.

Report 1247-1, "Economic Effects of Highway Bypasses on Business Activities in Small Cities" (with Reijo Helaakoski, Hani S. Mahmassani, C. Michael Walton, Mark A. Euritt, and S. Johann Andersen).

Report 1247-2, "Traffic and Spatial Impacts and the Classification of Small Highway Bypassed Cities" (with S. Johann Andersen, Hani S. Mahmassani, C. Michael Walton, and Mark A. Euritt).

Report 1247-3F, "Economic Impacts of Highway Bypasses," (with S. Johann Andersen, Mark A. Euritt, Hani S. Mahmassani, and C. Michael Walton).

Report 1269-1F, "Feasibility of Safety Rest Area Commercialization in Texas" (with Mark A. Euritt and Susan Grant).

Report 1281-1, "Reliability of Toll Road Revenue Forecasts for Selected Toll Roads in the United States," (with B.P. Dedeitch, R. Machemehl, M. Euritt and C.M. Walton).

Report 1282-1, "Multi-Modal Planning and Transportation Centers: Interim Report" (with Douglas Noble, Mark A. Euritt, and C. Michael Walton).

Report 979-1F, "Conversion of the Texas Department of Transportation 6- and 10-Yard Dump Truck Fleet From Standard to Automatic Transmissions" (with Jose Weissmann and Mark A. Euritt).

Report 1167-1, "The Development of Smoothness Specifications for Rigid and Flexible Pavements in Texas" (with Carl Bertrand).

Report 439-3, "Bridge Project Selection for Texas" (with Tony Tascione, W. R. Hudson, and Ned H. Burns).

Report 439-4F, "A Bridge Management System Module for the Selection of Rehabilitation Replacement Projects" (with José Weissmann, W. R. Hudson, and Ned H. Burns).

Report 969-1, "Field Evaluation of the Auto-Read Version of the Face Dipstick" (with Carl Bertrand and B. F. McCullough).

Report 969-2F, "Evaluation of FHWA Requirements for the Calibration of Pavement Roughness Instrumentation" (with Carl Bertrand and B. F. McCullough).

B. Southwest University Transportation Center VI (DOT) Projects

Principal Investigator

Evaluating High-Speed Ground Corridor (Project 71247)
Energy and System Cost Evaluation of Truck Size and Weight Changes (Project 60020)
Fuel and Time Savings through Expediting Pavement Performance (Project 60021)
Alternative Fueled Bus Impacts on Transit Networks and City Streets (Project 721913)
Prediction of Mobile Source Emissions and Fuel Consumption (Project 60032)
Multimodal Investment Analysis: ACorridor Study of Energy Efficiency and Cost Effectiveness (60062)
Expediting Construction in Urban Corridors: A Demonstration Project in Energy Impact Mitigation (Project 465520)

Reports

Report 71247-1, "The Technical, Engineering, and Economic Feasibility of a High-Speed Ground Corridor" (with Mohammed Suliman and B. F. McCullough).

Report 71247-2, "Preliminary Economic Evaluation of the High-Speed Ground Corridor" (with Salvador Gonzalez-Ayala and B. F. McCullough).

Report 60021-1 & -2, "Expediting Pavement Construction: A Methodology to Analyze Energy and User Costs Impacts" (with Hernán de Solminihac).

Report 60021-3, "Workzone Mobile Source Emission Prediction," (with P. Seshadri).

IV. GRADUATE STUDENT RESEARCH SUPERVISION

Ph. D. Supervision

Weissmann, José, "A Bridge Management System Module for the Selection of Rehabilitation and Replacement Projects," Doctoral Dissertation, The University of Texas, Austin, May 1990.

Lu, Jian, "Evaluation and Implementation of the Automatic Road Analyzer (ARAN), Doctoral Dissertation, The University of Texas, Austin, December 1990.

de Solminihac, Hernán, "Energy and User Costs Savings Through Expediting Pavement Construction," Doctoral Dissertation, The University of Texas, Austin, May 1992.

Suliman, Mohammad R., "Expediting Strategies to Mitigate the Adverse Effects of Pavement Construction in Texas," Doctoral Dissertation, The University of Texas, Austin, August, 1993.

Master's Student Supervision

Tascione, Tony, "Bridge Project Selection for Texas," Master's Thesis, The University of Texas, Austin, December 1987.

Hansen, Rex, "Truck Tire Pavement Contact Pressure Distribution Characteristics for 'Super Single' 18-22.5 and Smooth 11-24.5 Tires," Master's Thesis, The University of Texas, Austin, May 1989.

Pezo, Raphael, "Truck Tire Pavement Contact Pressure Distributions," Master's Thesis, The University of Texas, Austin, December 1989.

Gonzalez-Ayala, Salvador, "Pre-feasibility Study for Designing a Texas High-Speed Ground Corridor for the next Century," Master's Thesis, The University of Texas, Austin, May 1990.

Suliman, Mohammed, "Preliminary Economic Evaluation of the Highway Element of the Texas 2020 Corridor," Master's Thesis, The University of Texas, Austin, December 1990.

Helaakoski, Reijo, "Economic Effects of Highway Bypasses on Business Activities in Small Cities," Master's Thesis, The University of Texas, Austin, December 1991.

Andersen, Simen Johann, "Traffic and Spatial Impacts and the Classification of Small Highway Bypassed Cities," Master's Thesis, The University of Texas, Austin, May 1992.

Seshadri, Pattabiraman, "Work Zone Mobile Source Emission Prediction," Master's Thesis, The University of Texas, Austin, August 1992.

Friedman, Amanda D., "Opportunities for Private Sector Highway Financing," Master's Thesis, The University of Texas, Austin, August 1992.

Cato, Jacqueline Novella, "Effect of Highway Reconstruction on Roadway User Costs," Master's Thesis, The University of Texas, Austin, May 1993.

Arellano, Arturo Sanchez, "Logistics of the Colombia - Laredo International Solidarity Bridge," Master's Thesis, The University of Texas, Austin, May 1993.

Espinosa Rescala, Juan Carlos, "Effect of the North American Free Trade Agreement on the Transportation Infrastructure at Laredo, Texas - Nuevo Laredo, Tamaulipas," Master's Thesis, The University of Texas, Austin, May 1993.

Said, Claudia, "Transborder Traffic and Infrastructure Impacts on the City of Laredo," Master's Thesis, The University of Texas, Austin, August, 1993.

Jones, Michael A., "Cost Differences Between Expediting and Standard Urban-Freeway Construction," Master's Thesis, The University of Texas, Austin, December, 1993.

Trujillo Olguin, Eduardo, "Effectiveness of Accelerating Highway Rehabilitation in Urban Areas," Master's Thesis, The University of Texas, Austin, December, 1993.

Treviño González, Mario Gerardo, "U.S.-Mexico Trade Effects on the Monterrey-San Antonio Highway Corridor," Master's Thesis, The University of Texas, Austin, December, 1993.

Gilani, Syed Amer Saeed, "QUEWZEE-93," Master's Thesis, The University of Texas, Austin, May, 1994.

V. CONSULTING ACTIVITIES

FEDERAL HIGHWAY ADMINISTRATION (FHWA)

1992 - Present FHWA Study DTFH61-92-C-00099, "Impacts of Heavy Trucks on Bridge Investment" (Principal Investigator)

WORLD BANK

1987 Brazil - Fourth Urban Transport Project

1987 Cape Verde - Draft Transport Sector Review

1988 Angola - An Introductory Economic Review (Report No. 7283-Ang 2 Vols.) Transport Sector

1989 Mozambique - Transport Sector Review

1991 Nigeria - First Multistate Roads Project

1993 Venezuela - Cost Allocation Study (Advisor)

VI. PUBLICATIONS AND PRESENTATIONS

A. Books

Vehicle Operating Costs: Evidence from Developing Countries, The Johns Hopkins University Press, (ISBN 0-8018-3588-7), Baltimore and London, 1987.

B. Refereed Papers

"Mexican Truck Overloads: Pavement Consumption and Externalities," submitted for publication and presented to the Motor Vehicle Size and Weight Committee (A1B04) meeting at the 73rd Annual Meeting of the Transportation Research Board, Washington D.C., January 1994 (with B.F. McCullough).

"Work Intersection Zone Planner - WIZP: A Decision-Making Computer Model for Expediting Intersections," presented at the 73rd Annual Meeting of the Transportation Research Board, Washington D.C., January, 1994 (with H. de Solminihac, T. Dossey and B.F. McCullough).

"Large Truck Impacts on the Highway Infrastructure: The Bridge Dimension," presented at the American Society of Civil Engineers Conference on Infrastructure Management and to be published in the proceedings, Denver, Colorado, June, 1993 (with J. Weissmann).

"Modification of the QUEWZ Model to Estimate Fuel Costs and Tailpipe Emissions," presented at the 72nd Annual Meeting of the Transportation Research Board, and published in the *Transportation Research Record - TRR 1395*, Washington, D.C., January, 1993 (with P. Seshadri and H. de Solminihac).

"Conversion of the Texas Department of Transportation 6- and 10-Yard Dump Truck Fleet from Standard to Automatic Transmissions," presented at the 72nd Annual Meeting of the Transportation Research Board, Washington, D.C., January, 1993 (with J. Weissmann and M. Euritt).

"Analyzing Impacts of Highway Rehabilitation on Businesses," presented at the 72nd Annual Meeting of the Transportation Research Board, and published in the *Transportation Research Record - TRR 1395*, Washington, D.C., January, 1993 (with H. de Solminihac).

"Economic Impacts of Highway Bypasses," presented at the 72nd Annual Meeting of the Transportation Research Board, and to be published in the Transportation Research Record, Washington, D.C., 1993 (with J. Andersen).

"A Methodology for the Development of End-Result Smoothness Specifications," 12th Annual Transportation Convention, University of Pretoria, Pretoria, South Africa, June 29 - July 3, 1992 (with W.R. Hudson and T. Dossey).

"End-Result Smoothness Specifications for Acceptance of Asphalt Concrete Pavements," ISAP 7th International Conference on Asphalt Pavements, Design, Construction and Performance, August 16 - 20, 1992 (with W.R. Hudson, T. Dossey, and D.G. Goulias).

"The Impact of Turnpike Doubles and Triple 28s on the Rural Interstate Bridge Network," *Transportation Research Record - TRR 1319*, pp 32 - 42, Washington, D.C., April, 1992 (with J. Weissmann).

"Determining the Truck System Costs for the Pennsylvania Interstate 80 Corridor," 71st Annual Meeting of the Transportation Research Board and published in the *Transportation Research Record*, Washington, D.C., 1992 (with M. McNerney and M. Euritt).

"Load Rating Choice and Long Combination Vehicle Impacts on the Rural Interstate Bridge Network," 1991 Annual Transportation Research Forum Proceedings and published in the *Journal of the Transportation Research Forum*, Vol XXXII, Number 1, Virginia, 1991 (with J. Weissmann and R. Barnhart).

"Evaluation of a High-Resolution Profiling Instrument for Use in Road Roughness Calibration," Fifth International Conference on Low-Volume Roads, Raleigh, N.C., May, 1991 (with C. Bertrand).

"A Bridge Management System Module for the Ranking of Rehabilitation and Replacement Projects," *Proceedings of the ASTM Symposium on Extending the Life of Bridges,* ASTM STP 1100, Philadelphia, 1989 (with J. Weissmann, W.R. Hudson, and N. Burns).

"A Bridge Management System Module for the Selection of Rehabilitation and Replacement Projects," *Third International Conference on Microcomputer Applications in Transportation,* Vol 1, ASCE, San Francisco, May, 1989 (with J. Weissmann and W.R. Hudson).

"Measuring the Smoothness of Newly Constructed Concrete Pavement for Acceptance Standards," *Proceedings of the Fourth International Conference on Concrete Pavement Design and Rehabilitation,* Purdue University, 1989 (with C. Bertrand and W.R. Hudson).

"Influence of Road Surface Roughness on Vehicle Operating Costs: Reviewing the Evidence from Developing Countries," *Proceedings of the First International Symposium on Surface Characteristics,* ASTM ST 1031, State College, Pennsylvania, June, 1988.

"Calibrating the Relationship between Operating Costs of Buses and Road Roughness on Low-Volume Roads," *Fourth International Conference on Low-Volume Roads,* Transportation Research Record 1106 (Vol 2), pp 95-103, TRB, Washington, D.C., 1987 (with P.C. Curtayne, A.T. Visser, and H.W. du Plessis).

"The Use of Vehicle Operating Costs in Road Management," *Annual Transportation Convention,* Volume 2B, Pretoria, 1986.

"Setting Maintenance Levels for Aggregate Surface Roads," *Proceedings of TRB 64th Annual Meeting*, Transportation Research Board, Washington D.C., 1985 (with B.C. Butler and P. Flannagan).

"Implementing a Highway Maintenance Programme in Bolivia," *Proceedings of the Planning and Transport Research and Computation* (PTRC) 13th Annual Meeting, PTRC Volume P264, London, 1985 (with B.C. Butler).

"Predicting Road User Costs for Highway Investment Decisions," *Proceedings of the Planning and Transport Research and Computation (PTRC).* 11th Annual Meeting, PTRC Volume P237, London, 1983 (with A.D. Chesher).

"Vehicle Operating Costs in Brazil: Results of a Road User Survey," *Low-Volume Roads: Third International Conference*, Transportation Research Record 898, Washington, D.C., 1983 (with A.D. Chesher).

"Study of Road User Costs," Research on the Interrelationships Between Costs of Highway Construction, Maintenance, and Utilization, Final Report, Vol. 5, GEIPOT, Brasilia, Brazil, 1982.

"Vehicle Depreciation and Interest Costs: Some Evidence from Brazil," *Proceedings of the International Road Federation World Conference on Transportation Research,* IRF, London, 1980 (with A.D. Chesher and J.D. Swait).

"The Effect of Road Design and Maintenance on Vehicle Operating Costs-Field Research in Brazil," *Low-Volume Roads: Second International Conference, Transportation Research Record* 702, Washington, D.C., 1979 (with R.J. Wyatt, B.K. Moser, and L.P. Quadros).

"Classic Pricing Rules, Cost Plus Pricing and the Capacity Constrained Firm," *Journal of Business Finance*, Spring, 1975 (with F.M. Wilkes).

"Bank Loans and Small Business Financing in Britain," *Accounting and Business Research* No. 15, 1974 (with R.E.V. Groves).

"Jaguar Pricing Policy," *European Journal of Marketing,* Winter, 1973 (with F.M. Wilkes).

C. Publications

"Estimating Load Impacts on Highway Structures Using the National Bridge Inventory Database," Fourth Conference on Microcomputer Applications in Transportation, Washington, D.C., July, 1992 (with J. Weissmann).

"A Methodology for the Development of End-Result Smoothness Specifications," 12th Annual Transportation Convention, Pretoria, South Africa, June-July, 1992, (with T. Dossey and W.R. Hudson).

"User Costs and Financial Policy," Mexican Association of Roads XX Seminar of Transportation Engineering, Mexico City, Mexico, September, 1991.

"Evaluation and Implementation of the Roughness Measuring Subsystem of the ARAN Unit," Research Report No. 1223-1 for Research Project 1223 conducted for Texas State Department of Highways and Public Transportation, Austin, Texas, February 20, 1991 (with J. Lu, C. Bertrand, and W.R. Hudson).

"End Roughness Specifications and Quality Control of Pavement Construction," III Annual Transportation Engineering Conference, Monterrey, Mexico, October, 1990.

"High Speed Highways in the Year 2000," *Proceedings of the First International Seminar on Transport Systems and Urban Highways,* Acapulco, Mexico, September, 1990.

"Financing Toll Roads," *Proceedings of the First International Seminar on Transport Systems and Urban Highways,* Acapulco, Mexico, September, 1990.

"Evaluation of FHWA Requirements for the Calibration of Pavement Roughness Instrumentation," Research Report No. 969-2F, Research Project 3-18-88/89-969 for Texas State Department of Highways and Public Transportation, February 1990, (with C.B. Bertrand and B.F. McCullough).

"Investment Aspects of Toll Roads and Bridges," II Annual Transportation Engineering Conference, Monterrey, Mexico, November, 1989.

"Designing a Texas High-Speed Inter-City Corridor for the Year 2020," *1989 Transportation Research Forum,* Williamsburg, Virginia, October, 1989 (with B.F. McCullough and K.M. Marshek).

"Angola - An Introductory Economic Review," Volume II of 2, Document of United Nations Development Program - The World Bank, Report No. 7283-ANG, June 26, 1989.

"Angola - An Introductory Economic Review (2 Vols.) - Transport Sector," World Bank, Washington, D.C., 1988.

“Mozambique - Transport Sector Review,” World Bank, Washington, D.C., 1989.

Evaluating OFDA and FFP Grants to Care International in Mozambique, Report submitted to Office of Foreign Disaster Assistance and US A.I.D., Washington, D.C. Louis Berger International, Washington, D.C., June, 1988 (with W. L. McPherson and C. Bell).

“Staff Appraisal Report,” Fourth Urban Transport Project Report No. 6426a-BR, Document of the World Bank, May 5, 1987.

"Examining Truck Maintenance and Depreciation Data in Botswana," *Report for Overseas Unit of the TRRL,* Crowthorne, England, July, 1987.

"The Major International VOC Studies," *Symposium on Vehicle Operating Costs,* CSIR Conference Centre, Pretoria, 1987.

"Vehicle Depreciation as Affected by Road Condition and Utilization," *Symposium on Vehicle Operating Costs,* CSIR Conference Centre, Pretoria, 1987.

Estimating Vehicle Performance Measures (2 Vols.), FHWA Contract DTFH61-C-00160, FHWA, Washington, D.C., 1987 (with G.E. Elkins and B.C. Butler).

“Cape Verde - Draft Transport Sector Review,” World Bank, Washington, D.C., 1987.

“Bridge Project Selection for Texas,” Research Report 439-3, Strategies for Bridge Replacement Research Project 3-5-86-439 for Texas State Department of Highways and Public Transportation, November, 1987 (with T. Tascione, W.R. Hudson, and N.H. Burns).

“Research Into Vehicle Operating Costs: A Progress Report,” NITTR Contract Report, C/PAD/46.6, CSIR, Pretoria, South Africa, September, 1986.

"Preliminary Investigations into the Applicability of Available Vehicle Operating Cost Relations to South African Conditions," NITRR Technical Report RP/8 Pretoria, CSIR, April, 1985.

“Brazil First Urban Transport Project,” World Bank, Washington, D.C., 1985.

Present Worth Methods in the Economic Evaluation of Life Cycle Cost Maintenance Strategies, Report to TRDF for incorporation in the Penn. D.O.T. Pavement Management Systems, TRDF, Austin, Texas, 1985 (with F.M. Wilkes).

“User Cost Analysis Memos, 1980,” Research on the Interrelationships Between Costs of Highway Construction, Maintenance, and Utilization, Working Document 24, GEIPOT, Brasilia, Brazil, 1981.

“Research on the Interrelationships Between Costs of Highway Construction, Maintenance, and Utilization, Final Report III: Road User Costs Surveys,” GEIPOT, Brasilia, Brazil and TRDF, Austin, Texas, June, 1980.

“Tire Consumption and Tread Measurement,” Research on the Interrelationships Between Costs of Highway Construction, Maintenance, and Utilization, Working Document 4, Project Technical Memos, GEIPOT, Brasilia, Brazil, 1976 and 1977.

D. Papers/Presentations

"Mexican Infrastructure Concessions: Lessons for Latin America," Conference on Private and Public Infrastructure, Santiago, Chile, March 24 and 25, 1994.

"Privatization Funding: Needs, Theory and Strategies," 4th Construction Industry International Seminar, Santiago, Chile, September, 1993.

"Highway Privatization: Experiences, Benefits and Risks," 4th Construction Industry International Seminar, Santiago, Chile, September, 1993.

"Texas-Mexico Border Issues," 1st Annual Symposium of the Society of Photo-Optical Instrumentation Engineers, Albuquerque, New Mexico, August, 1993.

"Mexican Truck Overloads: The Cross Border Threat", Association of American Railroads (AAR) Annual Policy Symposium, Jackson Hole, Wyoming, July, 1993.

"Impact of a North American Free Trade Agreement on Texas," panel discussion at the Texas Transportation Institute Advisory Committee Meeting, Texas A&M, April, 1993.

"Transportation Impacts of a North American Free Trade Agreement," Texas Department of Transportation District Engineers/Division Directors meeting, Austin, April, 1993.

"Benefits of Intermodal Transportation," Systems II Conference, Association of Mexican Roads, Puerto Vallarta, Jalisco, Mexico, December, 1992.

"U.S. - Mexico Trade: Intermodal Solutions," U.S. Congressional Presentation, Association of American Railroads (AAR), Jackson Hole, Wyoming, June, 1992.

"Intermodal Transportation and U.S. - Mexico Trade," Center for Transportation Research 12th Annual Symposium, July, 1992.

"Rest Area Privatization," IV International Conference on Transportation Engineering, Monterrey Mexico, February, 1992.

"Longer Combination Vehicle Impacts on the Interstate Bridge Network Using National Bridge Inventory Data," Committee on Motor Vehicle Size and Weight (A1B04), 71st Annual Meeting of Transportation Research Board, 1992.

"User Cost and Financial Policy," 20th Annual Seminar on Transportation Engineering, Mexican Road Association, Mexico City, Mexico, September, 1991.

"Designing a Texas High-Speed Inter-City Corridor for the Year 2020," Center for Transportation Research 11th Annual Symposium, University of Texas, Austin, Texas, July, 1991.

"Transportation Privatization: Issues and Strategies," 11th Annual Symposium, Center for Transportation Research, Austin, July, 1991.

"Privatization of Roadside Facilities and Maintenance," Texas SDHPT HPR Program, Area II Research Meeting, Beaumont, Texas, May, 1991.

"The Impact of Turnpike Doubles and Triple 28s on the Rural Interstate Bridge Network," Committee on General Structures (A2CO1), 70th Annual Meeting of the Transportation Research Board, January, 1991.

"End Roughness Specifications and Quality Control of Pavement Construction," III Annual Transportation Engineering Conference, Monterrey, Mexico, October, 1990.

"High Speed Highways in the Year 2000," *Proceedings of the First International Seminar on Transport Systems and Urban Highways,* Acapulco, Mexico, September, 1990.

"Financing Toll Roads," *Proceedings of the First International Seminar on Transport Systems and Urban Highways,* Acapulco, Mexico, September, 1990.

"Develop Smoothness Specifications for Rigid and Flexible Pavements," Texas SDHPT HPR Program, Area II Research Meeting, San Angelo, Texas, August, 1990.

"Measuring the Smoothness of Newly Constructed Concrete Pavement for Acceptance Standards," *Proceedings of the Fourth International Conference on Concrete Pavement Design and Rehabilitation,* Purdue University, 1989.

"Texas 2020 -- The Technical, Engineering, and Economic Feasibility of a High Speed Ground Corridor," UTCP Meeting, Austin, Texas, 1989.

"Investment Aspects of Toll Roads and Bridges," II Annual Transportation Engineering Conference, Monterrey, Mexico, November, 1989.

"Designing a Texas High-Speed Inter-City Corridor for the Year 2020," 1989 Transportation Research Forum, Williamsburg, Virginia, October, 1989

"Tire Contact Pressure Distributions," Texas SDHPT HPR Program, Area II Research Meeting, Tyler, Texas, August, 1989.

"High-Speed Ground Corridor," Center for Transportation Research 10th Annual Research Symposium, University of Texas, Austin, Texas, July, 1989.

"High Speed Corridor Evaluation for the Year 2020," Center for Transportation Research Annual Symposium, University of Texas, Austin, Texas, June, 1989.

"Texas 2020: High Speed Ground Corridor," CTR Annual Symposium, University of Texas, Austin, Texas, June, 1989.

"Develop Smoothness Specifications for Rigid and Flexible Pavements," Texas SDHPT HPR Program, Area II Research Meeting, El Paso, Texas, March, 1989.

"Influence of Road Surface Roughness on Vehicle Operating Costs: Reviewing the Evidence from Developing Countries," *Proceedings of the First International Symposium on Surface Characteristics,* ASTM ST 1031, State College, Pennsylvania, June, 1988.

"*Evaluating Grants to Care International in Mozambique,*" Office of Foreign Disaster Assistance and US A.I.D., Washington, D.C. Louis Berger International, Washington, D.C., June, 1988

"The Effects of Road Condition on the Operating Costs of Buses," *Proceedings of the Annual Transportation Convention,* Pretoria, August, 1987.

"Examining Truck Maintenance and Depreciation Data in Botswana," *Report for Overseas Unit of the TRRL,* Crowthorne, England, July, 1987.

"Calibrating the Relationship between Operating Costs of Buses and Road Roughness on Low-Volume Roads," *Fourth International Conference on Low Volume Roads*, Washington, D.C., 1987.

"*Estimating Vehicle Performance Measures (2 Vols.),*" FHWA Contract DTFH61-C-00160, FHWA, Washington, D.C., 1987.

"The Major International VOC Studies," *Symposium on Vehicle Operating Costs,* CSIR Conference Centre, Pretoria, 1987.

Vehicle Depreciation as affected by Road Condition and Utilization," *Symposium on Vehicle Operating Costs,* CSIR Conference Centre, Pretoria, 1987.

"The Use of Vehicle Operating Costs in Road Management," *Annual Transportation Convention,* Pretoria, 1986.

"Implementing a Highway Maintenance Program in Bolivia," *Proceedings of the Planning and Transport Research Computation* (PTRC), 13th Annual Meeting, London, 1985.

"Setting Maintenance Levels for Aggregate Surface Roads," *Proceedings of the TRB 64th Annual Meeting,* Washington D.C., 1985.

"Predicting Road User Costs for Highway Investment Decisions," *Proceedings of the Planning and Transport Research and Computation* (PTRC), 11th Annual Meeting, London, 1983.

"Predicting Road User Costs for Highway Investment Decisions," *Proceedings of the Planning and Transport Research and Computation* (PTRC), 11th Annual Meeting, London, 1983.

"Vehicle Operating Costs in Brazil: Results of a Road User Survey," *Low-Volume Roads: Third International Conference,* Washington D.C., 1983.

JIEFENG QIN

EDUCATION

M.S.C.E. Virginia Polytechnic Institute & State University, Blacksburg, Virginia, May 1992

B.S. Shanghai Jiao Tong University, Shanghai, P.R. China, July 1988

PROFESSIONAL EXPERIENCES

9/92 - Research Assistant, Center for Transportation Research, The University of Texas at Austin

5/91 - 8/92 Research Assistant, Virginia Tech

7/88 - 8/90 Assistant Engineer, Shanghai Ship Research & Design Institute

MAJOR RESEARCH ACCOMPLISHMENTS

- Developing a macro-analysis framework which links the transportation planning, evaluation of TCMs, and air quality analysis.
- Using System dynamics and Catastrophe theory to develop transportation planning model.
- In charge of the development of output part in the software package REDIM2,0.

RESEARCH AND TECHNICAL REPORT

1. M. A. Euritt, J. Qin, J. Meesomboon, and C. M. Walton, Urban Transit Energy Impacts of Clean Air Legislation, Final Report, Southwest Region University Transportation Center, U.S. Department of Transportation. (in preparation)

PUBLICATIONS

1. M. A. Euritt; J. Qin, J. Meesomboon, and C. M. Walton, A Framework for Evaluating TCMs: Mobility, Air Quality, and Energy Consumption Tradeoffs, Transportation Research Record, Washington, D.C., 1994. (forthcoming)
2. Jiefeng Qin and Donald R. Drew, The Catastrophe Phenomena in System Dynamics Models, Modeling and Simulation; Proceedings of The Annual Pittsburgh Conference, Volume 23, Pittsburgh, PA, 1992.
3. M. A. Euritt, J. Meesomboon, J. Qin, and C. M. Walton, Framework for Evaluation of TCM Effectiveness, 4th National Conference on Transportation Planning Methods Applications, Volume I, Daytona Beach, FL, 1993.

SKILLS

- Demonstrated ability to use Turbo C++, FORTRAN
- Extensive work of NETSIM, TRANSYT-7F, TEXAS, MOBIL4.1, TRANPLAN
- Expert at HCM
- Working knowledge of AASHTO -- A Policy On Geometric Design Of Highways and Streets

PROFESSIONAL ACTIVITIES

- Phi Kappa Phi Honor Society, 1992 -
- ITE student member, 1991 -
- ASCE member, 1991 -
- ORSA member, 1994 -

MICHAEL T. MARTELLO
TRANSPORTATION ENGINEER

EDUCATION

Master of Science, Transportation Engineering, Civil Engineering, University of California, Berkeley, 1989
Bachelor of Science, Civil Engineering, University of Florida, Gainesville, 1984

YEARS OF EXPERIENCE: 7

PROFESSIONAL EXPERIENCE

Research Engineer

Center for Transportation Research, University of Texas
Involved in the Texas/Mexico Border Needs Study assessing transportation, economic and political characteristics of border communities as they relate to the need for additional binational entry systems. Responsibilities included conducting **Capacity Analysis** of twenty binational entry systems and preliminary development of a regional **TRANPLAN** network.

Transportation Research Center, University of Nevada, Las Vegas
Involved in the Colorado River Regional Transportation Study under the guidance of Professor Souleyrette. Primary responsibility was to work with TIGER and DIME files in **ARC/INFO GIS** software in order to develop a **TRANPLAN** network. Assisted in preparation of research paper for Clark County Department of Comprehensive Planning assessing various Transportation **Control Measures** as defined by the EPA.

Institute of Transportation Studies, University of California, Berkeley
Involved in **IVHS** research project under the guidance of Professor May. Responsibilities included coordinating with LADOT traffic operations staff the simulation modeling of seventy five signalized intersections in the Los Angeles SMART corridor utilizing **TRANSYT-7F** software and assessing potential benefits of an in-vehicle information system.

Traffic Engineering

DKS Associates, Oakland, California
Primary responsibilities were conducting traffic impact analyses, traffic operations studies and general civil design work. Duties included utilizing **FREQ10** freeway simulation software and the **1985 Highway Capacity Manual**; report writing and project management. Developed traffic signal timing plans for coordinated operation at 9 signals in Pittsburg, CA, as part of a **Fuel-Efficient Traffic Signal Management Program (FETSIM)** project.

General Civil

H.W. Lochner, Inc., St. Petersburg, Florida
Assistant transportation engineer. Responsibilities included geometric design of urban surface streets and limited access freeways and preparation of final design plans.

REPORTS

Weissmann, Angela J., Martello, M. et al. "A Comprehensive Overview of the Texas-Mexico Border: Demand and Revenue Analyses (Gulf to Laredo)". Research Report 1976-4, Center for Transportation Research, The University of Texas at Austin, March 1994.

Weissmann, Angela J., Martello, M. et al. "A Comprehensive Overview of the Texas-Mexico Border: Demand and Revenue Analyses (Eagle Pass to El Paso)". Research Report 1976-5, Center for Transportation Research, The University of Texas at Austin, April 1994.

Potential Benefits of In-Vehicle Information Systems in a Real Life Freeway Corridor Under Recurring and Incident -Induced Congestion. (Jul 1988, Univ. of California, Al-Deek, Martello, May, Sanders)

Assessment of Transportation Control Measures for Air Quality Improvement. (Aug 1992, Univ of Nevada, Vodrazka, Martello)

STEPHEN S. BERNOW

Vice-President
Tellus Institute

Senior Research Fellow
Stockholm Environment Institute - Boston

Education

Ph.D.	Experimental Physics, Columbia University, 1970
M.A.	Physics, Columbia University, 1965
B.S.	School of Engineering and Applied Science, Columbia University, 1963

Experience

1990- Present — Senior Research Scientist, Tellus Institute. Senior Research Fellow, Stockholm Environment Institute.

Responsible for directing Tellus' energy/environmental social costing projects, with a major focus on environmental externalities methodologies and valuation, and integrated resource planning (IRP). Integration on renewable energy resources and technologies into electric and other energy systems. Application of IRP, social costing and alternative approaches to energy, sustainable development and water resource planning.

1976-1989 — Senior Research Scientist, Energy Systems Research Group, Tellus Institute.

Responsible for a range of energy/environment planning and technology assessments, system modelling studies and policy analyses. Areas of focus include energy, environment. Analysis of the physical, economic, and environmental implications of alternative energy and resource planning strategies.

1974-1976 — Assistant Professor, Allen Center, State University of New York at Albany. Taught courses in social science/economics and science/society.

1972-1974 — Assistant Professor of Physics, Richmond College, City University of New York.

1969-1972 — Assistant Professor of Physics, Rutgers University at Newark.

Selected Articles, Books, Reports, Presentations

Transportation Energy and Environment

1993/1994	*U.S. DOE's Electric Vehicle Fuel Cycle Emissions Program* (EVTECA). Dr. Bernow selected as a reviewer of work done under this program.
1993	*The DOE Transportation Working Group for the Administration's Climate Change Action Pla* Dr. Bernow invited to contribute to the working group's deliberations and recommendations.
1993	*New York State Energy Office*. Dr. Bernow was invited to the Transportation Experts Group for the State's 1994 Energy Plan.
August 1993	*A Social Cost Analysis of Alternative Fuels for Light Vehicles*, presented at Transportation and Energy Strategies for a Sustainable Transportation System, Pacific Grove, California. Stephen Bernow and Mark Fulmer.
June 1993	"Applying an Integrated Energy/Environmental Framework to the Analysis of Alternative Transportation Fuels," presented at: European Council for an Energy Efficient Economy, 1993 Summer Study, Rungstedgaard, Denmark. June 1-5. Stephen Bernow and Mark Fulmer.
April 1993	*Trash, Traffic and Taxes: Elements of Market-Based Pollution Policy*. A report to: Pace University Center for Environmental Legal Studies. Tellus Study No. 92-148. Principal investigator.
August 1991	"Transportation on a Greenhouse Planet: A Least-Cost Transition Scenario for the United States," presented at Conference on Transportation and Global Climate Change: Long-run Options. Asilomar Conference Center, CA, August 25-28, 1991. Review draft, revised 9/12/91. John DeCicco, Stephen Bernow, Deborah Gordon, John Holtzclaw, Marc Ledbetter, Peter Mill, and Harvey Sachs.
December 1991	Transportation sections and Appendices C and D in *America's Energy Choices: Investing in a Strong Economy and a Clean Environment*, Union of Concerned Scientists, Cambridge, MA. Co-author.

Renewable Energy Resources

Forthcoming	*Integrating Renewable Electric Resources: A Case Study of Wind Reliability and Economics.* Report to the U.S. Department of Energy Innovative IRP Program, at Oak Ridge National Laboratory. Project Manager.

May 1994	"National Climate Change Policy and Clean Air Act Compliance: A Case Study of Combined CO_2/SO_2 Reduction". Procedings of the Fifth Annual NARUC/DOE Conference on Integrated Resource Planning. Kalispell, Montana. Presenter and co-author.
August 1993	*A Social Cost Analysis of Alternative Fuels for Light Vehicles*, presented at Transportation and Energy Strategies for a Sustainable Transportation System, Pacific Grove, California. Stephen Bernow and Mark Fulmer.
April 1993	*Renewable Energy for Massachusetts: A Strategy for Energy, Environment and the Economy*. A report to: Massachusetts Department of Energy Resources. Tellus Study No. 92-236H. Principal investigator.
October 1993	"Modelling Renewable Electric Resources: A Case Study of Wind Reliability," presented at: NARUC-DOE National Regulatory Conference on Renewable Energy, Savannah, Georgia. Oct. 3-6.
1992 - 1993	Attended **National Biofuels Roundtable**, including EPRI, ORNL, TVA, and the USFS. Washington, DC.
December 1991	*The Potential for Biomass to Mitigate Greenhouse Gas Emissions in the Northeastern U.S.* A Report to: Coalition of North East Governors (CONEG). Tellus Study No. 90-086. Principal Investigator.
December 1991	Renewables sections and Appendix E in *America's Energy Choices: Investing in a Strong Economy and a Clean Environment*, Union of Concerned Scientists, Cambridge, MA. Co-author.
September 1991	Attended National Audubon Society, Princeton Center for Energy and Environmental Studies, Experts **Workshop on Ecological Implications of Large Scale Biomass Energy Production**. New York.
June 1984	*An Assessment of the Proposed Ellenville Wind Energy Project.* ESRG Study No. 84-25. Principal investigator.
May 1981	*The Economics of Solar Hot Water Heaters as a Supply Alternative for Maui Electric: A Preliminary Appraisal.* Co-author.
September 1980	*Pollution Impacts of Solar Heat and Hot Water Systems.* ESRG Report 79-30/A. Co-author.
June 1980	*The Alternative Supply Scenario.* ESRG Study No. 79-29/4. A technical report in the ESRG Study for the U.S. General Accounting Office, *Reducing New England's Oil Dependence Through Conservation and Alternative Energy.* Co-author.

Social Costing, Environmental Externalities and Sustainability

Forthcoming	*Incorporating Environmental Externalities in Energy Decisions: A Guide for Energy Planners.* A report to the Swedish International Development Agency (SIDA). Co-author.
Forthcoming	"Environmental Impacts of Long Distance Energy Transport." Refereed paper for the ACEEE Asilomar Summer Study Conference. Co-author.
Forthcoming	*Environmental Externalities for Energy Resource Planning in Ontario: Theory, Methods and Values for Use in IRP.* For the Ontario Externalities Collaborative. Project manager.
Forthcoming	"From Social Costing to Sustainable Development: Beyond the Economic Paradigm". Stephen Bernow, Bruce Biewald, Paul Raskin.
Forthcoming	*New York State Environmental Externalities Cost Study.* Reports and computer model developed for Empire State Electric Energy Research Corporation, Electric Power Research Institute, New York State Energy Research and Development Authority. Co-author.
Forthcoming	Reviewer and contributor to the Intergovernmental Panel on Climate Change, Working Group III Report.
November 1993	*Development of Environmental Externality Values for Consumers Gas.* Draft report prepared for: Marika Hare, Consumers Gas. Tellus Study No. 93-197E. Co-author.
April 1993	"Environmental Sustainability as a Goal in Resource Planning and Policy," Office of Technology Assessment, Washington, DC. Stephen Bernow, Bruce Biewald. (Forthcoming, *Ecological Economics*)
April 1993	*Trash, Traffic and Taxes: Elements of Market-Based Pollution Policy.* A report to: Pace University Center for Environmental Legal Studies. Tellus Study No. 92-148. Principal investigator.
October 1992	"Incorporation of Social Costs in Integrated Resource Planning". Invited by International Institute for Energy Conservation (IIEC) for the Electric Generating Authority of Thailand, under a World Bank project.
September 1992	"Electromagnetic Fields (EMF) and Transmission Line Planning", presented at Eighth NARUC Biennial Regulatory Information Conference, Columbus, Ohio. Julia G. Brody, Stephen Bernow.

September 1992 "Coordinating Clean Air Act Compliance with Integrated Resource Planning," Eighth NARUC Biennial Regulatory Information Conference. September 11, 1992: Clean Air Act. Stephen Bernow, Bruce Biewald, Kristin Wulfsberg.

September 1992 "Direct Environmental Impacts of Demand-Side Management," invited paper at the American Council for an Energy Efficient Economy (ACEEE). 1992 Summer Study. Stephen Bernow, Bruce Biewald, Mark Fulmer, Karen Shapiro, Kristin Wulfsberg.

September 1992 "Climate Change and the U.S. Electric Sector," presented to NARUC at 4th National Conference on Integrated Resource Planning, Burlington, VT. September 1992. Bruce Biewald and Stephen Bernow.

May 1992 "Modelling Fuel Cycle and Site-Dependent Environmental Impacts in Electric Resource Planning", invited paper at OECD-IEA Expert Workshop on Life-Cycle Analysis of Energy Systems. Paris, France. May 18 and 19, 1992. Stephen Bernow, Bruce Biewald, David Wolcott. *Proceedings* published OECD/IEA, Paris, 1993.

April 1992 "The Clean Air Act and Environmental Externalities," invited paper at EPA/DOE/NRRI Workshop on *Developing Public Utility Commission Rules and Procedures for Electric Utility Compliance with the Clean Air Act of 1990.* Stephen Bernow, Bruce Biewald, Kristin Wulfsburg.

March 1992 "Environmental Externalities: The Experience of Other Jurisdictions," Arizona Workshop, March 11, 1992.

January 1992 "Environmental Concerns Regarding Electric Power Transmission in North America," *Energy Policy.* Stephen Bernow, Jan Beyea and John DeCicco. Vol 20, No 1.

October 1991	"Computer Tools for Integrated Urban Environmental Planning." Invited by the World Bank for presentation to the World Bank and the Beijing Environmental Protection Bureau. Beijing.
1991	"The Inclusion of Environmental Goals in Electric Resource Evaluation: A Case Study in Vermont," Chapter 13 in *Energy Efficiency and the Environment: Forging the Link*, Edward Vine, Drury Crawley, and Paul Centolella, eds. American Council for an Energy Efficient Economy in cooperation with Universitywide Energy Research Group, University of California, Berkeley. Stephen Bernow and Donald Marron.
1991	"Environmental Externalities Measurement: Quantification, Valuation and Monetization," Chapter 4.1 in *External Environmental Costs of Electric Power*, Olav Hohmeyer and Richard Ottinger, eds. Springer-Verlag, Berlin. Stephen Bernow, Bruce Biewald and Donald Marron.
March 1991	"Avoided Emissions and Environmental Dispatch," presented at the Conference on "Demand-Side Management and the Global Environment," Arlington, Virginia, April 22-23, 1991.
March 1991	"Environmental Benefits of DSM in New York: Long Island Case Study," presented at the Conference on "Demand-Side Management and the Global Environment, "Arlington, Virginia, April 22-23, 1991.
March 1991	"Full Cost Dispatch: Incorporating Environmental Externalities in Electric System Operation," *Electricity Journal*. Stephen Bernow, Bruce Biewald and Donald Marron.
January 1991	*The Environmental Costs and Benefits of DSM: A Framework for Analysis*, prepared for Electric Power Research Institute (EPRI). Tellus Study No. 90-177. Co-author.
January 1991	*The Potential Impact of Environmental Externalities on New Resource Selection and Electric Rates*, for and with the Massachusetts Division of Energy Resources. Tellus Study No. 90-165. Co-author.
September 1990	*Environmental Impacts of Long Island's Energy Choices: The Environmental Benefits of Demand-Side Management*. A report to the Long Island Power Authority (LIPA). Tellus Study No. 90-028A. Principal Investigator.
October 1990	"Full Cost Economic Dispatch: Recognizing Environmental Externalities in Electric Utility System Operation," paper presented at the National Association of Regulatory Utility Commissioners, Conference on Environmental Externalities. Jackson Hole, Wyoming, October 1-3, 1990. Stephen Bernow, Bruce Biewald and Donald Marron.

September 1990	"Environmental Externalities Measurement: Quantification, Valuation, and Monetization," paper presented at the Eighth NARUC Biennial Regulatory Information Conference, 1990. Columbus, Ohio. September 12-14, 1990. Stephen Bernow, Bruce Biewald and Donald Marron.
August 1990	"The Inclusion of Environmental Goals in Electric Resource Evaluation: A Case Study in Vermont," paper presented at the American Council for an Energy Efficiency Economy, (ACEEE) 1990 Summer Study. Stephen Bernow and Donald Marron.

Energy and Environment: Planning and Methods

Forthcoming	*National Climate Change Policy and Clean Air Act Compliance: A Utility Case Study of Combined CO_2/SO_2 Reduction.* Report Prepared in Cooperative Agreement with the U.S. EPA Acid Rain Division. Tellus Study No. 92-185. Principal Investigator.
Forthcoming	*Avoided Cost Methodology: A Workbook for Use in IRP.* For the U.S. EPA and U.S. DOE. Co-author.
February 1994	*Energy Choices Revisited: An Examination of the Costs and Benefits of Maine's Energy Policy.* Prepared for Mainewatch Institute. Tellus Study No. 93-034. Project co-director.
April 1993	*Towards Global Energy Security: The Next Energy Transition*, a draft technical report to: Greenpeace International. Tellus Study No. 91-146. Co-author.
February 1993	*Analysis of the Costs of GHG Reductions in the U.S.* Mid-Project Report. Tellus Study No. 92-200F. Co-author.
December 1992	*The Environmental Impacts of Demand-Side Management Measures.* A report prepared for: Electric Power Research Institute, TR-101573, Research Project 3121-05. Tellus Study No. 92-089. Project manager.
April 1991	"Confronting Uncertainty: Contingency Planning for Decommissioning," (Chapter 18 in *The Energy Journal*, Volume 12, Special Issue). Bruce Biewald and Stephen Bernow.
December 1991	*America's Energy Choices: Investing in a Strong Economy and a Clean Environment*, Union of Concerned Scientists, Cambridge, MA. Co-author.
September 1990	"Avoided Cost Contracts Can Undermine Least Cost Planning," *Energy Policy*. Stephen Bernow, Bruce Biewald and Donald Marron.

May 1990 — *Conservation and Capacity Optimization Alternatives to the PGT/PG&E Gas Pipeline Project*. Prepared for: California Public Utilities Commission under subcontract to: Jones & Stokes Associates, Inc., Sacramento, CA 95816. Tellus Study No. 90-03. Co-author.

November 1989 — "The Indexing of Energy Rates Paid to Non-Utility Resources: Some Threats to Least-Cost Electricity Planning." Stephen Bernow, Bruce Biewald, and Donald Marron.

September 1988 — "Electric Utility System Reliability Analysis: Determining the Need for Generating Capacity", Proceedings of the Sixth NARUC Biennial Regulatory Information Conference. Bruce Biewald and Stephen Bernow.

October 29, 1987 — "Nuclear Power Plant Decommissioning: Cost Estimation for Power Planning and Ratemaking," *Public Utilities Fortnightly*. Stephen Bernow and Bruce Biewald.

September 1987 — "Risk Sharing and the 'Used and Useful' Criterion in Utility Ratemaking" (ESRG Paper). Stephen Bernow and Richard Rosen.

August 1987 — "Cost Performance of Boiling Water Reactors," *Public Utilities Fortnightly*. Stephen Bernow, Bruce Biewald, R. Timothy Woolf.

September 1984 — *Energy and Development in Kenya: Opportunities and Constraints*. Published by the Beijer Institute, The Royal Swedish Academy of Sciences. Stephen Bernow, Paul Raskin and Phil O'Keefe, eds.

February 1979 — *Analysis of Costs and Scarce Fuel Savings Associated with Nine Eastern and North Central Center City Conversions to a District Heating System*. Stephen Bernow, D.J. Santini, A.A. Davis, and S.M. Marder. Argonne National Laboratory Report ANL/CNSV-TM-12.

August 1978 — *An Assessment of the Potential for District Heating in Four Major Eastern Cities*. Stephen Bernow and R.A. Rosen. Argonne National Laboratory Report ANL/ICES-TM-11.

May 1979 — "Feasibility of District Heating and Cooling of Core Areas of Major Northeastern U.S. Cities by Cogeneration from Central Station Power Plants," presented at the Northeast Regional Science Association meeting (Amherst, Mass.). Stephen Bernow and D.J. Santini.

Water Systems Planning

Ongoing — *Guidelines for Water Utility Managers to Implement an Effective Integrated Resource Planning (IRP) Process*, American Water Works Association Research Foundation Project 920-93. Tellus Study No. 93-140. Co-author.

Ongoing	*Review of Kentucky-American Water Company's Least-Cost Plan*, for the Kentucky Office of the Attorney General. Tellus Study No.94-097. Co-author.
Forthcoming	*Integrated Regional Water Planning: A Conceptual and Modelling Approach.* Integrated Resource Planning Seminar, 1994 AWWA Annual Conference, NYC, June 19, 1994.
August 1989	*Regulating the Kingsley Hydro-Electric Facility and Dam to Provide Scouring Flows on the Platte River.* A Report to the National Audubon Society. ESRG Report No. 89-134. Co-author.
May 1988	*Water Planning in Developing Countries: Directions for Computer Modeling.* ESRG Report No. 87-86. Co-author.

Other Tellus and SEI Reports

April 1992	*Incorporating Environmental Externalities in Electric System Planning.* A report to: Colorado Office of Energy Conservation. Exhibit 2 to Tellus Study No. 91-203/SB. Principal investigator.
December 1991	*Valuation of Environmental Externalities: Sulfur Dioxide and Greenhouse Gases*, for the Massachusetts Division of Energy Resources. Tellus Study No. 91-085. Co-author.
November 1991	*Valuation of Environmental Externalities for Electric Utility Resource Planning in Wisconsin.* A Report to: Citizens for a Better Environment, Milwaukee, WI. Tellus Study No. 91-104. Principal Investigator.
July 1990	*Incorporating Environmental and Economic Goals into Nevada's Energy Planning Process.* A report to the Nevada Office of the Consumer Advocate. Tellus Study No. 89-209. Principal Investigator.
May 1990	*Valuation of Air Emissions for Alternative Electric and Natural Gas Resources in California.* Prepared for: California Public Utilities Commission under subcontract to: Jones & Stokes Associates, Inc., Sacramento, CA 95816. Tellus Study No. 90-03D. Co-author.
May 1990	*Incorporating Environmental Externalities in the Massachusetts Electric Resource Bidding System.* A compilation of comments submitted by the Massachusetts Division of Energy Resources before the Department of Public Utilities in D.P.U. 86-36-G and D.P.U. 89-239. Tellus Study No. 90-015. Co-author.
May 1990	*Valuation of Environmental Externalities for Energy Planning and Operations.* May 1990 Update. Co-author.
March 1992	*Need for and Alternatives to Nuclear Plant License Renewal.* A report to: Vermont Department of Public Service. Tellus Study No. 91-248. Co-author.
January 1992	*Preliminary Study on Integrated Resource Planning for the Consumers' Gas Company, Ltd.* A Report to: Consumers Gas Company, Ltd. Tellus Study No. 91-001. Co-author.
September 1990	*Long Island Power Authority Comments on the LILCO 1991-92 Electric Conservation and Load Management Biennial Plan and the LILCO 1990 Long Range Electric Conservation and Load Management Plan.* Volume II: Appendices. Tellus Study No. 90-028. Co-author.
May 1990	*Evaluation of Repowering the Manchester Street Station.* A Report to: Rhode Island Division of Public Utilities and Carriers, Rhode Island Division of Statewide Planning, and Rhode Island Governor's Office of Housing, Energy and Intergovernmental Relations. Tellus Study No. 90-010. Co-author.
December 1989	*The Role of Hydro-Quebec Power in a Least-Cost Energy Resource Plan for*

	Vermont. A Report to: Vermont Public Service Board. ESRG Report. No. 89-078. Co-author.
November 1989	*Demand-Side Management Alternatives for the Cincinnati Gas & Electric Company*. A Report to: Ohio Office of Consumers' Counsel, Columbus. ESRG Report No. 89-115. Co-author.
October 1989	*Evaluation of Staffing Requirements for the Minnesota Department of Public Service Imposed by Potential Least Cost Planning Processes*. A Report to the Minnesota Department of Public Service. ESRG Report No. 89-18A. Principal Investigator.
December 1988	*Least Cost Integrated Planning Processes for Electric Utilities: Implementation in Five States.* A Report for the Missouri Office of the Public Counsel. ESRG Report No. 87-62. Co-author.
October 1988	*An Analysis of Physical Excess and Uneconomic Capacity Resulting from the Addition of Beaver Valley 2 and Perry 1 to the Centerior Generating System.* A Report for the Ohio Office of Consumers' Counsel. ESRG Report No. 88-38B. Principal investigator.
September 1988	*The Economics of Diablo Canyon: Analyses of the Proposed Settlement Agreement and the Continued Operation of the Plant.* A Report for the Redwood Alliance. ESRG Report No. 88-50R. Co-author.
April 1988	*Report on the Cost Allocation Issue Arising from the Proposed Merger of Utah Power and Light and Pacificorp, Maine.* A Report to the Public Service Commission of Utah on behalf of the Committee of Consumer Services. ESRG Report No. 87-107C. Co-author.
June 1987	*The New England Power Pool and New England's Electricity Future: Issues and Directions.* A report to the New Hampshire Consumer Advocate. ESRG Study No. 86-83A/1. Principal investigator.
June 1987	*Review of the Committee for Energy Awareness Study of the New England Power Supply Situation.* A memorandum to the New Hampshire Consumer Advocate. ESRG Study No. 86-83A/2. Co-author.
May 1987	*Concerning LILCO's Request for Operating Shoreham at 25% Power in the Summer of 1987,* Affidavit of Stephen S. Bernow to the Nuclear Regulatory Commission. Docket No. 50-322-OL-3 (Emergency Planning). ESRG Study No. 86-99A. Author.
May 1987	*Reliable Power on Long Island for the New Term (1987-1992).* Preliminary Report. Attachment 2 to above study.
May 1987	*The Fort St. Vrain Nuclear Plant: Economics and Related Issues.* A Report to the Colorado Office of Consumer Council (DRAFT). ESRG Study No. 86-04. Research Director.

April 1987	*Towards an Energy Transition on Long Island: Issues and Directions for Planning.* ESRG Study No. 87-05. Co-author.
May 1986	*Management Audit of Baltimore Gas and Electric Company's Fuel Procurement and Purchasing Practices.* A report to the Maryland Public Service Commission. ESRG Study No. 85-065/B. Co-author.
April 1986	*The Economics of Completing and Operating the Vogtle Nuclear Generating Facility.* ESRG Report No. 85-98. Co-author.
February 1986	*Approaches to the Development of Generating Plant Performance Standards for Palo Verde. Volume 1: Main Report.* ESRG Study No. 85-22/1. Co-author.
	Volume II: Technical Report. ESRG Study No. 85-22/2. Co-author.
October 1984	*Cost-Benefit Analysis of the Cancellation of Commonwealth Edison's Braidwood Nuclear Generating Station.* ESRG Study No. 83-87. Co-author.
May 1984	*Electric Rate Consequences of Cancellation of the Midland Nuclear Power Plant.* ESRG Study No. 83-81/1. Co-author.
May 1984	*Power Planning in Kentucky: Assessing Issues and Choices, Project Summary Report to the Public Service Commission.* ESRG Study No. 83-51. Co-author.
January 1984	*Electric Rate Consequences of Retiring the Robinson 2 Nuclear Power Plant.* ESRG Study No 83-10. Co-author.
December 1983	*Power Planning in Kentucky: Assessing Issues and Choices, Technical Report I, Long Range Forecasts of Electricity Requirements for Kentucky and its Six Major Utilities.* ESRG Study No. 83-51/TRI.
September 1986	*Incentives vs. Audits: The Regulation of Fuel Costs,* presented to the Fifth Biennial Regulatory Information Conference sponsored by the National Regulatory Research Institute in Columbus, Ohio. Stephen Bernow and Neil Talbot.
1982/83	*LEAP-LDC-Energy Alternatives Planning-System,* 3 volumes. Co-author.
August 1983	*Preliminary Evaluation of the OKA Audit of Marble Hill Nuclear Project Costs.* ESRG Study No. 83-48. Principal investigator.
August 1983	*An Evaluation of the New York Power Authority's Economic Justification for its Proposed Marcy-South 345 KV Transmission Facilities.* ESRG Study No. 83-45. Principal investigator.
July 1983	*Long Island Without the Shoreham Power Plant: Electricity Cost and System Planning Consequences.* ESRG Study No. 83-14. Co-author.

May 1983	*Report to the Counties of Orange, Dutchess, Sullivan, and Otsego, Re: Is the Proposed Marcy-South Project Justified? An Assessment of PASNY's Case for Construction.* ESRG Study No. 83-08. Principal investigator.
March 1983	*A Report to the Washington, D.C. Public Service Commission on the Research Programs of PEPCO and WG&L.* ESRG Study No. 83-11.
November 1982	*Issues in SADCC Energy Planning: Usage Patterns, Resource Potential and Regional Possibilities.* A Report for a seminar convened by Angola and hosted by Zimbabwe with cooperation from the Swedish International Development Agency. Co-author.
August 1982/ October 1982	Technical Assistance to the Boston Redevelopment Authority on Fuel Use, Emissions, and Air Quality Impacts of Alternative Energy Strategies for Boston Electric Company and the Central Business District, ESRG Study No. 82-04.
October 1982	*The Economics of Closing the Indian Point Nuclear Power Plant.* ESRG Study No. 82-40. Co-author.
August 1982	*LEAP, LDC Energy Alternatives Planning System, Volume 1 - Overview.* A Report to the Beijer Institute of the Royal Swedish Academy of Sciences. Co-author.
August 1982	*The Impacts of Early Retirement of Nuclear Power Plants: The Case of Maine Yankee.* ESRG Study No. 82-91.1 Co-author.
August 1982	*Nuclear Capacity Factors: The Effects of Aging and Saltwater Cooling.* ESRG Study No. 82-81. Co-author.
April 1982	*A Power Supply and Financial Analysis of the Seabrook Nuclear Station As a Generation Option for the Maine Public Service Company.* Co-author.
February 1982	*Energy Conservation and Employment in Ohio. A Report to the Office of the Consumers' Counsel, State of Ohio.* ESRG Study No. 80-27. Co-author.
February 1982	*Energy Planning for Small Developing Islands.* Report to United Nations Ocean Economics and Technology Branch, D.I.E.S.A., United Nations. ESRG Study No. 81-28. Principal investigator.
January 1982	*Energy Development in Kenya: Problems and Opportunities.* A report to the Kenya Ministry of Energy. ESRG Study No. 80-24. Co-author.
January 1982	*Long Range Capacity Analysis for Alabama Power Company and the Southern Company System.* A Report to Alabama Public Service Commission. ESRG Study No. 82-01/CE. Co-author.
October 1981	*LEAP, LDC Alternatives Planning Model, A Description.* ESRG Study No. 81-24. Co-author.

October 1981	*A Conservation Investment Scenario for The Northeast Utilities Connecticut Service Area.* ESRG Study No. 81-12/1. Co-author.
July 1981	*Long-Range Capacity Expansion Analysis for Alabama Power Company and the Southern Company System.* ESRG Study No. 80-63. Co-author.
June 1981	*An Analysis of the Need for and Alternatives to the Proposed Coal Plant at Arthur Kill* - A Report to: Robert M. Herzog, Director, New York City Energy Office and Allen G. Schwartz, Corporation Counsel for the City of New York. ESRG Study No. 81-21. Co-author.
February 1981	*District Heating Strategy Model Users Guide* developed for the Department of Energy under contract with Argonne National Laboratory, ESRG Study No. 80-57. Principal investigator.
January 1981	*The Conservation Investment Alternative for New York State.* ESRG Study No. 80-42. Co-author.
November 1980	*Economic and Need Analysis of the Proposed Pumped Storage Facility at Brumley Gap.* ESRG Report 80-08/R. Co-author.
October 1980	*The ESRG Electrical Systems Generation Model.* ESRG Report 80-12. Co-author.
September 1980	*Emissions Impacts of Diesel Cogeneration in New York City.* ESRG Report 79-30/B. Co-author.
September 1980	*Reducing New England's Oil Dependence Through Conservation and Alternative Energy: 1978-2000.* ESRG Report 79-29. Co-author.
February 1980	*Long Range Forecast of Eastern Wisconsin Utilities' and Western Wisconsin Utilities' Electric Energy Requirements and Peak Demands.* ESRG Study 79-28. Principal investigator.
October 1979	*The Annual Emissions and Air Quality Impacts of an Urban Area District Heating System: Boston Case Study.* ESRG Study No. 79-19. Principal investigator.
July 1979	*State Conservation Policy Case Forecast.* Vol. II of ESRG Study No. 79-12, *Electricity Requirements in New York State.* Co-author.
September 1978	*Update and Reconciliation of District Heating Studies of Argonne National Laboratory and Brookhaven National Laboratory.* ESRG Study No. 78-08. Principal investigator.
January 1978	*Industrial Cogeneration in New York State: Identifying and Overcoming Barriers.* ESRG Study No. 78-01, A Report to the New York State Energy Office. Co-principal investigator.

November 1977	*Profile of Targets for the Energy Advisory Service to Industry.* ESRG Study No. 77-09. A Report to the State Energy Office.
October 1977	*An Assessment of the Potential for District Heating in Four Major Cities.* ESRG Study No. 77-08, A Report to Argonne and Brookhaven National Laboratories. Principal investigator.

Agency	Case or Docket No.	Testimony Date	Topic
Michigan Public Service Commission	U-10059 U-10061 (Tellus 92-083)	May 1992	Costs and Benefits of the Proposed PSI Transmission Line (the Power Line)
Colorado Public Utilities Commission	91M-642EG (Tellus 91-203/SB)	April 1992	Environmental Externalities in IRP
Wisconsin Public Service Commission	05-EP-6 (Tellus 91-104)	November 1991	Valuation of Environmental Externalities for Electric Resource Planning in Wisconsin
Public Utilities Commission of Ohio	89-1001-EL-AIR (ESRG 89-125A)	March 1990	Excess Capacity, Beaver Valley 2, and the Edison Company
Arizona Corporation Commission	U-1345-88-180, U-1345-85-367, U-1345-86-062 (ESRG 88-096/C)	December 1988	Operating Performance Standards for Arizona Public Service Company
Public Utilities Commission of Ohio	88-170-EL-AIR (ESRG 038/B1)	October 1988	Excess Capacity and Cost Benefit Analysis of the Perry 1 and Beaver Valley 2 Nuclear Facilities - Cleveland Electric Illuminating Company
Public Utilities Commission of Ohio	88-171-EL-AIR (ESRG 88-038/B2)	October 1988	Excess Capacity and Cost Benefit Analysis of the Perry 1 and Beaver Valley 2 Nuclear Facilities - Toledo Edison Company
Public Utilities Commission of California	84-06-014, 85-08-025 (ESRG 88-050T2)	September 1988	Analysis of the Proposed Settlement on the Diablo Canyon Rate Case
Public Service Commission of Michigan	U-8789 (ESRG 87-54)	September 1988	Application of Detroit Edison Company to amend rate schedule (CASE SETTLED)

Public Service Commission of Utah	87-035-27 (ESRG 87-107C)	April 1988	Inter-Divisional Evaluation of Cost Allocation in the Merged Company (Pacificorp)
Georgia Public Service Commission	3673-U (ESRG 87-38)	August 1987	Excess Capacity and Cost Benefit Analysis of Vogtle Generating Station
Arizona Corporation Commission	U-1345-85-367 (ESRG 86-42A)	February 1987	Concerning Excess Capacity and Cost Benefit Analysis of Palo Verde Generating Station
Arizona Corporation Commission	U-1345-85-367(ESRG 86-42G)	February 1987	Concerning Performance Standards for Arizona Public Service Company
Michigan Public Service Commission	U-7660 (ESRG 86-37)	December 1986	Concerning the Fermi II Nuclear Facility: Further and Additional Evidence
Michigan Public Service Commission	U-8469 (ESRG 86-43)	December 1986	Concerning Performance Standards for the Fermi II Nuclear Facility
Illinois Commerce Commission	86-0249 (ESRG 86-64A)	October 1986	Concerning Cancellation of Braidwood 2
South Carolina Public Service Commission	86-188-E (ESRG 86-26/A)	July 1986	Catawba 2 Economic Analysis and Rate-making Treatment
Michigan Public Service Commission	U-8376 (ESRG 86-08)	May 1986	Performance Standards for the Belle River Plant
Maine Public Utilities Commission	85-212 (ESRG 85-89B)	April 1986	Excess Capacity Determination and Economic Cost-Benefit Analysis
Maine Public Utilities Commission	85-212 (ESRG 85-89B)	June 1986	Surrebuttal Testimony
Georgia Public Service Commission	3554-4 (ESRG 85-98)	April 1986	Economics of Completing versus Canceling the Vogtle Nuclear Facilities

Arizona Corporation Commission	U-1345-85-156 (ESRG 85-69/D)	February 1986	Excess Capacity and Economic Cost Benefit Analysis of Nuclear Plant
Connecticut Department of Utility	85-10-22 85-09-12 (ESRG 85-91A)	February 1986	Excess Capacity and Economic Cost Benefit Analysis of Nuclear Plant
Arkansas Public Service Commission	84-249-U (ESRG 85-08/1)	June 1986	Request for a Retail Rate Increase
Arkansas Public Service Commission	84-249-U (ESRG 85-08)	July 1985	Surrebuttal Testimony
		August 1985	Supplemental Testimony
		September 1986	Surrebuttal Supplemental Testimony
Illinois Commerce Commission	82-0855 (ESRG 85-17/SB)	June 1985	Rebuttal Testimony
Wyoming Public Utilities Commission	9454 Sub 25	January 1985	Examination of Excess Capacity on the Pacific Power and Light Company System: Reliability and Reserves, and the Economics of the Colstrip 3 Plant
Wyoming Public Utilities Commission	9441 Sub 20	December 1984	Examination of Excess Capacity on the Utah Power and Light Company System: Reliability and Reserves, and the Economics of the Hunter 3 Plant
Illinois Commerce Commission	83-0855	October 1984	Cost-Benefit Analysis of the Cancellation of Commonwealth Edison's Braidwood Nuclear Generating Station (Direct Testimony)
		June 1985	Rebuttal Testimony
Michigan Public Commission	U-7660	January 1984	Application of Detroit Edison Service Company for Authority to Amend its Rate Schedule Covering the Supply of Electric Energy and to Amend Other Miscellaneous Rates (Direct Testimony)

Catskill Center for Conservation and Development, Inc., et al.	1983 State Energy Master Planning & Long-Range Electric & Gas System Planning Proceeding	September 1983	Economics of Pumped Storage in NYPP
New York Public Service Commission	70126	August 1983	Evaluation of NY Power Authority's Economic Justification for its Proposed Marcy-South 345 KV Transmission Facilities
Illinois Commerce Commission	82-092	1983	Economics of Capacity Reserves
Federal Energy Regulatory Commission	2729	January 1981	Economics of Pumped Storage in NYPP
New York Public Service Commission	80003	August 1979	Nuclear economics
Connecticut Division of Public Utilities Control	781206, 718207	May 1979	Economic implications of alternative generation capacity construction
Michigan Public Service Commission	U-6006	April 1979	Reliability and reserve margins
New York Public Service Commission and U.S. Nuclear Regulatory Commission	Case No. 80006 Docket No. 50-549	March 1979	Nuclear economics
Wisconsin Public Service Commission	CA 5447	January 1979	Forecast critique and independent long-range forecast of electric energy and demand
Pennsylvania Public Utility Commission	R-77110-521	April 1978	Long-range forecast of electric demand

Consulting

1977-1978 — Consultant to Brookhaven National Laboratory's Less Developed Countries Energy Project

DR. JOHN DECICCO

Senior Associate
Ameican Council for An Energy-Effcient Economy

Dr. DeCicco is responsible for research, technology assessment, policy analysis, and advocacy work regarding energy efficiency. His specialty focuses on transportation, including vehicle technologies, transportation systems, and integration of economic development and environmental protection in transportation energy planning.

Under the leadership of Dr. DeCicco, ACEEE has developed an extensive expertise as well as the leading information on transportation fuel-efficiency supply curves. This includes information on both the available technologies and those most likely to emerge during the study's period of analysis. The information has been synthesized into a database containing the latest technology characteristics and their respective costs and anticipated savings.

His other efforts at ACEEE include policy and program analysis on national energy strategies, energy efficiency in buildings, and environmental impacts of energy use.

Previous to ACEEE, Dr. DeCicco was a staff scientist and engineer at the National Audubon Society, where he performed research and policy analysis on environmental impacts of energy use such as greenhouse gas emission, nuclear accidents, emissions from coal power plants, impacts of electric power lines, and environmental protection through energy conservation. He wrote both for technical audiences, and for the general public.

Dr. DeCicco holds a Ph.D. in mechanical engineering from Princeton University.

LIST OF PUBLICATIONS

DeCicco, J.M., and M. Ross. *An Updated Assessment of the Near-term Potential for Improving Automotive Fuel Economy*. American Council for an Energy-Efficient Economy, Washington, DC, November 1993.

eller, H., J. DeCicco, S. Laitner, and C. Dyson. *Twenty Years After the Embargo: the Costs of U.S. Oil Dependence and How They Can Be Reduced*. Report, American Council for an Energy-Efficient Economy and Public Citizen, Washington, DC, October 1993.

DeCicco, J.M., and D. Gordon. "Steering with Prices: Fuel and Vehicle Taxation as Market Incentives for Higher Fuel Economy". Presentation to the 1993 Asilomar Conference on Transportation and Energy, August 1993.

eller, H., J. DeCicco, and S. Nadel. *Cost-Effective Carbon Dioxide Reduction Strategies*. American Council for an Energy-Efficient Economy, Washington, DC, June 1993.

DeCicco, J.M., S.S. Bernow, D. Gordon, D.B. Goldstein, J.W. Holtzclaw, M.R. Ledbetter, P.M. Miller, and H.M. Sachs. "Transportation on a Greenhouse Planet: A Least-cost Transition Scenario for the United States". In D.L. Greene and D. Santini (eds.), Transportation and Global Climate Change: Long-run Options (Proceedings of Conference at Asilomar, CA, August 1991). American Council for an Energy-Efficient Economy, Washington, DC, 1993.

DeCicco, J.M., H.S. Geller, and J.H. Morrill. *Feebates for Fuel Economy: Market Incentives for Encouraging Production and Sales of Efficient Vehicles*. American Council for an Energy-Efficient Economy, Washington, DC, May 1993.

Geller, H., J. DeCicco, and S. Laitner. *Energy Efficiency and Job Creation: the Employment and Income Benefits from Investing in Energy Conserving Technologies.* Report, American Council for an Energy-Efficient Economy, Washington, DC, October 1992.

DeCicco, J.M. *Efficiency and Alternative Fuels: Convergent Strategies for Reducing Transportation Oil Use*. American Council for an Energy-Efficient Economy, Washington, DC, September 1992.

DeCicco, J.M. *Savings from CAFE: Projections of the Future Oil Savings from Light Vehicle Fuel Economy Standards.* Report, American Council for an Energy-Efficient Economy, Washington, DC, May 1992.

DeCicco, J.M. "Use a Vehicle-based Approach, But Lock in Each Company's Target." Presentation to the 1992 SAE Government/Industry meeting, and draft paper, American Council for an Energy-Efficient Economy, Washington, DC, May 1992.

DeCicco, J.M. "A critique of the National Research Council Study of the Potential for Improving Automotive Fuel Economy." Presentation to the 1992 SAE Government/Industry meeting. American Council for an Energy-Efficient Economy, Washington, DC, April 30, 1992.

DeCicco, J.M. "The Greenish Machine: On the Road to Reduced CO2 Emissions Via Alternative Fuels and Higher Fuel Economy." Paper presented to the Urban CO2 Reduction Project Conference, Miami, FL. American Council for an Energy-Efficient Economy, Washington, DC, March 1992.

DeCicco, J.M. *Preliminary Analysis of Revenues Expected from Maryland's Gas Guzzler Tax Surcharge and Gas Sipper Tax Credit Program.* American Council for an Energy-Efficient Economy, Washington, DC, November 11, 1992.

DeCicco, John M., Jan Beyea, and Stephen S. Bernow. "Environmental Concerns Regarding Electric Power Transmission in North America." *Energy Policy* 20(1):30-39, January 1992.

UCS et al. (Alliance to Save Energy, American Council for an Energy-Efficient Economy, Natural Resources Defense Council, and Union of Concerned Scientists). [J.M. DeCicco coordinated the transportation sector analyses and was principal author of the transportation sector technical appendices.] *America's Energy Choices: Investing in a Strong Economy and a Clean Environment.* Union of Concerned Scientists, Cambridge, MA, December 1991.

DeCicco, J.M. "Cost-effectiveness of Fuel Economy Improvement." Presentation to the National Academy of Sciences, Committee on Fuel Economy of Automobiles and Light Trucks, Workshop and Committee Meeting, Irvine, CA, July 8-12, 1991.

eCicco, J.M. *Advanced Automobile Development Challenge, a Publicly Funded Competition and Incentive Program for Bringing Super-efficient Automobiles to Market in the United States.* American Council for an Energy-Efficient Economy, Washington, DC, March 11, 1991.

Beyea, Jan, and John M. DeCicco. *Re-estimating the Noble Gas Releases from the Three Mile Island Accident.* Report to the Three Mile Island Public Health Fund, National Audubon Society, New York, NY, July 1990.

eCicco, John, Jim Cook, Dorene Bolze, and Jan Beyea. *The Carbon Dioxide Diet: a Citizens' Guide for Reducing Global Climate Disruption.* National Audubon Society Report, June 1990.

eCicco, John M. "Applying a Linear Model to Diagnose Boiler Fuel Consumption. "*ASHRAE Transactions* 496(1), February 1990.

eCicco, John M. "Energy Conservation and Outdoor-reset Control of Space Heating Systems." *Proceedings of the American Council for an Energy-Efficient Economy (ACEEE) 1988 Summer Study on Energy Efficiency in Buildings*, Asilomar, CA, August 1988.

DeCicco, John M., and Willett Kempton. "Behavioral Determinants of Energy Consumption in a Centrally-heated Apartment Building." *Energy Systems and Policy* 11(3):155-168, 1987.

eCicco, John M., and Gautam S. Dutt. "Domestic Hot Water Service in Lumley Homes: a Comparison of Energy Audit Diagnosis with Instrumented Analysis." *Proceedings of the American Council for an Energy-Efficient Economy (ACEEE) 1986 Summer Study on Energy Efficiency in Buildings*, Santa Cruz, CA, August 1986.

DeCicco, John M., and Willett Kempton. "Heating a Multifamily Building: Tenant Perceptions and Behavior." *Proceedings of the American Council for an Energy-Efficient Economy (ACEEE) 1986 Summer Study on Energy Efficiency in Buildings,* August 1986.

eCicco, John, Art McGarity, Les Norford, and Laurie Ryan. "Instrumented Buildings: Experiences in Obtaining Accurate Data." *Proceedings of the American Council for an Energy-Efficienct Economy (ACEEE) 1986 Summer Study on Energy Efficiency in Buildings*, August 1986.

DeCicco, John M., Gautam S. Dutt, David T. Harrje, and Robert H. Socolow. "PRISM Applied to a Multifamily Building: the Lumley Homes Case Study." *Energy and Buildings*, 9:77-88, 1986.

arrje, David T., John M. DeCicco, and Don L. Kirkpatrick. "Optimizing Building Control Strategies Using Short-term Energy and Comfort Monitoring." *Clima 2000*, 3:7-12, Energy

Management, Proc. VVS Kongres, VVS Messe, Copenhagen, Denmark, 1985.

DeCicco, John M., Herbert M. Eckerlin, and Albert S. Boyers. "An Evaluation of Some Thermal Performance Characteristics of the NCSU Solar House. *Proceedings of the 8th Passive Solar Conference, American Solar Energy Society*, Santa Fe, NM, September 1983.

Johnson, David H., and John DeCicco. "An Artificial Upwelling Driven By Salinity Differences in the Ocean. *ASME Seventh Annual Energy Sources Technology Conference and Exhibition*, New Orleans, LA, February 1984. Report SERI/TP-252-2149, Solar Energy Research Institute, Golden, CO, December 1983.

RICHARD HORNBY

Tellus Institute

Manager, Natural Gas Projects
Energy Group

Education

M.S.	Technology and Policy (Energy), Massachusetts Institute of Technology, 1979
B.Eng.	Industrial Engineering, Technical University of Nova Scotia, Canada, 1973

Experience

1986-Present Manager, Natural Gas Program
Energy Group
Directs the Natural Gas Program at Tellus
Responsible for natural gas load forecasting, supply planning, demand-side management, ratemaking and integrated resource planning. Also responsible for fuel supply planning and price projections.

1982-1986 Member, Canada-Nova Scotia Offshore Oil and Gas Board.
Served on Federal-Provincial Board responsible for regulating petroleum industry exploration and development activity offshore Nova Scotia.

1981-1986 Assistant Deputy Minister of Energy (1983-86), Director of Energy Resources (1982-83), Assistant to the Deputy Minister (1981-82).
Nova Scotia Department of Mines and Energy, Halifax, Canada.
Responsible for the development and implementation of government energy policies and programs covering both supply and demand.

1978-1980 Research Officer, Nova Scotia Research Foundation, Dartmouth, Canada.
Responsibility for energy projects, including energy supply/demand planning and industrial energy conservation.

1975-1977 Project Engineer, Canadian Keyes Fibre, Hantsport, Canada.
Responsibility for engineering projects including energy conservation, pollution control and production reporting.

1973-1975 Management Consultant, Imperial Group Limited, Bristol, England.
Provided industrial engineering services to subsidiaries in tobacco, food processing, brewing and packaging divisions.

Testimony

Agency	Case or Docket No.	Date	Topic
Kansas Corporation Commission	180,056-U	Feb. 1994	Oral Testimony (no written testimony) on establishment of IRP Rules for electric and gas utilities
Arizona Corporation Commission	E-1032-93-111 (Tellus 93-099)	Dec. 1993	Application of Citizens Utility Company, Arizona Gas Division, for an increase in its rates, and accompanying changes in rates and tariff design
		Jan. 1994	Sur-rebuttal testimony in above docket
Hawaii Public Utilities Commission	7257 (Tellus 93-144B5)	Dec. 1993	Identification of GASCO's concerns regarding DSM programs proposed by HECO for competitive energy end-use markets, specifically HECO's residential sector water heating program
Hawaii Public Utilities Commission	7261 (Tellus 93-171)	Sept. 1993	GASCO IRP
		Dec. 1993	Rebuttal testimony in above docket
Pennsylvania Public Utility Commission	R-932655 R-932655 C001 R-932655 C002 (Tellus 93-149)	Sept. 1993	Analysis of transportation service balancing charge proposed by PA Gas and Water
Pennsylvania Public Utility Commission	R-932676 (Tellus 93-092)	July 1993	Review of gas supply strategy and purchasing practices of Pennsylvania Gas and Water Company; recommendations to the PUC with respect to gas cost adjustments, gas supply policy issues and the purchasing practices of PG&W

		July 1993	Rebuttal Testimony in above docket
Public Utilities Commission of Rhode Island	2025 (Tellus 93-018)	April 1993	Review of request by Providence Gas Company for cost recovery for its activities related to development of an Integrated Resource Plan
Pennsylvania Public Utility Commission	I-900009 C-913669 (Tellus 91-074)	March 1993	Review of Equitable's maximum charges for transportation service and cost allocation methods in general
Arkansas Public Service Commission	92-178-U (Tellus 92-014)	August 1992	Reasonableness of certain sections of the proposed Stipulation and Agreement concerning gas cost and purchasing practices issues in Dockets No. 91-093-U (Arkla Energy Resources) and No. 92-032-U (Arkansas Louisiana Gas)
Colorado Public Utilities Commission	91R-642EG (Tellus 91-203)	August 1992	Draft, proposed gas integrated resource planning (IRP) rule
Pennsylvania Public Utility Commission	R-00922324 (Tellus 92-117)	July 1992	Review of the gas supply strategy and purchasing practices of PG&W; recommendations to the PUC with respect to gas cost adjustments, gas supply policy issues and the purchasing practices of PG&W
		July 1992	Supplemental Testimony in above docket
Pennsylvania Public Utility Commission	R-922180 (Tellus 92-039)	May 1992	Review of the application of the Peoples Natural Gas Company for an increase in its rates and for accompanying changes in the tariffed rate design
		June 1992	Rebuttal Testimony in above docket
		June 1992	Sur-Rebuttal Testimony in above docket

Michigan Public Service Commission	U-10030 (Tellus 91-120)	April 1992	Review of the 1992 Gas Cost Recovery Plan submitted by Consumers Power Company to determine if demand-side management is treated as a resource in its five-year forecast and supply plan and, if so, whether utilization of DSM as a resource is reasonable. Recommendations as to the role of DSM in minimizing the cost of gas service to customers.
Pennsylvania Public Utility Commission	R-912140 (Tellus 92-038)	March 1992	Review of the gas supply strategy and purchasing practices of T.W. Phillips, as well as recommendations to the PUC with respect to gas cost adjustments
Federal Energy Regulatory Commission	RP91-161-000 et al., RP91-160-000 et al. Tellus (91-175)	February 1992	Review of cost allocation and rate design issues in the application of Columbia Gas Transmission and Columbia Gulf Transmission (on behalf of PA OCA)
Arkansas Public Service Commission	91-093-U (Tellus 92-014)	February 1992	Establishment of a base cost of gas for Arkla Energy Resources (AER), modification of Purchased Gas Adjustment (PGA)
		June 1992	Surrebuttal Testimony in above docket
New Hampshire Public Utilities Commission	91-164 (Tellus 91-164)	January 1992	Role of embedded cost-of-service studies, level of customer charges, seasonal differential in commodity rates; and class revenue requirements (EnergyNorth Natural Gas, Inc.)
Arizona Corporation Commission	U-1551-89-102 & U-1551 -89-103 U-1551-91-069 (Tellus 90-203)	September 1991	Southwest Gas Corporation Audit of Gas Procurement Practices and Purchased Gas Costs (January 1986 - November 1990)
		December 1991	Prepared Rebuttal Testimony in above Dockets

Maryland Public Service Commission	8339 (Tellus 91-79)	July 1991	Review of several aspects of the application of Baltimore Gas and Electric Company for a change in its Gas tariffs
Public Utilities Commission of Rhode Island	1727 (Tellus 90-135)	June 1991	Review of gas procurement practices of Bristol and Warren Gas Company
	(Tellus 91-165)	September 1991	Supplemental Direct Testimony in above docket
New Mexico Public Service Commission	2367 (Tellus 91-030)	June 1991	Analysis of gas transportation policies proposed by Gas Company of New Mexico
Pennsylvania Office of Consumer Advocate	R-911889 (Tellus 91-025)	March 1991	Review of gas supply strategy and purchasing practices of T.W. Phillips
Michigan Public Service Commission	U-9752 (Tellus 90-099)	March 1991	Review of 1991 Gas Cost Recovery Plan submitted by Michigan Gas Company to Michigan PSC
Arkansas Public Service Commission	90-036-U (Tellus 90-041)	August 1990	Reasonableness of certain gas supply contracts, of Arkla, Inc. and its various subsidiary companies including the Arkla-Arkoma transactions
		September 1990	Prepared Rebuttal Testimony in above docket
Arizona Corporation Commission	U-1240-90-051 (Tellus 90-059)	August 1990	Application of Southern Union Gas Company for a change in tariffs
Public Utility Commission of Utah	89-057-15 (Tellus 89-242)	July 1990	Cost Allocation and Rate Design, Mountain Fuel Supply
		August 1990	Rebuttal and Sur-Rebuttal Testimony in above docket
Pennsylvania Public Utility Commission	R-901595 (Tellus 90-043)	June 1990	Application of Equitable Gas Company for changes to its tariffs

West Virginia Public Service Commission	90-196-E-GI 90-197-E-GI (Tellus 90-025)	May 1990	Expanded Net Energy Cost, coal supply strategy and contracting practices; APS
Pennsylvania Public Utility Commission	R-891572 (Tellus 90-08B)	March 1990	Purchased Gas Costs and Gas Procurement; T.W. Phillips Gas and Oil Co.
Public Utilities Commission of Colorado	89R-702G (Tellus 89-30A)	January 1990	Policies and rules for gas transportation service offered by public utilities regulated by the Commission
	(Tellus 89-30B)	January 1990	Supplemental Testimony
Arizona Corporation Commission	U-1551-89-102 and U-1551-89-103 (ESRG 89-01)	October 1989	Regulatory Oversight of Purchased Gas Costs
Public Utilities Commission of Rhode Island	1938 (ESRG 89-139)	October 1989	Sales Forecast, Cost Allocation, Rate Design; Narragansett Electric Company
Pennsylvania Public Utility Commission	R891293 (ESRG 89-92)	July 1989	Purchased Gas Costs & Gas Procurement; Pennsylvania Gas and Water
		July 1989	Rebuttal Testimony
Pennsylvania Public Utility Commission	R891236 (ESRG 89-48)	May 1989	Take-or-Pay Cost Recovery; Columbia Gas of Pennsylvania
New Jersey Board of Public Utilities	GR 88070-877 (ESRG 88-150A)	February 1989	Take-or-Pay Cost Recovery; Public Service Electric and Gas
New Jersey Board of Public Utilities	GR 88080-913- Phase II (ESRG 88-150C)	February 1989	Take-or-Pay Cost Recovery; South Jersey Gas Company

New Jersey Board of Public Utilities	GR 88081-019- Phase II (ESRG 88-150D)	February 1989	Take-or-Pay Cost Recovery; Elizabethtown Gas Company
New Jersey Board of Public Utilities	88080913 (ESRG 88-102)	December 1988	Take-or-Pay Cost Recovery; Elizabethtown Gas Company
Montana Public Service Commission	87.7.33, 88.2.4, 88.5.10, 88.8.23 (ESRG 88-117)	December 1988	Gas Procurement, Transportation Service, Gas Adjustment Clause; Montana-Dakota Utilities Company
New Jersey Board of Public Utilities	GR 88081-019 (ESRG 88-103)	November 1988	Take-or-Pay Cost Recovery; South Jersey Gas Company
New Jersey Board of Public Utilities	GR 88070-877 (ESRG 88-89)	October 1988	Take-or-Pay Cost Recovery; Public Service Electric and Gas
Public Service Commission of District of Columbia	Formal Case 874 (ESRG 88-58)	September 1988	Gas Acquisition, Gas Cost Allocation, Take-or-Pay Cost, Regulatory Oversight; District of Columbia Natural Gas
Illinois Commerce Commission	88-0103 (ESRG 88-68)	July 1988	Take-or-Pay Cost Recovery
Public Service Commission of West Virginia	240-G (ESRG 88-42)	June 1988	Gas Transportation Rate Design
Pennsylvania Public Utility Commission	R-880958 (ESRG 88-29)	June 1988	Purchased Gas Adjustment; Pennsylvania Gas & Water Company
Public Service Commission of Utah	86-057-07 (ESRG 87-111)	March 1988	Gas Transportation Rate Design; Mountain Fuel Supply

South Carolina Public Service Commission	83-126-G, 86-217-G (ESRG 87-106)	January 1988	Gas Supply and Rate Design; Piedmont Gas Company
South Carolina Public Service Commission	87-227-G (ESRG 87-64)	September 1987	Gas Supply and Rate Design; South Carolina Electric and Gas
Arizona Corporation Commission	U-1345-87-069 (ESRG 87-48)	September 1987	Fuel Adjustment Clause

Testimony Contributed to

Agency	**Case or Docket No.**	**Date**	**Topic**
Vermont Department of Public Service	5330 (ESRG 87-078)	December 1989	The Role of Hydro-Quebec Power in a Least-Cost Energy Resource Plan for Vermont
New Mexico Public Service Commission	1811 (ESRG 87-65)	January 1988	Fair Price for Coal Resources; Public Service of New Mexico
Public Utilities Commission of Ohio	87-1454-GA -For (ESRG 86-71)	November 1987	Long Term Gas Supply/Demand Forecast; Columbia Gas of Ohio
National Energy Board (Canada)	GH-2-85	December 1985	Natural Gas Exports - Surplus Determination

Tellus Research

October 1993	Comments of Joint Consumer Advocates on Certain Issues Raised by the Federal Energy Regulatory Commission's Notice of Public Conference dated October 28, 1993. Docket No. RM94-4-000. Tellus No. 93-264. Co-author.
August 1993	Comments on Gas Integrated Resource Planning, Docket No. 93-G-0362. Assistance to Pace University in developing comments on gas integrated resource planning. Tellus No. 93-163. Co-author.

August 1993	*Advertising Costs in Demand-Side Management Programs.* A report to: The Corporation Commission Staff, Phoenix, Arizona. Tellus Study No. 93-103. Co-author.
June 1993	*Proposed Rules Governing Integrated Resource Planning for Electric and Natural Gas Utilities Regulated by the State of Kansas.* In collaboration with Kansas Corporation Commission Staff. Tellus Study No. 92-105. Co-author.
May 1993	*GASCO, Inc. Integrated Resource Plan Report.* Volume 1 and 2. Before the Public Utilties Commission, State of Hawaii. Docket No. 7261. Project manager and principal investigator.
April 1993	Consultant to Pennsylvania Office of Consumer Advocate regarding FERC Order 636, Impact on Purchased Gas Costs, T.W. Phillips Gas and Oil Co. (Tellus No. 93-021)
1992-93	Consultant to Staff of the Maryland Public Service Commission. Review and critique of the DSM Plans of five Maryland natural gas utilities. Tellus Study No. 91-222. Project manager and principal investigator.
August 1992	*The Analysis of Residential Gas Heat Pumps as a DSM Measure from an Integrated Resource Planning Perspective.* A report to: The American Gas Cooling Center, Arlington, VA. Tellus Study No. 91-265. Co-author.
August 1992	*Comments on Gas IRP Rule and Issues,* on behalf of: Pennsylvania Office of Consumer Advocate. Docket No. L-00920066. Tellus Study No. 92-141. Author.
August 1992	Draft Comments to the New Mexico Attorney General in the Matter of an Inquiry by the New Mexico Public Service Commission into Integrated Resource Planning, for Natural Gas Utilities. Case No. 2449. Tellus Study No. 91-077. Principal investigator.
April 1992	*Projections of Fuel Prices in Vermont.* Submitted to: Vermont Department of Public Service. Tellus Study No. 92-043. Principal investigator.
February 1992	*Management Audit of Arkla, Inc. Regarding Its Compliance with the Least-Cost Purchasing Statute of the State of Arkansas.* A report to: The Staff of the Arkansas Public Service Commission. Tellus Study No. 91-080. Principal investigator. (Confidential report; not for public distribution)
January 1992	Preliminary Study on Integrated Resource Planning for the Consumers' Gas Company, Ltd. A report to: Consumers Gas Company, Ltd. Tellus Study No. 91-001. Co-author.

January 1992	Informal and Preliminary Responses to Generic Questions on Gas Utility Demand Side Management Cost Recovery Issues. Before the Pennsylvania Public Utility Commission, on behalf of: Office of Consumer Advocate. Tellus No. 91-252. Author.
1991-92	Consultant to District of Columbia Office of People's Counsel. Analysis and critique of the least-cost integrated plan of District of Columbia Natural Gas. Tellus Study No. 90-149. Project manager and principal investigator.
September 1991	*America's Energy Choices: Investing in a Strong Economy and a Clean Environment.* In collaboration with the Union of Concerned Scientists, the American Council for an Energy Efficient Economy, the Natural Resources Defense Council, and the Alliance to Save Energy. Tellus Study No. 90-067. Co-author.
1990	Assistance to Wisconsin Gas Company regarding appropriate avoided cost calculations. Tellus No. 89-145.
September 1990	*Environmental Impacts of Long Island's Energy Choices: The Environmental Benefits of Demand-Side Management*. A report to: Long Island Power Authority. Tellus Study No. 90-028A. Co-author.
July 1990	*Review of Southern Connecticut Gas Company's Conservation Impact Model.* Prepared for The Conservation Collaborative Group: Southern Connecticut Gas Company; Connecticut Department of Public Utility Control (DPUC); Prosecutorial Division, DPUC; Office of Policy and Management/Energy Division; Office of Consumer Counsel. Tellus Study No. 90-084. Co-author.
May 1990	*Conservation and Capacity Optimization Alternatives to the PGT/PG&E Gas Pipeline Project*. Prepared for: California Public Utilities Commission, under contract to: Jones & Stokes Associates, Inc. Tellus Study No. 90-03. Principal Investigator.
May 1990	*Evaluation of Repowering the Manchester Street Station*. A report to: Rhode Island Division of Public Utilities and Carriers, Rhode Island Division of Statement Planning, and Rhode Island Governor's Office of Housing Energy and Intergovernmental Relations. Tellus Study No. 90-010. Co-author.
February 1990	Consultant to Pennsylvania Office of Consumer Advocate regarding cost allocation and rate design issues, T.W. Phillips Gas and Oil Co. (R-891566). (Tellus 90-008)
1989	Evaluation of gas supply and non-utility generation regarding Vermont utilities, for the Vermont Public Service Board. Tellus No. 89-110B.

December 1989	Consultant to MCAAA on incentive ratemaking issues, Michigan Consolidated Gas Company, U-9475. (ESRG 89-213)
September 1989	Consultant to Maryland People's Counsel regarding review of three aspects of the application of Frederick Gas Company, Inc., for an increase in rates. (Study No. 89-137)
June 1989	*An Analysis of FERC Policy Statement Regarding Natural Gas Pipeline Rate Design.* A report prepared for the Maryland People's Counsel. ESRG Study No. 89-104. Principal Investigator.
June 1989	Consultant to Staff of the Wisconsin Public Service Commission, Calculation of Avoided Natural Gas Costs. ESRG Project No. 89-80.
November 1988	*Fuel Procurement Planning of Gas-Fired Cogeneration Projects Proposed for Massachusetts.* A report prepared for the Massachusetts Office of Energy Resources. ESRG Study No. 88-65. Principal Author.
1987	Consultant to Staff of Arkansas Public Service Commission, Natural Gas Purchasing Practices. ESRG Project No. 87-03.
April 1987	*A Review of Trends In Natural Gas Rate Design in the United States.* A report prepared for Gaz Metropolitain under subcontract to Econosult Limited. ESRG Study No. 87-24. Principal Author.
April 1987	*Towards an Energy Transition on Long Island: Issues and Directions for Planning.* A report prepared for Nassau and Suffolk Counties. ESRG Study No. 87-05.
November 1986	*An Evaluation of Kentucky's Fuel Adjustment Clause for Electric Utilities.* A report to the Kentucky Office of the Attorney General. ESRG Study No. 86-74. Principal author.

Other Energy Related Publications

May 1994	"Sensitivity Analysis of Avoided City-Gate Gas Costs." Presented at: NARUC/DOE Fifth National Conference of Integrated Resource Planning, Kalispell, MT, May 15-18. Co-author.
May 1993	"The Energy Policy Act of 1992 and Gas Integrated Resource Planning." Presented at: NARUC Workshop "Competition in the Energy Markets and its Impact on IRP", St. Louis, Missouri, May 25.
May 1993	"Policy Issues Associated with Gas Integrated Resource Planning." Presented at: Natural Gas Seminar, Public Utilities Commission of the State of Colorado, Denver, Colorado, May 19.

November 1992	"Sensitivity of Avoided City-Gate Gas Cost Estimates to Calculation Methods and Input Assumptions." A Working Paper presented at: Gas Integrated Resource Planning (IRP) Workshop, NARUC Gas IRP Subcommittee Meeting, NARUC Annual Conference, Los Angeles, CA. November 15. Co-author.
September 1992	"Natural Gas Planning: An IRP Case Study". Presented at: The NARUC Conference on Integrated Resource Planning, Burlington, Vermont. September 13-16. Co-author.
April 1992	"Major Sources of Controversy in Gas Least Cost Planning," presented at: Washington Gas Least Cost Planning Conference, Washington, D.C., April 7-8.
April 1991	"Calculating the Value of Avoided Gas Requirements: Methods and Results." Presented at: NARUC Third National Conference on Integrated Resource Planning, Santa Fe, NM, April 8-10, 1991.
September 1988	"Setting Rates for Unbundled Services to Meet Competition," Proceedings of the Sixth NARUC Biennial Regulatory Information Conference, Columbus, Ohio.
May 1986	*Energy Plan 1985.* Nova Scotia Department of Mines and Energy. Steering Committee Chairman.
October 1985	*Nova Scotia Oil and Gas Report 1985.* Nova Scotia Department of Mines and Energy. Editor.
June 1985	*Coal in Nova Scotia.* Nova Scotia Department of Mines and Energy. Editor.
October 1984	*Nova Scotia Oil and Gas Report 1984.* Nova Scotia Department of Mines And Energy. Editor.
June 1984	*Nova Scotia Natural Gas - An Alternative for the Northeast.* Nova Scotia Department of Mines and Energy. Editor.
October 1983	*Oil and Gas Exploration in Nova Scotia 1982-83.* Nova Scotia Department of Mines and Energy. Editor.
July 1983	*A Soft Energy Path for Nova Scotia.* Volume III of 2025: Soft Energy Futures for Canada. Report to Energy, Mines and Resources Canada by the Friends of the Earth. Co-author.
October 1982	*Oil and Gas Exploration in Nova Scotia 1981-83.* Nova Scotia Department of Mines and Energy. Author.

October 1979	*Energy, A Plan for Nova Scotia.* A proposal from the Energy Planning Task Force 1979. Editor and Coordinator.
November 1978	*An Assessment of Government Policies to Promote Investments in Energy Conserving Technologies.* Thesis, Massachusetts Institute of Technology. Author.

Other Professional Activities

January 1994	"Fuel Choice in Demand-Side Management: Creating a Level Playing Field for Gas and Electric DSM," a presention to: New England Chapter - International Association for Energy Economics, MIT Faculty Club.
November 1988	Invited Panelist: "State Gas Issues in an Era of Open Access Transportation," National Association of State Utility Consumer Advocates, San Francisco.
June 1986	Invited Speaker: "Offshore Gas and Oil: Progress and Prospects", Mining Society of Nova Scotia Annual Meeting, Ingonish, Nova Scotia.
August 1985	Invited Panelist: "The Canada-Nova Scotia Agreement on Offshore Oil and Gas Resource Management and Revenue Sharing", Canadian Bar Association Annual Meeting, Halifax, Nova Scotia.
May 1975	Invited Panelist: "Regulatory Approaches", Canadian Petroleum Association Offshore Operating Division Annual Workshop, Fairmont Hot Springs, British Columbia.
January 1985	Author: "Nova Scotia's Offshore Oil and Gas", Economic Council of Canada/University of Calgary Energy Conference, Calgary, Alberta.
June 1981	Co-author: "The Future of Coal Utilization in Nova Scotia" Chemical Institute of Canada Annual Conference, Halifax, Nova Scotia.

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MICHAEL LAZARUS

Associate Scientist
Tellus Institute

Manager, International Energy and Environment Program
Stockholm Environment Institute-Boston

PROFESSIONAL SUMMARY

Mr. Lazarus manages energy and environmental planning projects and performs analyses of economic and technical issues affecting energy and resource policy decisions. He directs projects in collaboration with energy agencies and NGOs in Africa, Asia, and Latin America, including the Philippines, Senegal, Tanzania, and the SADC Energy Sector in Angola. He organizes and conducts training workshops for energy planners, and has made presentations on energy and environment planning methods and studies at international workshops and seminars in Austria, China, Mali, Mozambique, Zimbabwe, the World Bank, and elsewhere. He directs the development, enhancement, and application of computer-based planning tools including the Long-range Energy Alternatives Planning (LEAP) System and the associated Environmental Data Base (EDB). He also conducts local, national, and global energy studies. He has testified before a US state regulatory commission on electric utility financial issues and has co-authored reports on demand forecasting, conservation, and power supply planning. He has published articles in both English and French.

EDUCATION

M.S.	Energy and Resources, University of California, Berkeley, 1984.
B.A.	Chemistry, Wesleyan University, 1981.

EXPERIENCE AND SELECTED RESEARCH

1985- present	Associate Scientist, Tellus Institute and Stockholm Environment Institute-Boston. Responsible for design and implementation of national and local energy and environment planning studies and training programs, jointly with local governmental and non-governmental counterpart agencies in numerous countries that have included Italy, Hungary, the Philippines, Senegal, Southern Africa (Tanzania, Zambia, Zimbabwe), and Venezuela. Lead investigator for studies on global energy and greenhouse gas futures. Manager of software development and dissemination programs, including design and application of a comprehensive energy assessment system (LEAP), an associated Environmental Data Base, and a regional energy planning system for the Southern African Development Community (SADC) Energy Sector. Other activities include fuel cycle analysis, greenhouse gas country studies, demand forecasting, evaluation of electric utility plans, analysis and valuation of environmental externalities, utility

financial analysis, preparation of manuals on environmental analysis and integrated resource planning, and assessment of water supply alternatives.

1985 Consultant, Energy and Environmental Engineering, inc., Cambridge, Massachusetts. Prepared draft report on the potential of renewable energy technologies to provide electricity, process heat, and cooling in Egypt for U.S. AID.

1985 Research Analyst, Associates in Rural Development, Burlington, Vermont. Assisted in the coordination of international projects in water supply and sanitation under the Water and Sanitation for Health (WASH) program. Prepared catalogue of water and sanitation technologies. Developed data base on commercial anaerobic digesters.

1983-1984 University of California, Berkeley. Assisted in teaching class on quantitative aspects of global environmental problems. Developed analysis and policy recommendations for maintaining California surface water quality and reducing trace mineral contamination for California Policy Seminar. Journal editor and program assistant for the UC Appropriate Technology Program.

1983 Consultant, San Francisco Department of City Planning, Energy Division. Conducted assessment of commercial sector demand for city-generated steam.

SELECTED REPORTS AND PUBLICATIONS

"Energy-Environment Scenarios for Senegal", *Natural Resources Forum*, February 1994. Lead Author.

Energy and Environment Planning Assistance Program (EEPAP), a report to Swedish International Development Agency (SIDA), December 1993. Co-author.

Towards a Fossil Free Energy Future: The Next Energy Transition, Greenpeace International, 1993. Principal Investigator.

"Integrated Energy-Environment Planning: Experiences from Costa Rica and the U.S.", *Proceedings* of the Energy Conference of Latin America and the Caribbean, Bogota, June 1993. Co-author.

Analysis of the Costs of Greenhouse Gas Reductions in the U.S., Status Report for Third Workshop of the UNEP Greenhouse Gas Costing Studies, Phase II, New Delhi, February 1993. Principal Investigator.

"Methods for Biomass Energy Planning", *Proceedings* of the FAO/RWEDP Expert Meeting on Data Assessment and Analysis for Wood Energy Planning, Chiang Mai, February, 1993. Co-author.

"Integrated Energy-Environment Planning: Experiences from the U.S. and Africa", *Proceedings* of Workshop on International Experience in Energy Policy Research and Planning, University of Cape Town, July 1992. Co-author.

Integrated Energy-Environment Planning: Initial Results from Senegal, prepared for the World Bank/Economic Development Institute Seminar on Energy Management and the Environment, July 1992.

"Regional Energy Development in Southern Africa: Great Potential, Great Constraints", *Annual Review of Energy and Environment*, 1991. Vol. 16, pp. 145-78. Co-author.

Valuation of Environmental Externalities: Sulfur Dioxide and Greenhouse Gases, A Report to the Massachusetts Division of Energy Resources, December 1991. Co-author.

"Energie-Environnement: Une approche de synthèse par le système LEAP", in *Liaison Energie-Francophonie*, Numero 8, 3e Trimestre 1990, Institut de l'Energie des Pays ayant en commun l'usage du Francais (IEPF), Canada, 1990.

Implementation of the Energy Planning System LEAP in the Technical and Administrative Unit (TAU), Energy Sector, of SADCC, Final Project Report to SIDA, December 1990. Co-author.

EDB: A Flexible Database System for Energy-Environmental Analysis, prepared for International Atomic Energy Agency (IAEA) meeting on Comparative Health and Environmental Impacts of Various Energy Systems, October 1990. Co-author.

The Application of Computerized Energy Planning in Tanzania Using the LEAP Model, SEI-B and Ministry of Energy Minerals and Water, Tanzania, April 1990. Co-author.

Methodological Aspects of Rural Energy Planning: A Computer-Based Approach, prepared for the Food and Agriculture Organization, and presented at the FAO/UNDP/ESCAP Regional Training Workshop on a Comprehensive Approach to Rural Energy Assessment and Planning in Asia, Beijing, China, September 1989.

A Water Information and Planning System for Developing Countries, October 1988. Co-author.

Closing the Gap: Preliminary Assessment of a Conservation Scenario for Meeting the Water Needs of the MWRA [Boston] Communities, November 1986. Co-author.

Electric Demand Forecast for Vermont Electric Cooperative: 1986-2005, June 1986. Co-author.

The Midland Options Study - A Response, evaluation of demand and supply options to meet Michigan electricity needs, May 1986. Co-author.

Testimony before the Arizona Corporation Commission (Case No. U-1345-85-367) on the financial simulation of the Arizona Public Service Company under various rate making treatments of its investment in the Palo Verde nuclear station.

INVITED LECTURER/SPEAKER

International Post-Graduate Course in Environmental Management, UNEP/Tufts Center for Environmental Management, 1990-1992.

Seminar on Energy Management Policy and the Environment, Economic Development Institute of the World Bank, July 1992.

Seminar on Tools and Analytical Methods for African Environmental Problems, ENDA-TM, Bamako, April 1992.

Seminar on Energy Policy and Planning, Harare, Zimbabwe, November 1988.

Third Annual SADCC Energy Ministers' Seminar, Maputo, Mozambique, May 1988.

LANGUAGES: French (fluent)

NATIONALITY: USA, France

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ROBERT M. MARGOLIS

Research Associate
Tellus Institute
Stockholm Environment Institute-Boston

EDUCATION

M.S.	Technology and Policy, Massachusetts Institute of Technology, Cambridge, MA, 1992.
B.S.	Electrical Engineering, with High Distinction, University of Rochester, Rochester, NY, 1988.

EXPERIENCE AND SELECTED RESEARCH

1992-present	Research Associate, Tellus Institute and Stockholm Environment Institute-Boston. Responsible for the development, enhancement, and application of various energy and environmental planning tools, including the Long-range Energy Alternatives Planning System (LEAP) and PoleStar. Activities include: analysis and development of global energy and greenhouse gas (GHG) futures focusing on issues of sustainability, analysis and valuation of GHG environmental externalities, and development of data and techniques for use in fuel cycle analysis.
1990-1992	Research Assistant, Center for Energy and Environmental Policy Research, MIT. Evaluated the modeling approach used for assessing policy options to stabilize global climate by the U.S. EPA and the Intergovernmental Panel on Climate Change (IPCC). Studied how models and model generated information were used in the policy formation process. Interviewed key participants in the IPCC process to determine how they thought about the models, how they interpreted the model results, and how they perceived the underlying analysis. Used the model to explore the relative effectiveness of various policy tools in the context of uncertainty.
1988-1989	Design Engineer, Advanced Sensors Group, Texas Instruments, Attleboro, MA. Designed, developed, and tested the lab's first semi-custom integrated circuit. Successfully interacted with customers, suppliers, engineers, and technicians to create a sensor which detects automobile wheel speed. Named as joint inventor in a patent for this sensor.

SELECTED REPORTS AND PUBLICATIONS

Background Documentations for the PoleStar Conventional Wisdom Energy Scenario--draft report. For SEI. February 1994. Author.

2050 Project Energy Base Study: Phase 1 Report, For 2050 Project, World Resources Institute. September 1993. Co-author.

Analysis of the Cost of Greenhouse Gas Reductions in the U.S., Status Report for Third Workshop of the UNEP Greenhouse Gas Costing Studies, Phase II, New Delhi, February 1993. Co-author.

Interpreting the IPCC Emissions Scenarios, MIT Center for Energy and Environmental Policy Research. Working Paper 92-011WP. October 1992.

Probabilistic Policy Experiments: The Use of Energy-Economic-Environmental Models in the Climate Change Policy Process, M.I.T. Center for Energy and Environmental Policy Research. Working Paper 92-012WP. October 1992.

HONORS

Best Thesis in Technology and Policy, MIT Technology and Policy Program, 1992.

Phi Beta Kappa Honor Society, University of Rochester, 1987.

Tau Beta Pi Engineering Honor Society, University of Rochester, 1986.

3/94

IRENE PETERS

Tellus Institute

Economist
Energy and Solid Waste Groups

EDUCATION

Ph.D.	Economics, Clark University, Worcester, MA, expected summer 1994.
M.A.	Economics, Clark University, Worcester, MA, 1987.
Vordiplom	Economics and Philosophy, Universität Trier, F.R. Germany, 1985.

EXPERIENCE

1989 - present — Tellus Institute, Economist.

Energy Analysis. Electricity demand forecasting. Incorporating socio-economic effects into energy planning. Review of macro-econometric models of energy consumption, and of Greenhouse Gas emission reduction models. Review of econometric and programming models of energy demand in the transportation sector.

Solid Waste and Materials Policy Issues. Valuation of environmental impacts of waste management. Tax and other incentives for the use of virgin vs. secondary materials. Econometric analysis of packaging taxes. Modelling consumer choice of residential waste disposal options.

Other Environmental Policy Issues. Measuring and normalizing pollution: inquiry into theoretical aspects and feasibility. Practicality of pollution taxes. Critique of U.S. and European Life Cycle Assessment and Eco-Balance methodologies. Water demand forecasting.

1986 - 1989 — Clark University, Economics Department.

Teaching Assistant for Statistical Theory, Theory of International Trade, and Introductory Economics Courses.

Research Assistant for a project on the impact of transportation on urban structure of beginning century Munich.

1984 - 1985 — Universität Trier, Economics Department.

Research Assistant for a project on the impacts of administrative reform of the German federal financial system on non-government organizations.

TELLUS PUBLICATIONS

forthcoming	*Incorporating Socio-economic Effects into Energy Planning Decisions.* Prepared for the Ontario Externalities Collaborative. Tellus Study No. 94-116.
June 1993	*California's Materials Incentives.* Prepared for the California Integrated Waste Management Board. Tellus Study No. 92-087. Co-author.
Feb. 1993	*Trash, Traffic and Taxes: Elements of Market-Based Pollution Policy.* A report to: Pace University Center for Environmental Legal Studies. Tellus Study No. 92-148. Principal Investigator.
June 1992	"Literature and Public Policy Review", prepared for the Council of State Governments, Lexington, KY and U.S. Environmental Protection Agency, New Jersey Department of Environmental Protection and Energy as part of the *CSG/Tellus Packaging Study.* Tellus Study No. 89-024. Co-author.
Nov. 1991	*The Wisconsin Advance Plan 6 Base Forecast: Evaluation and Recommendations.* A report to: Wisconsin Citizens Utility Board. Tellus Study No. 91-101. Co-author.
June 1991	*Pollution Prevention Measurement Project: Normalization Measures.* A report to: Washington Department of Ecology. Tellus Study No. 91-015. Co-author.
Feb. 1991	*Disposal Cost Fee Study*, prepared for the California Integrated Waste Management Board. Tellus Study No. 90-131. Co-author.

PAPERS AND PRESENTATIONS

May 1992	Life Cycle Assessment: An Economist's Perspective. *Integrated Environmental Management.*
Nov. 1991	Life Cycle Assessment: An Economist's Perspective. Paper presented at the 12th Annual Meeting of the Society for Environmental Toxicology and Chemistry, Seattle, WA.
Sept. 1991	Panel Discussant of German legislation on reduction of packaging waste, 1st International Congress on the Environment of the Dr. Jürgen Schneider Foundation for Technology Transfer, Darmstadt, Germany.
May 1991	Review Panel Participant for the German Packaging Study, carried out for the Umweltbundesamt, Berlin (Research Subsidiary of the German Federal Ministry for Agriculture, Forestry, and Environmental Protection)
May 1988	With Attiat Ott: Harmonization of the corporate income tax in the EC: Its effect on the allocation of loanable funds. Paper presented at the Conference of the Atlantic Economic Association, Barcelona, Spain.

PROFESSIONAL ASSOCIATIONS

American Economic Association
International Society for Ecological Economics
Association for Demand Side Management Professionals

AWARDS AND SCHOLARSHIPS

1988 - 1989 Quadrille Ball Scholarship of the Germanistic Society of America, in conjunction with the International Institute for Education

1983 - 1988 Scholarship of the Studienstiftung des deutschen Volkes (the Federal German Government Scholarship)

1985 - 1986 Scholarship of the German Academic Exchange Service

4/94

RICHARD A. ROSEN

Tellus Institute
Executive Vice-President

Director and Senior Scientist
Energy Group

Education

Ph.D.	Physics, Columbia University, 1974
M.A.	Physics, Columbia University, 1969
B.S.	Physics and Philosophy, M.I.T., 1966

Experience

1991-present	Director of Planning, Tellus Institute.
1977-present	Energy Group. Responsibility for a broad range of research on integrated resource planning energy conservation; electric generation planning issues; and modelling studies of long-range energy demand, utility system reliability, energy demand curtailment, and environmental externalities and energy planning.
1978-1980	Consultant to Brookhaven National Laboratory.
1979	Consultant to the National Academy of Sciences, Puerto Rico Energy Study Committee.
1976-1978	Assistant Physicist, Economic Analysis Division, National Center for the Analysis of Energy Systems, Brookhaven National Laboratory.
1974-1976	National Research Council - National Academy of Sciences Resident Research Fellow, Goddard Institute for Space Studies, New York.
1973	Instructor, Putney - Antioch Graduate School.

Testimony

Agency	Case or Docket No.	Date	Topic
Kansas Corporation Commission	180,056-U	February 1994	Oral Testimony (no written testimony) on establishment of IRP rules for electric and gas utilities

Public Utilities Commission of Hawaii	7257 (Tellus 93-144A3)	December 1993	Critique of HECO IRP plan. Recommendations re: better and simpler approach to taking environmental externalities into account in integrated resource planning
Arkansas Public Service Commission	93-132-U (Tellus 93-148)	November 1993	Review application of Arkansas Electric Cooperative Corporation (AECC) for a certificate of public convenience and necessity for the construction, ownership, operation, and maintenance of a hydro-electric generating facility at Dam No. 2 ("H.S. #2") on the Arkansas River
		January 1994	Sur-Rebuttal Testimony in above docket
Public Utilities Commission of Georgia	4152-U (Tellus 93-100)	August 1993	Review of ratemaking aspects of the Clean Air Act Compliance plans of Georgia Power Company and Savannah Electric and Power Company
Pennsylvania Public Utility Commission	A-110300 F. 051 (Tellus 92-026)	July 1993	Critique of certain aspects of the Joint Applicants' filing with respect to whether the Joint Applicants have satisfied the requirements of the Pennsylvania PUC's siting regulation
Public Utilities Commission of Ohio	91-635-EL-FOR 92-312-EL-FOR 92-1172-EL-FOR (Tellus 92-165)	April 1993	Comments and recommendations re: Cincinnati Gas & Electric Company's integrated resource plan submitted in the Company's 1992 Electric Long Term Forecast Report
Georgia Public Service Commission	4133-U, 4136-U (Tellus 92-078)	October 1992	Review of the need for new capacity on the Georgia Power Company, Savannah Electric & Power Company, and Southern Company system over the next three years, 1992-1995

Public Utilities Commission of Ohio	92-708-EL-FOR 92-1123-EL-FOR (Tellus 92-041A)	September 1992	Comment on Centerior Energy Corporation's integrated resource plan and Clean Air Act compliance plan submitted in the Company's Long Term Forecast Report; specific recommendations for action on behalf of the Company to improve components of its resource and Clean Air Act compliance planning process
Public Service Commission of the State of Georgia	4131-U, 4136-U (Tellus 91-266)	June 1992	Adequacy of the 1992 Integrated Resource Plans of Georgia Power Company (GPC) and Savannah Electric Power Company (SEPCO)
U.S. Bankruptcy Court - Manchester, NH	BK-91-11336 Chapter 11	March 1992	Adequacy of bankruptcy plan filed by New Hampshire Electric Cooperative, Inc.
Public Utilities Commission of Ohio	91-410-EL-AIR (Tellus 91-082)	December 1991	Ratemaking treatment of Cincinnati Gas & Electric Company's 39.63% share in the Zimmer plant under the jurisdiction of the Public Utilities Commission of Ohio (PUCO)
Public Utilities Commission of Ohio	92-418-EL-AIR (Tellus 91-091)	December 1991	Ratemaking treatment of Columbus Southern Power Company's 24.20% share in the Zimmer plant under the jurisdiction of the Public Utilities Commission of Ohio (PUCO)
Maine Public Utilities Commission	89-193, 89-194, 89-195 (ESRG 89-189B & 90-039)	August 1990	Review of Bangor Hydro-Electric Company's solicitation of bids with a request for proposals dated July 24, 1989, and its approach to the evaluation of the respondents' bids.
New Hampshire Public Utilities Commission	DF 89-085 (ESRG 90-051)	July 1990	Assessment of Eastern Utilities Associates' Plan to acquire UNITIL Corporation: Issues Affecting NH Consumers
		September 1990	Supplemental Testimony in above docket.
Florida Public Service Commission	891345-EI (ESRG 90-017)	April 1990	Rate base treatment of Gulf Power Company's 63-MW ownership share of the Scherer 3 generating unit.

Michigan Public Service Commission	U-9458 (ESRG 89-158)	February 1990	Implications of excess capacity on the Indiana Michigan system for the costs that should be included in the Company's 1990 PSCR plan.
Vermont Public Service Board	5330 (ESRG 89-078)	December 1989	Presentation of results of ESRG Study: *The Role of Hydro-Quebec Power in a Least-Cost Energy Resource Plan for Vermont.*
		February 1990	Further Testimony in above Docket
		February 1990	Surrebuttal Testimony in above Docket
Pennsylvania Public Utility Commission	R-891364 (ESRG 89-90A)	October 1989	Recommendations regarding the proper ratemaking treatment for PECo's Limerick 2 nuclear unit.
Florida Public Service Commission	881167-EI (ESRG 89-034)	May 1989	Ratebase Treatment of Gulf Power Scherer 3 Capacity
Federal Energy Regulatory Commission	ER88-630-000 (ESRG 88-153)	April 1989	Pass Through of Performance Incentive Program Charges by New England Power Company
Public Service Commission of the District of Columbia	Formal Case No. 877 (ESRG 88-128D)	February 1989	Evaluation of the Need and Justification for 210 MW CTs at Benning Road Site Proposed by PEPCO
	(ESRG 88-128E)	March 1989	Rebuttal Testimony
Michigan Public Service Commission	U-8871 (ESRG 88-32)	April 1988	Review of the Appropriate Avoided Costs for the CPCo System
	(ESRG 88-32A)	August 1988	Rebuttal Testimony
Maine Public Utilities Commission	87-268 (ESRG 30A)	April 1988	Review Related to the Staff's Evaluation of the Desirability of the Purchase of Power from Hydro Quebec Proposed by Central Maine Power

	87-268 (ESRG 87-30A1)	August 1988	Supplemental Testimony
Pennsylvania Public Utility Commission	M-870111, G-870087 G-870088 (ESRG 88-01)	February 1988	Review of Pennsylvania Power Company's Requested Recovery of Purchased Power Costs
Pennsylvania Public Utility Commission	R-870732 (ESRG 87-80)	November 1987	Investigation into Pennsylvania Power Company's Share of Perry 1 Nuclear Unit and Assessment of Physical Excess Capacity. Direct and Rebuttal Testimony.
Michigan Public Service Commission	U-7830 (ESRG 85-35E)	December 1987	Review of the Application of Consumers Power Company to Recover Its Midland Investment
Pennsylvania Public Utility Commission	R-870651 (ESRG 87-50D)	October 1987	Investigation into Whether Perry 1 and Beaver Valley 2 Capacity Is Economically Used and Useful on the Duquesne System.
Federal Energy Regulatory Commission	ER-86-694-001	September 1987	Analysis of NEPOOL's PIP Program on Behalf of Maine Public Utilities Commission
Maine Public Utilities Commission	86-85	June 1987	Investigation of Reasonableness of Rates
		August 1987	Surrebuttal
Maryland Public Service Commission	7972	February 1987	Investigation by the Commission of the Justness and Reasonableness of the Rates of Potomac Electric Power Company
Arizona Corporation Commission	U-1345-85-367	February 1987	Concerning the Prudence of Palo Verde Investment
Michigan Public Service Commission	U-8578	January 1987	Power Supply Cost Recovery Plan for Detroit Edison
Michigan Public Service Commission	U-8585	January 1987	Power Supply Cost Recovery Plan for Upper Peninsula Power Company

Pennsylvania Public Utility Commission	R-860378	September 1986	Economics of Duquesne Light Company's Share of Perry 1
		November 1986	Surrebuttal
Pennsylvania Public Utility Commission	R-850267	September 1986	Economics of Penn Power's Share of Perry 1
		November 1986	Surrebuttal
		March 1987	Supplemental
Michigan Public Service Commission	U-8348	July 1986	Palisades Performance Standards
Michigan Public Service Commission	U-8291	April 1986	Power Supply Cost Recovery Plan for Detroit Edison
Michigan Public Service Commission	U-8286	February 1986	Power Supply Cost Recovery Plan for Consumers Power
Michigan Public Service Commission	U-8297	January 1986	Power Supply Cost Recovery Plan for Upper Peninsula Power Company
Michigan Public Service Commission	U-8285	January 1986	Power Supply Cost Recovery Plan for Indiana & Michigan Company
Division of Public Utilities, Dept. of Business Regulation	85-2011-01 85-999-08	January 1986	Construction of a Transmission Line and Transmission Facilities in Southwestern Utah
New York Public Service Commission	28252	October 1985	Shoreham - Rate Moderation
		January 1986	Surrebuttal
Missouri Public Service Commission	ER-85-128 EO-85-185 EO-85-224	June 1985	Wolf Creek Excess Capacity and the Prudency of Company Planning
Federal Energy Regulatory Commission	ER-84-560-000	April 1985	Callaway Excess Capacity and a Review of Union Electric Planning

State Corporation Commission of the State of Kansas	120-924-U 142-098-U 142-099-U 142-100-U	April 1985	General Investigation by the Commission of the Projected Costs and Related Matters of the Wolf Creek Nuclear Generation Facility at Burlington, Kansas
Michigan Public Service Commission	U-8042	February 1985	Power Supply Cost Recovery Plan for Consumers Power Company
Michigan Public Service Commission	U-8020	January 1985	Power Supply Cost Recovery Plan for Detroit Edison Company
Massachusetts Department of Public Utilities	84-49, 84-50, 84-140, 627, 1656 & 1957	January 1985	Economics of Completing Seabrook 1 for Four Massachusetts Utilities
Michigan Public Service Commission	U-7830(M)	December 1984	Future Capacity Requirements of Consumers Power Company
New Hampshire Public Utilities Commission	84-200	November 1984	Investigation of Public Service Company of New Hampshire Financing Plan to Complete Construction of Seabrook 1
Michigan Public Service Commission	7830	October 1984	In the Matter of the Application of Consumers Power Company for Authority to Increase its Rates Applicable to the Sale of Electricity
Maine Public Utilities Commission	84-113	September 1984	Investigation of Seabrook Involvement by Maine Utilities
Missouri Public Service Commission	ER-84-168	August 1984	In the Matter of Union Electric Company of St. Louis, Missouri for Authority to File Tariffs Increasing Rates for Electric Service Provided to Customers in the Missouri Service Area of the Company
Michigan Public Service Commission	U-7785	April 1984	In the Matter of the Application of Consumers Power Company for Approval of a Power Supply Cost Recovery Plan and for Authorization of Monthly Power Supply Cost Recovery Factors for Calendar Year 1984

Ohio Power Siting Board	02-00022	February 1984	In the Matter of the Cleveland Electric Illuminating Company/Ohio Edison Company Amended Application to Construct and Operate a Transmission Facility Identified as the Perry-Hanna 345 kV Transmission Line
Michigan Public Service Commission	U-7775	February 1984	In the Matter of the Application of Detroit Edison Company to Implement a Power Supply Recovery Plan in its 1984 Electrical Rates
Maine Public Utilities Commission	81-276	July 1983	As to the Avoided Costs for Cogeneration and Small Power Production Facilities on the Maine Public Service Company System
South Carolina Public Service Commission	82-352-E	June 1983	Review of A.S. Beck Analyses Regarding the Economics of the Catawba Nuclear Station
North Carolina Utilities Commission	E-2, Sub 461	June 1983	Application by Carolina Power and Light Company for Increase in Electric Rates
Michigan Public Service Commission	U-7550	May 1983	Application of Detroit Edison Company for Authority to Implement a Power Supply Recovery Plan in its 1983 Recovery Rates
Michigan Public Service Commission	U-7512	April 1983	Application of Consumers Power Company for Authority to Implement a Power Supply Recovery Plan in its 1983 Recovery Rates
Pennsylvania Public Utilities Commission	R-822169	March 1983	Excess Capacity for Pennsylvania Power & Light Company
North Carolina Utilities Commission	E-100, Sub 47	February 1983	Power Plant Performance Standards and and Fuel Adjustment Clauses
Federal Energy Regulatory Commission	ER82-481	December 1982	Overview of Conservation and Generation Options
Kentucky Public Service Commission	83-14	December 1982	Review of the Kentucky-American Water Company Capacity Expansion Program

Maine Public Utilities Commission	81-276	December 1982	As to the Avoided Costs for Cogeneration and Small Power Producers
Maine Public Utilities Commission	81-114	November 1982	Maine Public Service Company Investigation of Power Supply Planning and Purchases
Maine Public Utilities Commission	82-174	October 1982	Capital Costs of the Seabrook Nuclear Units
Indiana Public Service Commission	36818	October 1982	An Economic Assessment of the Marble Hill Nuclear Station
New Hampshire Public Utilities Commission	DE81-312	October 1982	Investigation Into Supply and Demand of Electricity for Public Service Company of New Hampshire
Michigan Public Service Commission	U-6923	May 1982	Consumers Power Company Electricity Case
Alabama Public Service Commission	18337	January 1982	Long-Range Capacity Expansion Analysis
State of New York Energy Planning Board	SEMP II Hearings	November 1981	Conservation and Generation Planning
Pennsylvania Public Utility Commission	80100341	September 1981	Operating and Capital Costs: Limerick Nuclear Station; Surrebuttal
Maine Public Utilities Commission	MPUC 80-189	April 1981	Electric Energy Costs: Seabrook Nuclear Power Plants; Surrebuttal
Pennsylvania Public Utility Commission	I-80100341	February 1981	Operating and Capital Costs: Limerick Nuclear Generating Station
Ohio Public Utilities Commission	80-141 EL-AIR	December 1980	CAPCO Construction Program; Generation Planning
Michigan Public Service Commission	U-6360	September 1980	Generation Expansion Planning: Consumers Power Company
Pennsylvania Public Utility Commission	I-79070315	August 1980	CAPCO Construction Schedule; Surrebuttal

Connecticut Power Facility Evaluation Council	F-80	June 1980	Renewable Resource Electric Generation in Connecticut
Pennsylvania Public Utility Commission	I-79070317	March 1980	CAPCO: Generation Planning and Reliability
Michigan Public Service Commission	U-5979	June 1979	Forecast Critique and Adjustments: Consumers Power Company
Massachusetts Dept. of Public Utilities	19494	August 1978	Long-range Electric Demand Forecast: Boston Edison Company
Pennsylvania Public Utility Commission	438	March 1978	Long-range Forecast of Electric Energy and Demand (Philadelphia Electric Company)

Tellus Research

December 1993	*Aligning Rate Design Policies with Integrated Resource Planning*. A report to: National Association of Regulatory Utilities Commissioners. Tellus Study No. 92-047. Co-author.
August 1993	A Report to: The Public Service Commission of the State of Delaware Regarding Docket 35: Adoption of the Guidelines for Integrated Resource Planning by Electric Cooperatives. Tellus Study No. 93-053. Co-author.
August 1993	A Report to: The Public Service Commission of the State of Delaware Regarding Docket 39: PURPA Standards as Amended by the Energy Policy Act of 1992. Tellus Study No. 93-054. Co-author.
July 1993	*IRP Concepts and Approaches*. Report to Hydro-Quebec and the Public Interest Groups and Associations. Tellus Study No. 92-155. Project Manager.
June 1993	*Proposed Rules Governing Integrated Resource Planning for Electric and Natural Gas Utilities Regulated by the State of Kansas*. In collaboration with Kansas Corporation Commission Staff. Tellus Study No. 92-105. Project Manager.
May 1993	*Preliminary Study on Integrated Resource Planning for the Consumers' Gas Company Ltd.* Prepared for Consumers Gas Company, Ltd. Tellus No. 91-001. Project Co-manager. Not publicly available.

January 1992	*Sales Forecasts and Price Changes for New Hampshire Electric Cooperative.* Prepared for: Members Committee of New Hampshire Electric Cooperative. Tellus Project No. 91-173. Principal investigator.
September 1991	*America's Energy Choices: Investing in a Strong Economy and a Clean Environment.* In collaboration with the Union of Concerned Scientists, the American Council for an Energy Efficient Economy, the Natural Resources Defense Council, and the Alliance to Save Energy. Tellus Study No. 90-067. Co-author.
September 1990	*Environmental Impacts of Long Island's Energy Choices: The Environmental Benefits of Demand-Side Management.* Tellus No. 90-028A. Co-author.
July 1990	*Assessment of the Eastern Utilities Associates' Plan to Acquire UNITIL Corporation: Issues Affecting New Hampshire Consumers.* Exhibit 2 to Tellus No. 90-051. Project manager.
April 1990	*Comments on Pacific Power and Utah Power Resource and Market Planning Program.* On behalf of Committee of Consumer Services, Utah Department of Commerce. ESRG No. 90-050A. Author.
March 1990	*The Northeast Utilities Plan for Public Service Company of New Hampshire: Issues Affecting New Hampshire Consumers.* A report to: State of New Hampshire, Office of the Consumer Advocate. ESRG No. 90-019. Reviewer.
December 1989	*The Role of Hydro-Quebec Power in a Least-Cost Energy Resource Plan for Vermont.* A Report to the Vermont Public Service Board. ESRG No. 89-078. Principal investigator.
July 1989	*Rhode Island's Options for Electric Generation.* A Policy Statement of the Energy Coordinating Council. ESRG No. 89-004. Co-author.
March 1989	*Update of 1985 Study on the Economics of Closing vs. Operating Shoreham.* ESRG Report No. 89-051. Principal investigator.
July 1988	*The Cost to Ratepayers of the Proposed LILCO Settlement.* A Report to Suffolk County. ESRG Report No. 88-23. Co-author.
April 1988	*An Evaluation of Central Maine Power Company's Proposed Purchase of Power from Hydro Quebec.* A Report to the Maine Public Utilities Commission Staff. ESRG Report No. 87-30. Principal Investigator.
June 1987	*NEPOOL and New England's Electricity Future: Issues and Directions.* A Report to the New Hampshire Consumer Advocate. ESRG Study No. 86-83. Co-author.

May 1986	*Midland Options Study - A Response.* A report to the Michigan Department of the Attorney General. ESRG Study No. 85-35. Principal Investigator.
September 1984	*The Economics of Seabrook 1 from the Perspective of the Three Maine Co-Owners.* ESRG Study No. 84-38. Principal Investigator.
May 1984	*Power Planning in Kentucky: Assessing Issues and Choices. Project Summary Report to the Public Service Commission.* ESRG Study No. 83-51. Project manager.
April 1984	*Power Planning in Kentucky: Assessing Issues and Choices. Generation and Transmission System Planning.* ESRG Study No. 83-51/TR II. Project manager. Principal investigator.
April 1984	*Power Planning in Kentucky: Assessing Issues and Choices. Utility Financial Forecasts: Two Case Studies.* ESRG Study No. 83-51/TR IV. Project manager.
April 1984	*Draft Report: Electric Rate Consequences of Cancellation of the Midland Nuclear Power Plant.* ESRG Study No. 83-81. Principal investigator.
January 1984	*Electric Rate Consequences of Retiring the Robinson 2 Nuclear Power Plant.* ESRG Study No. 83-10.
January 1984	*Power Planning in Kentucky: Assessing Issues and Choices. Conservation as a Planning Option.* ESRG Study No. 83-51/TR III. Project manager.
December 1983	*Power Planning in Kentucky: Assessing Issues and Choices. Long Range Forecasts for Kentucky and its Six Major Utilities.* ESRG Study No. 83-51/TR I. Project manager.
July 1983	*Long Island Without the Shoreham Power Plant: Electricity Cost and System Planning Consequences; Summary of Findings.* ESRG Study No. 83-14/S. Co-author.
October 1982	*The Economics of Closing the Indian Point Nuclear Power Plants.* ESRG Study No. 82-40. Principal investigator.
October 1982	Final Report of the Kentucky Public Service Commission. ESRG Study No. 82-45. Co-author.
August 1982	*Nuclear Capacity Factors: The Effects of Aging and Salt Water Cooling.* A Report on Research in Progress. ESRG Study No. 82-81. Co-author.

August 1982	*The Impacts of Early Retirement of Nuclear Power Plants: The Case of Maine Yankee.* ESRG Study No. 82-91. Co-author.
April 1982	*A Power Supply and Financial Analysis of the Seabrook Nuclear Station as a Generation Option for the Maine Public Service Company.* ESRG Study No. 81-61. Principal investigator.
January 1982	*Guidelines for Designing Rates for Sales to Qualifying Facilities Under Section 210 of the Public Utilities Regulatory Policies Act.* ESRG Study No. 81-32. Co-author.
July 1981	*Long-Range Capacity Expansion Analysis for Alabama Power Company and the Southern System.* ESRG Study No. 80-63. Co-author.
June 1981	*An Analysis of the Need for and Alternatives to the Proposed Coal Plant at Arthur Kill.* A Report to: Robert M. Herzog, Director, New York City Energy Office and Allen G. Schwartz, Corporation Counsel for the City of New York. ESRG Study No. 81-21. Co-author.
October 1980	*The ESRG Electrical Systems Generation Model: Incorporating Social Costs in Generation Planning.* ESRG Study No. 80-12. A Report to the U.S. Department of Energy. Co-author.
September 1980	*Reducing New England's Oil Dependence Through Conservation and Alternative Energy.*. ESRG Study No. 79-29. A Report to the U.S. General Accounting Office. Co-author.
July 1980	*Preliminary Economic and Need Analysis of the Proposed Brumley Gap Pumped Storage Facility for the AEP System.* ESRG Study No. 80-08/P. Principal investigator.
July 1980	*The Potential Impact of Conservation and Alternative Supply Sources on Connecticut's Electric Energy Balance.* ESRG Study No. 80-09. A Report to the Connecticut Power Facility Evaluation Council. Co-author.
November 1979	*South Carolina Electric Demand Curtailment Planning.* A Report to the South Carolina Office of Energy Resources. Principal investigator.
May 1979	*Demand Curtailment Planning: Methodology.* ESRG Study No. 78-18. Chapter submitted to Brookhaven National Laboratory and the Department of Energy for the Electric Demand Curtailment Planning Study. Principal investigator.

May 1979	*Assessment of the New England Power Pool - Battelle Long Range Electric Demand Forecasting Model.* ESRG Study No. 79-06. A Report to the New England Conference of Public Utility Commissioners. Co-principal investigator.
October 1978	*The Employment Creation Potential of Energy Conservation and Solar Technologies: The Implications of the Long Island Jobs Study for New England, 1978-1993.* ESRG Study No. 78-16. Co-author.
November 1977	*Profile of Targets for the Energy Advisory Service to Industry.* ESRG Study No. 77-09. A Report to the New York State Energy Office. Co-Author.
October 1977	*The Effect on Air and Water Emissions of Energy Conservation in Industry.* ESRG Study No. 77-04. Co-author.
July 1977	*The Effects on Air and Water Emissions of Energy Conservation in Industry.* ESRG Study No. 77-04. Co-author.
June 1977	*Toward an Energy Plan for New York.* ESRG Study No. 77-03. A Report to the Legislative Commission on Energy Systems. Co-author.
April 1977	*Assessing Demand, Alternative Operating Strategies, and Utility Economics in the Service Territory of Orange and Rockland Utilities.* ESRG Report No. 77-01. Co-author.

Other Publications

1993	"How Should Electric Utilities Allocate Their Free EPA-Granted Allowances Among Retail and Wholesale Customers? An Unresolved Issue of Clean Air Act Compliance. Prepared for distribution at: The NARUC/NASUCA 1993 Annual Meetings, New York, NY. November 14. Co-author.
1992	"Bill Indexing," chapter in: *Regulatory Incentives for Demand Side Management,* edited by S. Nadel, et al. Published by ACEEE/NYSERDA. With David Moskovitz.
March 1978	*The Use of the Pulp and Paper Industry Process Model for R&D Decision Making.* Brookhaven National Laboratory Report No. BNL 24134. Co-author.
1976	"A Non-Linear Model for the Linewidth, Intensity, and Coherence of Astrophysical Masers," *Astrophysical Journal* vol. 190.

Papers

February 1993	"Integrated Resource Planning and Clean Air Act Compliance: Elements of Consistency." Prepared for Distribution at: The NARUC Energy Conservation Committee 1993 Winter Meeting, Washington, DC. Co-author.
September 1992	"Natural Gas Planning: An IRP Case Study." Presented at: The NARUC Conference on Integrated Resource Planning, Burlington, Vermont, September 13-16, 1992. Co-author.
February 1991	"The Clean Air Act Amendments of 1990 and Utility Least Cost Planning: Issues for State Regulators," for distribution at the NARUC Conservation Committee, 1991 Winter Meeting, Washington, D.C. Co-author.
February 1991	"Sustainable Development and the Future of Electric Utilities," for the Energy Conservation Coalition Electric Utility Industry Vision Paper Project, Washington, DC.
September 1989	"Six Fallacies in Computing Avoided Costs," delivered at the NARUC Least Cost Planning Conference, Charleston, S.C.
October 1988	"Ratemaking and Conservation: The Tune Should Fit the Dance," distributed at the NARUC Committee on Energy Conservation Meeting, San Francisco. October 30.
September 1987	"Electric Utility System Reliability and Reserves" (ESRG Paper). Co-author.
September 1986	"Risk Sharing and the 'Used and Useful' Criterion in Utility Ratemaking" (ESRG Paper). Co-author.
September 1986	*Risk Sharing, Excess Capacity, and the "Used and Useful" Criterion*, presented to the Fifth Biennial Regulatory Information Conference sponsored by the National Regulatory Research Institute in Columbus, Ohio.
July 24-28 1978	"Energy Use Modelling of the Iron and Steel Industry," Summer Computer Simulation Conference.
Nov. 12 1977	"Energy Conservation in Industry," Northeastern Political Science Association meeting, Mt. Pocono, Pennsylvania.

Related Professional Activities

Elected to Three-Year Term as a member of the Research Advisory Committee of The National Regulatory Research Institute, October 1, 1988 - September 30, 1991. Term extended through June 1992.

Invited Speaker

June 1993	The National Energy Summit, in conjunction with the Multi-Media Energy Education Project of the Jefferson Energy Foundation - "Balancing Energy-Environment-Economy (E^3)", Washington, DC. Panelist.
March 1992	American Gas Association Long Range Forecasting for Integrated Resource Planning Seminar - "How Externalities and Supply Costs Affect IRP".
December 1991	Edison Electric Institute -- Strategic Planning Committee - "Incorporating Environmental Externalities into Integrated Resource Planning".
November 1990	NARUC Energy Conservation Committee Meeting, Orlando, Florida - "Rate Impacts of Demand-Side Management Programs".
November 1990	NARUC and NASUCA Joint Annual Meeting, Orlando, Florida - "Environmental Externalities and Integrated Resource Planning".

Awards and Honors

1968-1974	Faculty Fellowship, Physics Department Columbia University.
1966-1970	New York State Regents Fellowship.
1967-1968	Adam Leroy Jones Fellow in Philosophy, Columbia University.

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Mark Fulmer

Tellus Institute

Research Associate
Energy Group

Education

M.S.E.	Princeton University, Mechanical and Aerospace Engineering, 1991.
B.S.	University of California, Irvine, Mechanical Engineering, 1986.

Experience

1990-present	Energy Group, Tellus Institute. Research Associate.
1988-1990	Princeton University, Princeton, New Jersey. Research Assistant, Center for Energy and Environmental Studies. Performed technical and economic analyses of gas turbine cogeneration in the cane sugar and alcohol industries.
1986-1988	Garrett Turbine Engine Company, Phoenix, Arizona. Engineer, Systems Analysis and Performance. Performed computer modelling of gas turbine compressor surge and stall phenomena. Performed engine transient modelling for digital controls development.

Testimony

Agency	**Case or Docket No.**	**Date**	**Topic**
Rhode Island Public Utilities Commission	2025	April 1993	Costs, savings and cost-effectiveness of the proposed Demand-Side Management Programs of Providence Gas Company.

Research Support for Tellus Testimony

Agency and Case or Docket Number	Tellus Witness	Date	Topic
Hawaii Public Utilities Commission 7257	R. Hornby (Tellus 93-144B5)	December 1993	Identification of GASCO's concerns regarding DSM programs proposed by HECO for competitive energy end-use markets, specifically HECO's residential sector water heating program.
Hawaii Public Utilities Commission 7261	R. Hornby (Tellus 93-171)	September 1993	GASCO IRP.
Pennsylvania Public Utility Commission R-932655, R-932655C001 R-932655C002	R. Hornby (Tellus 93-149)	September 1993	Analysis of transportation service balancing charge proposed by PA Gas and Water.
Pennsylvania Public Utility Commission	Richard Hornby (Tellus 93-092)	July 1993	Review of gas supply strategy and purchasing practices of Pennsylvania Gas and Water Company; recommendations to the PUC with respect to gas cost adjustments, gas supply policy issues and the purchasing practices of PG&W.
Pennsylvania Public Utility Commission R-00922324	Richard Hornby (Tellus 92-117)	July 1992	Review of the gas supply strategy and purchasing practices of PG&W; recommendations to the PUC with respect to gas cost adjustments, gas supply policy issues and the purchasing practices of PG&W
Rhode Island Public Utilities Commission	Carlton Bartels (Tellus 91-255)	April 1992	Review of the need for and comparative economics of a power facility in Portsmouth, RI
Rhode Island Division of Public Utilities and Carriers 1727	Richard Hornby (Tellus 90-135 and 91-165)	June 1991	Review of gas procurement practices of Bristol and Warren Gas Company

Tellus Research

Forthcoming	*National Climate Change Policy and Clean Air Act Compliance: A Utility Case Study of Combined CO_2/SO_2 Reduction.* Report Prepared in Cooperative Agreement with the U.S. EPA Acid Rain Division. Tellus Study No. 92-185. Co-author.
December 1993	*Economic Opportunities through Energy Efficiency and the Energy Policy Act of 1992*, for Environmental Improvement and Energy Resources Authority. A report to: The Missouri Legislature Pursuant to House Concurrent Resolution 16. Tellus 93-166. Co-author.
September 1993	*Research on Carbon Emissions Associated with Clean Air Act Compliance.* Progress Report for Tasks 1 and 2. Tellus Study No. 92-185A2. Co-author.
July 1993	*IRP Concepts and Approaches*. Report to Hydro-Quebec and the Public Interest Groups and Associations. Tellus Study No. 92-155. Co-author.
May 1993	*Integrated Resource Plan Report*. Volume 1 and 2. Before the Public Utilities Commission, State of Hawaii. Tellus Study No. 92-181. Co-author.
May 1993	*Trash, Traffic and Taxes: Elements of Market-Based Pollution Policy.* A report to: Pace University Center for Environmental Legal Studies. Tellus Study No. 92-148. Co-author.
January 1993	*Evaluation of Cost-Effective Fuel Switching for Residential Space Heat in Maine*, a draft report to the Maine Public Utilities Commission Staff. Tellus Study No. 92-063. Co-author.
December 1992	*The Environmental Impacts of Demand-Side Management Measures*, EPRI report TR-101573. Tellus Study No. 92-089. Co-author.
August 1992	*The Analysis of Residential Heat Pumps as a DSM Measure from an Integrated Resource Planning Perspective*. A report to: The American Gas Cooling Center. Tellus Study No. 91-265. Co-author.
June 1992	Evaluation of Public Service Electric & Gas, *Demand-Side Management Resource Plan* (Electric), submitted in Docket No. Ex-90040304. Submitted to: Rate Counsel Division, Department of Public Advocate. Tellus Study No. 92-055C. Co-author.

April 1992	*Evaluation of the Application of Aquidneck Power Limited Partnership to Construct an Energy Facility in Portsmouth, Rhode Island.* A Report to: The Rhode Island Division of Public Utilities and Carriers, The Governor's Office of Housing, Energy and Intergovernmental Relations, and The Department of Administration/Division of Planning. Tellus Study No. 91-255. Co-author.
February 1992	*Management Audit of ARKLA, Inc. Regarding Its Compliance with the Least-Cost Purchasing Statute of the State of Arkansas.* A report to: The Staff of the Arkansas Public Service Commission. Tellus Study No. 91-080. Co-author.
January 1992	*Preliminary Study on Integrated Resource Planning for the Consumers' Gas Company, Ltd.* A report to: Consumers Gas Company, Ltd. Tellus Study No. 91-001. Co-author.
June 1991	*Bristol and Warren Gas Company Evaluation of Gas Supply Strategy and Costs*, submitted to Division of Public Utilities and Carriers, State of Rhode Island and Providence Plantations. Exhibit 1 of Direct Testimony of Richard Hornby in Docket No. 1727. Tellus Study No. 90-135. Co-author.
January 1991	*The Environmental Costs and Benefits of DSM: A Framework for Analysis*, prepared for EPRI. Tellus Study No. 90-177. Co-author.

Papers on Environmental and Energy Issues

August 1993	"A Social Cost Analysis of Alternative Fuels for Light Vehicles," presented at: Transportation and Energy Strategies for a Sustainable Transportation System, Pacific Grove, CA. August 22-25. Co-author.
June 1993	"Applying an Integrated Energy/Environmental Framework to the Analysis of Alternative Transportation Fuels," invited paper at the European Council for an Energy Efficient Economy (ECEEE) 1993 Summer Study. Co-author.
March 1993	"The Role of Gas Heat Pumps in Electric DSM." Presented at: 6th National Demand-Side Management Conference, Miami Beach, Florida, March 24-26.

September 1992	"Natural Gas Planning: An IRP Case Study." Presented at: The NARUC Conference on Integrated Resource Planning, Burlington, Vermont. September 13-16. Co-author.
September 1992	"Direct Environmental Impacts of Demand-Side Management," invited paper at the American Council for an Energy Efficient Economy (ACEEE) 1992 Summer Study. Co-author.
September 1992	"Natural Gas Vehicles from an Integrated Resource Planning Perspective," presented at the Eighth NARUC Biennial Regulatory Information Conference, Columbus, Ohio. September 9-11.
January 1991	"The Co-Production of Electricity and Ethanol from Sugar Cane: A Technical and Economic Assessment," Master's Thesis and Center for Energy and Environmental Studies Report, Princeton University.
1990	"Cogeneration Applications of Biomass Gasifier/Gas Turbine Technologies in the Cane Sugar and Alcohol Industries" proceedings, Energy and Environment in the 21st Century, MIT Press, Cambridge, Massachusetts. Co-author.
1990	"A Technical and Economic Assessment of the Co-Production of Electricity and Alcohol From Sugar Cane" proceedings, IECEC-90, IEChE, New York, NY. Co-author.

Professional Associations

American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE).

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ATTACHMENT B

TELLUS INSTITUTE CLIENT LIST

NORTH AMERICA

Regional and Federal Agencies
Argonne National Laboratory
Brookhaven National Laboratory
Council of State Governments
Coalition of Northeastern Governors
Federal Energy Regulatory Commission
Regional Plan Asscoiation of the New York City Metropolitan Area
Northeast Interstate Waste Commission
Northeast Waste Management Officials Association
Northeast States for Coordinated Air Use Mgmt (NESCAUM)
New England Governors Conference
U.S. Department of Energy
U.S. Environmental Protection Agency
U.S. Congress Office Of Technology Assesment
U.S. Congress General Accounting Office
U.S. Army Corps of Engineers Hydrologic Research Center

Non-Governmental Agencies
Alliance to Save Energy
Alternative Energy, Inc., Portland, Maine
American Gas Cooling Center
American Council for an Energy Efficient Economy
Business and Professional People in the Public Interest, Chicago, Illinois
Catskill Center for Conservation and Development
Center for Envir. Management, Tufts Univ.
Citizens for a Better Environment
Conservation Law Foundation
The CS Fund
Consumers Energy Council of America
Council on Economic Priorities
Electric Power Research Institute (EPRI)
Empire State Electric Energy Research Corporation (ESEERCO)
Energy Foundation
Harvard Institute for International Development
Land and Water Foundation of the Rockies
National Association of State Utility Consumer Advocates (NASUCA)
National Consumer Law Council
National Science Foundation
National Association of Regulatory Utility Commissioners (NARUC)
Natural Resources Defense Council (NRDC)
National Wildlife Federation (NWF)
National Regulatory Research Institute (NRRI)
N.& S. Carolina: Jocassee Watershed Coalition
Papago Tribal Alliance
Pace University Center for Environmental Legal Studies
Pew Charitable Trusts
Public Issue Advocates, Lansing, Michigan

Technical Development Corporation
Union of Concerned Scientists (UCS)
World Resources Institute
Wilderness Society

State and Local Agencies
Arizona Corporation Commission
Arizona Residential Utility Consumers Office
Arkansas Attorney General
Arkansas Public Service Commission
Arkansas Residential Utility Consumer Office
California Energy Commission
California Integrated Waste Management Board
California Public Utilities Commission
Colorado Office of Consumer Advocate
Colorado Energy Office
Connecticut Dept of Public Utility Control
Connecticut Resources Recovery Authority
Delaware Public Service Commission
District of Columbia Public Service Commission
Georgia Consumers Utility Counsel
Georgia Public Advocate
Georgia Public Service Commission
Hawaii Department of Consumer Advocate
Hawaii Public Utilities Commission
Hull (Massachusetts) Municipal Light Plan
Illinois Attorney General
Illinois Commerce Commission
Illinois Governor's Office
Indiana Public Service Commission
Iowa Office of Consumer Advocate
Kansas Corporation Commission
Kansas Citizens' Utility Ratepayers Board
Kentucky Attorney General
Kentucky Public Service Commission
Louisiana Public Service Commission
Maine Office of the Public Advocate
Maine Public Utilities Commission
Maine Waste Management Agency
Maryland Office of Public Counsel
Maryland Public Service Commission
Massachusetts Attorney General
Massachusetts Energy Facility Siting Counsel
Massachusetts Energy Office
Massachusetts Division of Energy Resources
Massachusetts Office of Coastal Zone Management (Mass. Bays Program)
Massachusetts Port Authority
Metropolitan Area Planning Council, Mass.
Michigan Attorney General
Michigan Public Service Commission

Mississippi Public Service Commission
Minnesota Attorney General
Minnesota Department of Public Service
Minnesota Office of Waste Management
Missouri Office of Public Counsel
Montana Office of Consumers Counsel
Nashua, N.H. Department of Public Works
Nevada Office of Consumer Advocate
New Hampshire Consumer Advocate
New Hampshire Elec Coop Members Committee
New Haven, Conn. Department of Public Works
New Jersey Deprtment of Environmental Protection and Energy
New Jersey Office of Public Advocate
New Mexico Attorney General
New Mexico Public Service Commission
New York City Department of Sanitation
New York City Energy Office
New York State Energy Office
New York Public Service Commission
New York State Consumer Protection Board
NY State Dept. of Environmental Conservation
New York: Long Island Power Authority
New York: Suffolk County
North Carolina Waste Management Board
Ohio Office of the Consumers' Counsel
Ohio Public Utilities Commission
Ohio: City of Columbus
Ohio: City of Cincinnati
Pennsylvania Office of Consumer Advocate
Pennsylvania Public Utility Commission
Rhode Island Attorney General
RI Governor's Office of Energy Assistance
Rhode Island Department of Environmental Management
Rhode Island Public Utilities Commission
South Carolina Public Service Commission
Tennessee Valley Authority
Texas Public Utility Commission
Town of Braintree, Board of Selectmen
Utah Committee of Consumer Services
Utah Department of Public Utilities
Utah Public Service Commission
Ventura County Waste Management Division
Vermont Department of Public Service
Washington State Department of Ecology
Washington State Energy Office
Wisconsin Public Service
Wyoming Public Service Commission

Utilities
Boston Gas Company

Consumers Gas Company, Ontario, Canada
The Gas Company, Hawaii
Madison Gas & Electric Company
Ontario Hydro Company
Vermont Electric Cooperative Corporation
Wisconsin Gas Company
Wisconsin Electric Power Company

INTERNATIONAL

Bangladesh Center for Advanced Studies
Beijer Institute for Energy and Human Ecology
Beijing Environmental Protection Bureau
Central Mining Development Institute (Hungary)
Center for Policy and Implementation Studies, Jakarta
Companhia Energetica de Minas Gerais, Brasil
Electric Generating Authority of Thailand (EGAT)
Environmental Foundation Ltd. (Sri Lanka)
Environment and Development in the Third World (ENDA-TM, Senegal)
Ethiopian Energy Authority
European Community (EC)
GTZ (German AID Agency)
Global Infrastructure Foundation, Japan (GIF)
Green Action Zagreb
Institute of Economics of the Czeckoslovak Academy of Sciences
Institute of Geography, Russia
Institute for International Education (IIE)
Inter American Developmen Bank
Intergovernmental Panel on Climate Change (IPCC)
Intergovernmental Negotiating Committee (INC)
International Atomic Energy Agency (IAEA)
International Development Research Center (IDRC, Canada)
International Institute for Applied Systems Analysis (IIASA)
International Institute of Energy Conservation (IIEC)
International Energy Agency (IEA)
Kenya Ministry of Energy
Latin American Energy Organization (OLADE)
Mediterranean Action Plan of the United Nations
Ministry of Economics of the Slovak Republic
National Agency for Nuclear and Alternative Energy (ENEA, Italy)
National Energy Institute of Ecuador
Netherlands National Energy Center (ECN)
OKO Institute (Germany)
Organization for Economic Cooperation and Development (OECD)
Philippine Office of Energy Affairs
RISO National Laboratory (Denmark)

Romania, Ministry of Industry
Southern Africa Development Committee (SADCC)
Sri Lanka Ministry of Power and Energy
Stockholm Environment Institute (SEI)
Swedish International Development Agency (SIDA)
Tasmanian Tariff Review Steering Committee
Tanzania, Ministry of Energy and Minerals
Tata Energy Research Institute (TERI)
U.K. Department of Energy at Harwell (ETSU)
U.S. Agency for International Development (USAID)
United Center for Transnational Corporations (UNCTC)
United Nations Food and Agricultural Organization (FAO)
United Nations Environment Programme (UNEP)
UNEP Collaborative Center for Energy and the Environment
United Nations Development Programme (UNDP)
Volunteers in Technical Assistance (VITA)
The World Bank
Zambia, Ministry of Power, Transport and Communications
Zimbabwe, Ministry of Energy

ATTACHMENT C

LEAP/EDB USERS LIST
BROCHURE AND OVERVIEW

LEAP and EDB

TOOLS FOR INTEGRATED ENERGY-ENVIRONMENT ANALYSIS

SEI STOCKHOLM ENVIRONMENT INSTITUTE
Boston Center
Tellus Institute, Boston, USA

In cooperation with:

UNEP Collaborating Centre on Energy and Environment
RISØ National Laboratory
Denmark

UNEP ENERGY UNIT
Technology and Environment Branch
Nairobi
Kenya

Integrated Planning

Integrated planning expands the boundaries of conventional energy planning in two important ways. First, *demand-side measures* for improving efficiency are placed on an equal footing with energy supply options. Second, *environmental effects*, are explicitly considered in the evaluation of alternative energy plans. By including these considerations along with conventional and non-conventional energy supply options, a planner can formulate least-cost strategies for sustainable economic development.

The Need for Environmental Analysis

Energy production and use are major causes of environmental problems around the world.

- **Fossil fuel combustion** in power plants, motor vehicles, and other uses can lead to local air pollution, regional acid rain deposition, and global climate change. It accounts for most global nitrogen oxide, sulfur oxide, and carbon dioxide emissions.

- **Hydro, nuclear, geothermal,** and other energy sources can present other health and ecological risks, such as habitat loss, population displacement, long-term radioactive waste disposal, and surface water pollution.

- **The combustion and harvesting of biomass**, still the world's predominant cooking fuel and a promising option for advanced electricity and fuel production, can have significant human health and land use impacts.

Fair comparisons of the environmental consequences of energy supply options require the consideration of activities that occur both "upstream" (e.g., exploration, mining, transmission) and "downstream" (e.g., disposal and decommissioning) in the *full fuel cycle.*

The development of environmentally sound energy strategies, essential to local and global well-being, thus requires a framework that can consider and compare a full range of impacts across resources and technologies.

The Role of Capacity Building

An integrated energy and environmental planning process requires substantial institutional and human resource capabilities, which are often in short supply. Training, assistance, and methods adapted to local conditions can play a vital role in building these capabilities. Adaptable computerized modeling systems can serve as important educational, analytical, and institution-building tools. By providing a flexible framework for evaluating the impacts of projects and policies, well-designed tools can help institutions to screen proposed energy options, develop long-term action plans, and monitor progress at meeting planning objectives.

What are LEAP and EDB?

LEAP (the Long-range Energy Alternatives Planning system), and EDB (the Environmental Data Base) are user-friendly, computer-based tools for integrated energy-environment planning. The first version of LEAP was developed for the Kenya Fuelwood Project in 1981. With the support of numerous international agencies, it has been continuously enhanced and updated to meet the needs of researchers and government agencies in both developing and industrialized countries.

In 1988, with support from the United Nations Environment Programme (UNEP), the Stockholm Environment Institute - Boston (SEI-B) created the Environmental Data Base (EDB). EDB was designed to enable easy access to energy-related environmental loadings data and to encourage the formulation of environmentally informed energy policy. Today, SEI-B and the UNEP Collaborating Centre on Energy and the Environment (UCC) are jointly engaged in the further development of LEAP and EDB to cover a broader range of fuel cycle issues.

Hardware Requirements

LEAP and EDB can be run on any standard PC with MS-DOS, 640K RAM and a hard disk with at least 6 MB free space. For improved performance, a 386 PC or better with at least 2 MB of RAM is recommended.

LEAP Capabilities

LEAP is suitable for performing energy assessments of developing or industrialized countries, as well as of multi-country regions and local planning areas. Structured as a closely integrated family of computer programs, LEAP offers an accounting framework that can serve several purposes:

- as a **database** it provides a comprehensive system for maintaining energy information;
- as a **forecasting** tool, it enables the user to make integrated projections of energy supplies and demands over a medium or long-term planning horizon;
- as a **policy analysis** tool, it simulates and assesses the physical, economic and environmental effects of alternative energy programs, investments and actions;
- as a **training and institution building** tool, its simple structure, sample data sets, training notes and on-line help system make it a powerful educational resource.

The LEAP Approach to Energy Analysis

The design of LEAP is guided by a number of methodological considerations. These include:

The Scenario Approach: Scenario analysis uses the computer to simulate alternative energy and economic futures under a range of different assumptions. A wide range of "what if" questions can be asked, such as: "what if all achievable cost-effective efficiency policies are pursued?", or "what if innovative patterns of industrialization and urban development are pursued?" Evaluations of the physical, economic and environmental impacts of alternative scenarios can help to guide the selection of appropriate energy policies.

Integrated Planning: LEAP stresses the importance of conducting energy analysis within a comprehensive planning framework that includes all fuels in the energy system (commercial fuels, biofuels, renewable energy); different stages of the fuel cycle (primary resource extraction, conversion, transmission, distribution, and final end-use consumption); separate geographical and demographic areas; and different sectors of the economy (households, industry, transport, agriculture, etc.).

End-Use, Needs-Driven Approach: In LEAP, resource requirements and supply-side projections are driven by an analysis of the energy services required by different economic sectors. This approach places development objectives, such as the provision of end-use goods and services, at the foundation of energy analysis.

Flexibility and User-Friendliness: For a software tool to be useful it needs to be flexible, expandable and comprehensive. LEAP is designed as a model building tool, not a rigidly structured model. Its expandable data structures can be adapted to diverse energy systems and analytical objectives. Its use of simple models whose structures (and hence results) are readily understandable, and its simple and intuitive menu-driven user-interface make LEAP usable by analysts and decision-makers with little computing experience.

Overcoming Data Constraints: Insufficient and unreliable quantitative data are a common obstacle to the use of models. LEAP is intended to be used in an iterative fashion to overcome this obstacle. An initial data set is gathered based on readily available sources for the first planning exercise. Initial runs produce preliminary outputs and energy policy analyses which help evaluate the status of existing data and identify areas where more or better information is required. Data can then be collected in a second iteration of the process.

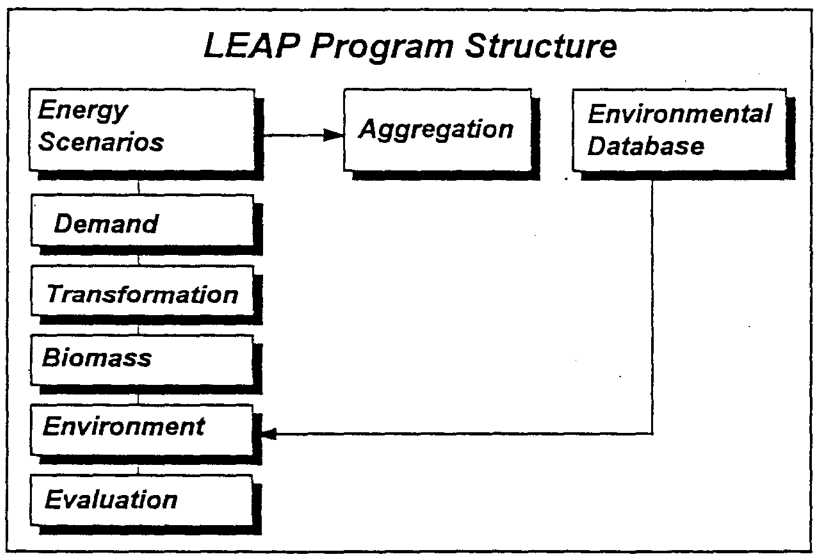
LEAP Program Structure

LEAP consists of two blocks of programs: Energy Scenarios and Aggregation. The Energy Scenario programs address the main components of an integrated energy analysis. The Aggregation program can then be used to assemble these area level results into multi-area results.

- **The Scenario Building programs** (Demand, Transformation, and Biomass) are used to develop current energy balances, projections of supply and demand trends, and scenarios representing the effects of different energy policies, plans and actions.

- **The Environment program** (linked with the associated Environmental Database) computes the air and water emissions, solid and hazardous waste generation and direct, on-site health and safety impacts of a given scenario.

- **The Evaluation program** compares the physical impacts of moving from one scenario to another, the economic costs and benefits, and the comparative environmental repercussions.

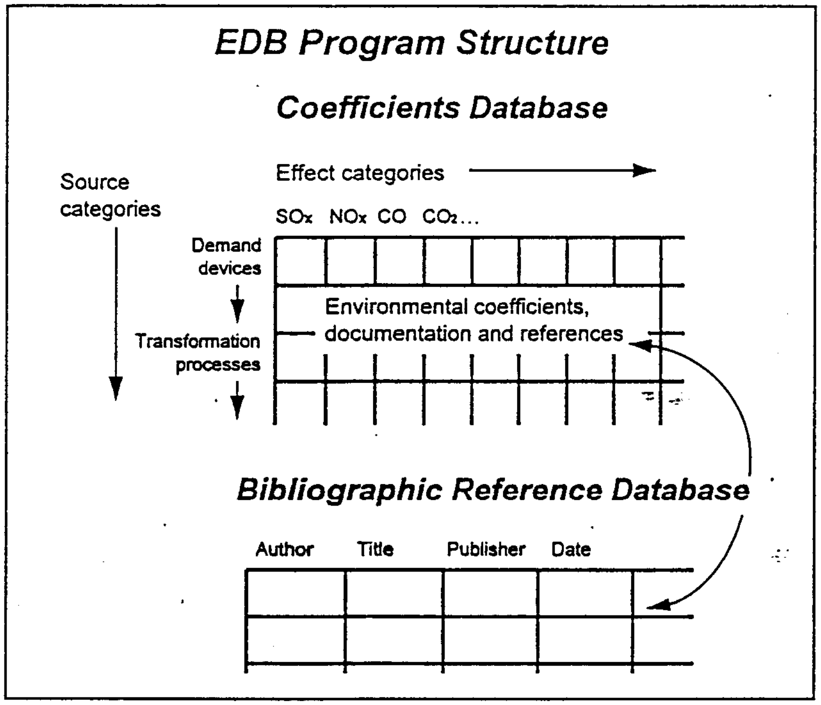


The Environmental Database

The Environmental Data Base (EDB), available separately or as part of the LEAP system, provides a comprehensive summary of information linking energy production, conversion and consumption activities to air and water emissions, and other environmental and health consequences.

- **As a stand-alone program,** it is an easy-to-use, fully referenced and annotated compendium of energy and environment statistics.

- **Linked to the LEAP Environmental program,** it provides measures of the environmental consequences of alternative energy futures.



Environmental research has generated large amounts of data on the emissions and impacts associated with energy processes and technologies. The Environmental Data Base (EDB) was conceived as a tool to gather these data from their many sources in a consistent, up-to-date, and easy-to-use form, and to make them accessible to analysts and policy makers worldwide. In addition, users can add additional data appropriate to local facilities or specific studies.

Database Coverage

Increasingly, analysts are tracking greenhouse gas emissions of energy options. EDB contains a wide range of technology-specific emission factors for all major greenhouse gases, and LEAP has been used for several climate-related analyses, including several of the country studies conducted as part of the UNEP Greenhouse Gas Costing project.

However, global climate change is but one of many important energy-related environmental problems. LEAP and EDB can also be used to examine other environmental consequences that may be of more immediate concern in many areas, such as the emissions of local air pollutants or land degradation related to unsustainable biomass use.

To date, EDB data have been gathered from over 60 references, with an emphasis on quantifiable effects. EDB contains data on emissions from household devices, agricultural equipment, refineries and on direct health and safety impacts of major energy transformation and extraction processes (for example, coal mining). Data relevant to both industrialized and developing countries are included.

SEI-B in collaboration with UNEP are currently expanding the coverage of EDB as part of the UNEP/SEI Fuel Cycle Analysis project. In addition, specific country studies continue to contribute to the database.

Selected Applications

Government agencies and research institutes in over 30 countries use LEAP and EDB for a variety of analytical tasks, from master plans to specific energy studies. LEAP/EDB applications span a wide range of conditions, from developing countries — where detailed energy data are often scarce, biomass energy use predominates, and capital constraints limit available options — to industrialized countries where emerging integrated resource planning efforts call for methods that cover all fuels and sectors and include environmental concerns.

The range of applications includes:

- **Senegal**, where ENDA-TM, local government agencies and SEI-B, assessed the economic and environmental implications of proposed energy strategies (3).

- **Tanzania, Zambia and Zimbabwe**, where government ministries have focused on building institutional capacity for energy planning, with LEAP used as a training and analytical tool. This work has assisted with the preparation of energy master plans in both Tanzania and Zambia.

- **The United States**, where Tellus Institute used LEAP as the analytical framework for a prominent national energy study that identified the potential for energy efficiency and renewable energy to provide long-term economic and environmental benefits (8).

- **Costa Rica**, where the Latin American Energy Organization (OLADE) and local agencies collaborated with SEI-B to evaluate the economic and environmental consequences of selected national energy policy options (11).

- **The Philippines**, where LEAP serves as an organizing and planning tool for decentralized rural energy planning.

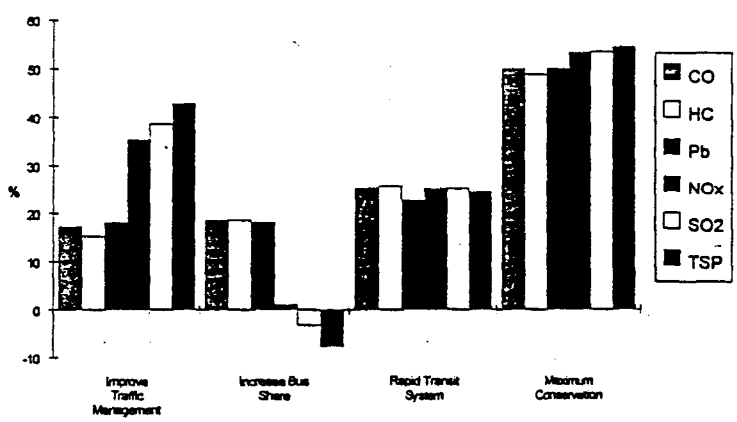
- **Venezuela**, where the Ministry of Energy and Mines have used LEAP to construct and evaluate scenarios to reduce CO_2 and other greenhouse gas emissions in the UNEP Greenhouse Gas Abatement Costing project (9,10). Other country teams using LEAP in the project included Egypt and Senegal.

- **India**, where researchers from the Tata Energy Research Institute and the UNEP Collaborating Centre on Energy and the Environment looked at options for minimizing air pollution from the transport sector in Delhi (2).

- The state of **Minas Gerais, Brazil**, where the local electric utility used LEAP to prepare forecasts and energy scenario analyses (1).

- Two **global energy and climate change studies** that looked at global strategies to control future carbon dioxide emissions (4, 7)

Impact of Policies to Reduce Air Pollution in Delhi
(% reduction from Base Case)



Further Reading

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Highlights of LEAP and EDB

- Runs on standard PCs under MS-DOS (requires 640K Ram and a hard disk with at least 6 MB free space).
- Structured as a set of closely integrated programs.
- Flexible and expandable data structures.
- Model-building system rather than a fixed model.
- Easy-to-use menu-driven interface.
- Straightforward data entry screens.
- Choice of modeling methodologies, e.g., end-use and/or econometric demand relationships.
- Powerful reporting system including graphics.
- Easy export of results to spreadsheet files.
- Integrated context-sensitive help and full documentation.
- Off-the-shelf training exercises, and on-site training available.

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ATTACHMENT D

AMERICA'S ENERGY CHOICES: TRANSPORTATION EXCERPTS

A SOCIAL COST ANALYSIS OF ALTERNATIVE FUELS FOR LIGHT VEHICLES

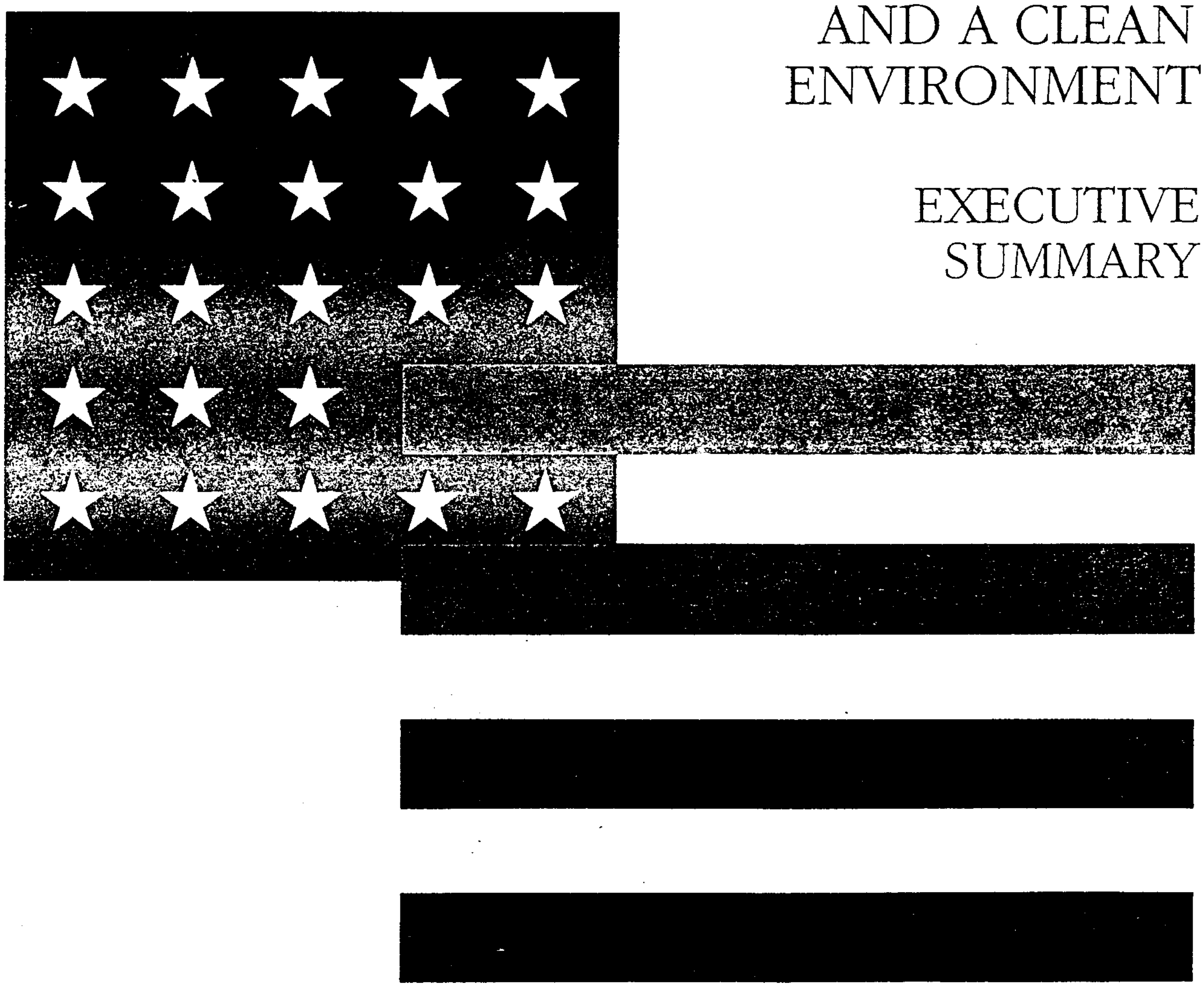
FEEBATES FOR FUEL ECONOMY

AN UPDATED ASSESSMENT OF THE NEAR-TERM POTENTIAL FOR IMPROVING AUTOMOTIVE FUEL ECONOMY

AMERICA'S ENERGY CHOICES

INVESTING IN A STRONG ECONOMY AND A CLEAN ENVIRONMENT

EXECUTIVE SUMMARY



ALLIANCE TO SAVE ENERGY

AMERICAN COUNCIL FOR AN ENERGY-EFFICIENT ECONOMY

NATURAL RESOURCES DEFENSE COUNCIL

UNION OF CONCERNED SCIENTISTS

AMERICA'S ENERGY CHOICES

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Authors and contributors

Many people and organizations worked together over the past year to produce this report. Four national organizations—the Alliance to Save Energy (ASE), the American Council for an Energy-Efficient Economy (ACEEE), the Natural Resources Defense Council (NRDC), and the Union of Concerned Scientists (UCS)—conceived and executed the project. The Tellus Institute of Boston was retained to perform scenario analysis.

Howard Geller of ACEEE, Daniel Lashof of NRDC, Alden Meyer of UCS, and Mary Beth Zimmerman of ASE made up the project's steering committee. Meyer served as project coordinator and wrote the executive summary. Geller was principal author of the methodology and overall results chapters, and provided substantial input to the policy chapter. Lashof was principal author of the background and policy chapters, and provided substantial input to the analysis chapters. Zimmerman was a contributing author for the background, methodology, and policy chapters.

The project was organized along sectoral lines. Analysts from the four sponsoring organizations, as well as independent researchers, developed the assumptions on technology costs and penetration rates for the various sectors. They then identified barriers to increased utilization of efficiency and renewable energy technologies, and proposed policies to overcome those barriers. David Goldstein (NRDC), Peter Miller (NRDC), and Robert Mowris were responsible for the buildings sector. Jennifer Jordan (ACEEE) and Daniel Lashof (NRDC) handled industry. John DeCicco (ACEEE), Deborah Gordon (UCS), John Holtzclaw, Marc Ledbetter (ACEEE), and Harvey Sachs collaborated on transportation. Michael Brower (UCS) handled renewables. Stephen Bernow and the staff of the Tellus Institute took responsibility for the utilities sector.

The Tellus Institute used the inputs from the sector analysts to evaluate the primary energy requirements, pollutant emissions, costs and benefits, and integration of electric supply and demand for each sector. Stephen Bernow led the Tellus team, which included Richard Rosen, Bruce Biewald, Kevin Gurney, Elizabeth Titus, Jeffrey Hall, and Delfit Singh on the technical analysis, and Rosen, Rick Hornby, Harvey Salgo, and George Sterzinger on the utility sector policy analysis. Bernow also helped write the methodology, analysis, and policy chapters.

Warren Leon (UCS) supervised the editing and production process. T. M. Hawley did final editing on the report. Michael Brower (UCS), Stephen Frantz, and Janet Wager (UCS) assisted with copyediting. Herb Rich and Lynda Dreyfuss of UCS designed and produced the report.

Many people provided helpful written comments on the initial draft: Brady Bancroft, Jan Beyea, Robert Bishop, William Chandler, Andrew Clarke, J. H. Cushman, Angus Duncan, Craig D. Ebert, Jae Edmonds, James A. Fay, Nick Federick, Christopher Flavin, T. J. Glauthier, Rick Heede, Raymon Lark, Mark D. Levine, Jack Lillywhite, Amory Lovins, James MacKenzie, Alan Miller, Michael Replogle, Howard Ris, Marc Ross, Danilo J. Santini, Lee Schipper, Linda Stuntz and the staff in the Policy, Planning, and Analysis Office of the US Department of Energy, Michael Totten, Gunner Walnet, Stephen Wiel, and John Wilson. The technical analysis for the buildings sector benefited from consultation with R. Balasubramanya, Jim Block, Lee Eng Lock, Mary Ann Piette, and Jack Wolpert.

The Union of Concerned Scientists served as fiscal agent for the project. The Changing Horizons Charitable Trust, the Educational Foundation of America, the Energy Foundation, and the John D. and Catherine T. MacArthur Foundation provided major financial support for the project. Additional support was provided to the sponsoring organizations by the Nathan Cummings Foundation, the George Gund Foundation, the Charles Evans Hughes Memorial Foundation, the Max and Anna Levinson Foundation, the Joyce Mertz-Gilmore Foundation, the Curtis and Edith Munson Foundation, the Pew Charitable Trusts, the Public Welfare Foundation, Alida Rockefeller, the Florence and John Schumann Foundation, and the Town Creek Foundation.

Overview

The vast and complex system by which energy is produced and used is increasingly at the heart of the environmental and economic challenges facing the United States. Our country is heavily dependent on highly polluting fossil fuels—particularly coal and oil. Moreover, it consumes these fuels in an exceedingly wasteful manner in comparison to our leading economic competitors, Europe and Japan. Thus, reducing fossil-fuel use is essential to America's long-term economic and environmental well-being. And yet, in the debate over national energy policy, economic and environmental issues are often portrayed as being at loggerheads. According to conventional wisdom, America cannot significantly change the way it produces and uses energy without sacrificing economic prosperity.

This report presents a strikingly different view of America's energy choices. America need not blindly follow past energy practices, but can steer a different course — one that will enhance public health and the environment, and save money at the same time. By combining strong economic and technical analysis with bold policy proposals, the report provides a sound basis for moving America away from its wasteful—and increasingly hazardous—use of fossil fuels toward the most efficient use of all energy resources, fossil and renewable. It further demonstrates that such a change in course will result in net economic savings amounting to trillions of dollars.

We initiated this project in order to examine the role that energy efficiency and renewable energy technologies can play in meeting the nation's economic and environmental challenges. We used a computerized energy modeling system designed by the Stockholm Environment Institute—Boston Center at the Tellus Institute, and tested four energy futures—a Reference case, which reflects current policies and trends; a Market case, which selects energy technologies based on the goal of minimizing the cost of energy services purchased by consumers; an Environmental case, which assigns monetary values to the environmental impacts of energy use; and a Climate Stabilization case, which seeks to meet predetermined targets for reduction of carbon dioxide (CO_2) emissions to the atmosphere. Analysts from the American Council for an Energy-Efficient Economy, Natural Resources Defense Council, Tellus Institute, and Union of Concerned Scientists, as well as several independent analysts, provided data and input to the study for over a hundred energy efficiency and renewable energy technologies. Each case assumes successively greater utilization of these technologies.

For each scenario, we estimate how much energy the US would need, how much of it would come from renewable sources, how emissions of key atmospheric pollutants would change, and the resulting net costs to energy consumers. In all cases, steady growth in GNP was assumed.

The results of the analysis were stunning. If current policies and energy-use trends continue until 2030, national energy consumption will rise 41 percent, renewable energy will continue to make only a modest contribution to our energy supply mix, petroleum consumption will increase by 16 percent, and carbon dioxide emissions will increase by 58 percent.

By contrast, the three other scenarios achieve dramatic reductions in energy use and air pollution emissions, a greater penetration of renewable technologies, and successively greater monetary savings. In our most aggressive case (the Climate Stabilization scenario):

- national energy requirements in 2030 would be cut nearly in half from the Reference case, with renewable energy sources providing more than half of our energy supply

- our nation's petroleum consumption would steadily decrease to just one-third of current levels by 2030

- carbon dioxide emissions would be cut by more than 25 percent from 1988 levels by 2005, and by more than 70 percent by 2030

- consumers would save $5 trillion in fuel and electricity costs over the next 40 years; subtracting the $2.7 trillion additional investment needed to achieve this, we estimate a net savings of some $2.3 trillion.

Our conclusion: whether one simply wants to minimize costs to consumers, or to mitigate global warming, vigorous adoption of energy-efficiency measures and accelerated use of renewable energy sources make sense.

Despite the logic of pursuing this course, it will not happen automatically. Current government policies and the marketplace are structured in a way that encourages the wasteful use of fossil fuels, not the efficient use of all available energy resources. Thus, in this report, we present an array of policies that can shift the nation from its current path toward any of the more beneficial energy futures we outlined.

In contrast to President Bush's National Energy Strategy (NES), which emphasizes reliance on fossil fuels and nuclear power with very limited energy-efficiency improvements, this report provides a sound basis for enhancing America's economic and environmental well-being.

Background

During the last 20 years, the United States has experienced three major political and economic crises related to our energy practices, particularly our dependence on oil. That excessive dependence remains as burdensome as ever.

Our current wasteful use of energy also threatens the United States's ability to compete in world markets. Imported oil is the single largest component of our trade deficit. In many instances, US industry remains much less energy efficient than its competitors in Europe and Japan. Perhaps most important, US companies are at risk of losing out to foreign competitors in the battle over the expanding world market for energy-efficient appliances, vehicles, and processes, as well as renewable energy technologies.

Energy production and use also inflict heavy damage on the environment. To slow global warming, protect wilderness areas, reduce acid rain and urban smog, we must change the ways in which we obtain and consume energy.

The last two decades showed that energy efficiency could be a pillar of US energy policy. Between 1973 and 1986, total US energy consumption remained level—and CO_2 emissions actually *dropped*—while our economy expanded by almost 40 percent. Both energy consumption and CO2 emissions have since increased, however, because of a decline in the real price of oil and the contraction of federal energy-efficiency programs under the Reagan administration. In the same period, federal support of renewable energy technologies declined dramatically, despite evidence of their promise.

In 1989 we became optimistic that a new era in energy policy might be dawning. Energy Secretary James Watkins announced that he had been instructed by President Bush to develop a comprehensive national energy strategy. Secretary Watkins's efforts to carry out the president's wishes revealed a broad-based public consensus that energy efficiency should be at the core of the proposed NES. The summary by the Department of Energy (DOE) of its series of public hearings held across the country proclaimed that:

> *The loudest single message was to increase energy efficiency in every sector of energy use. Energy efficiency was seen as a way to reduce pollution, reduce dependence on imports, and reduce the cost of energy.*

The summary also revealed strong support for accelerated development of renewable energy sources.

Unfortunately, the final NES report, though strong on rhetoric, did not embrace these energy efficiency and renewable energy opportunities. Rather than calling for a decrease in our nation's dependence on oil, it anticipated a 13-percent increase in total oil consumption by 2010. Rather than attempting to decrease CO_2 emissions, it anticipated a 26-percent increase over the same period. And rather than presenting policies to foster the renewable energy industries that must dominate the 21st century if America is to be clean, prosperous, and secure, it proposed continued reliance on fossil fuels and nuclear power.

Objectives, scenarios, and modeling assumptions

This study was originally conceived as an alternative to the administration's NES. The objectives were to examine a range of plausible energy futures, each conforming to broad programmatic themes, and to suggest policies that could move us toward each of these futures. Instead of attempting to predict what would happen as a result of specific policies, the study describes what *could* happen within assumed technological, resource, and market constraints. The result, we hope, will be to motivate further exploration and adoption of the policy, technology, and institutional initiatives that could lead us toward desirable outcomes.

We start with a Reference scenario, adapted from Department of Energy projections reflecting current policies, practices, and trends. Total energy use in 2030 is 17 percent less in our Reference case than in the NES reference case because of adjustments in the industrial and transportation sectors to reflect more realistic trends. Our three alternative scenarios are all designed to deliver essentially the same level and quality of energy services as the Reference scenario, but to do so at lower cost and with less environmental damage by employing greater end-use energy efficiency, efficient new power supplies, infrastructure changes, and renewable energy investments. The alternative scenarios are:

- a **Market** scenario, making use of cost-effective energy-efficiency and renewable energy technologies, assuming moderate market penetration rates, with no accounting for environmental or security costs beyond those embodied in current trends and policies (e.g., the Clean Air Act)

- an **Environmental** scenario, employing additional energy-efficiency and renewable energy resources to the extent justified by the environmental and security costs of fossil fuels, and assuming more rapid market penetration rates

- a **Climate Stabilization** scenario, designed to achieve carbon dioxide emissions targets consistent with an effective international program to limit global warming (a 25-percent reduction in US CO_2 emissions by 2005 and at least a 50-percent reduction by 2030).

Our method in each scenario was to adopt efficiency and renewable resources starting with the least expensive options and proceeding to more expensive ones as needed. For example, a wide range of energy-efficiency measures were ranked according to their cost per unit of energy saved. We combined this information with detailed data on the existing stock of buildings, appliances, vehicles, and industrial equipment, along with projections of future changes in these stocks, to construct "conservation supply curves," representing the *technical potential* for efficiency improvements.

To estimate how much of this potential could be developed—the *economic potential*—we compared the incremental costs of energy savings to the incremental costs of new energy supply. We then estimated the rate at which those savings could be implemented—the *achievable potential*—by considering limitations imposed by such factors as rates of capital stock turnover, the existing infrastructure, and market inertia. The achievable potential varied in successive scenarios, reflecting increasingly aggressive development and adoption of new technologies.

A similar method was used to evaluate renewable resources. We compared the cost and performance of renewable energy technologies to competing fossil-fuel technologies, adopting those found to be cost competitive in order of ascending cost. Market penetration was gradual, reflecting constraints such as the rates of retirement of existing power plants. As would be expected, more costly renewable energy options were introduced sooner in the Environmental and Climate Stabilization scenarios than in the Market scenario, reflecting the inclusion of environmental and security costs in the price of fossil fuels.

This analysis yielded, for each scenario, projections of energy use by fuel type for each major energy sector—buildings, industry, transportation, and utilities. We also generated estimates of the emissions of seven atmospheric pollutants: sulfur dioxide (SO_2), nitrogen oxides (NO_X), carbon dioxide (CO_2), methane (CH_4), carbon monoxide (CO), total suspended particulates (TSPs), and volatile organic compounds (VOCs).

Finally, we compared the costs and benefits of each of the alternative scenarios to the Reference case, considering the incremental investments in new equipment as costs and the net reduction in fuel use as savings (but disregarding the indirect benefits from reduced pollutant emissions).

We used the current costs of those energy-efficiency technologies already available, and kept them constant over time, rather than reduce them to reflect potential production, distribution, and market efficiencies that might be realized as implementation expands. Costs and performance assumptions for more speculative efficiency technologies were estimated by our analysts. For those renewable energy technologies that are not yet fully mature, we relied on estimates of their future costs and performance based on analysis of current trends and likely technological advances. In several cases in the transportation and industry sectors, we were unable to develop cost and benefit estimates for individual technologies, so we used estimates of average returns for a range of potential efficiency improvements.

We calculated the annual capital and fuel costs over the life of each investment, using a 3-percent real discount rate to convert those costs to present (1990) dollars. To test the sensitivity of our results to our choice of discount rates, we recalculated the net present value of the investments made in each scenario and the savings generated from these investments using a 7-percent discount rate.

Summary of results

The Market, Environmental, and Climate Stabilization scenarios all lead to substantial reductions in primary energy requirements and pollutant emissions from the Reference scenario; they also produce substantial cost savings for US consumers and business.

For all the scenarios, we compare energy intensity (the amount of primary energy used per dollar of gross national product) and carbon intensity (the amount of CO_2 emitted per unit of primary energy consumed). The Reference scenario embodies some energy-efficiency improvements, resulting in a 42-percent decrease in energy intensity over the 40-year period, or 1.3 percent per year. However, the fuel mix, especially a growing use of coal for electricity generation, results in an 11 percent increase in carbon intensity.

In the three other scenarios, the energy and carbon intensities *both* decrease over the 40-year period at a progressively greater rate from scenario to scenario, as a result of additional efficiency improvements and a shift to less carbon-intensive fuels.

The rates of energy-intensity reduction in our Market, Environmental, and Climate

Summary Results

	1988	2000	2010	2030
GNP[1] (Billion $1990)	5,292	7,090	8,941	12,792
Reference Case				
Primary Energy (Quads)	85.3	96.4	105.0	120.2
Primary Renewable Energy (Quads)	7.4	9.8	11.2	15.5
CO_2 (Billion tons)	5.3	6.0	6.8	8.3
Energy/GNP (kBtu/$)	16.1	13.6	11.7	9.4
CO_2/Energy (lb/MMBtu)	124.3	123.4	128.6	138.0
Market Case				
Primary Energy	85.3	88.5	83.4	82.2
Primary Renewable Energy	7.4	10.2	14.8	29.0
CO_2	5.3	5.4	4.7	3.8
Energy/GNP	16.1	12.5	9.3	6.4
CO_2/Energy	124.3	121.1	112.5	92.2
Environmental Case				
Primary Energy	85.3	82.2	72.7	70.2
Primary Renewable Energy	7.4	10.6	15.6	29.3
CO_2	5.3	4.9	3.7	2.7
Energy/GNP	16.1	11.6	8.1	5.5
CO_2/Energy	123.3	118.7	102.6	78.1
Climate Stabilization Case				
Primary Energy	85.3	78.4	68.9	61.9
Primary Renewable Energy	7.4	12.4	18.1	32.8
CO_2	5.3	4.4	3.2	1.5
Energy/GNP	16.1	11.1	7.7	4.8
CO_2/Energy	123.3	112.0	91.7	48.8

[1] GNP growth is taken from the NES.

Stabilization scenarios are not unprecedented. US energy intensity fell by an average of 2.4 percent per year between 1973 and 1986; the three scenarios anticipate decreases ranging from 2.1 percent to 2.8 percent per year.

The rates of transition from fossil to renewable fuels envisioned in our scenarios also have historical precedent. Over the 40-year period, we project renewables increasing from 9 percent of current energy supply to 36 percent in the Market scenario, 42 percent in the Environmental scenario, and 53 percent in the Climate Stabilization scenario. The shift from coal to petroleum and natural gas was comparably rapid in the middle of this century, with coal use declining from 70 percent of our energy supply in 1920 to less than 20 percent in 1970. Our average growth rate of 3.7 percent per year in renewable energy supply between 1988 and 2030 in the Climate Stabilization scenario is less than the rates of growth in oil and natural gas consumption in the decades prior to the 1973 oil price shock.

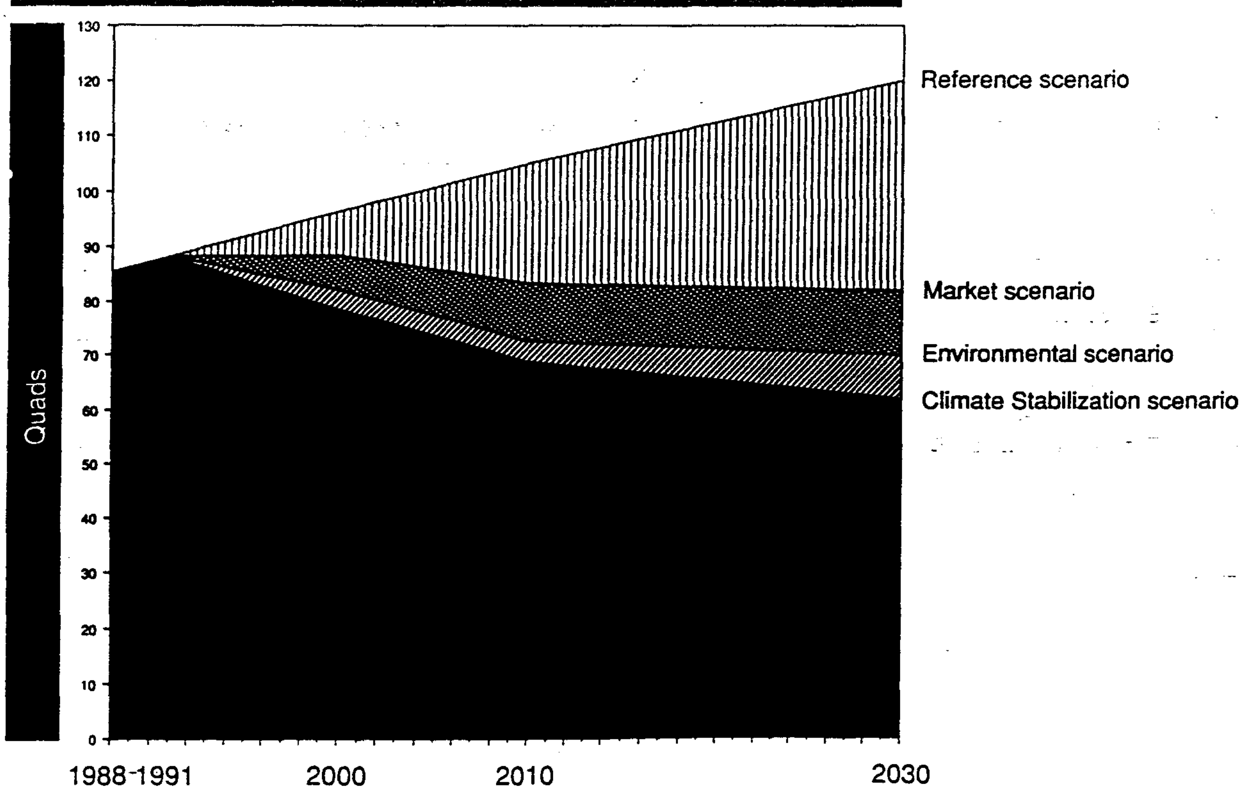
Our analysis shows that it is the *combination* of steadily declining energy intensity and steadily increasing renewable energy supplies that yields the greatest environmental, security, and monetary benefits for the nation.

Primary Energy requirements

Our Reference scenario projects that the primary energy requirements of the United States will increase by about 41 percent during the next 40 years, from the 85 quadrillion Btus, or quads, that the country required in 1988, to 120 quads in 2030. Oil consumption increases 15 percent over current levels. Although the *amount* of energy supplied by renewable sources in the Reference scenario will double during the same period, the *share* of US energy demand supplied by renewables increases only slightly, from 9 percent to about 13 percent.

In the Market scenario, the United States' primary energy requirements fall sharply to 82 quads in 2030. This is 32 percent less than the Reference scenario

Primary Energy Requirements



projections. Oil consumption decreases some 40 percent.

In the Environmental scenario, primary energy requirements decrease to just 70 quads in 2030, about 42 percent less than the Reference scenario projections for that year. Oil consumption is reduced by 54 percent.

Finally, in the Climate Stabilization scenario, the United States requires only 62 quads of primary energy in 2030—about half the Reference scenario levels and more than one-fourth lower than actual demand in 1988. Oil consumption is cut by two-thirds from today's levels. Renewable resources more than quadruple over the 40-year period, providing more than half of all energy requirements by 2030.

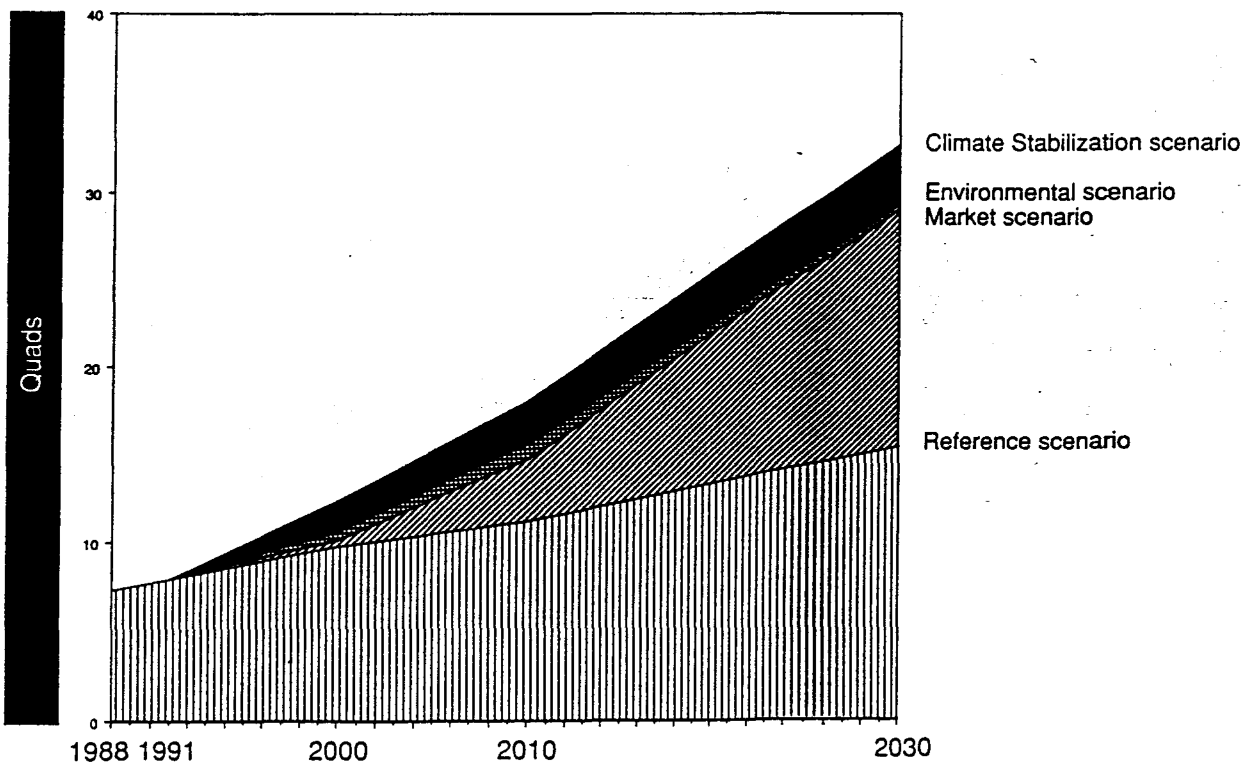
Pollutant emissions

We generated emissions data for seven atmospheric pollutants but focused especially on CO_2, SO_2, and NO_x. The latter two are the prime causes of acid rain. In addition, NO_x is an important contibutor to smog. CO_2 is by far the dominant greenhouse gas produced by energy use.

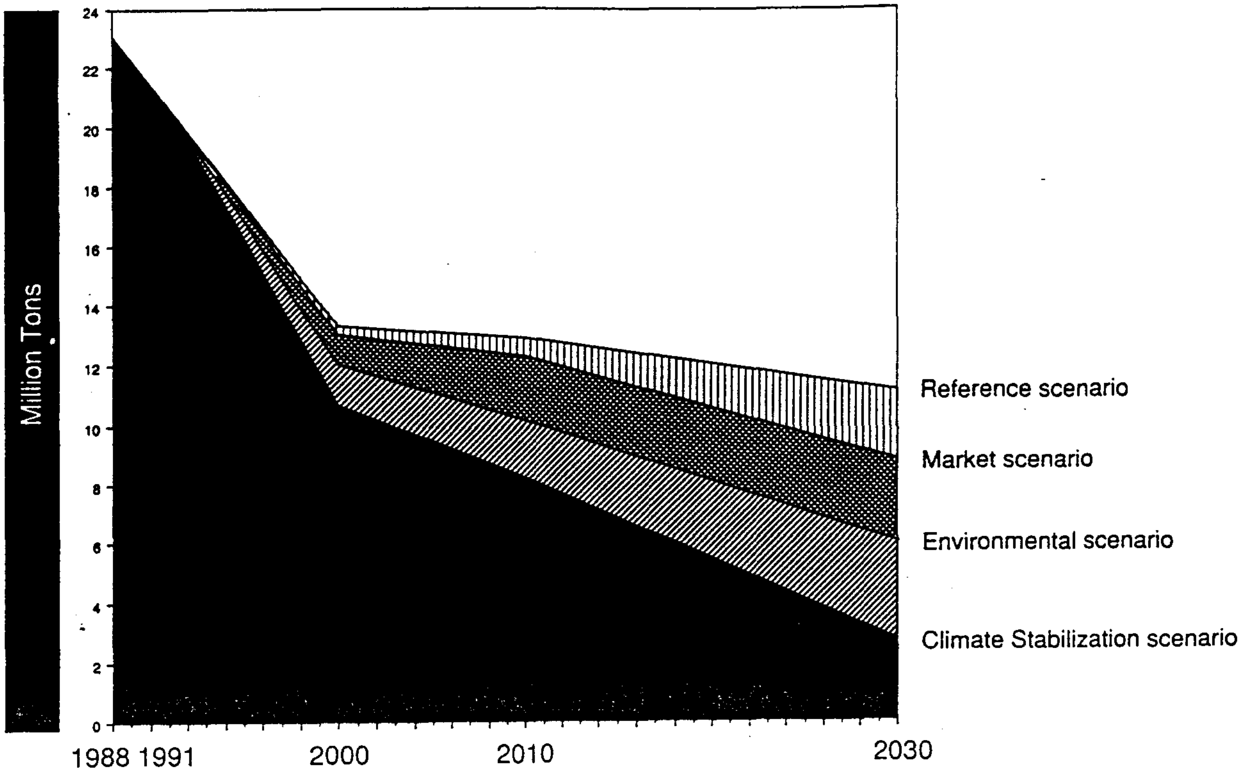
Our study projects that emissions of SO_2 and NO_x will decline even in the Reference scenario, principally because of the requirements mandated by the recently amended Clean Air Act. In the Reference scenario, SO_2 emissions decrease by 42 percent between 1988 and 2000, and NO_x emissions decrease by 16 percent. By 2030 in the Reference scenario, SO_2 emissions fall by 52 percent and NO_x emissions fall by 24 percent relative to 1988 emissions levels.

These emissions would be further reduced in the three other scenarios, with their increased energy efficiency and use of cleaner fuels. In the Environmental scenario, for example, dramatic reductions would be achieved: SO_2 emissions would drop nearly 75 percent between 1988 and 2030, while NO_x emissions would drop by nearly two-thirds. The Climate Stabilization scenario would see even further reductions in SO_2 and NO_x emissions, as a result of still-greater energy-efficiency gains and use of cleaner fuels and the retirement of substantial coal-fired generating capacity in the electric sector.

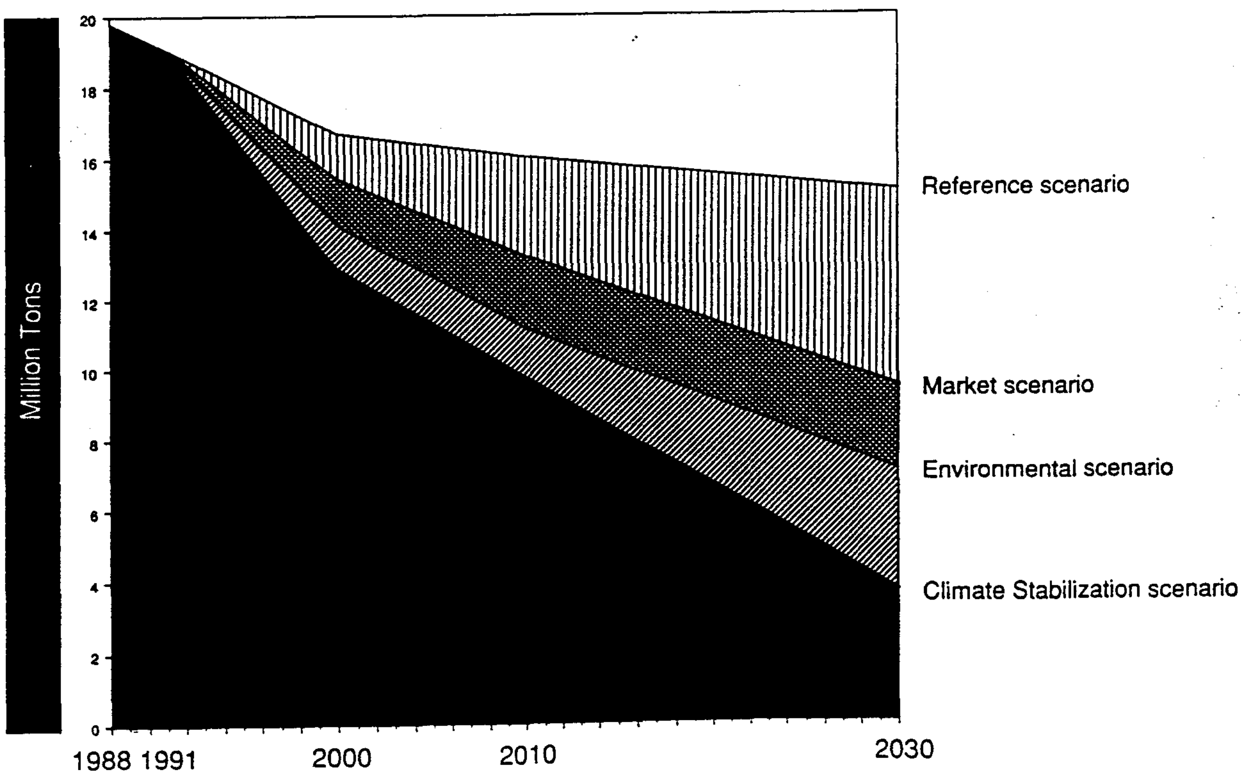
Primary Renewable Energy Supply



SO_x Emissions



NO_x Emissions



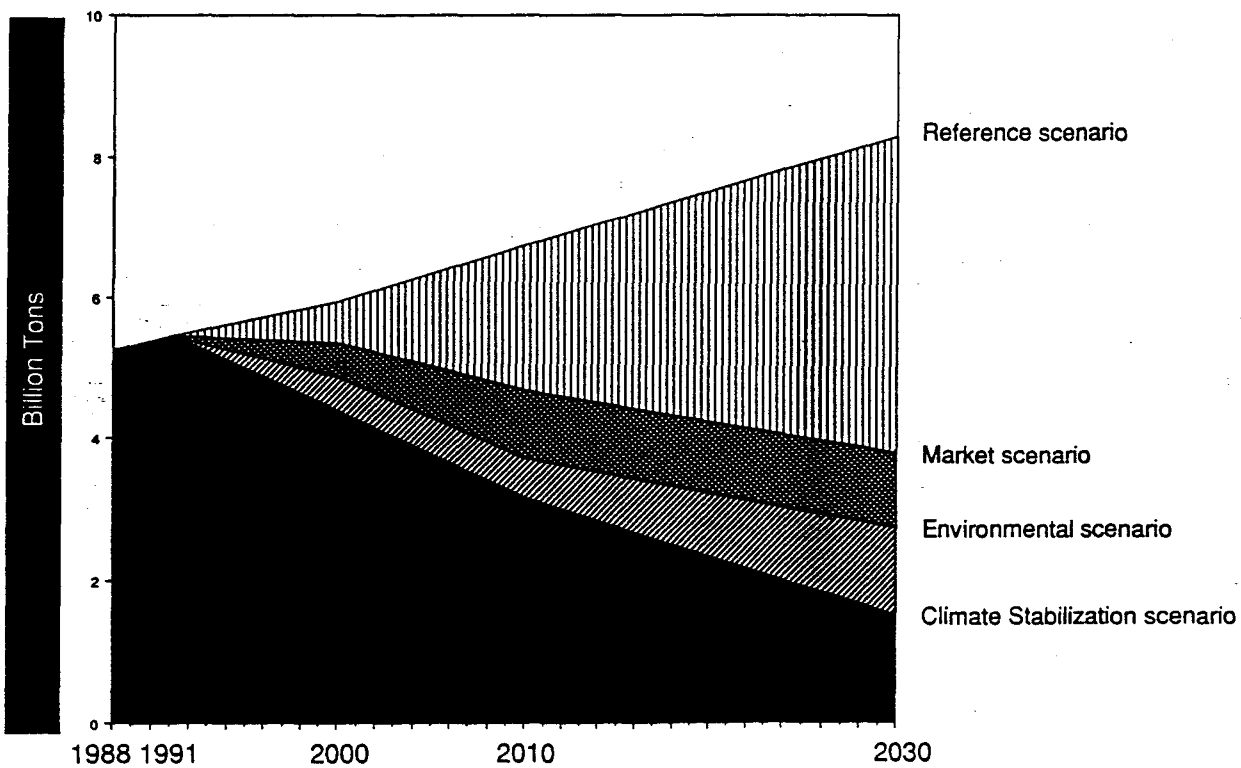
In the Reference scenario, new electricity-generating technologies are predominantly coal-fired and have fairly stringent SO_2 and NO_x controls, but no restrictions on CO_2 emissions. The consequence is that while emissions of the first two pollutants decline between 1988 and 2030, CO_2 emissions *increase* nearly 60 percent as electricity demand and coal use grow.

The Market and Environmental scenarios, on the other hand, project significant reductions in CO_2 emissions because of increased energy efficiency, switching from coal and oil fuels to natural gas, and increased use of renewable energy sources. In the Market scenario, CO_2 emissions decrease by 28 percent between 1988 and 2030; in the Environmental scenario, CO_2 emissions decrease by 48 percent over the same period.

The Climate Stabilization scenario leads to more than a 25-percent reduction in CO_2 emissions by 2005 and a 71-percent reduction from 1988 levels by 2030. This dramatic drop is attributable to additional efficiency improvements and further shifts from coal to gas as an energy source for electricity generation, shifts from coal to electricity as an industrial power-source, the greater use of renewable fuels, and more efficient technologies for heating in the residential, commercial, and industrial sectors.

We compared our CO_2 emission results with those of six other recent assessments of national energy requirements and the potential for limiting future carbon dioxide emissions. Two of these scenarios were developed by DOE as part of its National Energy Strategy, two by the Office of Technology Assessment of the US Congress, one by ICF, Inc. for the US Environmental Protection Agency, and one by a group using the MARKAL model developed at Brookhaven National Laboratory. Among these, our study is unique in combining aggressive pursuit of both energy efficiency and renewable energy technologies. Also, our study used a lower discount rate for evaluating the cost-effectiveness of these technologies, reflecting our intent to maximize long-term benefits to society. These differences explain why our Environmental and Climate Stabilization scenarios project greater reductions in CO_2 emissions than the other studies. In these other studies,

CO_2 Emissions



CO_2 emissions in 2010 range from 13 percent higher to about 25 percent lower than base-year emissions. In our Climate Stabilization scenario, CO_2 emissions are 40 percent lower in that year.

Costs and Savings

Our study demonstrates that, far from being a costly drag on the economy, increased use of renewable energy technologies and energy efficiency can save American consumers and businesses hundreds of billions of dollars over the next 40 years.

The savings in fuel and electricity that result in our non-Reference scenarios substantially exceed the investment costs in each case. The net savings in the Market scenario total nearly $1.8 trillion over the 40 year period, increasing to nearly $2.1 trillion in the Environmental scenario and nearly $2.3 trillion in the Climate Stabilization scenario. If a 7-percent discount rate is used instead of a 3-percent rate, the net savings are reduced to about $0.6 trillion in all three scenarios, reflecting the reduced value of future savings.

It may seem counterintuitive that the net savings are greatest in the Climate Stabilization scenario, especially since some higher-cost efficiency, fuel-switching and renewable energy options are employed to achieve the additional carbon dioxide emissions reductions compared with the Market and Environmental scenarios. It turns out that the higher cost of these options at the margin is more than offset by the greater penetration of lower cost options assumed to result from more aggressive policy measures envisioned in this scenario. Our cost results do not include economic adjustment costs or economic benefits from reducing pollution.

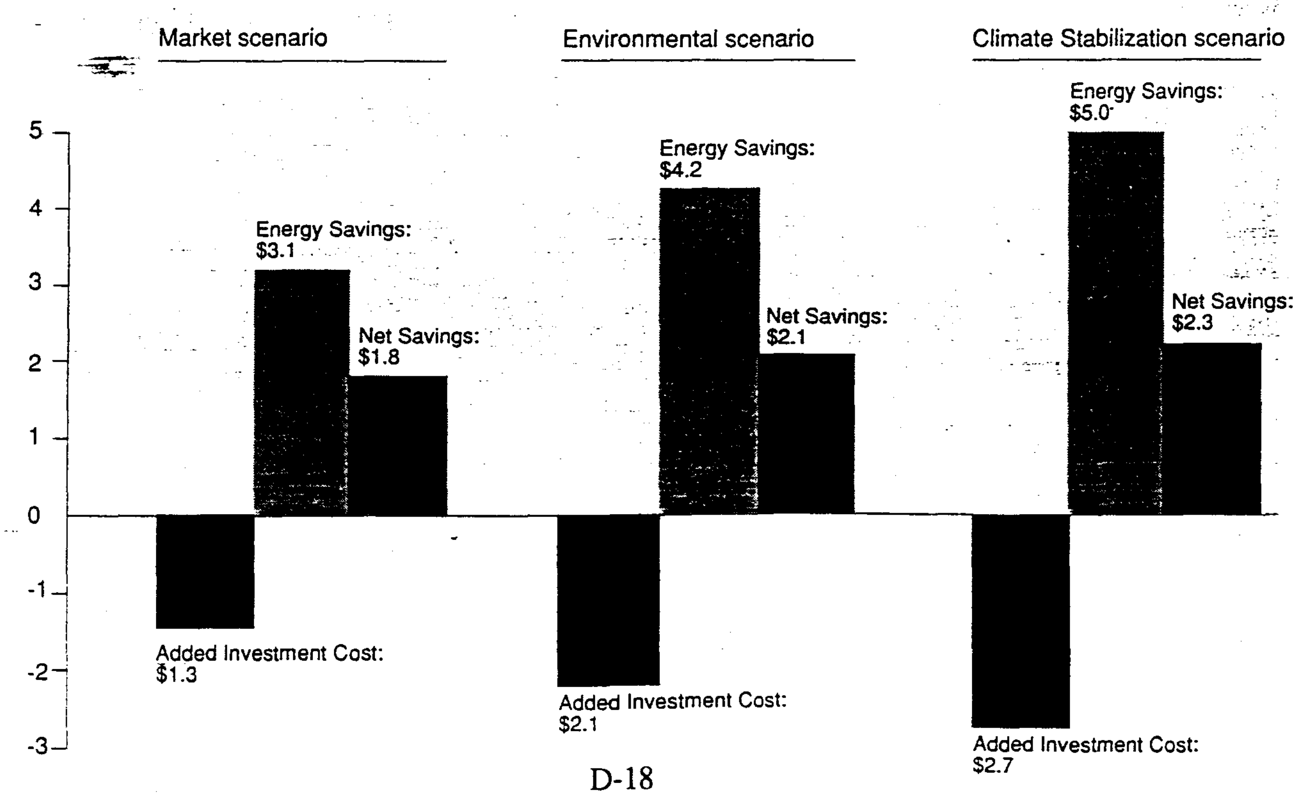
While our cost results are approximate, they indicate that, far from being a burden, greater energy efficiency and accelerated development of renewable energy sources would provide society with significant economic dividends, as well as clear environmental benefits.

Analysis and Results by Sector

We now highlight the key assumptions and findings for each sector examined in the

Costs and Savings Compared to Reference Case

Cumulative Present Value (Trillion 1990 Dollars) at 3% Discount



report: buildings, industry, personal and freight transportation, and electric utilities. The results are numerically presented in tables at the end of the Executive Summary.

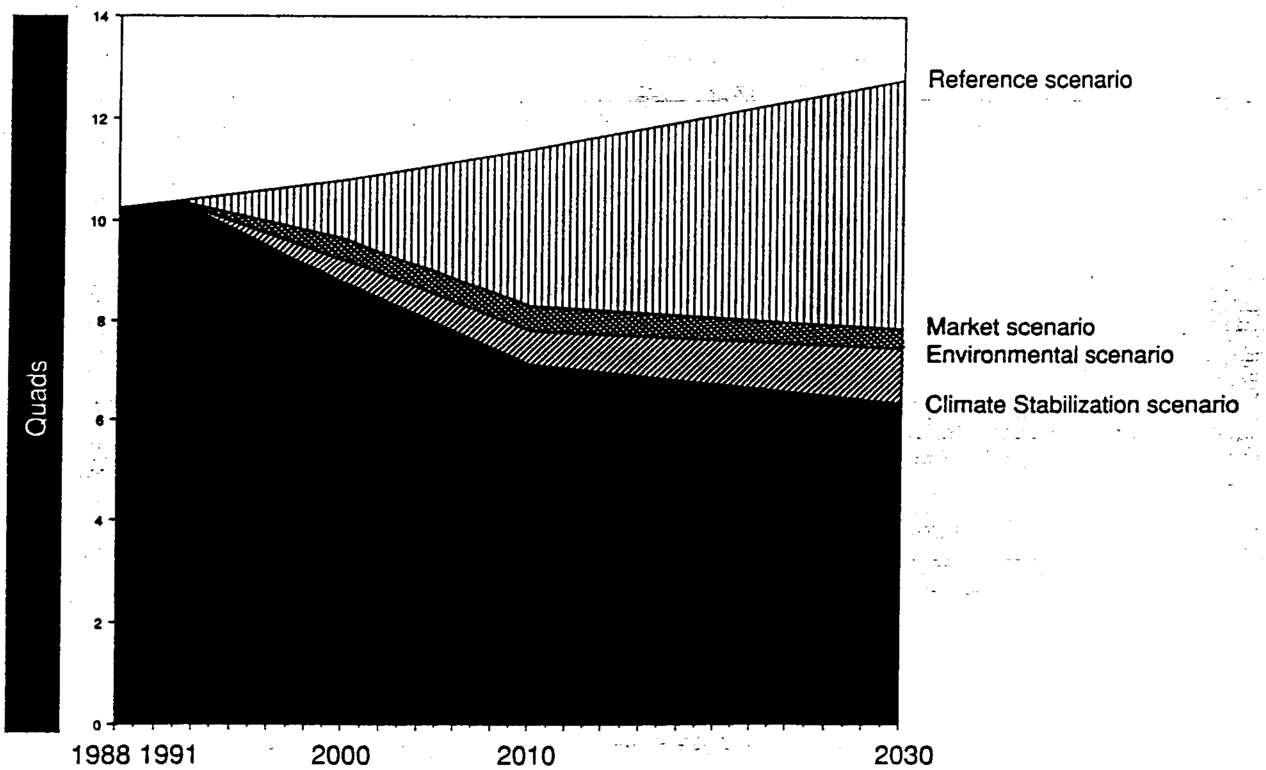
Buildings. Our analysis reveals a tremendous potential for cost-effective energy savings in the residential and commercial buildings sectors. These savings would result from the use of more than 60 types of conservation technologies and measures currently available, ranging from more efficient lighting, windows, and appliances in existing residences to more efficient heating, ventilating, and air conditioning systems in new commercial buildings. We did not include measures that our analysts judged to be too uncertain in terms of availability, performance, and/or cost. The energy savings potential varies from 40 percent in new educational buildings to 87 percent for retrofit of existing electric-resistance-heated single-family homes. Commercial office space retrofits fall in between, with savings averaging about 70 percent.

It will take time to develop the conservation programs and manufacturing and distribution capacity to implement these measures, as well as to commercialize some of the technologies. Our estimates of the rate at which the technologies will penetrate the market are based on a review of experiences with existing policies and programs, as well as anticipated results from new programs.

In addition to efficiency gains, we project greater use of renewable energy technology in the buildings sector. We evaluated solar water heating, passive solar building design, solar district heating with seasonal storage, and geothermal district heating options. Savings obtained from these options range from 20 percent to 50 percent of final heating and hot water demand (depending on scenario and region). Firewood continues to supply a small but significant fraction of energy use in this sector.

Energy use in residential buildings . In the Reference scenario, energy use in the resi-

Residential Energy Consumption



dential sector increases from about 10 quads in 1988 to almost 13 quads in 2030. In contrast, energy consumption would fall 24 percent in the Market scenario, 27 percent in the Environmental scenario, and 38 percent in the Climate Stabilization scenario. In all our scenarios, electricity gradually increases its share of residential energy use while the shares of natural gas and oil decrease.

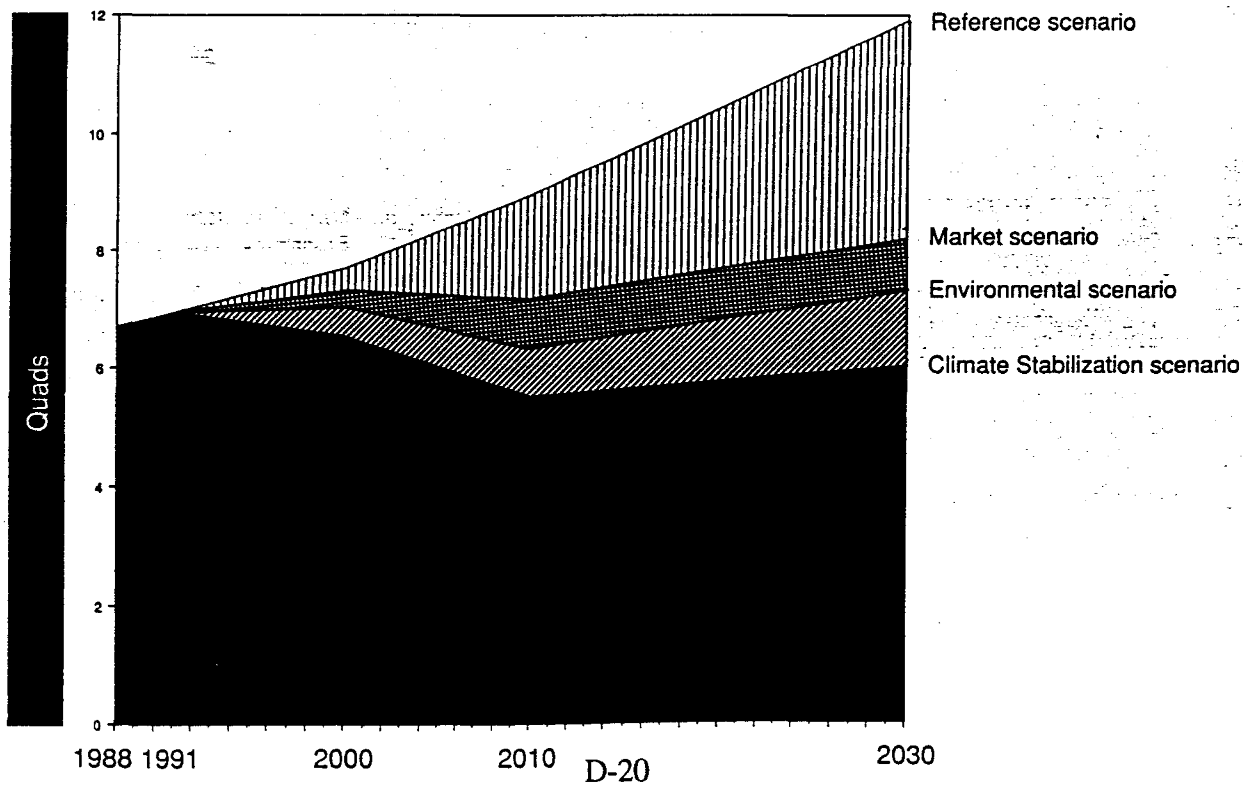
Renewable energy sources contribute between 11 percent of total residential energy supply in the Reference scenario to 33 percent in the Climate Stabilization scenario in 2030, compared to 9 percent in 1988.

Energy use in commercial buildings. Energy use in the commercial sector increases 78 percent, from almost 7 quads in 1988 to almost 12 quads in 2030 in the Reference scenario. It rises in the Market and Environmental scenarios, but by much less—22 percent and 9 percent respectively. The Climate Stabilization scenario projects a decrease of 10 percent. As in the residential sector, electricity provides a larger share of the energy over time, as do renewable energy sources.

Industry. There is enormous potential for US industries to improve their energy-efficiency. However, the analysis was complicated by the fact that US industries are extremely heterogenous and information about industrial processes is limited (and in many cases proprietary). Our analysis of energy efficiency thus relied primarily on assumed rates of energy intensity reduction in various industrial subsectors, but was complemented by some analysis of specific efficiency measures. Three renewable energy resources were considered: wood wastes, solar-thermal energy, and geothermal energy.

All the scenarios assumed the same increase in dollar output of basic materials such as steel or paper. It is important to note, however, that we did not follow the assumptions about growth in production of basic materials used by DOE, because we believe they fail to adequately reflect fundamental structural shifts that are taking place in the economy. Our assumptions regarding industrial output reflect trends indicating a steady and significant shift in economic output away from basic industries and toward light industry and the service sector.

Commercial Energy Consumption



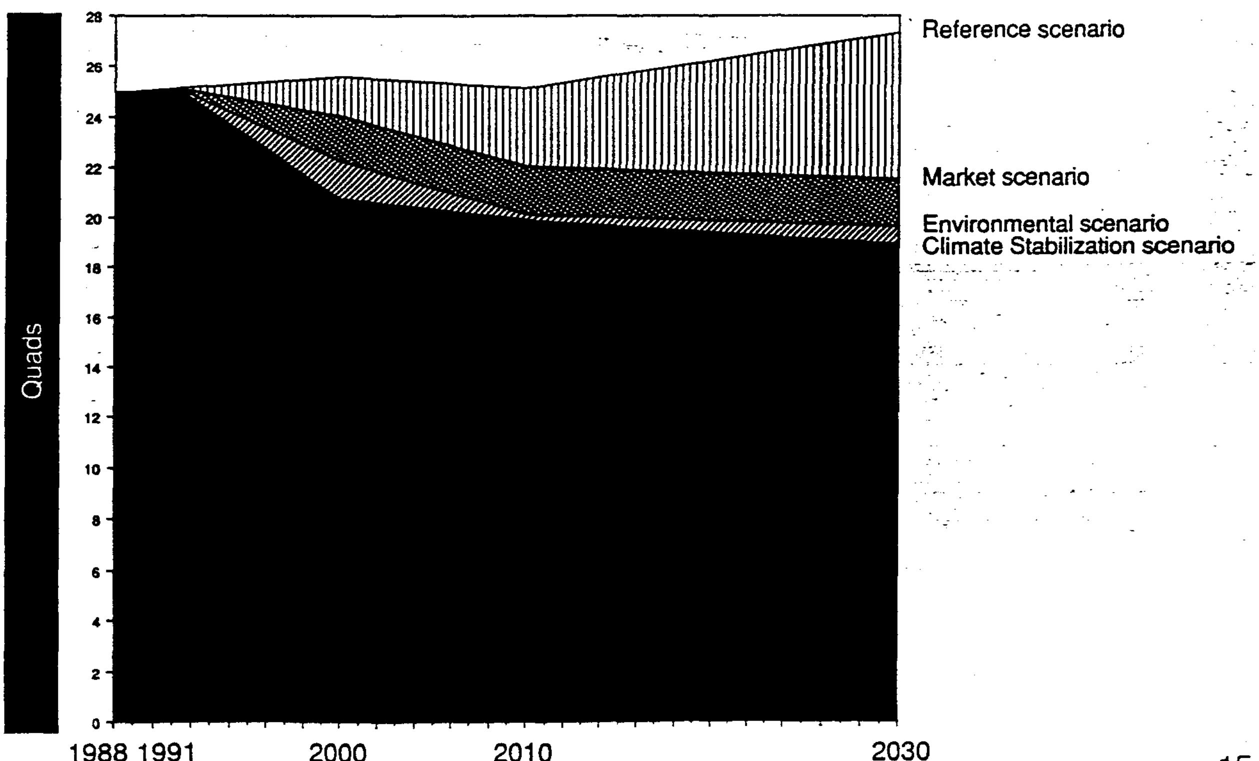
The Reference case shows a modest increase in energy use in the industrial sector from 25 quads in 1988 to 27 quads in 2030. The other three scenarios indicate significant reductions from 1988 levels—14 percent in the Market scenario, 21 percent in the Environmental scenario, and 24 percent in the Climate Stabilization scenario. In addition to these energy savings through efficiency improvements, we project greatly expanded contributions to energy supply from cogeneration, solar, and geothermal resources, particularly in the Environmental and Climate Stabilization scenarios, where our assumptions about pollution taxes on fossil fuels improve the economic competitiveness of these resources.

Transportation sector. The aim of US transportation policy should be to move people and freight from one point to another in the most efficient manner possible without sacrificing convenience and safety.

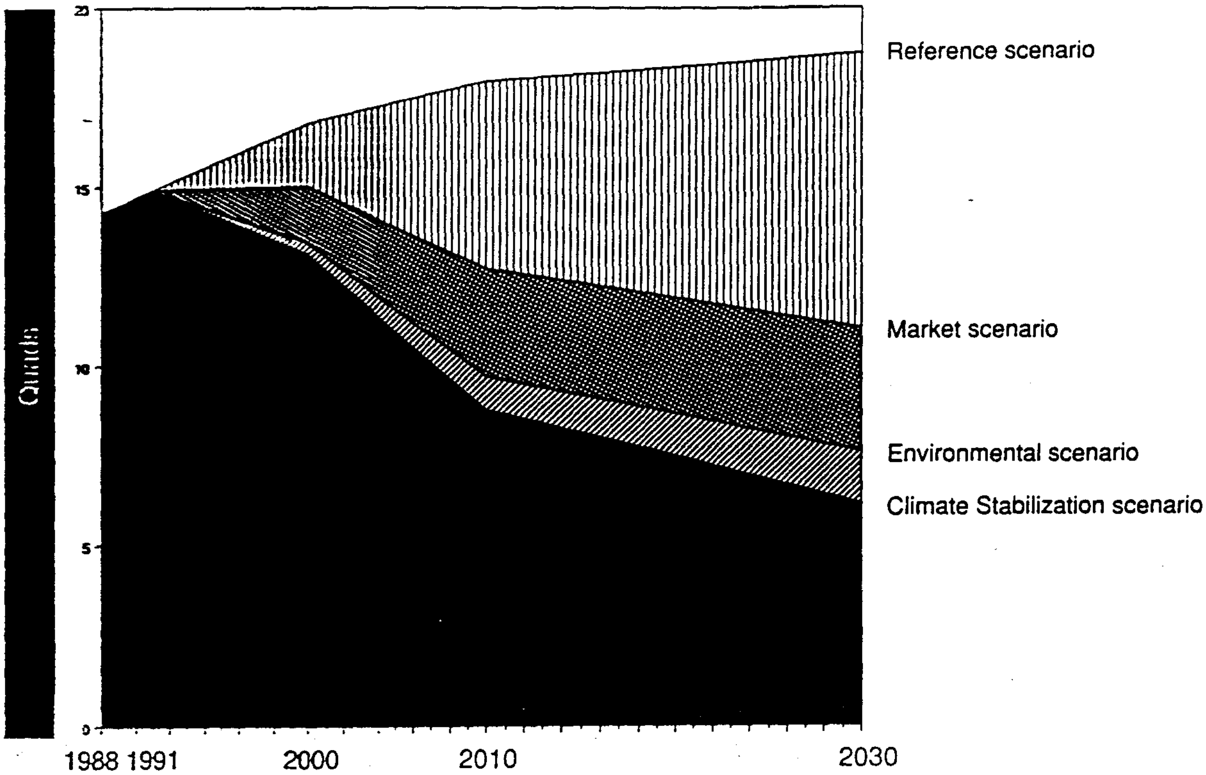
Personal transportation. Our analysis covers all modes of personal travel—private passenger vehicles, public transit, and intercity air, rail, and bus. It demonstrates that energy efficiency can be increased by improving vehicle technology by shifting to more efficient transportation modes, by changing land-use patterns, and by implementing measures that reduce wasteful travel (such as single-occupant commuting). At the same time, emissions of CO_2 and other pollutants can be reduced by improving efficiency and switching to less polluting fuels.

The fuel efficiency of light vehicles increases in each scenario, but at different rates. We assume the average rated fuel economy of new cars in 2010 reaches 37 miles per gallon (mpg), 50 mpg, 54 mpg, and 59 mpg in the Reference, Market, Environmental, and Climate Stabilization scenarios, respectively. We assume that by 2030 the average rated fuel economy of new cars is 41 mpg in the Reference scenario, 56 mpg in the Market scenario, and 75 mpg in the Environmental and Climate Stabilization scenarios. Also, we assume that the current gap between rated and actual on-road fuel economy declines in the three non-Reference scenarios because of revised test procedures. This implies even greater

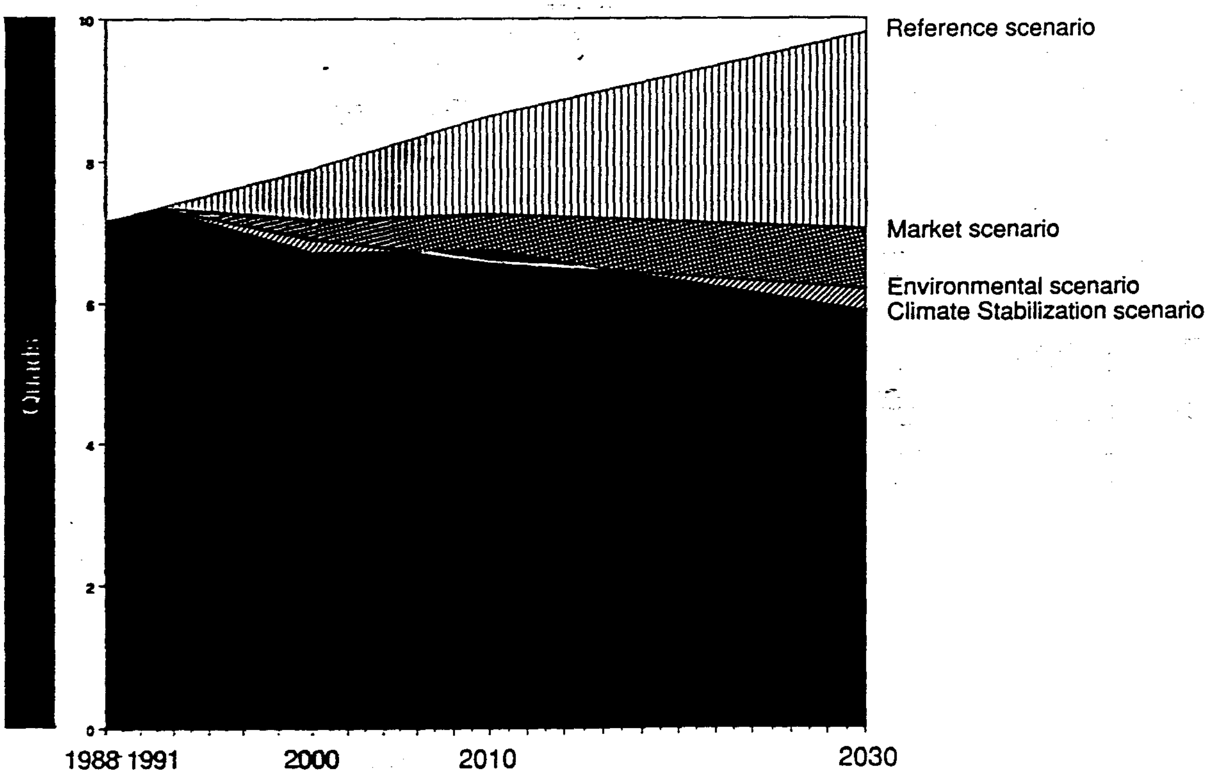
Industrial Energy Consumption



Personal Transportation Energy Consumption



Freight Transportation Energy Consumption



energy savings than suggested by the fuel economy ratings alone.

In recent years, gains in automobile fuel efficiency have been offset by increases in the number of miles that Americans drive. Our Reference scenario assumes continuation of current transportation policies and urban-growth patterns, leading to a 60-percent increase in vehicle miles travelled (VMT) between 1990 and 2030 in the personal transportation sector. VMT is reduced in our other three scenarios because of expanded mass transit, land-use policies which increase urban density (especially along transit corridors), and implementation of transportation demand management measures such as high-occupancy vehicle lanes and parking restrictions. The combined effect of these assumptions is to limit growth in VMT over the 1990-2030 period to 32 percent in the Market scenario, 6 percent in the Environmental scenario and 5 percent in the Climate Stabilization scenario.

In the Reference scenario, overall energy use in the personal transportation sector increases dramatically, from over 14 quads in 1988 to almost 19 quads in 2030. The other three scenarios project sharp declines instead: 23 percent in the Market scenario, 47 percent in the Environmental scenario, and 57 percent in the Climate Stabilization scenario.

Much of the energy for personal transportation could be supplied by electricity and by biofuels such as methanol, ethanol, and hydrogen. We assume that biofuels would be produced from wastes or energy crops, such as short-rotation trees and grasses, that would be grown on a large scale and converted to fuel using thermochemical and biochemical processes now under development. Based on cost comparisons with conventional gasoline and diesel fuel, we projected that biofuels would begin penetrating the personal and freight transportation sectors within 10 years, and, by 2030, would account for 33 to 43 percent of total energy use for personal transport in our three alternative scenarios.

By 2030, petroleum consumption, which presently accounts for 98 percent of the energy used for personal transportation, supplies just 61 percent in the Market scenario, 50 percent in the Environmental scenario, and 42 percent in the Climate Stabilization scenario. The combination of efficiency gains and fuel substitution reduces 2030 petroleum consumption in the Climate Stabilization scenario to just 14 percent of the level projected for the Reference scenario.

Freight transportation. Because heavy trucks are the most energy-intensive mode of transportation, we performed an in-depth analysis of the cost effectiveness of energy-efficiency measures for these vehicles. During the next 40 years, we anticipate that freight-transportation technologies will change significantly—diesel engines will incorporate turbocompounding and low-heat rejection technologies and gas turbines; electric vehicles will become more competitive; and fuel cells will become widely used. Fuel cells are an emerging technology that can supply useful energy from either alcohol or hydrogen, both of which can come from a renewable source. We project that natural gas will become a prominent fuel for moving freight.

Although we assume delivery of 35 percent more freight in 2030 than today, our analysis shows that efficiency improvements can more than compensate for this growth in service demand, resulting in stable or declining energy consumption and pollutant emissions. Although the cost projections for the technologies that will bring about those efficiency increases have large uncertainties, we estimate that these energy-use reductions would be cost effective in every scenario. With changes in land-use patterns and urban-transportation policies, there could be additional savings, but we did not analyze the impact of those factors for freight transportation.

Overall energy use in the freight sector increases from more than 7 quads in 1988 to almost 10 quads in 2030 in the Reference scenario, as compared to reductions of 2 percent in the Market scenario, 14 percent in the Environmental scenario, and 18 percent in the Climate Stabilization scenario. As with personal transportation, the share of 2030 energy requirements supplied by petroleum falls from 89 percent in 1988 to 69 percent in the Market scenario, 58 percent in the Environmental scenario, and 19 percent in the Climate Stabilization scenario. Alternatives such as biofuels, natural gas, and electricity make up the difference.

Electricity supply. Each successive scenario reflects greater levels of efficiency and hence lower electricity requirements, greater shares of power supplied from renewable resources, and a shift to fossil-fueled power plants with lower pollutant-emission rates. We limited the power-supply options in the Reference, Market, and Environmental scenarios to near-term conventional and advanced fossil technologies and electric-generating facilities that use renewable resources. Some penetration of more advanced coal technology (fuel cells and magnetohydrodynamic facilities) was assumed in the Market and Environmental scenarios in later years. In the Climate Stabilization scenario, we included natural gas fuel cells as an option after 2010.

Our analysis of renewable energy considered 13 technologies—from hydro-electric-plant upgrades to advanced-geothermal technologies (geopressured and hot dry rock). We considered not only direct costs, but other factors such as physical limitations on the resource and the incremental cost of storage needed to compensate for variability of wind and solar output.

Our scenarios assumed neither the introduction of advanced nuclear-reactor designs nor the relicensing of existing nuclear power plants. The cost of construction and operation of existing plants has been rising. Insufficient information is available on the engineering design of advanced reactors to confidently project their costs. In addition, the problem of long-term waste disposal remains unresolved and is unlikely to be resolved any time soon. Public opposition to new nuclear-plant construction remains high, and the industry remains threatened by the possibility of a catastrophic accident at an existing plant.

The Bush administration energy strategy assumes that these hurdles can be overcome, leading to a doubling of the nation's nuclear capacity by 2030. We instead adopt DOE's base-case assumption that nuclear's role in our mix of energy sources will steadily diminish, producing less than 10 percent of current output levels by the year 2030.

In the Reference scenario, new plant additions are primarily coal-fired and natural gas combined cycle units, with some expansion of renewable capacity and completion of those nuclear units now under construction. In the other three scenarios, efficiency gains hold down the need for increases in total generating capacity, and renewable generation fills in for the phase-out of nuclear output, as well as for the successively greater reduction in coal-fired generation as we move from the Market scenario to the Climate Stabilization scenario.

In the Reference and Market scenarios, we assume only about one-third of existing coal-fired plants are retired at the end of their design lifetimes. In the Environmental scenario, two-thirds are assumed retired because of the relatively high emissions costs of these plants. In the Climate Stabilization scenario, all of the current coal-fired capacity would be replaced by natural gas-fired plants, fuel cells, and renewable energy resources.

In the Reference case, overall electricity requirements increase by 90 percent between 1988 and 2030. In the Market scenario, total generation increases by just 12 percent over the same period, while in the Environmental and Climate Stabilization scenarios, total generation decreases by 8 percent and 14 percent, respectively. The non-Reference scenarios thus greatly reduce fuel combustion and the need for new capacity to meet demand.

In addition, renewable energy resources play an increasingly important role. In the Reference scenario, renewable energy sources supply nearly 14 percent of total electric generation by 2030; this share increases to 40 percent, 52 percent, and 61 percent, in the Market, Environmental, and Climate Stabilization scenarios, respectively. Wind, solar, advanced geothermal, and biomass account for the largest shares of new renewable supply.

Policies for a clean and prosperous America

The results discussed above describe a range of *possible* energy futures for the United States. In the sections that follow, we summarize the energy policies that would move the nation from the Reference scenario toward a cleaner, more competitive, and more secure future.

Several of the policies described here are quantitatively linked to the energy scenarios; for example, the Environmental scenario incorporates increased taxes on gasoline, and new taxes on pollution, to reflect the environmental and national security costs of energy. Various of the scenarios also assume the implementation of such policies as the incorporation of environmental costs in utility planning, automobile efficiency standards, and energy-efficient building codes. Other policies are more difficult to model. For example, we could not reliably estimate the precise costs and savings of integrating land-use and transportation planning or of establishing cooperative research-and-development (R&D) centers for energy-intensive industries.

We have therefore not attempted to estimate the effectiveness of each individual policy. Rather, we present sets of policies that appear consistent with achieving the cost-effective opportunities for increased efficiency and renewable energy production reflected in the scenarios. Some of the policies apply only to one or another of the scenarios, while other policies apply to all scenarios, although perhaps at different rates of implementation. While all of the authors and sponsoring organizations do not necessarily endorse each policy, we believe that the policies outlined show that the nation can move in the direction of our three non-Reference scenarios.

The policies presented here are broad-based and complex; they deserve further analysis and development. In the development of the next version of the national energy strategy, the Department of Energy—in conjunction with other federal agencies and the states—should employ least-cost principles and analyze the policies needed to achieve scenarios similar to the ones described in this report. To be truly successful, this effort must include publication of a draft policy document, including analysis of both selected and rejected options for comment. In turn, DOE should consider and respond to the comments received before issuing its final strategy and policy proposals.

The policies presented here do not call for a return to price controls and crash programs to promote specific fuels. But they recognize the market biases and barriers that currently favor energy production over energy efficiency: tax-breaks and other subsidies for preferred energy-technologies and fuels; lack of information on, or availability of, energy-saving and renewable energy technologies; the tendency among builders or equipment-purchasers to minimize initial costs because they do not pay operating costs; the high costs of capital for consumers who want to invest in efficiency and renewable energy measures; and the widespread failure to reflect the true costs to society of environmental damage from energy production and use.

Some of the policies discussed here have already been implemented in a number of states and localities, and others are under active consideration. What is lacking is a coherent national policy that ensures the implementation of effective policies in all jurisdictions and reflects the public interest in affordable energy services, national security, and environmental protection.

Rather than asking "How can we produce enough energy?" energy policymakers should ask: "How can we ensure that our energy system provides the services we want at the least cost?" Reformulating energy policy in this way recognizes the fact that no one is interested in energy for its own sake. Consumers want the services that energy helps to provide—light, comfort, mobility, and the ability to transform raw materials into useful products. From this perspective, energy not wasted is as valuable as energy produced.

In implementing energy policy, particular attention must be paid to issues of equity and fairness, as well as to the impact of the transition to a new mix of energy resources. For example, higher taxes on energy may well be justified to reflect the societal costs of pollution in energy prices, but some of the revenues from such taxes must be used to offset their disproportionate impact on lower-income and rural Americans. Similarly, while the nation (and the world) must shift away from reliance on coal and oil if we are to lessen the risk of ecologically disastrous rates of global warming, consideration must be given to the need for job retraining and economic conversion strategies for those workers and regions of the country that will be most affected by this shift.

The policies we present here reflect three guiding principles that the United States must follow in order to obtain the economic and environmental benefits of the non-Reference scenarios. Energy policymakers in the United States should:

- Harness market forces
- Make efficiency the standard
- Invest in the future

These three basic approaches are described below.

Harnessing market forces

Ensuring effective competition among options for energy supply and efficiency, and reflecting environmental costs in energy markets, are essential steps in achieving our policy objectives. The elements of this strategy include ensuring that investments in efficiency are as profitable as those in supply, using market incentives and standards to promote efficient technologies, eliminating barriers (such as tax policies) that unfairly hinder the development of renewable resources, and shifting some of the tax burden from income to pollution.

Promote least-cost planning. State utility commissions should eliminate regulatory incentives for increased energy sales, require all utilities to develop least-cost plans that allow supply-side and demand-side measures to compete on an equal footing, and ensure that least-cost investments are the most profitable investments for the utility. By least-cost plans, we mean those that take account of environmental impacts.

The federal government can also play an important role, such as by requiring that wholesale power purchases, which are regulated by the Federal Energy Regulatory Commission (FERC), are consistent with the relevant state least-cost plans. The federal Power Marketing Administrations, which sell power produced at publicly financed dams and powerplants, should be required to give preference in their power sales to utilities that engage in least-cost planning. In addition, the federal government should require the Tennessee Valley Authority to engage in meaningful least-cost planning.

Establish a production tax credit for renewable energy supplies. To help correct for the different tax treatment of fuel expenses versus capital investment (which biases energy choices away from capital-intensive renewable technologies towards fuel-intensive fossil technologies), and to help the renewable energy industries expand their levels of production so as to achieve significant economies of scale, the federal government should establish and expand production tax credits for renewable energy supply. A performance-based tax credit of 2.5 cents per kilowatt-hour for renewable electricity production, along with a tax credit of $2 per million Btu for heat supplied to large industrial and commercial users from renewable sources, would do much to accelerate renewable energy commercialization. These credits would be available for a limited time, and would be gradually phased out for the industry as a whole as the technologies matured. Additional federal and state tax credits should be implemented as needed to promote residential renewable investments, such as solar hot water.

Use market incentives to promote efficient technologies. One way to overcome consumer resistance to the higher up-front costs of some more efficient technologies is to incorporate part of the long-term energy costs at the point of sale. This can be done by charging fees on inefficient technologies or rebates for efficient ones. When both are combined, the practice is know as "feebates." Several utilities are already using this approach to encourage their customers to purchase high-efficiency appliances, lighting, and other equipment. The use of such incentives should be greatly expanded in all states and at the federal level.

Price incentives at the point of vehicle purchase, for example, can be an important complement to mileage standards in stimulating consumer demand for cleaner and more efficient vehicles. The present gas-guzzler tax, an established mechanism which has been effective in raising the fuel economy of low-mpg cars, should be expanded to a system of "feebates" linked to whether a model is below or above the average fuel economy of the new vehicle fleet.

We also suggest the adoption of usage-based fees for automobile drivers, to reflect more fully the cost of automobile use. An example of such a fee is pay-as-you-drive insurance, which would charge a portion of insurance premiums on the basis of miles driven. Other examples include eliminating the tax exemption for employer-subsidized automobile parking at commercial lots, and increasing the use of highway tolls—which could include fees based on automated detection of passing vehicles.

Shift some of the tax burden from income to pollution. To reflect the environmental and national-security costs of various energy sources, the government could assess fees on fossil fuel consumption, with part or all of the revenues used to reduce income or other taxes. This would result in shifting a substantial portion of the nation's tax burden from labor to pollution.

In our Environmental scenario, the environmental and other societal costs of driving are reflected in prices through a 50-cent-per-gallon increase in gasoline taxes. For industrial and utility sources, emissions of NO_x, hydrocarbons, CO, TSPs, and SO_2 from sources larger than a given size would be taxed. The taxes in this scenario would raise almost $150 billion at current levels of consumption and emissions. That amount represents more that 50 percent of current social security and unemployment insurance taxes.

A tax on the emissions of CO_2, levied at a rate of $25 per ton, or $92 per ton of carbon, in conjunction with the policies described in the Market and Environmental scenarios, appears to be of the right magnitude for achieving the emissions targets specified in the Climate Stabilization scenario. Such a tax might be set at a rate of about $1.50 per million Btu on gas, and $2.60 per million Btu on coal, with oil somewhere in between; nonfossil fuels would pay no tax. In the near term, the tax would raise roughly $140 billion per year; total environmental tax revenues would then be $290 billion per year, or more than current social security and unemployment insurance taxes. An alternative to a CO_2 tax is to auction CO_2 emission permits equal in quantity to the target emissions levels in each year.

Making efficiency the standard

According to our analysis and numerous other studies, an enormous reservoir of cost-effective energy-efficiency measures exists in the United States. Efficiency standards can be extremely effective in accelerating the exploitation of this resource.

Increase automobile fuel-economy standards to cut US oil dependence. Corporate Average Fuel Economy (CAFE) standards have been the principal force behind a 75-percent increase in on-road automobile efficiency since 1973. Improved CAFE standards are now long overdue. Already-identified technological improvements can raise the fuel economy of new cars from 28 mpg to 46 mpg during the next 10 years, while maintaining vehicle size, performance, and safety. This can be done at an average cost of conserved energy of only about $0.50 per gallon—half the current price of gasoline. In addition, more stringent standards must be extended to light trucks and minivans. In the Market scenario, we assume that automobile CAFE standards will rise to 40 mpg in 2000; for the Environmental and Climate Stabilization scenarios, we assume more stringent standards. The CAFE standards for autos, minivans, and light trucks assumed in the Market scenario would result in oil savings of 2.5 million barrels per day by 2005.

Set building and equipment efficiency-standards to minimize lifecycle costs. New standards for buildings, appliances, and other energy-using equipment can achieve large gains in energy efficiency at minimal administrative and enforcement costs. Standards should be set, and gradually raised over time, in such areas as new construction, existing building retrofits, appliances, lamps, and motors. The federal government should update and strengthen the national model energy code, require states and localities to meet or exceed this code, and require that federally financed or subsidized buildings also meet it.

Federal appliance standards already in effect will produce energy and cost savings. They should be extended to new products such as incandescent and fluorescent lamps, motors, light fixtures, showerheads, commercial refrigeration equipment, commercial heating-and-cooling equipment, distribution transformers, and office equipment.

Require effective energy management at federal government facilities. Government agencies are major occupants of buildings and users of transportation services. The federal government is the nation's largest energy consumer, spending $8.7 billion per year in its own facilities, and another $3.9 billion annually on the energy expenses of low-income households. Conservative estimates show that the federal government can save more than $850 million per year in its own buildings by making cost-effective efficiency improvements. Federal, state and local governments should invest in such efficiency measures, as well as cost-effective renewable energy production, not only to save taxpayers' money but also to generate a market for state-of-the-art products. A revolving fund of at least $500 million, administered by DOE, would establish a means of financing cost-effective efficiency investments proposed by any federal agency.

Investing in the Future

Targeted investments in R&D, infrastructure, and educational programs are essential to realize the goals suggested in our scenarios. Funding allocations must be reoriented, an efficient transportation network must be developed, and expertise in the technologies and policies of energy-efficiency and renewable energy must be expanded.

Give energy-efficiency and renewables their fair share of federal R&D dollars. Scarce R&D funds should be allocated according to the potential contribution their recipients can make to providing least-cost energy services. To follow this principle, federal R&D efforts should shift away from the current, heavy emphasis on nuclear energy and fossil fuels, and more priority should be given to energy efficiency and renewable energy R&D. Increasing the share of DOE's R&D budget devoted to energy efficiency and renewable energy research from 15 percent to 67 percent during the next decade would provide the basis for sustained development of new technologies. This would imply an eventual funding level of about $2 billion per year, if the overall R&D budget remains constant. As part of this increase, DOE should expand the use of cost-shared joint ventures with private industry to help commercialize advanced energy-efficiency and renewable energy technologies.

Develop an integrated transportation network to increase access and cut congestion. A range of policies are needed to reduce the steady increase in vehicle-miles travelled (VMT) by providing a wider range of transportation choices, and encouraging the use of the most cost-effective combination of transportation modes for each application. The policies include the market-based measures discussed above to ensure that automobile users pay the full costs of driving, and encompass zoning changes that would discourage sprawl and encourage in-fill development in cities, towns, and surrounding suburbs; high-occupancy-vehicle lanes and ridesharing programs that would increase passenger occupancy in personal vehicles; and substantial increases in funding for rail- and bus-transit projects.

Expand education, training, and certification programs in energy-efficient and renewable energy design and construction. One important barrier to increasing energy-efficiency and renewable energy utilization is a lack of qualified personnel, from designers of national programs, to conservation program managers at utilities, to inspectors of construction sites for compliance with energy-efficient building codes. The federal and state governments, in conjunction with the private sector, should expand support for these types of educational and training programs and expand programs that effectively disseminate information.

Conclusion

It is up to the nation's energy policymakers, at all levels of government and in the private sector, to seize the opportunities outlined in this study so that our nation can realize a "win-win" energy future—one that combines prosperity and environmental integrity. By choosing an energy future based on energy efficiency and renewable energy, we can take a giant step towards leaving our children a cleaner planet and a more sustainable way of life.

The policies needed to achieve such a future are by no means simple: they involve basic changes in the way we price energy, construct buildings, manufacture goods, and transport ourselves. Changes of this magnitude are never easy to make, but the consequences of *not* moving forward will be increased oil imports, increased carbon emissions, and ultimately higher costs of using energy.

Tables

SO_x Emissions (Million Tons)

	1988	2000	2010	2030
Reference Case	23.10	13.30	12.90	11.10
Market Case	23.10	13.03	12.30	8.81
Environmental Case	23.10	12.06	10.18	6.01
Climate Stabilization Case	23.10	10.70	8.23	2.71

NO_x Emissions (Million Tons)

	1988	2000	2010	2030
Reference Case	19.81	16.72	16.03	15.05
Market Case	19.81	15.47	13.25	9.47
Environmental Case	19.81	14.16	11.19	7.07
Climate Stabilization Case	19.81	12.90	9.78	3.67

CO_2 Emissions (Billion Tons)

	1988	2000	2010	2030
Reference Case	5.26	5.95	6.75	8.29
Market Case	5.26	5.36	4.69	3.79
Environmental Case	5.26	4.88	3.73	2.74
Climate Stabilization Case	5.26	4.39	3.16	1.51

Residential Energy Consumption (Quads)

	1988	2000	2010	2030
Reference Case	10.23	10.80	11.38	12.76
Market Case	10.23	9.63	8.29	7.82
Environmental Case	10.23	9.23	7.79	7.44
Climate Stabilization Case	10.23	8.76	7.11	6.33

Commercial Energy Consumption (Quads)

	1988	2000	2010	2030
Reference Case	6.70	7.70	8.94	11.91
Market Case	6.70	7.32	7.17	8.18
Environmental Case	6.70	7.04	6.34	7.31
Climate Stabilization Case	6.70	6.52	5.51	6.03

Industrial Energy Consumption (Quads)

	1988	2000	2010	2030
Reference Case	24.98	25.58	25.13	27.33
Market Case	24.98	24.04	22.06	21.60
Environmental Case	24.98	22.28	20.14	19.64
Climate Stabilization Case	24.98	20.76	19.88	18.96

Personal Transportation Energy Consumption (Quads)

	1988	2000	2010	2030
Reference Case	14.28	16.78	17.97	18.76
Market Case	14.28	15.03	12.69	11.02
Environmental Case	14.28	13.47	9.73	7.61
Climate Stabilization Case	14.28	13.11	8.77	6.16

Freight Transportation Energy Consumption (Quads)

	1988	2000	2010	2030
Reference Case	7.17	7.90	8.64	9.81
Market Case	7.17	7.20	7.28	7.06
Environmental Case	7.17	6.92	6.62	6.20
Climate Stabilization Case	7.17	6.72	6.76	5.89

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AMERICA'S ENERGY CHOICES

INVESTING IN A STRONG ECONOMY AND A CLEAN ENVIRONMENT

TECHNICAL APPENDIXES

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Appendix C: Personal Transportation Sector Analysis

This appendix details the assumptions and analysis for personal travel, which is taken to include all motorized, non-freight travel in the United States. The discussion is divided into three major sections: (1) travel demand, (2) light vehicle fuel economy, and (3) intercity travel by air and rail. A brief final section summarizes the transportation energy use projections, by scenario and year, with the freight sector results included for comparison. The organization of the appendix is outlined in the following table of contents by section; a list of tables and figures is also given.

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PERSONAL VEHICLE TRAVEL DEMAND

Reference Scenario

Estimates of the future growth in personal light duty vehicle miles of travel (VMT) were developed using a model based on projected population growth and expected saturation in recent trends of more driving by women. The estimate is derived as follows:

$$VMT_t = (VMT_{t-n}) [(1+POP)(1+VPP)(1+VMV)]^n$$

where:

VMT_t is the total light vehicle miles of travel in year t;

n is the number of years projected;

POP is the average annual growth rate of the driving age population;

VPP is the average annual growth rate of the number of vehicles per person;

VMV is the average annual growth rate of the number of annual miles driven per vehicle per year.

The calculation starts with the EIA[1] estimate of the 1990 passenger vehicle and light truck VMT of 1,762 billion miles.[2] In the discussion that follows, the three factors driving VMT growth--POP, VPP, and VMV--are analyzed in turn.

VMT growth analysis. According to the U.S. Bureau of Census and information received from the Senate Judiciary Committee (which handled the immigration bill), the driving age population is projected to grow as shown in the following table.

Table C1
Projected Driving Age Population of the United States (millions)

Population group:	1990	2000	2010	2020	2030
Age 16 and over	193.0	210.1	227.4	238.5	245.8
Plus: new immigrants		1.2	2.7	4.6	6.8
Less: age 85 and older	3.3	4.6	6.1	6.7	8.1
Driving age population	189.7	206.7	224.0	236.4	244.5
Consecutive annual growth rates		0.86%	0.81%	0.54%	0.34%
Index number	1	1.0896	1.1808	1.2462	1.2889

[1] Non-specific references to EIA throughout this appendix refer to EIA/SR (1990), the "Service Report" which documents the analyses of energy conservation potential which were conducted for the National Energy Strategy. This EIA report and associated information served as an invaluable source of statistics and background for our analyses.

[2] This VMT estimate is 9% lower than the estimate of 1,935 billion miles derived from FHWA highway statistics (passenger cars plus 90% of two-axle/four-tire trucks). We were unable to resolve the discrepancy between the EIA and FHWA estimates and chose the EIA estimate in order to maintain better consistency with the National Energy Strategy analyses. FHWA estimate is from FHWA (1988) and preliminary data for 1989-90 from K.H. Welty (FHWA Travel Monitoring Division, Washington, DC), personal communication, January 1991.

The ratio of vehicles per person (VPP) in 1988 was 0.93 and the ratio has been growing at 1.4% per year recently, but at some point we are going to reach saturation, presumably around 1 vehicle per person. It is possible that the ratio of vehicles per person may become a little higher than unity, but to the extent that it does, it will surely cause a corresponding reduction in the growth of miles per vehicle. People just can't drive more than one car at a time. (Let's hope mankind doesn't find a way around this limit.) Reno (1988) estimated that the saturation ratio could be as high as 1.09, which is based on the assumption that 95% of the population will achieve vehicle ownership rates as high as the current rate (1.15) for the highest income quintile of the population. Assuming this saturation rate is reached by 2010, the ratio will increase at an average annual rate of 0.7%.

Many econometric models assume that VMT per vehicle (our VMV variable) grows with income. However, we have difficulty accepting a strong linkage, based on the following considerations. Using the average reference GNP growth rate projection of 2.5%/yr and a population growth rate of 0.6%/yr (Bureau of Census), per capita income will increase 45% by 2010. Using the statistics shown in Table C2, we can roughly estimate the effect this income increase will have on VMT per vehicle.

Table C2
VMT and Household Income

Household annual income ($)	VMT per vehicle (mile/year)	VMT index	Number of households (10^6)
Less than 10,000	8,409	1.00	10.2
10,000-14,999	9,270	1.10	11.8
15,000-19,999	9,898	1.18	8.3
20,000-24,999	10,478	1.25	8.6
25,000-34,999	10,342	1.23	16.0
35,000-49,999	10,986	1.31	12.9
50,000-74,999	11,111	1.32	8.8
75,000 and up	11,428	1.36	4.5
Average of all classes	10,331	--	81.3

Source: EIA/RTECS (1990)

A 45% increase in per capita income would roughly increase the income for each of the tabulated classes to that of the next higher class. If we calculate what the average per vehicle VMT would be, assuming that each of the above categories were bumped to the next higher level, and that an income increase in the highest income category doesn't result in an increase in per vehicle VMT, the result would be 10,558 per vehicle. This is only 2.2% higher than the current average, indicating that an increase in income could have very little effect on per vehicle VMT. Because this effect is so small, we neglect it in our calculations.

Another factor that could affect miles of travel per vehicle is the substantial increase in the number of miles driven by women, primarily caused by women entering the work force. We know that women are driving more every year, but we don't know the extent to which this is being channeled into an increase in automobile ownership as opposed to an increase in per vehicle miles of travel. Charles Lave of UC Irvine argues that increased driving by women won't increase VMT because women already take as many person trips as men, and therefore, an increase in women miles of driving just means that women are switching places in cars with men. Furthermore, he points out that the growth in female participation in the workforce has greatly slowed lately and is only projected to increase by 2% in the next decade.

We have already assumed that vehicle ownership will climb to a saturation level equal to the vehicle ownership rate in the highest income class (in which women presumably have ready access to vehicles). Then, in order to estimate the maximum contribution women can make to VMT, we could assume that per vehicle VMT will be saturated when women are driving as many miles per year as men. But that would ignore Lave's conclusions, so we assume that growth in driving by women will cut the gap between men's and women's driving in half.

In 1985, men drove above 75% more miles per year than women. Assuming that saturation is achieved by 2000 and that all drivers drove as much as men, the average miles of travel per vehicle would be 12,345 instead of 10,400 in 1990. Assuming this gap were cut in half by 2000, annual miles of travel per vehicle would increase at an annual rate of 0.9%.

Projections and comparison with EIA. Using Equation (1) and the above information, personal light vehicle miles of travel for future years are estimated as follows:

Projection year	Base VMT (10^9)		Annual growth rate factors: POP	VPP	VMV			Projected VMT (10^9)
2000	(1,762)	[	(1.0085)	(1.007)	(1.009)	$]^{10}$	=	2,250
2010	(2,250)	[	(1.0079)	(1.007)	(1)	$]^{10}$	=	2,610
2030	(2,610)	[	(1.0038)	(1)	(1)	$]^{20}$	=	2,820

These estimates are substantially below those projected for later years by EIA, as shown in the following comparison:

Comparison of projected VMT, this study vs. EIA (1990)
(Annual travel, 10^9 miles)

	1900	2000	2010	2020	2030
This study	1762	2250	2610	2711	2820
EIA	1762	2092	2547	2968	3370

Our 2000 estimate is about 10% higher than EIA's, but our 2030 estimate is about 15% lower. EIA uses a demographic/econometric approach, using driving age population, an income effect, and a price effect to grow VMT. In the early years, their rates of growth are substantially below the growth rates observed in the last five years. In the later years, after the driving age population stops growing, they assume income increases coupled with slow increases in the cost of driving will cause continued growth in VMT. Figure C1 shows these projections, along with the lower VMT projections resulting from the policy-driven scenarios described below.

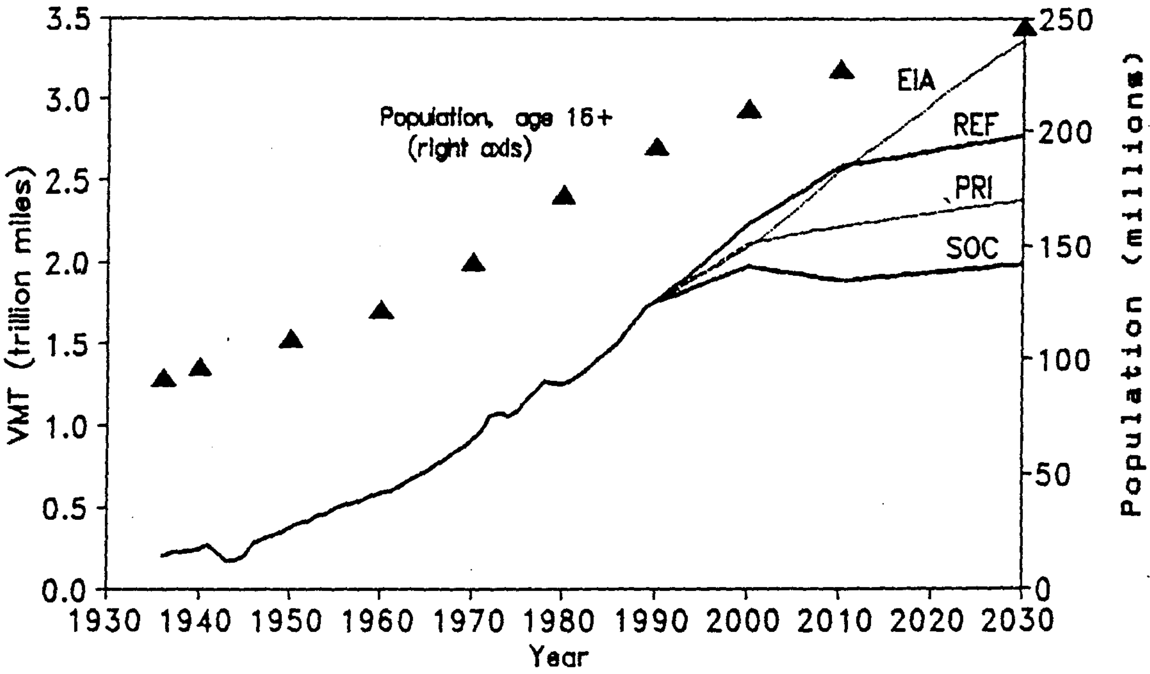

Figure C1. **Past and Projected Light Duty Vehicle Travel in the United States**

Key to projections:

EIA	EIA/SR (1990) reference scenario
REF	Reference scenario for this study
PRI	Market scenario
SOC	Environmental scenario

N.B. The VMT projection of climate stabilization scenario is very slightly below that of the environmental scenario and is not shown; see Table C17.

Cost of driving effects. The reference projection developed here is strictly demographically based and so is insensitive to the cost of driving. Since our analyses incorporate large changes in vehicle operating efficiency and increased efficiency can reduce the cost of travel, thereby increasing the amount of travel. This is known as the "rebound" effect (e.g., Greene 1991). The key parameter for characterizing this effect is the elasticity of vehicle miles of travel (VMT) with respect to cost per distance of travel (e.g., cents per mile). The latter is the ratio of the consumer price of motor fuel to on-road fuel economy. In our least cost scenarios, we examine the effects of taxes and pay-as-you-drive automobile insurance on VMT; these effects are estimated through separate analyses described in the next section. The remaining effect to be addressed depends only on vehicle fuel economy and the base fuel price (which is the same for all scenarios, since we do not analyze effects of reduced U.S. motor fuel demand on oil prices).

The base cost of driving, C, is computed as the projected base price of gasoline (assuming alternative motor fuels to be comparably priced) and our estimated on-road fuel economy for the entire vehicle stock. Integrating the definition of elasticity yields

$$VMT_2/VMT_1 = \exp[\epsilon \ln(C_2/C_1)]$$

The elasticity ϵ is taken to be -0.07, as used in EIA/TED (1990). This is slightly smaller than the range of -0.10 to -0.15 estimated by Greene (1991) using past data, but it is not inconsistent with the downward trend he pointed out in discussing his results, in which he noted that an elasticity as small as -0.05 may be appropriate for more recent conditions. If fuel prices are relatively stable as fuel economy goes up, then fuel cost becomes an ever smaller share of overall operating costs, and one would expect a lower sensitivity. We apply the resulting change in VMT as an additive correction factor to our base VMT along with the additive correction due to land use and transportation demand control measures as discussed below.

Policy Scenarios

This section describes the analysis of the potential reductions in total light vehicle miles of travel (VMT) achievable through a combination of changes in land use patterns and economic incentives.

The reference case clearly demonstrates the results expected with a continuation of current transportation policies and urban development patterns. The most important effect will be continued urban sprawl, driven by housing finance policies, zoning policies, and road construction policies, all predicated on a presumption of automobile-based development. These growth patterns will remain strong, even with localized reactions against the loss of natural areas and agricultural lands. While they are most obvious in sprawling sunbelt cities, even the older cities of the rustbelt are now ringed with sprawl.

The alternative scenarios are based on the well-established potential to reduce automobile use through a combination of transportation demand management (TDM), an urban planning focus on increased density, and provision of increased transit. Numerous studies have demonstrated that increased densities with mixed-use development can reduce automobile use.[3] For example, studies in the San Francisco, New York and Chicago areas show that VMT declines 30% each time density doubles, if neighborhood commercial business is allowed (Holtzclaw 1990).

[3] See, for example, Pushkarev, Zupan, and Cumella (1982); Newman and Kenworthy (1984); and other studies reviewed in the latter and in Holtzclaw (1990).

While we believe there is compelling cross-sectional evidence for modern, efficient transportation systems that are much less automobile dependent than we now find in most of the U.S., such possibilities are not always captured in transportation models. There is a definite need for better planning and growth management tools appropriate for our evolving urban and suburban areas. New and improved least-cost land-use/transportation planning methods are needed along with enhanced data collection to support the analytic, planning, and program evaluation efforts.

Because of the difficulty of quantifying in economic terms the many costs and benefits of changes in land use patterns, this analysis does not delineate scenarios in terms of marginal costs as do the analyses for other sectors. Rather, we present two scenarios that are intended to represent the bounds of plausible futures. The environmental scenario presents the results of an aggressive set of policies and programs that would result in substantial changes in settlement patterns and would require greater political consensus and determination. The market scenario, the impact of which is taken as 50% of that of the environmental scenario, assumes less aggressive actions and a more moderate political atmosphere, though substantial changes from present policies will obviously still be required.

Densification and improved transit. The potential for mass transit to reduce automobile dependence is well established. For example, in their study of U.S. cities with and without rail, Pushkarov *et al.* (1982) found that the direct transfer of travel between rail and car could not completely explain the differences in travel among the cities. They argue that the higher density associated with the presence of rail corridors leads to lower ownership and use of automobiles. Pushkarov *et al.* estimated that this densification can lead to an indirect savings of four times the actual miles travelled by train. Similarly, the Holtzclaw (1990) study of the San Francisco Bay Area found that every passenger mile travelled (PMT) on transit by central city residents reduced per capita automobile mileage (VMT) by 8 miles compared to suburban driving patterns, giving a transit leverage of 8-to-1. Even in developing suburban areas, a transit leverage of 4-to-1 was achieved after 13 years of high-speed rail transit (BART) service. Conversely, the opposite effect has also been demonstrated. Behnman and Bezlinger (1976) showed that when density is reduced, vehicle occupancy decreases and automobile use increases.

These studies document the process whereby as mixed-use infill around transit stations and in transit corridors makes areas more convenient and pedestrian-friendly, average trip lengths are reduced. Consequently, more trips are made by foot, bicycle or transit, and transit and auto trips are shorter. As a result of this reduction in trip lengths and the improved feasibility of walking or bicycling,[4] it is not necessary to provide a passenger-mile of transit to replace every mile of auto use that would have occurred with continued sprawl. Instead, each transit-mile replaces 4 to 10 automobile miles.

A limitation of our analysis is that it does not account for the effects of automobile trip length. If the mix of trips by length changes significantly, the changes in fuel consumption and emissions may not be directly proportional to changes in VMT.[5] For example, fuel economy is worse and emissions are higher under cold start conditions, so reducing trip length with no change in the number of trips may yield a smaller reduction in fuel use and emissions than VMT (there is, however, room for technology changes to greatly reduce such discrepancy). Another example is to compare (a) substitution of a 2-mile park and ride trip for an 8-mile automobile trip with (b) substitution of a 2-mile bicycle trip for a 2-mile car trip. The former results in a greater reduction in VMT, but the latter may result in a comparable reduction in energy use and perhaps a greater reduction in emissions. Similarly, "traffic calming" and other strategies to improve the walkability of an area are likely to have benefits that are disproportionately greater than the associated reduction in VMT.

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[4] Fuel energy use is zero for bicycling and walking; these non-motorized modes are estimated to presently account for about 2% of personal travel in the U.S. (Gordon 1991).

[5] We are grateful to Michael Replogle for pointing out this issue and suggesting the examples.

In the environmental scenario, recent growth patterns are assumed to persist until 1995, when a phase-in of effective mixed-use infill strategies begins. We assume that new development after 1995 proceeds as follows: 12.5% is infill onto vacant land in areas already suburbanized; 37.5% is higher density mixed-use infill in urban transit corridors; and the remaining 50% is continued sprawl. The higher density urban areas are assumed to initially have a density of 5 times the regional average and hold 20% of the regional population. After 2000, new development is 25% suburban infill and 75% high density urban infill, with no further encroachment onto rural or undeveloped areas. Growth in auto mileage is therefore reduced by the suppression of additional sprawl, which would have increased per capita auto use (as evidenced in the reference scenario). Growth in VMT is also reduced by the densification occurring with infill, which reduces per capita auto use. Even though 75% of the growth in the environmental scenario is in central cities, in projecting transit services needed to maintain adequate mobility in the population we conservatively assume a transit leverage of only 6-to-1 (i.e. 1 passenger-mile on transit reduces auto mileage by 6 miles).

The policy scenarios assume the adoption of federal regulations and financial incentives that would achieve urban and suburban infill with compact, mixed-use development, particularly near transit stations and in transit corridors. Also needed is public education on the economic, social and environmental benefits of such development patterns. These scenarios also assume aggressive federally-funded transit expansion.

Transportation demand management. The policy scenarios also assume the adoption of economic incentives and other market-based measures, called Transportation Demand Management measures (TDM), to discourage driving and encourage transit use. The TDMs proposed here have all been considered, implemented, and assessed in varying degrees throught the country (Deakin 1989; Suhrbier *et al.* 1979). Our estimate of the impact of these policies is largely based on the recent detailed analysis of the effectiveness of TDMs in the San Francisco Bay area given by Harvey (1990).

The San Francisco Bay Area is fairly representative of U.S. urbanized areas because it has experienced the same general sprawl growth outside the central cities which has been common throughout the country. In 1988, the Bay Area was already approximately 10% denser than the average of all major U.S. urbanized areas.[6] Therefore, use of the San Francisco area provides a conservative baseline from which to judge TDM effectiveness. Moreover, our environmental scenario envisions an increase in average density of 22% from 1995 to 2030, resulting in average densities only somewhat greater than current for the San Francisco Bay area.

While the effectiveness of specific TDMs can be expected to vary among cities, our analysis approximates the net effectiveness of the full package of TDMs. Table C3 presents these estimates as applied for our analysis. Note that the net VMT reductions shown in the table are calculated with all TDMs operating together (i.e., no double-counting), and include secondary changes in VMT as travelers react to the initial traffic changes. It is assumed that these programs are implemented halfway by 2000 and implemented fully by 2010. The degree of implementation and resulting effects in the market scenario are taken to be one-half those of the environmental scenario, for which the detailed analysis was performed. The resulting estimated reduction in VMT as a result of the TDMs is 16.5% for the environmental scenario and 8.25% for the market scenario.

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[6] The major urbanized areas considered are: Atlanta, Boston, Chicago, Dallas-Ft. Worth, Denver, Detroit, Houston, Angeles-Long Beach, New York, Philadelphia, Phoenix, Pittsburgh, Sacramento, San Diego, San Francisco-Oakland, San Jose, and Washington, D.C.; personal communication from David McElhaney (Federal Highway Administration), to John Holtzclaw, 14 December 1989.

Table C3
Projected impacts of Transportation Demand Management (TDM)

(a) Effect of market-based measures (other than gas tax):

	VMT reduction
Commercial area parking charge of $0.01 per minute	4.6%
Subsidized transit and ridesharing	2.1%
Subsidized off-peak transit	1.5%
Employee parking charge of $3 per day	1.2%
Regional congestion pricing to achieve only slightly congested roads (level of service C)	1.1%
Mileage- and smog-based registration fee (average $125 per vehicle)	0.2%
Subtotal for market-based measures	10.7%

(b) Adding effects of gasoline pricing changes by scenario:

CLIMATE STABILIZATION SCENARIO	
effect of $1.74/gallon price increase[1]	7.1%
TOTAL, adjusted to avoid double counting	17.5%
ENVIRONMENTAL SCENARIO	
effect of $1.50/gallon price increase[2]	6.1%
TOTAL, adjusted to avoid double counting	16.5%
MARKET SCENARIO	
assumed to be half as effective as environmental case	
TOTAL, adjusted to avoid double counting	8.25%

Notes:

[1]Includes $1 for pay-as-you-drive insurance, $0.50 gasoline tax (for externalities other than CO_2), plus $0.24 carbon tax.

[2]Includes $1 for pay-as-you-drive insurance, $0.50 gasoline tax (for non-CO_2 externalities only).

Since these TDMs offer incentives to walk, shorten and consolidate auto trips, carpool, vanpool, switch to transit and further densify, the same leverage of 6-to-1 is assumed for calculating the effect of the proposed TDMs on transit ridership: 1 passenger-mile on transit replaces 6 personal vehicle miles. While some market-based measures reduce transportation costs by providing better transit alternatives, others increase the direct economic costs of driving in order to reduce driving and thereby reduce external costs including air pollution, energy depletion, and congestion. Any net revenues generated above those needed to provide transit service, can be used to provide transportation subsidies to low income citizens or to replace other taxes.

Combined effects on VMT and PMT. The results of the personal vehicle travel demand analysis are presented in Table C4 for both the market and the environmental scenarios. Figure C1 compares these VMT projections with our reference scenario and the EIA/SR (1990) projections. Reference scenario VMT increases steadily from 1.76 trillion miles per year (10^{12}mi/yr) in 1990 to 2.82 x 10^{12}mi/yr in 2030, with average annual growth rates of 2.0%/yr 1990-2010 and 0.4%/yr 2010-2030, or an average of 1.2%/yr over the 40-year projection period. The projected results of our proposed policy changes are significantly lower VMT levels, reaching only 2.32 x 10^{12}mi/yr by 2030 in the market scenario and only 1.87 x 10^{12}mi/yr in the environmental scenario. Thus, the market scenario holds VMT growth through 2030 to an average of 0.7%/yr and the environmental scenario essentially stabilizes VMT. For the latter scenario, few or no new highways are needed after 1995, since all new development is in areas with roadway infrastructure alreay in place and since total VMT by 2030 is no higher than the 1995 level.

Table C4
Summary of Light Vehicle Travel Analysis

	1990	2000	2010	2030
REFERENCE PROJECTIONS				
Population, age 16 and over (10^6)	193	210	227	246
Personal vehicle VMT (10^{12})	1.76	2.25	2.61	2.82
Urban transit PMT (10^9)	42	46	49	53
MARKET SCENARIO				
(1) Impacts of density increases:				
VMT (10^{12})		2.20	2.40	2.53
VMT as percent of reference case		98%	92%	90%
PMT (10^9)		50	77	90
PMT average annual growth rate from 1990		1.7%	3.0%	1.9%
(2) Impacts of density increases and TDM:				
VMT (10^{12})		2.11	2.20	2.32
VMT as percent of reference case		94%	84%	82%
PMT (10^9)		65	110	125
PMT average annual growth rate from 1990		4.4%	4.8%	2.7%
ENVIRONMENTAL SCENARIO				
(1) Impacts of density increases:				
VMT (10^{12})		2.14	2.18	2.24
VMT as percent of reference case		95%	84%	79%
PMT (10^9)		60	114	139
PMT average annual growth rate from 1990		3.6%	5.0%	3.0%
(2) Impacts of density increases and TDM:				
VMT (10^{12})		1.96	1.82	1.87
VMT as percent of reference case		87%	70%	66%
PMT (10^9)		90	174	200
PMT average annual growth rate from 1990		7.6%	7.1%	3.9%
CLIMATE STABILIZATION SCENARIO				
(1) Impacts of density increases:				
VMT (10^{12})		2.14	2.18	2.24
VMT as percent of reference case		95%	84%	79%
PMT (10^9)		60	114	139
PMT average annual growth rate from 1990		3.6%	5.0%	3.0%
(2) Impacts of density increases and TDM:				
VMT (10^{12})		1.77	1.80	1.85
VMT as percent of reference case		79%	69%	66%
PMT (10^9)		122	177	204
PMT average annual growth rate from 1990		10.7%	7.2%	4.0%

Abbreviations:

PMT - Passenger Miles of Travel per year on transit
TDM - Transportation Demand Management (see Table C3)
VMT - Vehicle Miles of Travel per year by personal light vehicles

Transit. The densification and TDM effects induce increases in urban transit usage, as summarized in Table C5. In the reference case, PMT is flat over the 40-year horizon. Under the assumption described above that PMT grows by one-sixth the shrinkage in VMT relative to the reference case, we project a five-fold increase in PMT by 2030, or an average PMT growth rate of 4.3%/yr in the environmental case. Transit ridership is thus estimated to increase from 42 billion passenger miles per year in 1990 to 200 x 10^9mi/yr in 2030 for the environmental scenario and 125 x 10^9mi/yr for the market scenario. With an assumed efficiency improvement rate averaging 1.3%/yr,[7] transit energy end-use increases from 0.15 Quads in 1990 to 0.33 Quads in 2030.

Regarding the investment needed for transit, based on statistics reported in Gordon (1991) we estimate that there is no added cost (capital and operating) beyond what would have been needed for roads (construction and maintenance) displaced by shifting demand from personal vehicles to transit. A recent study by Moffet (1991) which evaluated the societal costs of various personal transportation modes found that a shift from private vehicles to rail and bus transit is unlikely to substantially increase direct costs to society. Moreover, consideration of additional induced reductions in VMT and environmental externalities would imply a significant reduction in societal costs from such a shift.

Generally, clustering of development tends to reduce long-term capital costs as well as induce improvements in overall transportation system efficiency. This will be particularly true if efforts are made to provide sufficient affordable housing near transit nodes and to ensure a good match of residential communities with the distribution of jobs. Personal vehicle travel is not, therefore, shifted exclusively to transit. Much of it is replaced by higher vehicle occupancy, walking and biking, and shorter travel distances. Such shifts will entail investments in walkways, bicycle paths, traffic calming measures, and related people-friendly infrastructure.[8]

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[7] Based on an energy intensity (Btu/vehicle mile) decrease of 43% for buses, assuming conservation potential similar to that for freight trucks (see Appendix D) and a decrease of 39% for rail (EIA/SR, p. 218); and a 50%-50% split between bus and rail transit.

[8] See, for example, Replogle (1988); Lowe (1990); Gordon (1991).

Table C5
Urban Transit Energy Use by Scenario

Scenario and year:	1990	2000	2010	2030
REFERENCE				
Bus PMT (10^9)	22.1	23.4	25.3	27.3
Rail PMT (10^9)	19.2	22.1	23.9	25.8
Rail share	0.465	0.486	0.486	0.486
Bus intensity (Btu/PMT)	3276	3094	2862	2652
Rail intensity (Btu/PMT)	3880	3371	3117	2888
Bus efficiency index	1.00	0.94	0.87	0.81
Rail efficiency index	1.00	0.87	0.80	0.74
Bus consumption (TBtu)	72	72	72	72
Rail consumption (TBtu)	74	74	74	75
Total energy use (TBtu)	147	147	147	147
MARKET				
PMT (10^9), from Table C4	41	65	110	125
Bus effy index (see Table D6)	1.00	0.85	0.76	0.61
Rail effy index (EIA/SR, p. 210)	1.00	0.91	0.84	0.70
Bus consumption (TBtu)	72	88	123	104
Rail consumption (TBtu)	74	97	140	123
Total energy use (TBtu)	147	185	263	227
ENVIRONMENTAL				
PMT (10^9), from Table C4	41	90	174	200
Bus effy index (see Table D6)	1.00	0.83	0.73	0.57
Rail effy index (EIA/SR p. 218)	1.00	0.89	0.79	0.61
Bus consumption (TBtu)	72	119	187	155
Rail consumption (TBtu)	74	131	208	171
Total energy use (TBtu)	147	250	395	327
CLIMATE STABILIZATION				
PMT (10^9), from Table C4	41	122	177	204
Bus consumption (TBtu)	72	161	190	159
Rail consumption (TBtu)	74	178	212	175
Total energy use (TBtu)	147	339	402	333

NOTES:

Reference case PMT estimates are based on APTA (1990), Table 1, with subsequent growth proportional to population growth.

Rail efficiency improvements are from EIA/SR (1990), p. 210, 218, as noted. Bus efficiency improvements taken to occur at the same rate as heavy trucks, as described in freight transportation analysis (Appendix D).

Climate case efficiencies are same as in least societal cost case.

1 TBtu = 10^{12}Btu (0.1 Quad)

City	System opened	Ridership, 10^6 PMT (and year) Initial	Subsequent	Avg/yr growth
Washington, DC	1976	582 (1975)	1558 (1990)	6.8%
Toronto	1954	332 (1954)	1188 (1975)	6.3%
Portland, OR	1985	163 (1986)	197 (1990)	4.9%
Vancouver	1986	95 (1986)	113 (1990)	4.4%

Table C6
Transit Ridership Increases on Urban Rail Systems

Our analysis projects densification-driven increases in transit ridership that range up to 5%/yr, or doubling within 15 years. Doubling of transit ridership in 11 to 16 years has been observed in the past after new rail systems are opened, as shown by the statistics in Table C6. However, in the case of major system expansions as in Washington, DC, some of the growth in ubran rail system ridership came at the expense of bus ridership. While such annual transit growth rates may appear very ambitious, they will be achievable since the revenues from the market-based TDM measures can be used to expand transit systems and improve service.

LIGHT VEHICLE FUEL ECONOMY

This section describes our assumptions and analysis for the energy efficiency and fuel mix of the light duty vehicle fleet, including cars and light trucks. The resulting projections of fuel requirements for light duty vehicles use the VMT projections described above and the technology assumptions discussed below. Table C7 summarizes the projected fuel economies for new automobiles based on assumptions for each scenario. Figure C2 shows the energy intensity projections (on-road averages using a gasoline energy-equivalent basis) for the scenarios. We give the most general discussion for the reference scenario. For the other scenarios, the discussion specifies only the differences from the reference scenario. Tables C14, C15, C16, and C17, which are placed at the end of this appendix, summarize the results of our fuel economy analyses for the four scenarios.

Table C7
Projected Fuel Economies of New Automobiles

PROJECTIONS BY SCENARIO	1988	2000	2010	2030
EPA test (55/45) MPG				
Reference[a]	28.6	33	37	41
Market[b]		40	50	56
Environmental[c]		43	54	75
Climate stabilization[c]		46	59	75
On-road vs. test short fall				
Reference[d]	20%	20%	25%	30%
Market[e]		25%	20%	0%
Environmental[e]		20%	10%	0%
Climate stabilization[e]		20%	10%	0%
Annual rates of on-road improvement[f]				
Reference	4.1%[g]	1.1%	0.7%	0.5%
Market		3.0%	2.9%	1.7%
Environmental		4.3%	3.7%	2.1%
Climate stabilization		5.3%	3.7%	1.8%

NOTES

a) EIA/SR (1990), Table G-3.

b) For 2000, authors' target, based on Ross *et al.* (1991); for 2010 and 2030, the medium risk and high risk estimates, respectively, given by EEA (1990) for 2010, adjusted downward to reflect elimination of shortfall.

c) As in note (b), with more ambitious schedule and assuming further technical improvements, optimization for on-road driving, and improvement of driving conditions (e.g., speed limit enforcement), so that shortfall is eliminated while the 75 mpg (EEA high-risk estimate for 2010) is achieved by 2030.

d) EIA/SR (1990), Table 3-4, p. 85.

e) Authors' targets, as discussed in notes (b) and (c).

f) For new vehicles, from previous year to projection year, as calculated from the test MPG and shortfall assumptions.

g) New automobiles 1977-1988, from Heavenrich *et al.* (1991), Table 1, and assuming a 15% shortfall in 1977.

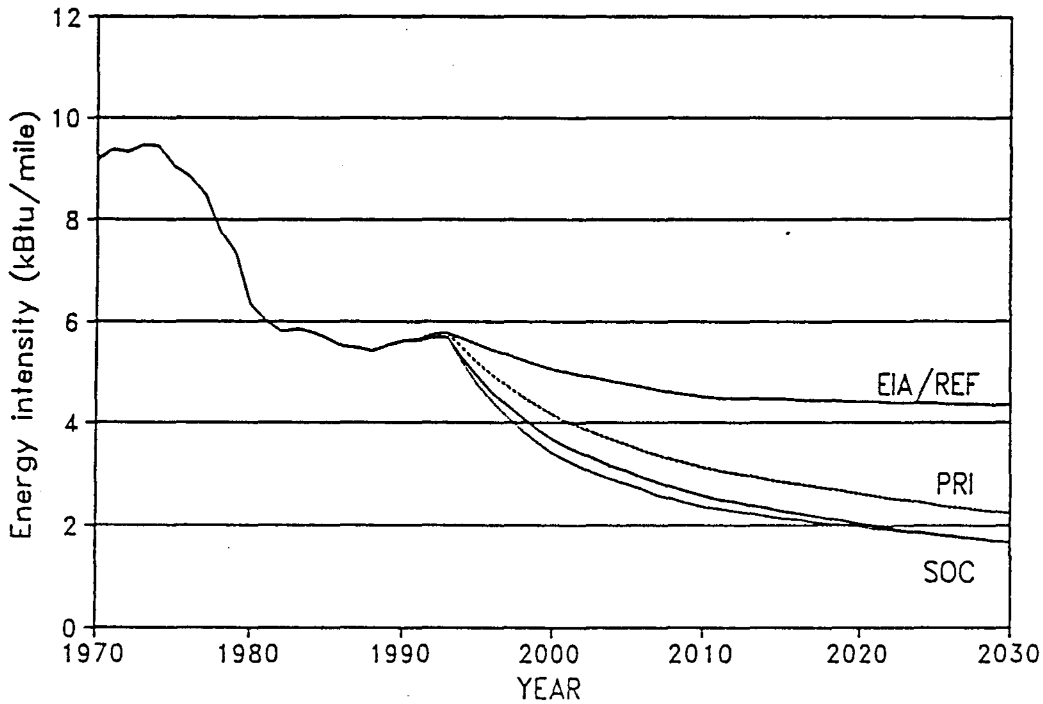

Figure C2. Past and Projected Energy Intensity of New Automobiles in the U.S.

Key to projections:

REF Reference scenario, both this study and EIA/SR (1990)

PRI Market scenario

SOC Environmental scenario

The projection for the climate stabilization scenario is shown unlabeled, slightly below that of the environmental scenario.

Reference Scenario

The reference case analysis fairly well matches that of the EIA/SR base case except in the underlying VMT, for which we use our own results as described above. The summary table for the reference case is Table C14. The key assumptions are as follows:

(1) EIA's econometric/technological projections of new car fuel economy (both conventional and alternatively fueled vehicles) are used.

(2) The projected fuel economy of the light duty vehicle stock is calculated using stock models as described below.

(3) Projected efficiencies of alternatively fueled light vehicles are based on EIA/SR (1990), Table 3.7. Fuel economy values are defined on a gasoline energy-equivalent basis and listed as relative efficiencies. For example, a neat methanol car is rated at 36 mpg if it travels 36 miles on the energy equivalent of one gallon of gasoline (at 125 kBtu/gallon, which is equivalent to 1.93 gallons of methanol at 64.6 kBtu/gallon). If the corresponding conventional gasoline vehicle is rated at 33 mpg, then the relative efficiency of the methanol vehicle is 36/33, or 1.1, which is the form given in our tables. End-use consumption by fuel type is then calculated as

$$\frac{\text{(VMT) (fraction VMT by fuel) (conventional kBtu/mile)}}{\text{(relative efficiency)}}$$

(4) EIA gives electric vehicle efficiencies on a primary basis, in contrast to those of other fuels, which are given as end-use efficiencies. For consistency, we converted electric vehicles to end-use efficiency by multiplying by a factor of 2.5, based on the ratio of assumed primary to vehicle efficiencies (83% for oil well to gas pump and 33% for power plant to wall plug).

(5) Four to five decimal digits are preserved in the values by fuel type, just to show that something is there even when it is too small to be significant in the total. Bottom-line projections of total light vehicle consumption in Quads are rounded to three digits.

(6) The difference between EPA-rated and on-road fuel economy is assumed to be the same for all light vehicle types. The gap increases to 25% by 2010 and 30% by 2030, as assumed in EIA/SR.

(7) All capital, operation, and maintenance costs are assumed to be zero in the reference case, by definition.

(8) The VMT share for each type of light vehicle is taken from EIA/SR.

(9) The fraction of VMT due to light trucks, as calculated from EIA/TED, increases to 32% by 2010 and remains constant thereafter.

(10) Alternative vehicle technologies not used in EIA's reference case, such as hybrid electric, are not included in this analysis.

(11) The diesel share of conventional vehicle fuel consumption is fixed at 2.3% for all years, as in EIA/SR (1990), Table G-3.

(12) As with EIA, flexible fuel vehicles are assumed to run on 1/3 gasoline and 2/3 methanol.

Stock models. A stock model was used to estimate the average EPA-rated fuel economy of all vehicles on the road (the vehicle stock) based on usage statistics for conventional vehicles. The model uses estimates of survival probability and annual driving distance (miles of travel per vehicle) by age cohort from the DOT regulatory analysis of the 1986 CAFE rollback; separate survival and travel distance tables are used for cars and light trucks. The stock model assumes that the mix of vehicles with regard to age remains constant over time, thereby avoiding the need to project annual new vehicle sales, which are highly uncertain. Further details on the ACEEE stock model and its application to projecting light duty vehicle fuel consumption are given by DeCicco (February and March, 1991). In contrast to the ACEEE model, the EIA/TED (1990) stock model uses projections of new car sales and then weights the VMT using survival and annual driving distance. Nevertheless, the net effect of the two approaches is similar and should not cause a great difference in the results.

Summary tables. This description of the light vehicle reference scenario summary table (Table C14) also applies to the summary tables for the other scenarios, all of which are presented in the same format. As noted earlier, these full-page summary tables are located at the end of the appendix.

(1) The first section of the table pertains to VMT, which is given in billions (10^9) of miles. The underlying projection is shown in the first line. The second line shows the percent of VMT that can be eliminated by the land use and transportation demand management. The third line shows the cost of driving effect, which accounts for fuel economy "rebound" and changes in the base fuel price (i.e., the projected price escalation, including existing taxes but not including taxes added in our policy scenarios, the effects of which are covered in the TDM analysis). The fourth line gives the net VMT remaining after these adjustments. The last line of this section gives the fraction of VMT due to light trucks, which is the same for all scenarios.

(2) The next section of the table specifies the gasoline price for each scenario year and the resulting average base fuel cost of driving, not counting taxes added for the policy scenarios. This driving cost, listed in cents per mile, is used to estimate the "rebound," as discussed above in the "Cost of driving effects" subsection under Travel Demand.

(3) The next section of the table pertains to new vehicle fuel economy, given in miles per gallon (mpg, gasoline energy-equivalent). New vehicle fuel economies are shown as unadjusted EPA-rated values, using the composite of 55% urban and 45% highway ratings. The projected average new light vehicle fuel economy is computed as the VMT-weighted average of automobiles and light trucks.

(4) The on-road MPG values are the estimated actual fuel economy of vehicles in use, accounting for the degradation of on-road efficiency compared to EPA-rated fuel economy. The degradation factor (shortfall) is given as the percent reduction of the EPA-rated value.

(5) Stock fuel economy pertains to all vehicles in use during the scenario year, computed using the stock turnover model as discussed above. Average energy intensity (kBtu/mile) is computed on a gasoline-equivalent basis of 125 kBtu/gallon.

(6) The average annual improvement rates are given for new vehicles and the stock as whole, using estimated on-road fuel economy in both cases. Values are given as the average from the previous period, e.g., the value listed under the year 2000 gives the average rate from 1990 through 2000. Note that the rate of fuel economy increase is the same as the corresponding rate of decrease in energy intensity (consumption per distance traveled by a vehicle, e.g., Btu/mile), assuming a fixed calorific value for conversion.

(7) The next section of the table gives the assumed relative efficiencies by vehicle fuel type, with a gasoline internal combustion engine vehicle taken as the base. All values are given as relative end-use efficiency, i.e., not counting conversion and transportation losses that occur before the fuel is used in a vehicle.

(8) Shares of VMT by fuel type--self explanatory.

(9) End-use consumption is calculated as the product of the net VMT, the share of VMT by fuel type, and the average light vehicle energy intensity divided by the relative efficiency according to fuel type. The results, as well as the bottom-line totals over all vehicle types, are given in Quads (10^{15}Btu) of energy end-use.

Market Scenario

The results of the market scenario analysis are summarized in Table C15. The primary source for our least-cost estimates of automotive fuel economy is Ross *et al.* (1991), which was adapted for our economic assumptions as shown in Table C8. The level of automobile fuel economy estimated to be fully cost-effective is 42 mpg in year 2000. However, the implementation rate of efficiency technologies judged to be cost-effective is inhibited in the near-term by political and market barriers. We therefore held the market scenario projection to 40 mpg by 2000. By way of comparison, Carlsmith *et al.* (1990) estimated a 38.5 mpg cost-effective level[9] for new automobiles in 2000. EIA/SR (1990) specifies 33.5 mpg for their very high conservation case, a trivial increase over their reference case projection of 33.1 mpg.

A year 2010 technology assessment is provided by EEA (1990), but no cost information is given. Rather, EEA identifies three "risk levels" related to their judgements regarding the probability of commercialization by 2010. EEA's "low risk" baseline for 2001 is 38 mpg, somewhat lower than our 40 mpg target for the market scenario, the achievement of which is predicated on new CAFE standards. The low, medium, and high risk level automobile fuel economies in 2010 given by EEA are 46 mpg, 53 mpg, and 74 mpg, respectively (all are EPA-rated estimates).

For the market scenario, we assume the "medium risk" level of 53 mpg for 2010 and postpone a 75 mpg level until 2030. These are EPA-rated values with an assumed current shortfall of 20%. As discussed below, these estimates are scaled back in proportion to the reduction in shortfall, so that no additional technology is required beyond that assumed for the EEA estimates. In the EEA analysis, the size class mix of the fleet is held constant and no new special classes (such as commuter cars) are introduced. The analysis is therefore conservative, since smaller, special purpose vehicles may be of growing importance in certain niches of the market (e.g., small, sporty commuter cars). Performance is also held constant, and so futher gains could be obtained if there is some reversal of the recent trend towards faster acceleration and top speed capabilities.

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[9] Carlsmith *et al.* (1990) derive their estimate from Difiglio *et al.* (1989) using a 7% discount rate and $1.43/gallon gasoline price.

Table C8
Automobile Efficiency Technologies and Cost/Benefit Assumptions

	TECHNOLOGY	Indiv. New car MPG inc. (%)	Retail Price Inc. ($)	Market Share Inc. (%)	AvgCum Consumer Cost ($)	Fleet EPA MPG	Cost of Consv. Energy ($/gal)	Cum Avg CCE ($/gal)
	Base: 1987 new fleet					28.3		
1	Transmission mgmt	9.0	60	75	45	30.2	0.15	0.15
2	Roller cam followers	1.5	15	37	51	30.4	0.24	0.15
3	Torque conv. lockup	3.0	35	16	56	30.5	0.28	0.16
4	Overhead cam	6.0	74	69	107	31.7	0.31	0.21
5	Adv friction reduction	6.0	80	80	171	33.0	0.36	0.25
6	Intake valve control	6.0	80	75	231	34.3	0.39	0.27
7	Front wheel drive	10.0	150	23	266	35.0	0.46	0.29
8	4 valves / cylinder	6.8	105	100	371	36.9	0.51	0.33
9	Idle off	15.0	250	50	496	39.0	0.62	0.37
10	Accessory improve	1.7	29	80	519	39.4	0.68	0.38
11	Aerodynamic, Cd 0.30	4.6	80	85	587	40.5	0.72	0.40
12	Multi-point fuel inj	3.5	67	56	624	41.1	0.82	0.42
13	Continuous vary trans	4.7	100	45	669	41.6	0.94	0.43
14	Lube & tire improve	1.0	22	100	691	41.9	0.99	0.44
15	5sp auto OD trans	4.7	150	40	751	42.5	1.47	0.47
16	Weight reduction	6.6	250	85	964	44.1	1.83	0.56
17	Advanced tires	0.5	20	100	984	44.2	2.01	0.57

Economic assumptions:

Discount rate	3%
Time horizon (term)	10 years
Early depreciation factor	0.96
Net CRF	0.1125
On-road MPG ratio in 2000	0.77 (1 - shortfall)
Average use	11,850 miles/year

Based on Ross *et al.* (1991), technology group 2, additive calculation.

Light trucks. Lacking a conservation supply curve for light trucks, we assumed that the same rates of improvement, relative to current fuel economy, will be cost-effective. According to Bureau of the Census (1987), 73% of light truck usage is strictly for personal transportation. The fraction of light trucks having justifiably high power requirements relative to automobiles is therefore small. There are also opportunities for fuel economy improvement that are particularly applicable to light trucks, such as diesel engines for some applications, use of turbo- or supercharging in smaller displacement engines, convertible aerodynamic tailgates for pickup trucks, variable displacement engines, and other technologies that focus on improving part-load performance. Furthermore, because light trucks have been leniently regulated in the past, the present level of technical advancement for fuel economy is well behind that of automobiles. Therefore, we judge it conservative to assume that the rate of cost-effective fuel economy improvement for light trucks keeps pace with that of automobiles. This assumption is applied for all years in the alternative scenarios.

Improvement rates. A context for the rates of fuel economy improvement can be obtained by examining the historical rate of improvement since the early 1970's, shown in the Table C9. The historical maximum for automobiles is 4.1%/yr assuming constant shortfall, or 3.7%/yr assuming a shortfall increase from 10% to 20%. These historical rates of improvement are not exceeded in the market case. Note that the overall rate of stock improvement exceeds the rate of new vehicle improvement in latter years because of the time lag involved in stock turnover.

Table C9
Historical Improvement Rates for the Fuel Economy of New Light Duty Vehicles

	EPA-rated MPG 1975	EPA-rated MPG 1988	On-road MPG 1975	On-road MPG 1988	Average change rate (%/year)
Automobiles	15.8	28.6	14.2	22.9	3.7
Light trucks	13.7	21.2	12.3	17.0	2.5
All light vehicles	15.3	25.9	13.8	20.7	3.2

Fuel economy statistics from Heavenrich *et al.* (1991), Table 1.
Shortfall assumptions of 10% in 1975 (EPA 1980) and 20% in 1988 (ACEEE estimate).

Eliminating shortfall. Based on studies from the late 1970's and early 1980's (see, e.g., EPA 1980), EPA adjusts the test cycle fuel economy ratings downward by an average of 15% (10% for the city rating and 22% for the highway rating) when publishing the ratings and labeling vehicles (see, e.g., EPA Oct. 1990). This difference between the test estimates and on-road experience is termed fuel economy "shortfall." Westbrook and Patterson (1989) have estimated that the shortfall may grow to 30% by 2010; they attribute the shortfall mainly to greater congestion plus a greater share of city driving and higher highway speeds. Our estimate is that the present shortfall is at least 20%. There is also evidence that the shortfall for light trucks may be greater than that for cars, perhaps already as high as 27% for light trucks.[10] In spite of this well-known and probably growing discrepancy between the test cycle results and actual on-road experience, unadjusted values are still used for CAFE compliance purposes.

It is clearly in the public interest that unbiased estimates of vehicle fuel economy be used for both regulatory and sales information purposes. From an economic point of view, one requirement for a well-functioning market is that the parties have correct information, so a requirement for an unbiased rating system ("truth in testing") would help remedy this market flaw. Public debate on fuel economy policy making is also misinformed by the bias in the test estimates used for compliance purposes. At

[10] P. Patterson (Department of Energy, Washington, DC), personal communication, 1991.

least some of adjustments that need to be made to improve the accuracy of the estimates are already known and EPA has performed surveys of on-road driving characteristcs that can be used to refine the adjustments.[11] What is lacking is a mandate either to change the test procedure (which may not be necessary) or to utilize appropriately adjusted and unbiased estimates for all reporting and compliance purposes. It would also be worthwhile to establish an ongoing in-use fuel economy calibration program, based on instrumenting a representative sample of vehicles and regularly analyzing the in-use performance data. Such a program is quite feasible because of the growing use of computers and electronics in vehicles and the potentially low cost of the hardware.

Although congestion is the largest contributor to the gap and the land use and TDM strategies described above are projected to reduce VMT, they may not reduce congestion for the vehicles on the road. A significant cause of congestion is breakdowns, due to flat tires, overheating, running out of fuel, and the like. Therefore, improved maintenance and further manufacturer attention to vehicle reliability could reduce congestion and thereby help to reduce shortfall. Another aspect of the shortfall can be addressed through enforcement of a 55 mph speed limit. Tailpipe emissions worsen as speeds go above 55 mph as well as during congested conditions. We therefore assume speed limit enforcement to be cost effective in light of both environmental and safety considerations.

Eliminating shortfall while maintaining a given numerical fuel economy standard can require additional technology changes in vehicles, with the attendant implications of additional cost and lead time. Most assessments of potential fuel economy improvement utilize test cycle fuel economy, i.e., the unadjusted 55/45 city/highway cycle average rating; this is true of the EEA and Ross *et al.* assessments referenced in this study. Therefore, it is necessary to lower the fuel economy targets when projecting the feasibility of reduced shortfall on the basis of such assessments. This is done to obtain our market scenario estimates for 2010 and 2030, as listed in Table C7. For example, for 2030, the EEA (1990) high-risk 2010 estimate of 75 MPG for new automobiles was adjusted downward by 25% to 56 MPG.

For the environmental and climate stabilization cases, a more ambitious combination of shortfall reduction and improved fuel economy is assumed, so that the nomimal 75 MPG in 2030 is also the on-road fuel economy of the new vehicles. This estimate is therefore an extrapolation beyond presently published assessments, made under the assumption that the changes needed, which may include additional innovation over the 40-year time horizon, will be cost-effective considering the added avoided externality costs of fuel consumption assumed for these scenarios. It should be noted that at least part of the shortfall can be addressed through a re-optimization of vehicle technologies to better reflect the actual driving conditions, for example, relatively more attention to performance under congested conditions.

Alternatively fueled vehicles. We did not perform an independent analysis of the potential penetrations of alternatively fueled vehicles. For the market scenario, VMT shares of alternatively fueled vehicles are directly taken from the EIA/SR "high conservation" case.

As described above, the relative efficiency for an alternatively fueled vehicle is defined as the factor by which the conventional vehicle fuel economy, converted to an end-use energy per mile basis at the gasoline value of 125 kBtu/gallon, is multiplied to obtain the end-use energy per mile assumed with the alternative fuel. Our policy scenario estimates of relative efficiencies were obtained by adjusting the reference values obtained from EIA/SR (1990). The reference case relative efficiency is multiplied by a scale factor, defined as the ratio of reference MPG to scenario MPG for conventional vehicles, to obtain the adjusted relative efficiency. For example, in the market scenario for year 2030, we project a conventional vehicle fuel economy of 56 MPG. Reference scenario conventional vehicles

[11] K. Hellman (EPA, Office of Mobile Sources, Ann Arbor, MI), personal communication, 1991.

are at 41 MPG and EIA/SR implies an end-use efficiency factor of 5.0 for electric vehicles in that year. Therefore, we scale the efficiency factor by 41/56, yielding an efficiency factor of 3.6 for electric vehicles in the market scenario for year 2030.

This scaling is conservative in that it would correspond to the alternatively fueled vehicles not improving as much as conventional vehicles in our policy-driven scenarios. On the other hand, some of the EIA/SR estimates of relative efficiency appear to be inconsistent with their projected absence of improvement for conventional vehicles, in that many of the efficiency technologies (particularly load reduction technologies, such as aerodynamics, structural materials substitution, improved tires, etc.) are independent of the type of power plant in the vehicle. Therefore, we generally imposed two constraints on the scaling: monotonicity through time and a lower bound of one. In other words, we assume sufficient improvement in the efficiency of alternatively fueled vehicles so that (1) they do not backslide relative to conventional vehicles when our policies push the latter to higher fuel economy levels and (2) their end-use efficiency is no worse than that of conventional vehicles.

Fuel economy and safety. We have not incorporated a safety cost into our cost-benefit analyses for improving light vehicle fuel economy. First of all, our analyses are based on holding the size mix of the fleet constant. Weight reduction is involved, but studies purporting to show a significant adverse safety impact from fleetwide weight reduction are quite controversial and far from conclusive. Safety advocates find no conflict between improved fuel economy and vehicle crashworthiness, which is primarily a function of design (Freidman 1991).

Studies on the issue of safety and fuel economy are highly sensitive to methodological biases. There is a general failure to make distinctions between parameters such as weight, exterior dimensions, interior volume, horsepower, and other elements of design in the attempt to correlate safety and efficiency performance. The relevant comparisons are not simply between large and small cars, but among all vehicles on the road, in particular as this mix is influenced by fuel economy. Therefore, passenger uses of light trucks, vans, and utility-type vehicles, and more generally, issues of disparity in size and safety any vehicles need to be considered. For example, the size or weight of larger vehicles may confer some safety advantage on their occupants, but may also enhance their aggressivity relative to other vehicles.

For many externalities, such as air pollution, costs are difficult to quantify. Nevertheless, there is strong evidence that they are significantly greater than zero and therefore a bias will result from ignoring them. Particularly since our projected increases in fuel economy rely on technology improvement rather than downsizing, we do not believe there is sufficient evidence to demonstrate that, overall, the safety impacts of improving fuel economy are significantly greater than zero. If future studies show that some methods of improving fuel economy have a net adverse impact on safety, then there may be a need to restrict fuel economy improvements to those without such impact. In any case, we expect that the effect of such possible contraints on fuel economy will be small; for example, an upper bound on the "mitigation cost" of hypothetical safety impacts can be had from the estimate of less than 0.8 mpg for the effect on fuel economy improvements due to expected new safety *and* emissions standards (Plotkin 1991).

Environmental Scenario

The environmental case is obtained by taking the potentials partially realized in the market case to their fully cost-effective levels, accounting for externalities. These results are shown in Table C16. This scenario assumes a gasoline tax of $0.50/gallon, covering societal costs of air pollution and transportation systems (highway as well as transit subsidies). The resulting gasoline price assumed in the year 2000 is $1.81/gallon ($1.51/gallon levelized). A full implementation of all measures estimated to be cost-effective up to a fuel price of $1.47/gallon by 2000, as listed in Table C8, yields an

EPA-rated fuel economy for new vehicles of 42.5 mpg, or 53% above the 1990 fleet. We assume that the shortfall gets no worse than the present estimate of 20%. The on-road stock therefore improves 30% by 2000.

By 2030, we assume new cars would reach a fuel economy of 75 mpg, with shortfall being eliminated as discussed earlier. This value is based on the "high-risk" estimate of EEA (1990) for 20 years sooner; it is also within the range of existing prototypes (see, e.g., Bleviss 1988). Achieving this level of improvement includes further refinement of existing technologies as well as new technologies now in active development, such as two-stoke engines, advanced electronic transmission control, electric hybrid drive trains, idle-off, regenerative braking, and materials substitution, among others (not all need be used in all vehicles, since some of these technologies address the same sources of inefficiency, particularly losses at part-load). Some portion of the average fuel economy gain can be also achieved through a combination of mix shifts, performance shifts, and specialty vehicles. Cost information is not available for technologies beyond those already fully demonstrated. For the 2010, therefore, we are assuming that applications of the identified technologies will be cost-effective compared to the assumed gasoline price of $2.10/gallon (1990$, including externalities taxes).

Note that the stock average efficiency improvement rate (shown in Table C16 and Table C7) lags the new vehicle rated fuel economy improvement rate over the first decade. This is because the overall average includes older vehicles, and even though new vehicles are rapidly improved, it still takes a while for stock turnover to occur. Once a "wave" of rapidly advancing technology is steadily entering the stock, the overall rate of improvement catches up.

Relative efficiencies for alternatively fueled vehicles are based on EIA/SR (1990) values, scaled as described earlier. The fuel shares are also from EIA/SR, this time using their "very high conservation" projections. Since our scenario pushes efficiency farther, there should be no constraints on fuel availability. Alcohol fueled vehicles (both combustion and fuel cell) are combined under the category "biofuels," which is projected to contribute two-thirds of the light duty vehicle supply by 2030. It should be noted that our assumption that the alcohol fuels are biofuels, renewably produced, differs from EIA/SR, which does not restrict alcohol to renewable sources. After biofuels, the next largest category is electric vehicles. A hydrogen category is listed as a place holder, since hydrogen utilized in a fuel cell is a promising possibility which could displace some of the other fuels over the 40-year horizon (DeLuchi *et al.* 1991).

Climate Stabilization Scenario

The climate stabilization scenario was obtained by pushing efficiency slightly farther, to 46 mpg for new automobiles in the year 2000. No changes in efficiency assumptions from those of the previous scenario were assumed for 2030. However, for 2030, we assumed a 15% hydrogen fuel share and also increased the natural gas fuel share to 5%. The results of this last scenario are summarized in Table C17.

Investment Costs

For each policy scenario, we estimated the added investment costs needed for the technologies used to achieve the efficiency improvements above the level of the reference scenario. For light duty vehicles, we based this on the conservation technologies assessment given in Table C8 and used the procedure that follows.

Let AC_x be the average cost of saved energy at the cost-effective level for scenario x, with AC_1 representing the average cost of technologies to reach the level of efficiency specified in the reference scenario. Let S_x represent the energy savings for scenario x, relative to frozen efficiency. By definition, the investment required to achieve the savings is AC_xS_x. Therefore, the added average cost between two scenarios, say 1 and 2, per unit of additional savings, is

$$AAC_{12} = \frac{AC_2S_2 - AC_1S_1}{S_2 - S_1}$$

For motor vehicles, the fuel savings are

$$S_x = K\left(\frac{1}{F_0} - \frac{1}{F_x}\right)$$

where F_x is the cost-effective fuel economy for scenario x, F_0 is the baseline (frozen efficiency) fuel economy, and K is some constant depending on VMT, shortfall, etc. (which cancels out since savings appears in both the numerator and denominator of the equation for AAC). Algebra then yields the relation

$$AAC_{12} = \frac{AC_2(1-e_2) - AC_1(1-e_1)}{e_1 - e_2}$$

where $e_x = (F_0/F_x)$ is the energy intensity index for scenario x relative to frozen efficiency. Note that the added average cost is always at least as large as the marginal cost (MC) of the lower scenario, e.g., AAC_{12} is greater than or equal to MC_1. Since the reference scenario is assumed to represent "business as usual," the required added investment cost estimates are AAC_{12}, AAC_{13}, and AAC_{14}, for the market, environmental, and climate stabilization scenarios, respectively.

Since we only have technology cost estimates for the near-term (our supply curve is for the year 2000), we extrapolated the cost estimates for later years. Assuming that the higher levels would be cost-effective at the avoided fuel costs projected for the least cost scenarios and assuming further that the shape of the conservation supply curve stays the same (in terms of the ratio of average cost to marginal cost), we simply scale the costs by the ratio of levelized fuel price for the latter year to that for the year 2000. The analysis and results for all scenario years are summarized in Table C10. The same method was applied for investments in heavy truck fuel economy, as discussed in Appendix D.

Table C10
Average Added Costs of Improving Automobile Efficiency

(a) Analysis for year 2000:

Scenario	Measure Number	Fuel Economy (mpg)	Marg CCE ($/gal)	Avg CCE ($/gal)	Energy intensity index	Added avg.cost ($/gal)
Baseline	0	28.3	0.00	0.00	1.000	--
Reference	5	33.0	0.36	0.25	0.858	0
Market	11	40.5	0.72	0.40	0.699	0.53
Environmental	15	42.5	1.47	0.47	0.666	0.63
Climate Stabilization	17	44.1	1.83	0.57	0.642	0.78

(b) Extrapolation for later years:

Scenario	Yr 2000 Added Avg.Cost	Levelized fuel costs ($/gal)			Extrapolated added avg. cost	
		2000	2010	2030	2010	2030
Market	0.53	1.01	1.19	1.49	0.63	0.79
Environmental	0.63	1.51	1.69	1.99	0.71	0.83
Climate Stabilization	0.78	1.76	1.94	2.24	0.86	0.99

PERSONAL INTERCITY TRAVEL

Reference case projections of personal air transportation were obtained from the EIA/TED (1990) model for the 1988 to 2010 period and extrapolated both the activity level and fuel efficiency from 2010 to 2030, broadly consistent with pre-2010 trends and the EIA/SR (1990) results. Table C11 summarizes the intercity travel analysis. Activity is measured in personal miles traveled (PMT). Fuel efficiency is represented as seat-miles per gallon (SM/gal) of jet fuel or inversely as Btu per seat-mile (Btu/SM).

Significant improvements in aircraft efficiency are possible, especially over the long run as the stock is replaced (Greene 1990). Presently, passenger aircraft fuel economy averages 39 seat-miles per gallon (SM/gallon). The market, environmental, and climate stabilization scenarios were developed by assuming increasingly faster levels of efficiency improvement and mode shifting–from air to some form of high-speed rail–based on existing and new technologies. We did not analyze the limited intercity rail and bus service presently available, assuming that all future growth will be in air travel or in new high speed rail systems as discussed below. Neither did we analyze fuel substitution possibilities, and so we assume continued use of petroleum fuels for aircraft.

Table C11
Summary of Intercity Air and High Speed Rail Analysis

Scenario and year:	1988	2000	2010	2030
REFERENCE				
Air PMT (10^9)	513	762	1082	1772
Air SM/gallon	39	51	62	73
Air energy intensity index	1.000	0.765	0.629	0.534
Air energy use (Quads)	2.91	3.31	3.86	5.37
MARKET				
Air PMT (10^9)	513	762	1017	1577
HSR PMT (10^9)	0	0	65	195
Air SM/gallon	39	51	62	73
Air energy intensity index	1.000	0.765	0.629	0.534
HSR energy intensity index	1.000	1.000	0.904	0.740
Air energy use (Quads)	2.91	3.31	3.63	4.78
HSR energy use (Quads)	0.00	0.00	0.09	0.21
TOTAL, Air+HSR (Quads)	2.91	3.31	3.72	4.99
ENVIRONMENTAL				
Air PMT (10^9)	513	762	984	1479
HSR PMT (10^9)	0	0	98	293
Air SM/gallon	39	51	73	100
Air energy intensity index	1.000	0.765	0.534	0.390
HSR energy intensity index	1.000	1.000	0.904	0.740
Air energy use (Quads)	2.91	3.31	2.98	3.27
HSR energy use (Quads)	0.00	0.00	0.13	0.32
TOTAL, Air+HSR (Quads)	2.91	3.31	3.11	3.59
CLIMATE STABILIZATION				
Air PMT (10^9)	513	762	952	1382
HSR PMT (10^9)	0	0	130	390
Air SM/gallon	39	51	79	150
Air energy intensity index	1.000	0.765	0.494	0.260
HSR energy intensity index	1.000	1.000	0.904	0.740
Air energy use (Quads)	2.91	3.31	2.67	2.04
HSR energy use (Quads)	0.00	0.00	0.17	0.43
TOTAL, Air+HSR (Quads)	2.91	3.31	2.84	2.46

PARAMETERS

Jet fuel energy content:	135 kBtu/gallon
Base air energy intensity:	3.462 kBtu/seat mile (fully loaded)
Base HSR energy intensity:	0.900 kBtu/seat mile (fully loaded)
Load factor (both air and HSR):	0.61

HSR efficiency improvements are assumed to be 1%/yr for all scenarios, starting from a the year 2000 base of 0.9 kBtu per seat mile.

Reference Scenario

Based on the EIA/TED model and some additional assumptions, we obtained the results shown for the reference scenario in Table C11. Overall intercity travel demand, as measured by passenger miles of travel (PMT), is expected to more than triple by 2030, growing at average rates of 3.5%/yr 1988-2010 and 2.5%/yr 2010-2030. The fuel efficiency increases over the 1988-2010 period are taken from EIA/TED (1990), with the 62 SM/gal level for 2010 being in agreement with Greene (1990). The target of 73 SM/gal for 2030 is the lower end of the range which Greene estimates could be achieved by 2010 assuming rapid enough investment and equipment turnover. With these efficiency assumptions and no mode shifting, energy end-use for intercity air travel would grow from the present level of about 2.9 quads to 5.4 quads by 2030.

Policy Scenarios

For the market scenario, we assume no aircraft efficiency improvements beyond those of the reference scenario. For the remaining two scnearios, we assumed faster penetration of more efficient aircraft, based on the highest efficiency levels estimated by Greene (1990). These technology penetration assumptions are not based on a specific cost-benefit analysis, rather, we assume that use of the more efficient technologies is cost-effective when considering the environmental costs of fuel use. For the environmental scenario, the projected commercial aircraft efficiency increases to 73 SM/gal by 2010 and 100 SM/gal by 2030. For the climate stabilization scenario, it increases to 79 SM/gal by 2010 and 150 SM/gal by 2030.

Because of the large growth in air travel, the resulting airport congestion, and anticipated limits in new airport construction, several regions of the country are considering high-speed trains for intercity passenger service. The options include various forms of fast steel-wheel trains, such as the French *Train de Grande Vitesse* (TGV), as well as magnetic levitation (Maglev) vehicles. We do not attempt to distinguish these in our analysis, but classify them together as high-speed rail (HSR) options. HSR is considered to be competitive (on both energy cost and travel time) at distances of generally 600 miles or less for routes with large travel demand, as shown in Figure C3 (Johnson *et al.* 1989, which specifically addressed Maglev). Such shorter trips, estimated to account for about one-third of current domestic air PMT, are much more energy intensive than longer flights. Figure C3 shows one suggested plan for a U.S. intercity HSR network, taken from the Maglev conceptual plan of Johnson *et al.* (1989).

We assumed that there would be an air-to-HSR PMT shift of one-third of all short trips for the market scenario, one-half of the short trips for the environmental scenario, and two-thirds of the short trips for the climate stabilization scenario, phased-in linearly between 2000 and 2030. We use 900 Btu/SM as an estimate[12] of HSR energy end-use in 2000 and assume an improvement rate of 1%/yr thereafter. HSR energy use then grows to 0.32 Quads by 2030, contributing a net 8% reduction of intercity travel energy use compared to the reference case. Counting the aircraft efficiency improvements, the environmental scenario projection of energy use for intercity travel is 33% lower than the reference projection, or 3.6 quads in 2030, of which 0.3 Quads is HSR and the remainder is air. Projections for all scenario years are given in Table C11.

[12] A mid-range value of rail and Maglev estimates obtained from D. Rote (Argonne National Laboratory, personal communication, 1991).

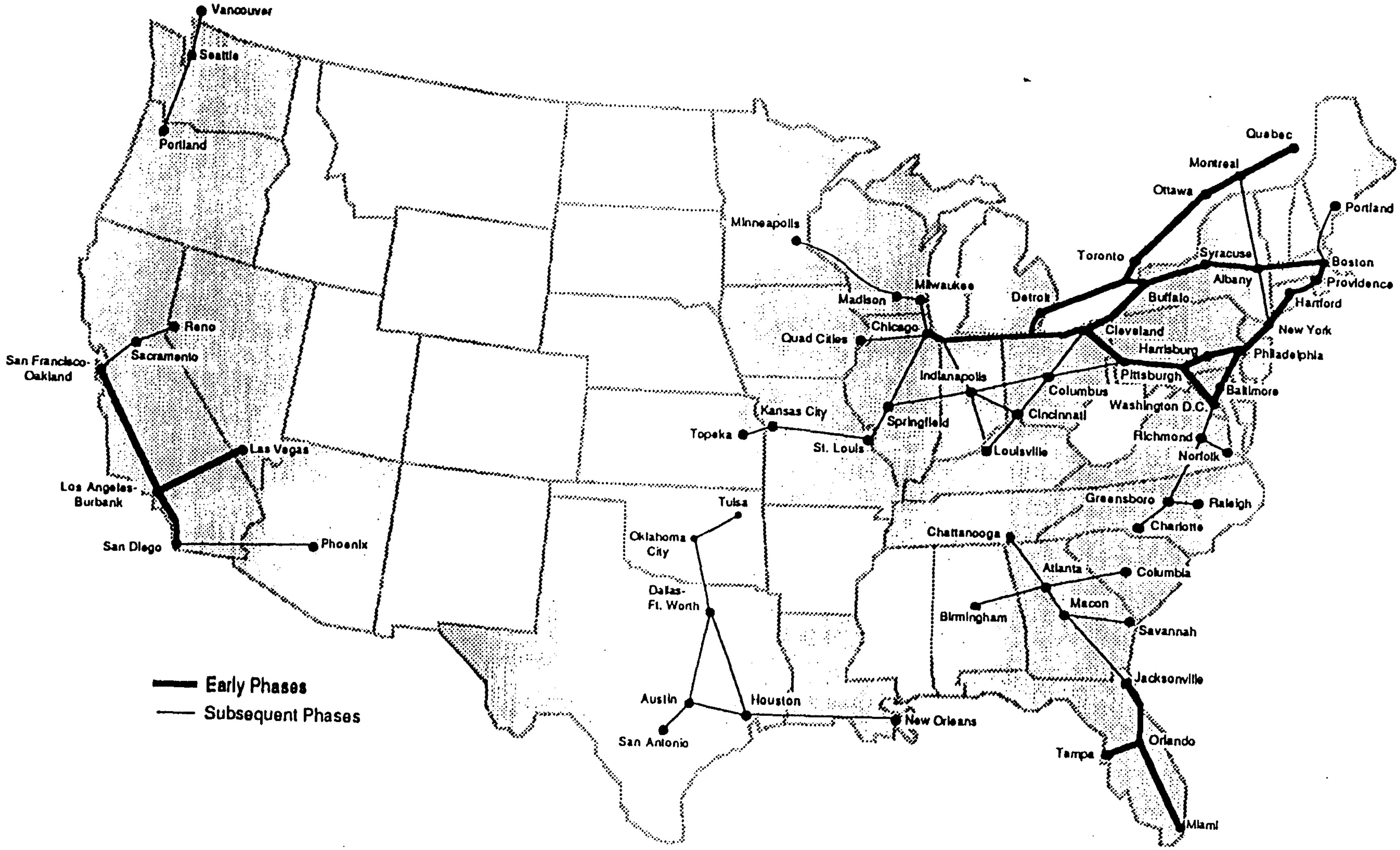

Figure C3. Hypothetical high-speed rail (HSR) network for connecting hub airports in high traffic, short distance corridors. Taken from Johnson et al. (1989), Figure 8.

GENERAL SUMMARY OF TRANSPORTATION RESULTS

This section provides a overall summary of our energy end-use projections for the entire U.S. transportation sector, with freight transportation included for completeness. Table C12 gives a breakdown of energy savings according to technology improvement and mode shift, as discussed below. Table C13 summarizes the energy end-use projections by scenario and projection year. This summary table is not fully comparable to the results given in the main text since it was not run through the LEAP model; nevertheless, it provides a similar self-consistent set of projections with which to compare the transportation subsectors.

The reference case has overall transportation energy demand growing 20% by 2010. In contrast, there are absolute reductions (from the current level) of 10%, 26%, and 30% for the market, environmental, and climate stabilization scenarios, respectively, by 2010. Similarly by 2030, the alternative scenarios yield absolute reductions of 20%, 39%, and 45%, respectively, in contrast to 30% growth for the reference case.

Presently, light duty vehicles are the dominant transportation energy user and they are projected to remain so in the reference case. In the policy scenarios, energy requirements and CO_2 emissions by the freight subsector fall in absolute terms, but the potential drop is not nearly so dramatic as that for light vehicles. All of the policy scenarios project that freight will become the dominant user of transportation energy by 2030. The absolute fall in energy consumption from present levels is 15%, so there is a greater burden on fuel switching in the freight subsector if we were to seek a 50% cut in CO_2 emissions from that subsector alone by 2030.

It is instructive to break down the reductions in energy use into components of technology improvement and mode shift. Here we do this for all parts of the transportation sector, including for comparison the freight results as well. Table C12 shows the breakdown for the environmental scenario by 2030. The market and climate stabilization scenarios have a similar breakdowns for their respective lower and higher levels of energy use reduction. The analysis reveals that improved technologies are responsible for three-fourths of the reduction and shifts to less energy-intensive modes account for the remainder. This is significant because the majority of the technology improvements have already been identified today even though the projection is for 40 years out. Widespread commericialization of the efficient transportation technologies involves some uncertainty and costs are not fully identified. Nevertheless, there is still room for technological innovation, the additional gains from which are not reflected in the scenarios. The mode shift portion rests on assumptions about policy changes to profoundly affect land use patterns and transportation infrastructure. As noted earlier, the mode shift projections are largely grounded in comparative data for areas that have developed according to different patterns. There is a lack of data on areas that have made a transition through time from highway-mode intensive transportation to denser development and a multi-modal transportation system.

These results for the U.S. transportation sector show that while there is a larger reliance on technology improvement in achieving energy use reductions consistent with a greenhouse constrained economy, technology cannot be expected to achieve the needed energy use reductions alone. Shifts to more efficient modes of transportation are, of course, critical for addressing local air pollution problems in many parts of the country. Significant policy changes needed are to push both technology improvement and shifts to more efficient modes. The three-to-one ratio suggested here is not fully certain, of course, and technological advances could reduce the burden on mode shifting. This breakdown was not, however, forordained, since the analyses were done independently under similar guidelines about likely cost-effectiveness, externality costs, and policy change.

Besides reducing energy consumption through efficient technologies and shifts to less intensive modes, the other way to cut CO_2 emissions is to switch to renewable fuels. With the steep energy use reductions indicated here, there is relatively less burden on fuel switching. For example, the amount of CO_2 emitted per unit of transportation energy end-use drops by 17% in the environmental scenario. Our dominant reliance on technical and structural improvements in the efficiency of energy use in the transportation sector increase the likelihood that a fuel supply system which is renewable (in the sense of a replenishable supply with no net CO_2 emissions) can also be sustainable in the broader sense of having minimal disruptions to natural ecosystems.

Table C12
Technological and Structural Components Of Energy Savings
Environmental Scenario vs. Reference Scenario

	Energy use, Quads	Quads of reduction (percent of reduction)		Energy use, Quads
	Reference scenario	Technology improvement	Mode shift	Enviro. scenario
Personal travel (non intercity)	13.45	7.50 (77%)	2.29 (23%)	3.66
Freight	9.80	2.73 (76%)	0.87 (24%)	6.20
Intercity travel	5.37	1.35 (76%)	0.43 (24%)	3.59
Transportation sector, overall	28.62	11.58 (76%)	3.59 (24%)	13.45

Note: The breakdown was obtained by factoring the ratio of Environmental to Reference case energy use, E, into an efficiency portion, p, and a mode shift portion, q, according to $E_{ENV}/E_{REF} = (1-p)(1-q)$. The absolute energy reduction, $E_{ENV} - E_{REF}$, was then broken into two components proportional to p and q. The percent contributions of technology improvement and mode shift to the reduction are thus taken to be $p/(p+q)$ and $q/(p+q)$, respectively.

Table C13
Overall Summary of Transportation Energy Use Results

SCENARIO (by end-use activity)	Projected energy end-use (Quads) 1990	2000	2010	2030
REFERENCE				
Light vehicles	11.70	13.30	13.80	13.30
Freight	7.26	7.90	8.66	9.81
Intercity passenger	2.91	3.31	3.86	5.37
Urban transit	0.15	0.15	0.15	0.15
TOTAL	22.0	24.7	26.5	28.6
MARKET				
Light vehicles	11.70	11.40	8.50	5.40
Freight	7.26	7.20	7.30	7.05
Intercity passenger	2.91	3.31	3.72	4.99
Urban transit	0.15	0.19	0.26	0.23
TOTAL	22.0	22.1	19.8	17.7
ENVIRONMENTAL				
Light vehicles	11.70	10.00	6.10	3.30
Freight	7.26	6.92	6.64	6.19
Intercity passenger	2.91	3.31	3.11	3.59
Urban transit	0.15	0.25	0.40	0.33
TOTAL	22.0	20.5	16.3	13.4
CLIMATE STABILIZATION				
Light vehicles	11.70	9.60	5.50	3.30
Freight	7.26	6.72	6.61	5.88
Intercity passenger	2.91	3.31	2.84	2.46
Urban transit	0.15	0.34	0.40	0.33
TOTAL	22.0	20.0	15.4	12.0

Table C14
Summary of Light Vehicle Analysis, Reference Scenario

	1990	2000	2010	2030
VMT, base (billion miles)	1762	2250	2610	2820
Land use/TDM effect	0.0%	0.0%	0.0%	0.0%
Cost of driving effect	0.0%	-0.5%	-1.1%	-1.9%
Net light vehicle VMT	1762	2238	2580	2766
Light truck fraction	29%	31%	32%	32%
Gasoline price (1990$/gallon)	1.09	1.32	1.59	1.94
Avg driving cost (cents/mile)	5.8	6.3	6.8	7.6
New vehicle fuel economy (EPA mpg)				
Automobiles	28	33	37	41
Light trucks	21	25	27	31
Average new light vehicle	25	30	33	37
On-road fuel economy (mpg)				
Shortfall, on-road vs. EPA	20%	20%	25%	30%
New light vehicle average	20	24	25	26
Stock fuel economy (on-road mpg)				
Automobiles	21	23	26	28
Light trucks	15	18	19	21
Stock average on-road	19	21	23	25
Average energy use (kBtu/mi)	6.65	5.92	5.36	4.92
Average annual improvement rate				
New light duty vehicles		1.7%	0.3%	0.2%
Light duty vehicle stock		1.2%	1.0%	0.4%
RELATIVE EFFICIENCY BY FUEL TYPE				
Petroleum	1.00	1.00	1.00	1.00
Natural gas	1.00	1.00	1.00	1.00
Biofuels	1.00	1.00	1.07	1.20
Hydrogen	1.00	1.30	1.50	2.00
Electric (end-use from grid)	2.50	3.30	3.80	5.00
SHARES OF VMT BY FUEL TYPE				
Petroleum	100.000%	99.958%	99.790%	92.770%
Natural gas	0.000%	0.007%	0.035%	1.200%
Biofuels	0.000%	0.021%	0.105%	3.630%
Hydrogen	0.000%	0.000%	0.000%	0.000%
Electric (end-use from grid)	0.000%	0.014%	0.070%	2.400%
END-USE CONSUMPTION (Quads)				
Petroleum	11.715	13.253	13.814	12.629
Natural gas	0.000	0.001	0.005	0.163
Biofuels	0.000	0.003	0.014	0.412
Hydrogen	0.000	0.000	0.000	0.000
Electric (end-use from grid)	0.000	0.001	0.003	0.065
LIGHT VEHICLE TOTAL (Quads)	11.7	13.3	13.8	13.3

Table C15
Summary of Light Vehicle Analysis, Market Scenario

	1990	2000	2010	2030
VMT, base (billion miles)	1762	2250	2610	2820
Land use/TDM effect	0%	-6%	-16%	-18%
Cost of driving effect	0.0%	0.1%	1.0%	2.5%
Net light vehicle VMT	1762	2117	2220	2382
Light truck fraction	0.29	0.31	0.32	0.32
Gasoline price (1990$/gallon)	1.09	1.32	1.59	1.94
Avg driving cost (cents/mile)	5.8	5.7	5.0	4.1
New vehicle fuel economy (EPA mpg)				
Automobiles	28	40	50	56
Light trucks	21	30	38	42
Average new light vehicle	25	36	45	51
On-road fuel economy (mpg)				
Shortfall, on-road vs. EPA	20%	25%	20%	0%
New light vehicle average	20	27	36	51
Stock fuel economy (on-road mpg)				
Automobiles	21	25	35	52
Light trucks	15	19	27	39
Stock average on-road	19	23	32	47
Average energy use (kBtu/mi)	6.65	5.41	3.93	2.64
Average annual improvement rate				
New light duty vehicles		3.0%	2.9%	1.7%
Light duty vehicle stock		2.1%	3.2%	2.0%
RELATIVE EFFICIENCY BY FUEL TYPE				
Petroleum	1	1	1	1
Natural gas	1.0	1.0	1.0	1.0
Biofuels	1.0	1.0	1.0	1.0
Hydrogen	1.0	1.1	1.1	1.5
Electric (end-use from grid)	2.5	2.8	2.8	3.6
SHARES OF VMT BY FUEL TYPE				
Petroleum	100.000%	96.980%	78.110%	29.750%
Natural gas	0.000%	0.400%	0.710%	0.060%
Biofuels	0.000%	1.920%	16.770%	49.490%
Hydrogen	0.000%	0.000%	0.000%	0.000%
Electric (end-use from grid)	0.000%	0.700%	4.410%	20.700%
END-USE CONSUMPTION (Quads)				
Petroleum	11.715	11.111	6.815	1.872
Natural gas	0.000	0.046	0.062	0.004
Biofuels	0.000	0.220	1.463	3.115
Hydrogen	0.000	0.000	0.000	0.000
Electric (end-use from grid)	0.000	0.029	0.137	0.362
LIGHT VEHICLE TOTAL (Quads)	11.7	11.4	8.5	5.4

Table C16
Summary of Light Vehicle Analysis, Environmental Scenario

	1990	2000	2010	2030
VMT, base (billion miles)	1762	2250	2610	2820
Land use/TDM effect	0.0%	-13.0%	-30.0%	-34.0%
Cost of driving effect	0.0%	0.5%	2.2%	4.4%
Net light vehicle VMT	1762	1969	1884	1986
Light truck fraction	0.29	0.31	0.32	0.32
Gasoline price (1990$/gallon)	1.09	1.32	1.59	1.94
Avg driving cost (cents/mile)	5.8	5.4	4.3	3.1
New vehicle fuel economy (EPA mpg)				
Automobiles	28	43	54	75
Light trucks	21	32	41	56
Average new light vehicle	25	39	49	68
On-road fuel economy (mpg)				
Shortfall, on-road vs. EPA	20%	20%	10%	0%
New light vehicle average	20.2	30.8	44.3	67.8
Stock fuel economy (on-road mpg)				
Automobiles	21	27	41	69
Light trucks	15	20	31	52
Stock average on-road	19	25	37	62
Average energy use (kBtu/mi)	6.65	5.10	3.34	2.01
Average annual improvement rate				
New light duty vehicles		4.3%	3.7%	2.1%
Light duty vehicle stock		2.7%	4.3%	2.6%
RELATIVE EFFICIENCY BY FUEL TYPE				
Petroleum	1	1	1	1
Natural gas	1.0	1.0	1.0	1.0
Biofuels	1.0	1.0	1.0	1.0
Hydrogen	1.0	0.9	0.9	1.0
Electric (end-use from grid)	2.5	2.3	2.3	2.5
SHARES OF VMT BY FUEL TYPE				
Petroleum	100.00%	97.67%	68.22%	5.83%
Natural gas	0.00%	0.40%	0.96%	0.08%
Biofuels	0.00%	1.92%	24.43%	66.38%
Hydrogen	0.00%	0.00%	0.00%	0.00%
Electric (end-use from grid)	0.00%	0.01%	6.39%	27.71%
END-USE CONSUMPTION (Quads)				
Petroleum	11.715	9.812	4.296	0.233
Natural gas	0.000	0.040	0.060	0.003
Biofuels	0.000	0.193	1.539	2.650
Hydrogen	0.000	0.000	0.000	0.000
Electric (end-use from grid)	0.000	0.001	0.175	0.442
LIGHT VEHICLE TOTAL (Quads)	11.7	10.0	6.1	3.3

Table C17
Summary of Light Vehicle Analysis, Climate Stabilization Scenario

	1990	2000	2010	2030
VMT, base (billion miles)	1762	2250	2610	2820
Land use/TDM effect	0.0%	-13.0%	-31.0%	-34.0%
Base cost of driving effect	0.0%	0.8%	2.9%	4.7%
Net light vehicle VMT	1762	1976	1876	1994
Light truck fraction	0.29	0.25	0.25	0.25
Gasoline price (1990$/gallon)	1.09	1.32	1.59	1.94
Avg driving cost (cents/mile)	5.8	5.2	3.9	3.0
New vehicle fuel economy (EPA mpg)				
Automobiles	28	46	59	75
Light trucks	21	35	44	56
Average new light vehicle	25	42	54	69
On-road fuel economy (mpg)				
Shortfall, on-road vs. EPA	20%	20%	10%	0%
New light vehicle average	20.2	34.0	48.9	69.2
Stock fuel economy (on-road mpg)				
Automobiles	21	28	45	70
Light trucks	15	21	33	52
Stock average on-road	19	26	41	65
Average energy use (kBtu/mi)	6.65	4.88	3.04	1.94
Average annual improvement rate				
New light duty vehicles		5.3%	3.7%	1.8%
Light duty vehicle stock		3.1%	4.8%	2.3%
RELATIVE EFFICIENCY BY FUEL TYPE				
Petroleum	1	1	1	1
Natural gas	1.0	1.0	1.0	1.0
Biofuels	1.0	1.0	1.0	1.0
Hydrogen	1.0	0.9	0.9	1.0
Electric (end-use from grid)	2.5	2.3	2.3	2.5
SHARES OF VMT BY FUEL TYPE				
Petroleum	100%	89.99%	62.00%	5.00%
Natural gas	0%	5.00%	5.00%	5.00%
Biofuels	0%	5.00%	25.00%	50.00%
Hydrogen	0%	0.00%	1.00%	15.00%
Electric (end-use from grid)	0%	0.01%	7.00%	25.00%
END-USE CONSUMPTION (Quads)				
Petroleum	11.715	8.683	3.537	0.193
Natural gas	0.000	0.482	0.285	0.193
Biofuels	0.000	0.482	1.426	1.932
Hydrogen	0.000	0.000	0.063	0.580
Electric (end-use from grid)	0.000	0.001	0.174	0.386
LIGHT VEHICLE TOTAL (Quads)	11.7	9.6	5.5	3.3

LIST OF ACRONYMS

ACEEE	American Council for an Energy-Efficient Economy
BART	Bay Area Rapid Transit (San Francisco)
CAFE	Corporate Average Fuel Economy
DOE	Department of Energy
DOT	Department of Transportation
EIA	Energy Information Administration (DOE)
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration (DOT)
GNP	Gross National Product
HSR	High Speed Rail
LEAP	Long-range Energy Alternative Planning (model, Tellus Institute)
PMT	Person Miles of Travel
RTECS	Residential Transportation Energy Consumption Survey (EIA)
SAE	Society of Automotive Engineers
SM	Seat Mile
TCM	Transportation Control Measure
TDM	Transportation Demand Management
TED	Transportation Energy Demand (module of EIA model)
TIUS	Truck Inventory and Use Survey (Bureau of the Census)
VMT	Vehicle Miles of Travel
VMV	Miles driven per Vehicle per year
VPP	Vehicles Per Person

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Appendix D: Freight Transportation Sector Analysis

This appendix documents the accounting model used to project future freight energy consumption. We estimate the amount of fuel required to provide the U.S. economy with freight services for the years 2000, 2010, and 2030, based on a projection of shipping demand (ton miles moved per year). For each of the the four scenarios defined for this study (reference, market, environmental, and climate stabilization), we analyzed the potential efficiency improvements and fuel substitutions and calculated the effect on end-use energy requirements. Summary tables giving projections of freight activity and fuel use by mode for each scenario are listed at the end of the appendix.

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GENERAL ASSUMPTIONS

Five freight modes are considered in our analysis: truck, rail, domestic water, liquids pipeline, and air. Two other major modes, international shipping and natural gas pipelines, are treated outside of our model; their respective fuel requirements are added at the end. The demand for freight services is driven by the amount and types of industrial output. Therefore, energy demand by the freight sector mode is estimated in two steps. First, the activity level of each mode is estimated based on industrial activity and assumptions about mode shares. Then, fuel use by each mode is estimated based on assumptions regarding energy efficiency and the fuel mix.

The overall level of freight activity is the held the same for each scenario, reflecting the study's assumption of equal economic activity for all scenarios. Consistently with our industrial sector analysis, neither overall GNP nor industrial output by commodity group vary among the scenarios. Differences among scenarios are due only to our assumptions about the energy efficiency and fuel mix used by each mode and the amount of mode shifting from truck to rail. The resulting projections for each scenario are summarized in Tables D9-D12 at the end of the appendix.

The assumptions used to develop our reference scenario match those of EIA/SR (1990) except for the difference in underlying industrial output due to our independent model of the industrial sector. In particular, reference assumptions of mode share, energy intensity, and fuel mix are the same as those of EIA.

Our industrial sector is modeled differently than EIA's, reflecting trends toward lowered materials intensity and a shift toward services. Since we do not assume any difference in overall economic activity as measured by GNP, commercial sector activity is correspondingly larger, as modeled by higher growth of commercial floor space in our buildings sector. We did not increase the output indices (for commodity groups or retail trade) which might be associated with this offsetting increase in commercial activity. Also, we did not incorporate feedback for changes in freight demand due to shifts in industrial output that might be induced by our policy scenarios. These issues and related trends which can impact the future fuel requirements for freight transportation are further discussed in Sachs and DeCicco (1991). Reflecting this underlying difference in industrial materials output, freight sector energy demand in the reference scenario is 23%, or 2.2 Quads, lower than EIA's in 2030.[1]

[1]The comparison is for the comparably modeled domestic freight modes (truck, rail, domestic shipping), which EIA projects at 9.7 Quads in 2030 (EIA/SR, p. 202), vs. our reference projection of 7.5 Quads.

SUMMARY OF ANALYSIS

Demand for Freight Services

Estimates of 1985 annual demands for freight shipping by mode for each industrial commodity group were obtained from the Argonne National Laboratory FRATE model.[2] These estimates were aggregated to the 12 commodity groups used in EIA/TED (1990), which are listed here in Table D1. The first 11 are the industrial subsectors as used in our industrial sector analysis; the 12th is retail trade.

Table D1
Commodity Groups used for Projecting Freight Demand

Group	Description	SIC codes
1	Chemicals, Rubber, Plastics	28,30
2	Primary metals	33
3	Food	20
4	Paper	26
5	Refinery	29
6	Stone, Clay, Glass	32
7	Metal durable	34-38
8	Other manufacturing	21-25,27,31,39
9	Agricultural	1,2,7,8,9
10	Mining, including oil wells	10-14
11	Construction	15-17
12	Retail trade	

The commodity groups are from EIA (Feb. 1990), Table 3, p. IV-13, plus the added group for retail trade. Growth rates for groups 1-11 are as specified for the industrial sector; retail trade is assumed to grow at the same rate as GNP.
The SIC (standard industrial) codes to which the EIA groups correspond were obtained from J. Holt, (Energy Information Administration), pers. comm., Dec. 1990.

Normalizing the set of shipping demands by the total shipping demand for each commodity group results in a mode shares matrix, shown in Table D2. The mode shares matrix can be used to map shipping requirements by commodity group to demand for freight services by each mode. Mode shifting can then be modeled by proportionally changing row elements of the mode shares matrix. Growth in demand is driven exogenously by industrial growth, using the same growth rates over the projection period as are used for our industrial sector model.

Based on their modeling inputs, the EIA/SR (1990, p. 104) shows demand for freight services (ton-miles per year) growing at 1.9%/yr through 2030. EIA assumed no differences in demand among scenarios, and no shifts among transportation modes. As noted earlier, our industrial sector model reflects our assumption of a reduced rate of material consumption (per unit GNP or per capita) relative to investments in services. The economy is likely to provide more highly processed goods, which have more value per unit weight (Williams *et al.* 1987). As a result, the average growth in demand for freight services as measured in ton-miles is only 0.75%/yr over the 40-year horizon of our scenarios. There may, however, be an energy intensity effect in which the lower tonnages require faster shipment,

[2]Tables of freight shipping demand by commodity group and mode calibrated to 1985, from A. Vyas (Argonne National Laboratory, Argonne, IL), personal communication, December 1990.

Table D2 Freight Activity and Mode Shares for Commodity Groups for 1985						
Commodity group	Activity, 10^9ton-miles per year	Share of freight activity for commodity by mode: Truck	Rail	Water	Air	Pipe
1	285.87	0.4053	0.4345	0.1585	0.0015	0.0000
2	113.12	0.6774	0.2498	0.0720	0.0009	0.0000
3	358.39	0.7298	0.2104	0.0597	0.0005	0.0000
4	97.58	0.4920	0.4950	0.0120	0.0003	0.0000
5	488.00	0.1770	0.0420	0.3090	0.0000	0.4710
6	157.91	0.7910	0.1750	0.0330	0.0002	0.0000
7	189.33	0.8047	0.1771	0.0101	0.0081	0.0000
8	216.25	0.7454	0.2337	0.0184	0.0019	0.0000
9	452.53	0.6693	0.1858	0.1371	0.0082	0.0000
10	1295.94	0.0260	0.2586	0.4576	0.0000	0.2579
11	150.76	1.0000	0.0000	0.0000	0.0000	0.0000
12	139.96	1.0000	0.0000	0.0000	0.0000	0.0000

Source: ACEEE calculations based on tabulations from ANL FRATE model, pers. comm. from A. Vyas (Argonne National Laboratory), 1990.

because there is more value added per unit weight. While our freight sector projections do reflect the lowered material intensities of our industrial sector model, we have not modeled an additional induced shift toward faster, potentially more energy-intensive freight modes.

Although the air freight portion of the overall freight sector is currently small, about 0.2% of ton-miles but 2% of energy end-use according to our baseline statistics (Table D8), it is the fastest growing portion. There is evidence that the assumed growth rates for air freight are too low, at least in the near term. With our assumption of a fixed mode share and the underlying industrial growth rates, demand for air freight as measured in ton-miles is projected to grow at 2.3%/yr through 2000 and 1.9%/yr over the 40-year study horizon. Recent history shows much more rapid growth in air freight and this is expected to continue, at least for the next decade or so. Mintz and Vyas (1991) report an average growth rate for air freight ton-miles of 4.9%/yr from 1970-1985 and project an average growth rate of 3.5%/yr through 2010. Presently, about 70% is carried as "belly freight" on passenger flights, but the use of dedicated cargo aircraft is expected to grow. Further discussion of the freight energy use implications of high-value, time-sensitive goods is given by Sachs and DeCicco (1991).

Mode Shifts

We progressively increased the amount of truck freight diverted to rail in more aggressive scenarios and in more distant time horizons. This may seem to run counter to the trend towards greater time value of shipments, however, it is not conventional bulk commodity rail service that we see growing. Rather, it is expanded competitiveness of intermodal services, which take advantage of inherent efficiencies of rail and the congestion avoidance possible with the use of an exclusive, fully scheduled right-of-way. Rail shipping uses about one fourth as much energy per ton mile as trucks.

Increasing the intermodal share will save energy if the rail system is near enough to origins and destinations. If not, the postulated savings are lost in drayage, i.e., extra truck shipping to and from the rail terminals.[3]

At present, a small fraction (probably less than 5%) of purely domestic freight moves in intermodal service (containers or trailers on flatcars or dedicated vehicles, and "carless" trailers). Intermodal shipping has, however, doubled in the past decade and has good continued growth potential in selected markets (Roberts and Fauth, 1988). There are many barriers to increasing intermodal shares, of which the most important is that intermodal service takes longer for hauls less than about 500 miles, while the average distances are 252 miles for truckload shipments and 548 miles for less than truckload shipments (Sachs and DeCicco 1991).

We estimated the potential for intermodal freight shifts for each commodity sector. The base year shipping and truck share data are listed in Table D3 along with our assumptions of the portion of freight that most likely must remain on trucks. With conventional technologies and increasing time value of freight, our resulting estimate is that up to 12% of intercity truck ton-miles could move to rail for the purposes of our alternative scenarios. We used this estimate in the environmental and climate stabilization scenarios for 2030, as shown in Table D4. In the market scenario, we assumed that 5% would move. For 2000 and 2010, these maximal shift estimates are interpolated downward.

Table D3
Estimation of Maximum Truck-to-Rail Mode Shift Potential

	Commodity group	Shipping in 1985 (10^9ton-mi)	Current truck share	Portion that cannot shift to rail
1	Chemicals, Rubber, Plastics	286	41%	80%
2	Primary metals	113	68%	80%
3	Food	358	73%	80%
4	Paper	98	50%	100%
5	Refinery	488	18%	100%
6	Stone, Clay, Glass	158	79%	100%
7	Metal durable	189	80%	80%
8	Other manufacturing	216	75%	80%
9	Agricultural	453	67%	100%
10	Mining, including oil wells	1296	3%	100%
11	Construction	151	100%	80%
12	Retail trade	140	100%	90%

No modal shifts are assumed for the other freight modes (air, domestic shipping, and domestic water shipping). As noted earlier, this is likely to imply an underestimate for air freight. Domestic water and rail have similar energy efficiencies (402 and 443 Btu/ton-mile, respectively) and fuel use capabilities, so the impact of shifts between these two modes is small. We have not included shifts to transportation services that may be important forty years from now, such as Maglev or other high speed rail (HSR) technologies, integrated transportation networks, and displacement by electronic media. These possibilities and related energy-use aspects of intermodal shipping are discussed further by Gordon (1991) and Sachs and DeCicco (1991).

[3]Because rail routes are more circuitous than trucks routes, one should add approximately 10% to the ton-miles shifted. Such an adjustment would increase rail ton-miles by about 3%, which, using our projected activity levels, would imply an additional 0.01 Quad; this was neglected in our analysis.

Table D4 Assumed Truck-to-Rail Mode Shifts				
	Portion of truck traffic that moves to intermodal rail transport:			
Scenario	1990	2000	2010	2030
Reference	0	0	0	0
Market	0	3.3%	3.9%	5.0%
Environmental	0	3.3%	6.0%	12.0%
Climate Stabilization	0	3.3%	6.0%	12.0%

Energy Intensity

The present efficiencies of freight modes vary greatly: 270 Btu/ton-mile for pipelines, 400 for domestic water, 440 for rail, 1900 for trucks, and 19,000 for air freight. Our estimates of the future energy intensity (fuel use per unit of activity, e.g., Btu/ton-mile) were derived from several sources. In the reference case, our estimates for trucking match the VMT-weighted average of EIA/SR (1990) estimates, which are tabulated by truck type (light, medium, heavy). For air, rail, and domestic shipping, we also used the EIA projections of energy intensity.

We determined that the EIA/SR (1990) "High Conservation" excursion corresponded closely to our market scenario and that the EIA "Very High Conservation" excursion corresponded closely to our environmental scenario. We used these EIA excursions as guides for our work, with the exceptions of trucking and air freight. In the climate stabilization scenario for rail and water-borne freight, we used the same values as in the environmental scenario, lacking better information. For liquids pipelines, we estimated improvement in efficiency by assumping the introduction of better operations and equipment. The resulting projections of energy intensity (Btu/ton-mile) and intensity index by mode (for 1990=1) are given by scenario in Tables D8-D11.

Trucking. For the alternative scenarios, our projections of trucking energy intensity are based on the fuel economy assessment of Sachs *et al.* (1991). Table D5 lists the technologies for improving heavy truck fuel economy and their estimated cost-effectiveness.

The total technical potential is for a 101% improvement, which would bring heavy trucks to 10.5 mpg. Without reduced speed, the potential is 86%, corresponding to 9.6 mpg for heavy trucks. We exhaust technologies for which cost information is available at a level well below the projected avoided costs of fuel consumption in years 2000 and later. Measures up to the technical potential are therefore cost-effective in all scenarios. We used different rates of penetration among the scenarios, assuming that penetration of the new technologies would be greater according to the greater margins of cost-effectiveness resulting from the higher avoided fuel costs used in the more aggressive scenarios.

Since the Sachs *et al.* analysis covered only "heavy-heavy" (within class 8) trucks, we assumed that a similar level of improvement could be achieved by freight trucks on average. The heaviest trucks dominate the freight activity in terms of VMT. Also, even higher levels of improvement are projected for light duty vehicles, as discussed in Appendix C, and so the light and medium classes of freight trucks are bracketed by these assessments for passenger vehicles and heavy trucks. Therefore, we are comfortable with this extrapolation even though a specific assessment for all classes for freight trucks was not performed. We scaled the average freight truck fuel economy by the improvement in heavy truck fuel economy, so that the level of 15.9 mpg for all freight trucks corresponds to a level of 9.6 mpg for heavy trucks. These fuel economy projections are summarized in Table D6. In the market scenario, for example, we project possible improvements of 16% by 2000, 36% by 2010, and 85% by

2030. By way of comparison, Carlsmith *et al.* (1990) project average freight truck efficiency improvements of 22% by 2000 and 32% by 2010; the EIA/SR (1990) "high conservation" scenario projects improvements of 16% by 2000 and 28% by 2010.

Table D5
Fuel Economy Technologies for Heavy Trucks

TECHNOLOGY CATEGORY	Cost of Changes	MPG Benefit	Life of measure (miles)	Annual savings (gals)	CCE ($/gal)
1 Aerodynamics-tractor	$3,000	14%	750,000	1,441	$0.26
2 Aerodynamics-trailer	$2,000	5%	750,000	559	$0.44
3 Engine control technologies	$4,000	16%	750,000	1,618	$0.31
4 Other avail. engine tech.	$1,500	15%	500,000	1,530	$0.16
5 Drive train	0	7%	750,000	767	$0.00
6 Tires	$700	8%	80,000	869	$0.66
7 Weight reduction	$3,000	1%	750,000	116	$3.20
8 Speed reduction (per year)	$15,000	15%	100,000	1,530	$4.95
9 Engines-in development	$10,000	20%	750,000	1,955	$0.63
TOTAL (technical potential)		101%			

Based on Sachs *et al.* (1991), for a baseline fuel economy of 5.2 MPG.

Table D6
Projected Fuel Economies of Freight Trucks

(a) **Fuel economy (mpg):**
The first value listed is the average of all freight trucks; the value in parentheses is the heavy truck fuel economy projection from which the average was derived.

Scenario	1990	2000	2010	2030
Reference	8.6 (5.2)	9.1 (5.5)	9.6 (5.8)	10.6 (6.4)
Market		10.0 (6.1)	11.7 (7.1)	15.9 (9.6)
Environmental		10.6 (6.4)	13.0 (7.9)	17.3 (10.5)
Climate Stabilization		11.0 (6.7)	13.0 (7.9)	18.5 (11.2)

(b) **Ratios to base year:**

Scenario	1990	2000	2010	2030
Reference	1	1.06	1.12	1.23
Market		1.16	1.36	1.85
Environmental		1.23	1.51	2.01
Climate Stabilization		1.28	1.51	2.15

Table D7 gives our estimates of the added cost of technology improvement, which were derived from the estimates in Table D5 using the same methodology as described in Appendix C (see Table C10 and its related discussion).

Table D7 Added Costs for Heavy Truck Efficiency Improvements						
	Energy intensity index (1990 = 1)			Added average cost ($/gallon)		
Scenario / year	2000	2010	2030	2000	2010	2030
Reference	0.945	0.896	0.811	0	0	0
Market	0.860	0.735	0.541	0.09	0.23	0.72
Environmental	0.811	0.662	0.497	0.13	0.29	0.76
Climate Stabilization	0.782	0.662	0.465	0.16	0.29	1.03
Note: Excludes costs or benefits of speed reduction.						

Air freight. We believe that the reference case projections of energy efficiency for air freight are probably too low, since air transport has shown great efficiency gains in the past and additional improvements are available. For the other scenarios, we assumed the same improvements in air freight technology as we used in our passenger air analysis (see Table C11). These projections are based on Greene (1990), assuming greater adoption of more advanced technologies in the more aggressive scenarios.

Energy end-use. For all scenarios, we computed total fuel demand for each mode in each projection year as the product of projected activity (ton-miles per year) and projected energy intensity (Btu/ton-mile). These projections are summarized in Tables D8-D12, for each of the four scenarios, respectively. For all scenarios, particular sources and assumptions are given in notes accompanying the tables. The energy use estimates for each mode were summed to yield total freight fuel demand for each scenario at each time interval.

As noted earlier, the reference projection is lower than that of EIA/SR (1990) because of our changes in the industrial sector. On the basis of the unchanged GNP growth rate, averaging 2.1%/yr over the 40 year study horizon, our reference scenario entails an average downward trend of 1.4%/yr in the freight energy intensity of the U.S economy. This decomposes into a 0.5%/yr reduction due to structural shifts in the economy (as discussed in our industrial analysis section) and a 0.9%/yr reduction due to reference freight mode efficiency improvements (consistent with EIA/SR 1990).

Fuel Mix Allocation

In this project, we have aggregated fuel categories to reflect uncertainties about the technologies that will become available. We aggregate gasoline and diesel as petroleum liquids, which are differentiated from natural gas. We include continuing use of electricity for about 3% of rail transportation. Except for hydrogen in the climate stabilization case, we consider all renewable fuels to be in the form of alcohol, e.g., we do not differentiate between alcohol and biodiesel.

The allocation of renewable fuels available for transportation uses (derived in the Renewable Energy Supply analysis) was partitioned between freight and passenger modes. (The reference scenario includes no renewable fuels.) All alcohol is considered to be made from renewable supplies. As a result, for truck fuel in 2010 and 2030 in the market and environmental scenarios, our estimated use of alcohol is lower than that predicted by the EIA, which does not restrict alcohol to renewable sources. Because hydrogen can replace natural gas in some applications, it is broken out as a separate category. We restrict hydrogen use to the climate stabilization case, specifying a hydrogen contribution of 1 Quad in 2030 and phasing it in by interpolating back for earlier scenario years. The hydrogen is considered to be renewably generated (e.g., from biomass), as discussed in the chapter on energy supply.

The renewable fuel allocation was subtracted from the projected total freight sector fuel requirements to determine the amount of non-renewable fuel required in each scenario. In the CO_2-constrained climate stabilization scenario, non-renewable fuel was limited to one half the 1990 value (6.5 Quads) in 2030 (3.25 Quads), and to 0.8 times the 1990 value in 2000 (5.2 Quads). We interpolated between these values for 2010 (4.55 Quads). We recognize three non-renewable fuel classes: electricity, natural gas, and petroleum liquids (gasoline, diesel, residual oil).

Freight sector electricity use is restricted to rail and pipelines. For rail applications, we diverge from the EIA by allowing electricity use to grow in proportion to the total growth of rail ton-miles instead of remaining constant. Nevertheless, it remains small, reaching only 0.017 Quads/year (end-use) in 2030. We did not account for possible electrification of rail lines that might be warranted because of clean air requirements in urban regions. Neither did we consider possible electrification of urban delivery trucks, which may also be prompted by clean air requirements. Pumping energy for pipelines uses more electricity, but it decreases from 0.24 quads to 0.20 quads between 1990 and 2030, due to an assumption that equipment efficiencies will rise more quickly than demand growth.

We assume that natural gas can become a prominent land freight fuel, contributing as much as 2.5 Quads in 2030 (45% of total use in the climate stabilization scenario). Natural gas is widely available, relatively low cost, and burns rather cleanly. Compressed or liquified natural gas may be suitable for fleet vehicles, heavy trucks, and rail (where liquified natural gas might be carried in tenders behind the locomotive). Natural gas was considered to be available in whatever quantities would be needed at costs competitive with petroleum liquids. In the market and environmental scenarios for trucking, we assumed penetration of natural gas at the rate postulated by the EIA. In the climate stabilization scenario, we moved 95% of all non-electric, non-renewable fuel use away from petroleum liquids, to natural gas. For rail, we use natural gas as the only non-electric, non-renewable fuel. We replace all distillate fuel oil used for water shipping with natural gas in the climate stabilization case by 2030, but do not change the residual fuel use. We do not forecast any use of natural gas for air freight. Although liquified natural gas has acceptable energy density, concerns about crashworthiness make it an unlikely choice. Thus, the major freight uses of natural gas are in trucks and rail plus pipelines (natural gas used to pump natural gas).

In essense, our approach for the alternative scenarios was to use petroleum liquids (gasoline, diesel, and residual fuel oil) as the "fuels of last resort," computing them as the difference between non-renewable demand and the supply of natural gas and electricity.

Table D8
Freight Transportation Reference Scenario

	1990	2000	2010	2030
ACTIVITY (Gt-mi) [a]	------	------	------	------
Truck	1755	2019	2332	2969
Rail	830	872	929	993
Water	851	863	888	898
Air [b]	7.8	9.5	11.7	16.5
Pipeline [c]	846	862	888	901
TOTAL	4288	4625	5049	5778
TRUCKS				
Avg load (ton/vehicle)	5.59	5.59	5.59	5.59
VMT (10^9)	314	361	417	531
MPG	8.6	9.1	9.6	10.6
ENERGY INTENSITY INDEX				
Truck	1	0.945	0.896	0.811
Rail [e]	1	0.961	0.929	0.869
Water [e]	1	1.000	1.000	1.000
Air [g]	1	0.793	0.648	0.512
Pipeline	1	1.000	1.000	1.000
E. INTENSITY (Btu/ton-mile)				
Truck [h]	2808	2654	2516	2278
Rail	443	426	412	385
Water	402	402	402	402
Air [g]	18809	14916	12188	9630
Pipeline [f]	271	271	271	271
ENERGY BY MODE (Quads)				
Truck	4.927	5.357	5.867	6.765
Rail	0.368	0.371	0.382	0.382
Water	0.342	0.347	0.357	0.361
Air	0.146	0.142	0.143	0.159
Pipeline	0.229	0.234	0.241	0.244
OTHER (NOT MODELED) (Quads)				
Nat. gas pipelines [d]	0.535	0.551	0.573	0.586
International shipping [e]	0.717	0.896	1.095	1.310
ENERGY BY FUEL (Quads)				
Petroleum	6.490	7.104	7.834	8.967
Natural gas	0.535	0.551	0.573	0.586
Electricity (end-use)	0.239	0.243	0.251	0.254
Renewables	0.000	0.000	0.000	0.000
TOTAL ENERGY USE (Quads)	7.263	7.898	8.658	9.807

FUEL SHARES	1990	2000	2010	2030
	------	------	------	------
Petroleum				
Truck	100.0%	100.0%	100.0%	100.0%
Rail	97.4%	97.4%	97.4%	97.4%
Water	100.0%	100.0%	100.0%	100.0%
Air	100.0%	100.0%	100.0%	100.0%
Pipeline	0.0%	0.0%	0.0%	0.0%
Natural Gas				
Truck	0.0%	0.0%	0.0%	0.0%
Rail	0.0%	0.0%	0.0%	0.0%
Water	0.0%	0.0%	0.0%	0.0%
Air	0.0%	0.0%	0.0%	0.0%
Pipeline	0.0%	0.0%	0.0%	0.0%
Electricity				
Truck	0.0%	0.0%	0.0%	0.0%
Rail	2.6%	2.6%	2.6%	2.6%
Water	0.0%	0.0%	0.0%	0.0%
Air	0.0%	0.0%	0.0%	0.0%
Pipeline	100.0%	100.0%	100.0%	100.0%
Renewable				
Truck	0.0%	0.0%	0.0%	0.0%
Rail	0.0%	0.0%	0.0%	0.0%
Water	0.0%	0.0%	0.0%	0.0%
Air	0.0%	0.0%	0.0%	0.0%
Pipeline	0.0%	0.0%	0.0%	0.0%

Notes for Table D8, Freight Transportation Reference Scenario

[a] Activity levels in 10^9 ton-miles per year (Gt-mi) for 1990 are from ACEEE calculations based on estimates for the ANL FRATE model (A. Vyas, Argonne National Laboratory, pers. comm. 1990), unless otherwise specified. Levels for subsequent year are calculated based on our assumed industrial output growth rates.

[b] Air freight activity for 1990 from Mintz and Vyas (1991), Table 3.12; subsequently scaled according to ACEEE freight demand growth calculations as in [a].

[c] Pipeline mode energy use is defined here as other than the natural gas used to power natural gas pipelines, which is listed in the "other" category (not part of our freight accounting model). Pipelines are dominated by crude oil and petroleum products, which are the only products covered in the EIA reference model. We include water, coal slurry, and the electricity used for natural gas pipelines, according to ORNL (1991), Table 2.6. The activity basis is estimated by scaling the oil products activity (547 Gt-mi in 1990) by the ratio of overall-to-oil products pipeline electricity use (244.8/158.4 = 1.545), from ORNL (1991), Table 2.6.

[d] 1990 value is from ORNL (1991), Table 2.6; subsequent values scaled parallel to oil pipelines.

[e] EIA/SR, Table G-5, p. 202.

[f] Pipeline energy intensity is from Mintz and Vyas (1991), Table 3.13, which is reported for oil pipelines. We assume that this applies on average to pipelines carrying other products; since we scaled the activity levels according to energy use (note [c]), the propagated error will be relatively small.

[g] Air freight efficiency improvement taken to be the same as for air passenger travel, as given in Appendix C; the 1990 energy intensity of air freight is from Mintz and Vyas (1991), p. 53.

[h] Based on the average loading factor (tons/vehicle) and fuel economy (MPG), assuming an average fuel energy content of 135 kBtu/gallon.

Table D9
Freight Transportation Market Scenario

	1990	2000	2010	2030
ACTIVITY (Gt-mi) [a]				
Truck [b]	1755	1952	2241	2821
Rail [b]	830	939	1020	1142
Water	851	863	888	898
Air	7.8	9.5	11.7	16.5
Pipeline	846	862	888	901
TOTAL	4288	4626	5049	5778
TRUCKS				
Avg Load (ton/vehicle)	5.59	5.59	5.59	5.59
VMT (10^9)	314	349	401	505
MPG [c]	8.6	10.0	11.7	15.9
ENERGY INTENSITY INDEX				
Truck [d]	1	0.857	0.735	0.541
Rail [e]	1	0.919	0.842	0.700
Water [e]	1	0.975	0.950	0.900
Air [f]	1	0.793	0.648	0.512
Pipeline [g]	1	0.975	0.950	0.900
E. INTENSITY (Btu/ton-mile)				
Truck	2808	2408	2065	1518
Rail	443	407	373	310
Water	402	392	382	362
Air [g]	18809	14916	12188	9630
Pipeline	271	264	257	244
ENERGY BY MODE (Quads)				
Truck	4.927	4.700	4.627	4.282
Rail	0.368	0.382	0.380	0.354
Water	0.342	0.338	0.339	0.325
Air	0.146	0.142	0.143	0.159
Pipeline	0.229	0.228	0.229	0.220
OTHER (NOT MODELED) (Quads)				
Nat. gas pipelines [g]	0.535	0.537	0.544	0.527
International shipping [e]	0.717	0.874	1.040	1.179
ENERGY BY FUEL (Quads)				
Petroleum	6.490	6.351	6.168	4.864
Natural gas	0.535	0.584	0.742	1.452
Electricity (end-use)	0.239	0.238	0.239	0.229
Renewables	0.000	0.028	0.153	0.501
TOTAL ENERGY USE (Quads)	7.263	7.201	7.301	7.045

FUEL SHARES	1990	2000	2010	2030
Petroleum				
Truck	100.0%	98.4%	93.7%	69.3%
Rail	97.4%	97.4%	87.7%	77.9%
Water	100.0%	100.0%	93.5%	87.0%
Air	100.0%	100.0%	100.0%	100.0%
Pipeline	0.0%	0.0%	0.0%	0.0%
Natural Gas				
Truck [h]	0.0%	1.0%	3.0%	19.0%
Rail [i]	0.0%	0.0%	9.7%	19.5%
Water [j]	0.0%	0.0%	6.5%	13.0%
Air	0.0%	0.0%	0.0%	0.0%
Pipeline	0.0%	0.0%	0.0%	0.0%
Electricity				
Truck	0.0%	0.0%	0.0%	0.0%
Rail	2.6%	2.6%	2.6%	2.6%
Water	0.0%	0.0%	0.0%	0.0%
Air	0.0%	0.0%	0.0%	0.0%
Pipeline	100.0%	100.0%	100.0%	100.0%
Renewable [k]				
Truck	0.0%	0.6%	3.3%	11.7%
Rail	0.0%	0.0%	0.0%	0.0%
Water	0.0%	0.0%	0.0%	0.0%
Air	0.0%	0.0%	0.0%	0.0%
Pipeline	0.0%	0.0%	0.0%	0.0%

Notes for Table D9, Freight Transportation Market Scenario

[a] Unless otherwise specified below, activity levels as well as notes and sources are the same as for the reference case, Table D8.

[b] Reflect truck-to-rail mode shifting as specified in Table D4.

[c] Using Table D5 (based on Sachs *et al.* 1991), we estimate a 85% improvement in heavy truck fuel economy from full penetration of existing technologies and those that are presently near commercialization. As discussed in text, we assume that this level of improvement is ultimately applicable to all trucks and is reached by 2030. Intermediate years are interpolated from the resulting average improvement rate of 1.55% per year.

[d] Based on MPG values and assuming no change in average loading factor.

[e] EIA/SR (1990), Table H-5, p. 210.

[f] Air freight efficiency improvement taken to be the same as for air passenger travel, as given in Appendix C.

[g] Pipeline efficiency improvement taken to be the same as domestic waterborne freight, assuming a comparable level of improvement is applicable to motors and pumping equipment.

[h] Freight truck natural gas fuel shares taken from EIA/SR, Table H-5, p. 210.

[i] Phase in a rail freight shift to natural gas, reaching 20% of the non-electric rail by 2030.

[j] Phase in a shift of domestic waterborne freight to natural gas fuel, displacing 20% of the 66% non-residual oil share by 2030.

[k] Renewable fuels assumed to be in form of alcohol and fuel shares taken from EIA/SR, Table H-5, p. 210, unless limited by our estimated supply of renewables, as discussed in text.

Table D10
Freight Transportation Environmental Scenario

	1990	2000	2010	2030
ACTIVITY (Gt-mi) [a]				
Truck [b]	1755	1952	2192	2613
Rail [b]	830	939	1069	1350
Water	851	863	888	898
Air	7.8	9.5	11.7	16.5
Pipeline	846	862	888	901
TOTAL	4288	4626	5049	5778
TRUCK				
Avg load (ton/vehicle)	5.59	5.59	5.59	5.59
VMT (10^9)	314	349	392	467
MPG [c]	8.6	10.6	13.0	17.3
ENERGY INTENSITY INDEX				
Truck [d]	1	0.815	0.664	0.498
Rail [e]	1	0.895	0.796	0.612
Water [e]	1	0.950	0.900	0.800
Air [f]	1	0.793	0.512	0.373
Pipeline [g]	1	0.950	0.900	0.800
E. INTENSITY (Btu/ton-mile)				
Truck	2808	2288	1864	1397
Rail	443	396	353	271
Water	402	382	362	322
Air [g]	18809	14916	9630	7016
Pipeline	271	257	244	217
ENERGY BY MODE (Quads)				
Truck	4.927	4.465	4.086	3.650
Rail	0.368	0.372	0.377	0.366
Water	0.342	0.330	0.321	0.289
Air	0.146	0.142	0.113	0.116
Pipeline	0.229	0.222	0.217	0.195
OTHER (NOT MODELED) (Quads)				
Nat. gas pipelines [g]	0.535	0.537	0.544	0.527
International shipping [e]	0.717	0.851	0.984	1.047
ENERGY BY FUEL (Quads)				
Petroleum	6.490	5.931	5.204	3.572
Natural gas	0.535	0.729	1.006	1.913
Electricity (end-use)	0.239	0.232	0.226	0.205
Renewables	0.000	0.027	0.204	0.500
TOTAL ENERGY USE (Quads)	7.263	6.918	6.642	6.190

FUEL SHARES	1990	2000	2010	2030
Petroleum				
Truck	100.0%	96.4%	86.5%	54.3%
Rail	97.4%	87.7%	77.9%	58.4%
Water	100.0%	93.5%	87.0%	74.0%
Air	100.0%	100.0%	100.0%	100.0%
Pipeline	0.0%	0.0%	0.0%	0.0%
Natural Gas				
Truck [h]	0.0%	3.0%	8.5%	32.0%
Rail [i]	0.0%	9.7%	19.5%	39.0%
Water [j]	0.0%	6.5%	13.0%	26.0%
Air	0.0%	0.0%	0.0%	0.0%
Pipeline	0.0%	0.0%	0.0%	0.0%
Electricity				
Truck	0.0%	0.0%	0.0%	0.0%
Rail	2.6%	2.6%	2.6%	2.6%
Water	0.0%	0.0%	0.0%	0.0%
Air	0.0%	0.0%	0.0%	0.0%
Pipeline	100.0%	100.0%	100.0%	100.0%
Renewable [i]				
Truck	0.0%	0.6%	5.0%	13.7%
Rail	0.0%	0.0%	0.0%	0.0%
Water	0.0%	0.0%	0.0%	0.0%
Air	0.0%	0.0%	0.0%	0.0%
Pipeline	0.0%	0.0%	0.0%	0.0%

Notes for Table D10, Freight Transportation Environmental Scenario

[a] Unless otherwise specified below, activity levels as well as notes and sources are the same as for the reference case, Table D8.

[b] Reflect truck-to-rail mode shifting as specified in Table D4.

[c] We assume that the 85% fuel economy improvement (Table D5, based on Sachs *et al.* 1991) is reached by 2020 through faster penetration of the technologies. The 101% improvement based on inclusion of weight reduction and lower speeds is then reached by 2030, even though the latter has a high cost (due to the value of travel time--see text). Intermediate years are interpolated from the resulting average improvement rates of 2.1%/yr 1990-2020 and 0.8%/yr 2020-2030.

[d] Based on MPG values and assuming no change in average loading factor.

[e] EIA/SR, Table I-5, p. 218.

[f] Air freight efficiency improvement taken to be the same as for air passenger travel, as given in Appendix C.

[g] Pipeline efficiency improvement taken to be the same as domestic waterborne freight, assuming a comparable level of improvement is applicable to motors and pumping equipment.

[h] Natural gas fuel shares taken from EIA/SR, Table I-5, p. 218.

[i] Phase in a rail freight shift to natural gas, reaching 40% of the non-electric rail by 2030.

[j] Phase in a shift of domestic waterborne freight to natural gas fuel, displacing 40% of the 66% non-residual oil share by 2030.

[k] Renewable fuels assumed to be in form of alcohol and fuel shares taken from EIA/SR, Table I-5, p. 218, unless limited by our estimated supply of renewables, as discussed in text.

Table D11
Freight Transportation Climate Stabilization Scenario

	1990	2000	2010	2030
ACTIVITY (Gt-mi) [a]				
Truck	1755	1952	2192	2613
Rail	830	939	1069	1350
Water	851	863	888	898
Air	7.8	9.5	11.7	16.5
Pipeline	846	862	888	901
TOTAL	4288	4626	5049	5778
TRUCK				
Avg load (ton/vehicle)	5.59	5.59	5.59	5.59
VMT (10^9)	314	349	392	467
MPG [b]	8.6	11.0	13.0	18.5
ENERGY EFFICIENCY INDEX				
Truck [b]	1	0.781	0.664	0.464
Rail	1	0.895	0.796	0.612
Water	1	0.950	0.900	0.800
Air [c]	1	0.793	0.474	0.249
Pipeline [d]	1	0.900	0.800	0.700
E. INTENSITY (Btu/ton-mile)				
Truck	2808	2193	1864	1303
Rail	443	396	353	271
Water	402	382	362	322
Air	18809	14916	8915	4683
Pipeline	271	244	217	190
ENERGY BY MODE (Quads)				
Truck	4.927	4.281	4.086	3.404
Rail	0.368	0.372	0.377	0.366
Water	0.342	0.330	0.321	0.289
Air	0.146	0.142	0.104	0.077
Pipeline	0.229	0.210	0.193	0.171
OTHER (NOT MODELED) (Quads)				
Nat. gas pipelines	0.535	0.537	0.544	0.527
International shipping	0.717	0.851	0.984	1.047
ENERGY BY FUEL (Quads)				
Petroleum	6.490	5.358	4.264	1.125
Natural gas	0.535	0.739	1.304	1.846
Electricity (end-use)	0.239	0.220	0.202	0.180
Renewables	0.000	0.406	0.839	2.730
TOTAL ENERGY USE (Quads)	7.263	6.723	6.609	5.881

FUEL SHARES	1990	2000	2010	2030
Petroleum [e]				
Truck	100.0%	88.5%	68.0%	1.0%
Rail	97.4%	78.4%	49.4%	1.4%
Water	100.0%	88.5%	72.0%	0.0%
Air	100.0%	95.0%	80.0%	50.0%
Pipeline	0.0%	0.0%	0.0%	0.0%
Natural Gas [f]				
Truck	0.0%	3.0%	15.0%	32.0%
Rail	0.0%	14.0%	28.0%	39.0%
Water	0.0%	6.5%	13.0%	30.0%
Air	0.0%	0.0%	0.0%	0.0%
Pipeline	0.0%	0.0%	0.0%	0.0%
Electricity				
Truck	0.0%	0.0%	0.0%	0.0%
Rail	2.6%	2.6%	2.6%	2.6%
Water	0.0%	0.0%	0.0%	0.0%
Air	0.0%	0.0%	0.0%	0.0%
Pipeline	100.0%	100.0%	100.0%	100.0%
Renewable [g]				
Truck	0.0%	8.5%	17.0%	67.0%
Rail	0.0%	5.0%	20.0%	57.0%
Water	0.0%	5.0%	15.0%	70.0%
Air	0.0%	5.0%	20.0%	50.0%
Pipeline	0.0%	0.0%	0.0%	0.0%

Notes for Table D11, Freight Transportation Climate Stabilization Scenario

[a] Unless otherwise specified below, activity levels as well as notes and sources are the same as for the environmental scenario, Table D10.

[b] For this scenario, year 2030 only, we have extrapolated beyond the assessment of Table D5 by assuming that, under pressure to meet the climate contraint, truck efficiency continues to improve at 2%/yr from 2010-2030.

[c] Air freight efficiency improvement is taken to be the same as for the air passenger travel climate stabilization scenario, as discussed in Appendix C.

[d] There is an added improvement in pipeline efficiency over the environmental scenario, assuming some further optimization of pumping systems.

[e] Petroleum shares are the remainder after using allocations of natural gas and available renewables as needed to cut the petroleum share as low as possible (with rounding).

[f] Natural gas penetration rates are assumed to be more aggressive than in the environmental scenario.

[g] Renewable fuels are assumed to be an unspecified combination of alcohol, biodiesel, and hydrogen. Available renewable allocations are taken as 0.5 Quad in 2000, 1 Quad in 2010, and 3 Quads in 2030. With the exception of air freight, renewables are used as needed to make petroleum share as small as possible. No attempt was made to back out either petroleum in international shipping or natural gas, but unused renewable allocations could presumably be applied to these uses to obtain addition CO_2 emissions reductions.

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A Social Cost Analysis of Alternative Fuels for Light Vehicles

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A Social Cost Analysis of Alternative Fuels for Light Vehicles

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ABSTRACT

In this paper, we perform a social cost analysis of alternative fuels for light duty vehicles, comparing natural gas, electricity, methanol, and gasoline. The fuels were analyzed in two different scenarios, referred to as "near-term" and "longer-term", reflecting evolution of technologies and environmental requirements. In each scenario, we ascribe values to environmental impacts (in particular, externalities) from air pollution, based on two alternative conditions or settings, one reflecting air pollutants released in an severely polluted urban area and the other reflecting air pollutants released in a populated, yet less polluted area. Air emissions from fuel extraction, processing and transportation are included in the analysis, and valued at the externality costs corresponding to the populated, yet less polluted area. As other externalities associated with light vehicle transportation such as congestion and energy security are not included, the social cost analysis presented here should be considered partial.

We find that in the *near term*, light duty vehicle travel using gasoline will likely continue to have the lowest direct cost, and the lowest social cost, for either of the environmental settings (externalities values). These results assume that all vehicles meet the relatively stringent requirements of the US 1990 Clear Air Act Amendments, which restrict emissions to levels much lower than is typical of cars on the road today.

In the *longer-term*, light duty vehicle travel using electricity potentially will have the lowest direct cost, and the lowest social cost, either of the environmental settings (externalities values). However, the advantage of electric vehicles is not decisive, and any number of different, yet plausible sets of assumptions could change the results such that any of the fuel could be "least cost".

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INTRODUCTION

In this paper, we present a "social cost" analysis of alternative fuels for light duty vehicles -- gasoline, natural gas, methanol and electricity -- taking account of projected improvements in vehicle efficiencies and changes in vehicle emissions requirements. More accurately, this analysis might be considered a "partial" social cost analysis, because other impacts that may not be fully internalized, such as energy security, congestion, water pollution, accidents and safety, noise have not been included. Also, technologies such as solar or hydrogen fuelled cars, which are not expected be market-ready within the decade, were not considered.

We applied a "societal perspective" in five respects. First, we applied monetary environmental externalities costs to air pollutant emissions. Second, we included all costs of the different vehicles, without regard to whether the cost is incurred by the fuel provider, vehicle owner or otherwise. Third, we ignored taxes, subsidies and other transfer payments[1]. Fourth, we used a social discount rate: 3% real. Finally, we took the full "fuel cycle" into account by estimating the "upstream" emissions from fuel extraction, production and delivery.

We applied two sets of monetized environmental externality costs (cost per ton of pollutant emitted) to the direct vehicle emissions, one set adopted by the California Public Utility Commission, based on Southern California air quality regulations, and one adopted by the Massachusetts Department of Public Utilities, for electric utility resource planning, (Bernow and Marron 1990, California PUC 1991). These reflect conditions in two settings, respectively, a severely polluted densely populated urban area (the South Coast Air Quality Management District -- SCAQMD -- in southern California) and a less polluted urban area. Both sets of values are based principally on the "regulators' revealed preference" method, using the marginal costs of pollution control at the point of emissions embodied in exiting environmental policy and regulation for the externalities values to be used in utility sector planning. The lower, Massachusetts, values were applied to the upstream emissions throughout the analysis[2].

Ideally, integrated energy/environmental planning for transportation would address the complex trade-offs between mode choice and related land-use, frequency and distance of trips, environmental impacts in media other than air, and other economic factors. However, because the integrated planning paradigm is relatively new, and most alternatively fuelled vehicles are in their infancy, we took a limited approach, examining the costs and benefits of alternative vehicle fuels relative to major competing fuels in light duty vehicles, and held other factors constant.

ASSUMPTIONS

Two basic scenarios were evaluated, referred to as "near-term" and "longer-term." For natural gas and methanol vehicles (NGVs, MVs), the longer-term scenario assumes a *well* *developed* market: factory built, dedicated vehicles and high sales at the public refuelling stations. For electric vehicles (EVs), the longer-term scenario assumes a long battery life and the low end of the incremental cost estimates. The near-term scenario for natural gas and methanol fuelled vehicles assumes the present, *minimally developed* market: retrofitting existing cars and low load factors at the public refuelling stations. The near-term EV scenario assumes near term forecasts of battery life and incremental vehicle costs. The basic vehicle model and operating characteristics (miles driven, driving conditions) was assumed constant across the different fuels.

Vehicle Cost and Performance

Table 1 presents the vehicle costs of the alternatively fueled vehicles. As the table shows, NGVs are anticipated to be about 17% more costly than gasoline vehicle in the near term and about 7% more costly in the longer term. The bulk of this additional cost is for the high pressure compressed natural gas cylinder necessary to store the on-board fuel. MVs are expected to be only marginally more expensive than gasoline vehicles in the near term and equivalent in the longer term. EVs are assumed to be 70% more expensive in the near term and 15% more expensive in the longer term than gasoline vehicles, with the majority of the additional costs due to the batteries. All costs in the longer-term scenario account for the additional costs necessarily incurred by the internal combustion engine vehicles in order to meet the more stringent emissions requirements (California Air Resources Board 1990).

The standard gasoline vehicle, MV and near term NGV are assumed to have a vehicle life of about 125 000 miles, or 12 years at our assumed annual vehicle miles travelled. EVs are assumed to have a somewhat extended life--150 000 miles (15 years). This is due to simpler powertrain, and the fact the electric motors have much longer lives than internal combustion engines. The one year life extension for NGVs in the longer-term is due to the anticipated advantage of reduced engine wear when burning a gaseous fuel[3].

This reduction in NGV engine wear also accounts for the reduced maintenance cost estimated for NGVs in the longer term scenario. The reduced EV maintenance costs is due to the relative simplicity of the EV drivetrain relative to vehicles with internal combustion engines (e.g., Deluchi 1992). The reduced insurance cost for EVs is due to the fact that the insurance costs are levelized over more years, and that the insurance costs in the latter years are not only discounted more but also are lower due to reduced insurance coverage of the older vehicle (Deluchi 1992). Note that this analysis does not take into account other possible differences collision or liability insurance rates between EVs and gasoline vehicles.

The base gasoline vehicle efficiencies in the two scenarios are based on Union of Concerned Scientists 1991[4]. In the near term, no efficiency advantages are assumed for MVs or NGVs, but in the longer-term, we assume some increased efficiencies due to the implementation of engines optimized around the higher octanes of the alternative fuels.

Table 1: Summary of Assumptions

	Gasoline (a)	Natural Gas (b)	Methanol (c)	Electricity (d)
Vehicle Costs (1)				
Near-Term	$14,000	$16,500	$14,400	$24,000
Longer-Term	$14,370	$15,400	$14,370	$16,170
Vehicle Life, Years (2)				
Near-Term	12	12	12	15
Longer-Term	12	13	12	15
Levelized Annual Maintenance Cost (3)				
Near-Term	$436	$436	$436	$291
Longer-Term	$436	$353	$436	$291
Levelized Annual Insurance Cost (4)				
Near-Term	$468	$484	$468	$443
Longer-Term	$468	$471	$468	$443
Fuel costs $/GJ				
High fuel (5)	$8.09	$4.25	$14.00	$13.89
High distribution (6)	$1.14	$4.02	$3.51	$7.01
High Total	$9.23	$8.27	$17.51	$20.90
Low fuel (5)	$6.28	$3.75	$9.00	$8.33
Low distribution (6)	$1.14	$2.14	$2.13	$7.01
Low Total	$7.42	$5.89	$11.13	$15.34
Vehicle Efficiency				
Near Term, l/100km (7)	7.8			
Relative to Gasoline (8)		1.00	1.00	3.4
Longer Term, l/100km (7)	4.7			
Relative to Gasoline (8)		1.1	1.15	2.9

Note and Sources:

(1) (a) Longer term gasoline vehicle incremental costs from California Air Resources Board 1990 (emissions control improvement) and Union of concerned Scientists 1991 (efficiency improvement).
(b) Incremental NGV costs based on DOE 1990, California Air Resources Board 1990, US EPA 1990 and Deluchi et al, 1988.
(c) Incremental Methanol costs based on estimates from DOE 1990, California Air Resources Board 1990, US OTA 1990, Deluchi et al, 1988, and Krupnick et al 1990.
(d) Incremental Electric Vehicle costs based on estimates from DOE 1990, California Air Resources Board 1990.

(2) (a) Based on a 192 000 km vehicle life
(b) Natural Gas vehicle life assumed to be the same in Near-Term, and 1 year longer in the longer-term (8.3% longer). The longer life of NGVs is due to reduced engine wear during cold-starts. Deluchi et al 1988 estimates NGV to have 23% longer life than gasoline equivalent.
(c) Assumes same life as gasoline vehicle
(d) Based on Deluchi 1992, which estimated EV having 33% longer life than standard gasoline vehicles (mileage Basis)

(3) (a) From Deluchi 1992 and FHWA 1990. Levelized over life of vehicle.
(b) In longer term, assumes maintenance at 80% of that of gasoline vehicle (Deluchi and Sperling, 1988).
(c) Assumes the same as gasoline vehicles.
(d) From Deluchi 1992.

(4) (a)From Deluchi 1992. Assumes collision damage insurance is carried for first 5 years.
(b) Calculated using methodology in Deluchi 1992. Assumes that the vehicle carries collision damage insurance for first 6 years.
(c) Assumes the same as gasoline vehicles.
(d) From Deluchi 1992. Assumes that the vehicle carries collision damage insurance for first 6.5 years.

(5) (a) From EIA 1993, Tables D3 and E3. Levelized from 1995 to 2010.
(b) From EIA 1993; Tables E3 and F3, delivered industrial price. Levelized from 1995 to 2010.
(c) Based on Estimates from DOE 1990, EPA 1990, Deluchi et al 1988, Krupnick 1990, EPA 1990.
(d) Assumes range of fuel and operating cost for existing coal-steam or natural gas combined cycle power plants.

(6) (a) From EPA 1989
(b) From Deluchi et al 1988
(a) From EPA 1990
(d) Assumes $500 for home recharger, levelized over life of vehicle.

(7) (a) Based on Union of Concerned Scientists 1991, Table C7
(b) Based on Deluchi et al 1988.
(c) Based on Deluchi et al 1988.
(d) Based on Union of Concerned Scientists 1991, Table C15. UCS 1991 assumes that EVs will increase in efficiency, however not as quickly as gasoline and other IC engine vehicles.

The particularly high efficiency of electric vehicles illustrates two interesting points related to motor efficiency and vehicle design. First, electric motors are much more efficient than any kind of heat engine, whose efficiency is ultimately limited by thermodynamics. Thus, EVs are inherently more efficient per unit of energy *directly* consumed by the vehicle. However, when the efficiency of the power plant supplying electricity to the vehicle is taken into account, the primary fuel use per mile travelled by an EV is comparable to that of combustion engine driven vehicles. Second, because of the very low energy and power density of the batteries, many efficiency improvements such as very low drag design, very light materials, and low friction tires will likely be standard on EVs[5]. This contrasts with NGVs, particularly retrofit ones, which at least in North America are typically middle- to large-sized American built automobiles.

Fuel Costs

The electricity and gas costs used here reflect North American utility *marginal costs*, including transmission and distribution. Use of marginal costs more accurately reflects the true resource cost than do rates or tariffs, and it eliminates the assumption of political or strategic pricing of the fuels[6]. For gasoline and methanol, we assume that the market prices reflect producers' marginal cost of gathering, transporting and refining the fuels. The costs of gasoline and natural gas power plant fuel were taken from the US Department of Energy's long range energy outlook (EIA 1993). Methanol prices were based on various estimates for the production and distribution cost of methanol (DOE 1990, California Air Resources Board 1990, U.S. OTA 1990, DeLuchi et al 1988, Krupnick et al 1990.)

Because of the differences among the States, and ever evolving energy policy, all sales taxes, fuel taxes, and government grants are excluded from our analysis.

Vehicle Emissions

The vehicle emission factors presented in Tables 2 and 3 are used throughout the analysis. In the near-term scenario, we assume gasoline vehicle emissions meet the requirements of the 1990 U.S. Clean Air Act Amendments (CAAA). In the long-term scenario, we assume gasoline vehicle emissions meet the requirements of the California Ultra-Low Emissions Vehicle (ULEV) standards. Tailpipe emissions from alternatively fueled vehicles in either scenario are assumed to be the lower of either the appropriate standard or published estimates of vehicle emissions characteristics.

It is likely that EVs would be recharged during off-peak hours when low operating cost "baseload" units would be on the operating margin of the utility system. The mix of such units and their emissions factors would differ from one utility system to another, particularly in the near term, and could change over time as cleaner plants are brought into service. In the near-term scenario, we have assumed that EVs would be charged with power generated from a mix of existing coal plants with the characteristics of those now

Table 2. Pollutant Emissions Factors for Gasoline, Methanol and Natural Gas Vehicles, Grams Pollutant per mile.

	Near Term (1)			Longer Term (2)		
	Gasoline	Natural Gas	Methanol	Gasoline	Natural Gas	Methanol
CO2	307	230	477	184	125	477
NOx	0.4000	0.4000	0.4000	0.2000	0.2000	0.2000
VOC	0.1250	0.0625	0.0838	0.0400	0.0100	0.0268
CO	3.4000	1.4000	3.4000	1.7000	0.2000	1.7000
TSP	0.0032	0.0000	0.0000	0.0032	0.0000	0.0000
SOx	0.0470	0.0000	0.0000	0.0470	0.0000	0.0000

Notes and Sources:

(1) Near Term Assumes gasoline vehicles meet the emissions promulgated in the 1990 U.S. Clear Air Act Amendments (CAAA);
CO2 values based on 7.8 l/100 km gasoline efficiency
NGVs VOC emissions are assumed to be 50% less than gasoline standards (including reactivity adjustments)
Methanol VOC emissions are assumed to be 33% less than gasoline standards (including reactivity adjustments).
Methanol vehicles CO emissions are assumed to meet applicable standards (i.e., no emissions benefits).
NGVs and Methanol vehicles NOx emissions are assumed to meet applicable standards (i.e., no emissions benefits).
MV and NGV particulate and SOx emissions are assumed to be negligible relative to that of gasoline vehicles.
(2) Long-Term Assumes gasoline vehicles meet California Ultra-Low Emissions Vehicle requirements;
CO2 values based on 4.7 l/100 km gasoline efficiency
NGVs and Methanol vehicles NOx emissions are assumed to meet applicable standards (i.e., no emissions benefits).
Methanol vehicles CO emissions are assumed to meet applicable standards (i.e., no emissions benefits).
NGVs and Methanol vehicles NOx emissions are assumed to meet applicable standards (i.e., no emissions benefits).
Note that other species other than those shown will be emitted, however, data is less complete for these species and their contribution to net externality costs are assumed to be small relative to those shown above and therefore omitted.
MV and NGV particulate and SOx emissions are assumed to be negligible relative to that of gasoline vehicles.
See text for further discussion and references on emissions characteristics.

Table 3. Pollutant Emission Factors for Electric Generation and Electric Vehicles.

	NOx	SOx	CO2	CH4	CO	TSP	VOC
Existing North-Central US Coal (meeting 2000 standards) gram per kWh	2.3700	4.1800	937	0.0062	0.1320	0.2244	0.0220
Effective Electric Vehicle Emissions at 0.222 kWh/km (near term scenario) gram per km	0.5261	0.9280	208	0.0014	0.0293	0.0498	0.0049
New Natural Gas Combined Cycle gram per kWh	0.2762	0.0021	416	0.0001	0.0769	0.0454	0.0294
Effective Electric Vehicle Emissions at 0.156 kWh/km (longer-term scenario) gram per km	0.0431	0.0003	65	1.56E-05	0.0120	0.0071	0.0046

Source:
Union of Concerned Scientists (1992), Technical Appendices, Tables I1,I2,I3, and H3.

serving the North Central US. In the longer-term scenario, we have assumed that EVs would be charged with power generated from a new natural gas combined cycle power plant with steam injection for NO_X reduction and an oxidizing catalyst for CO and VOC reduction. To the degree that a different mix of marginal plants were available during EV recharging times, or could evolve over time, the marginal externalities costs (as well as the marginal cost of electricity for recharging) would differ from those assumed here.[7] However, the two technologies chosen represent a reasonable envelope of "clean" and "dirty" technologies that could realistically be used for EV charging.

Upstream Emissions

The air emissions due to oil, gas and coal extraction, processing and transportation included in the analysis are shown in Table 4. The primary source for upstream emissions estimates is Deluchi 1991. These values were corroborated and supplemented with data from DOE 1983 and Frische 1990.

The "downstream" pollution associated with equipment disposal are not addressed here. However, based on earlier work at Tellus on the pollution generated during the life-cycle of various materials indicated that the majority of pollution impacts occur in production and operation rather than disposal (Tellus Institute, 1991).

Table 4. Upstream Pollutant Emissions, Pound per MMBTU Consumed by Vehicle.

				Electricity generated from	
Pollutant	Natural Gas	Gasoline	Methanol	Coal	Natural Gas
CH4	0.42	0.14	0.26	2.12	0.53
CO	0.16	0.21	0.16	0.09	0.24
NMOC	0.01	0.02	0.02	0.01	0.02
NOx	0.24	0.18	0.44	0.10	0.35
CO2	70.19	70.69	101.25	18.93	46.51
SOx	2.86E-06	0.09	2.86E-06	0.01	7.15E-06

Sources:
CH4, CO, NMHC, NOx and CO2:
Natural Gas, Gasoline emissions calculated from Deluchi 1991, Volume 1, Tables 2,3 and 10.
Electric emissions from Deluchi 1991, Volume 1, Table 2 and 3 and Volume 2, Table D-8.
SOx:
Natural Gas and coal from DOE 1983, extraction, production and transportation.
Gasoline from Frische, 1990;
Methanol assumed to be produced from natural gas, and thus has the same SOx emissions as gas

Valuing Air Emissions Externalities

To value the air emissions in a social costing analysis, the externality values presented in Table 5 were applied to the tailpipe emissions of the vehicles and to the power plant emissions for electric vehicles. In both scenarios, we considered two sets of externality values, nominally referred to as "congested urban" and "urban/suburban." The congested urban values were derived from air quality regulation in the Los Angeles area and the urban/suburban values are those adopted in Massachusetts for electric resource planning. Other values could be used within the same framework. For example, recent values were developed by the California Energy Commission for the SCAQMD region (CEC 1993, based on "damage costing" techniques which attempt to estimate impacts at the ends of the various pollutant pathways, and to value them using market or market-like behavior. The externalities for which these values were estimated included primarily human health, visibility and crop impacts. The CEC values for SO_2, NO_x, and VOC are between one-third and one-half of the PUC values, while its value for TSP is about eight times the PUC value. A discussion of the "damage costing" and "regulators revealed preference" approaches to externalities valuation can be found in (Bernow and Biewald 1993).

The upstream emissions were valued at the lower urban/suburban costs throughout the analysis[2]. A more detailed analysis of externalities would distinguish between localized urban pollution and more dispersed regional pollution, and demographic, climatological and emissions patterns.

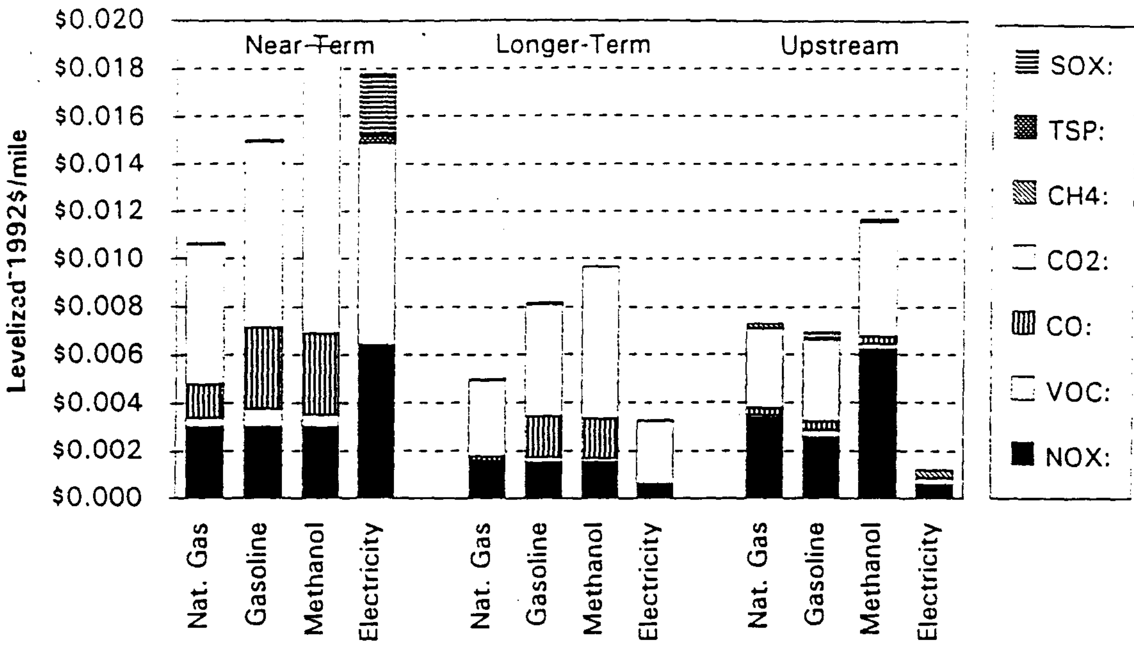
The contributions of the individual pollutants to the overall externality cost are shown in Figure 1. For the urban/suburban values, NO_X and CO_2 emissions contribute the most to the externality costs. For the vehicles using internal combustion engines, CO emissions also contribute; for EVs, SO_X emissions contribute substantially[8]. In the longer term, CO_2 emissions dominate the overall externality cost for all four fuels, owing to the dramatic reductions in other pollutants from more stringent regulations. The congested urban value externality value for EVs is relatively large because of the combination of higher SO_X emissions and the very high value placed on sulfur emissions in the Los Angeles area by regulators in California. For the upstream emissions, NO_X and CO_2 emissions account for the majority of the externality costs.

Table 5. Environmental Externality Costs, Levelized $/Ton.

	NOX	VOC	CO	CO2	CH4	TSP	SOX
Urban/Suburban	$6,793	$5,539	$909	$23	$230	$4,180	$1,568
Congested Urban	$28,524	$20,374	$909	$23	$220	$6,171	$21,306

(1) Urban/Suburban Values are those adopted in Massachusetts for use in electric resource planning (Bernow and Marron 1990).
(2) Congested Urban Values from California Public Utilities Commission, 1991. Applicable to the greater Los Angeles area.

Figure 1: Urban/suburban Externality Costs by Pollutant.



It is also important to note that the net emissions costs in the longer-term scenario are much less that in the near term scenario, owing to the projected vehicle efficiency improvements, the very stringent emissions requirements and, in the case of the EVs, the relatively clean and efficient electricity generation.

RESULTS

Baseline Results

Table 6 summarizes the lifecycle costs with and without environmental externalities. In the near term, with only direct costs included (e.g, not environmental externalities), gasoline vehicles have the lowest cost, followed by natural gas, methanol and electricity. In the longer-term scenario, electric vehicles have the lowest direct cost, followed by natural gas, gasoline and methanol.

The inclusion of environmental externalities increases the cost of travel but, because the net externality values are so similar among the fuels (except electricity) they do not change the cost relationships between the different fuels. Nor are the externality costs particularly high relative to the other costs of purchasing and operating a vehicle. In the near term scenario, the congested urban environmental externality cost makes up less than 10% for the combustion engine vehicles and about 25% for the EV. In the long-term scenario, these fractions are even less. However, it is important to note that we assume vehicles that pollute much less than typical 1992 new cars, let alone the fleet on the road today. If the urban/suburban externality values were applied to the tailpipe emissions of the U.S. 1988 fleet average (Union of Concerned Scientists 1991), the resulting externality cost would be almost three times greater than that of gasoline vehicles in the near-term scenario, and almost five times greater in the longer-term scenario. On the other hand, MOBIL5 simulations and measurements of actual on-road emissions characteristics tend to be higher than the standards used here, indicating that our estimates of the emissions contributions to total costs for the IC engine vehicles are relatively conservative.

The assumption of the type of fuel used to generate the electricity for the EV is critical to these results. If, in the near term scenario a new natural gas combined cycle powerplant were assumed, then EVs would have life-cycle costs comparable to natural gas vehicles (but still not as low as gasoline). On the other hand, if an existing coal fired power plant were assumed to be used in the longer-term scenario, then the EV's advantage would disappear.

Table 6. Levelized Average Cost of Travel, $/mile.

a. Cost Components

	Vehicle	Insurance and Repair	Fuel	Externality Values: Upstream	Externality Values: Tailpipe/PowerPlant: Congested Urban	Externality Values: Tailpipe/PowerPlant: Urban/ Suburban
Near-Term						
Natural Gas	$0.167	$0.091	$0.031	$0.007	$0.011	$0.021
Gasoline	$0.141	$0.091	$0.036	$0.007	$0.015	$0.028
Methanol	$0.145	$0.091	$0.063	$0.012	$0.019	$0.030
Electricity	$0.202	$0.075	$0.020	$0.001	$0.018	$0.071
Longer-Term						
Natural Gas	$0.146	$0.083	$0.017	$0.004	$0.005	$0.010
Gasoline	$0.145	$0.091	$0.022	$0.004	$0.008	$0.015
Methanol	$0.145	$0.091	$0.034	$0.006	$0.010	$0.015
Electricity	$0.138	$0.074	$0.016	$0.002	$0.003	$0.005

b. Totals

	Without Externalities	With Externalities, Tailpipe/Power Plant at: Congested Urban Costs	With Externalities, Tailpipe/Power Plant at: Urban/ Suburban Costs
Near-Term			
Natural Gas	$0.289	$0.307	$0.317
Gasoline	$0.269	$0.291	$0.303
Methanol	$0.299	$0.330	$0.341
Electricity	$0.297	$0.316	$0.369
Longer-Term			
Natural Gas	$0.245	$0.254	$0.259
Gasoline	$0.258	$0.270	$0.277
Methanol	$0.270	$0.286	$0.291
Electricity	$0.228	$0.233	$0.235

Finally, if EVs were charged using a renewable resource, the externality costs would be even lower, potentially making electricity the least-cost fuel. This highlights the important point that if air-emissions externalities are included in transportation analysis, the marginal electric generating facilities serving the EVs must be identified and their emission characteristics understood.

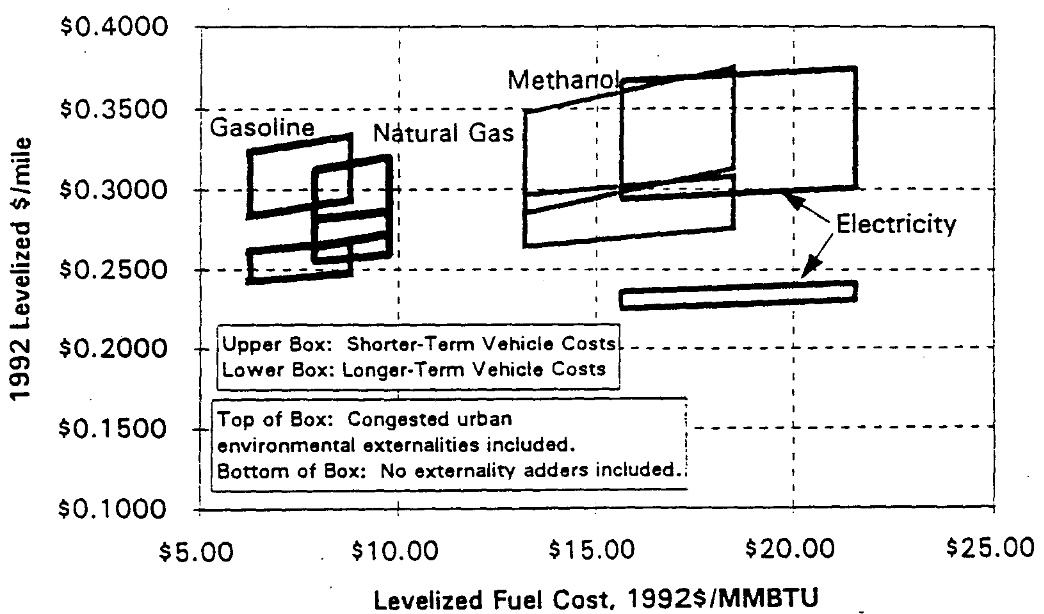
A second interesting variation considers the near-term scenario where the vehicles are located in an highly polluted urban area but the marginal electric generating station is located in a more remote area. When the congested urban externality values are used for the tailpipe emissions and the urban/suburban values are used for regionally dispersed power plant emissions, then electric vehicles come close in cost to natural gas and methanol (but still not as low as gasoline).

Sensitive of Results to Kev Parameters

Figure 2 illustrates the sensitivity of the results to variations in a number of important parameters. The x-axis in Figure 2 shows the fuel cost, including all fuel production, distribution and infrastructure costs; the y-axis is the levelized cost per mile of travel.

For each fuel there are two "boxes." The lower box for each fuel assumes the vehicle characteristics and costs of the longer-term scenario; the upper-box for each fuel assumes the vehicle characteristics and costs of the near-term scenario. The bottom of each box

Figure 2: Sensitivity of Levelized Average Cost of Travel to Fuel Cost, Externality Values, Vehicle Cost and Efficiency



represents the cost per mile of travel without environmental externalities. The top of each box is the cost per mile when the congested urban externality values are included. The area enclosed by the box represents the range of costs which could be expected for the given vehicle cost and efficiency assumptions.

The sensitivity of the results to fuel costs is seen in the slopes of the bottom of each box. The steeper the slope, the less fuel-efficient the vehicle and the more sensitive the cost per mile is to fuel cost. However, none of the vehicles shown here is particularly sensitive to fuel cost; an almost 50% increase in fuel cost for NGV increases the per mile cost by only 3.5%. Even the most sensitive case, methanol in the near-term, a 50% increase in fuel costs increases the per-mile cost only 5.4%.
The figure also illustrates that the cost per mile of travel is highly sensitive to assumptions concerning vehicle cost and efficiency. The large gap between tho two electric vehicle cases is due to the huge variation in assumed vehicle costs. The difference between the near term and longer term boxes for methanol is due almost exclusively to the assumed fuel economy differences between the two scenarios.

Limitations and Uncertainties

The large "gaps" between the sensitivity boxes in Figure 2 for the same fuel, owing to differing assumptions on alternative fuel vehicle cost and fuel economy, make it very difficult to draw definitive conclusions regarding the relative merits of alternative vehicle fuels. While it is true that in the longer-term, EVs look to have a potential cost-per-mile advantage, if the vehicle costs do not come down as much as projected, if the vehicle life advantage assumed here does not occur, or if one of many other assumptions prove to be inaccurate, the results would change-- i.e., stay in the range of the upper box.

Market uncertainty, characteristics of service and consumer behavior are very important issues treated only cursorily in this study. The ranges that the alternative fueled vehicles can travel between refuelling are generally significantly less than a gasoline vehicle (OTA 1990). EVs will not be able to be charged in four minutes or less, as can gasoline, methanol and even natural gas vehicles (OTA 1990) Vehicles using different fuels will perform differently; MVs are expected to have *better* power and acceleration than gasoline vehicles, but with potential difficulties starting in cold weather. NGVs are anticipated to have slightly reduced performance relative to gasoline (owing to increased weight of the fuel cylinder) but decreased engine wear (Deluchi et al 1988). EVs will be much quieter and are expected to have reduced maintenance costs and hassle. How will consumers react to these differences? How should policy makers take these factors into account when contemplating alternative fuels policies? These are important questions whose answers are beyond the scope of this study.

A related issue not explicitly dealt with in this study was the dynamics of technological change. The analyses here are, for the most part, snapshots of present technologies and one possible scenario of the future. How would a region or nation move from the present status quo to one of the longer-term scenarios described here? If technology progresses significantly differently than what we have assumed here, particularly in terms of vehicle costs, then the result could tilt in favor or against any of the fuels. On the other hand, would different policies contribute to or retard pace of technological change to different degrees for the different technologies?

With regard to externalities, it should be noted that this analysis includes only air emissions, and not other non-priced impacts on the environment, human health and amenity. Also, the tailpipe emissions estimated here for the various IC engine vehicles are based on *standards*; rigorous modelling and empirical studies indicate that actual *on-road* emissions are generally higher than the standards, and would result in still higher externality costs.

Finally, it should also be reiterated that this analysis is from a "societal" perspective, and hence uses a low, societal discount rate. Using a higher, corporate or individual discount rate would tend to penalize vehicles with higher up-front costs, primarily EVs, and favor those with higher annual operating costs. The analysis is based on avoided fuel cost and ignores the fact that the costs would be split between various parties, e.g., fuel suppliers, federal and state governments, individual users, etc.). Full retail prices are not reflected; in particular, fuel taxes are not included; therefore, an individual user's perspective would be different.

POLICY IMPLICATIONS

A key to setting policies on alternative fuels is understanding the goals which the policies are to meet, as fuel choice is not an end in itself. By including only direct and environmental externality costs, we have implicitly assumed that the goal of alterative fuels in light duty vehicles is primarily improved air quality, subject to economic efficiency (which vehicle type is the least cost). Other quite reasonable goals for an alternative fuels policy might include energy security, domestic economic development, safety, or others. Moreover, alternative fuels policy is itself best placed within the broader context of integrated transportation energy and environment policy. Then, issues of urban congestion, land use, and the quality and place of *mobility* with the broader frame of *access* to goods, services and other societal activities, must come into play. Working towards these other goals might, in some cases, conflict with and, in others, contribute to the specific environmental goals addressed here. Nonetheless, our discussion focuses on policies that address those environmental goals, and how alternative vehicle fuels might fit in.

Standard Setting. Setting tailpipe and evaporative emissions standards is the most common transportation-environmental policy, resulting in the dramatic reductions in emissions seen since the early 1970s. Figure 1 indicates that setting standards can still be effective in reducing emissions. Emissions standards currently address only CO, NO_X and volatile organic compounds. The externality savings of the reductions in the Near Term standards (1990 Clean Air Act) to the Longer Term standards (California Ultra-Low emissions Vehicle) is still significant, let alone the difference in emissions between the typical cars on the road today and the levels assumed in the Near Term Scenario.

Setting tight standards also limits the effectiveness of using alternative fuels. Some of the inherent emissions benefits of using natural gas or methanol are eliminated when more stringent standards are applied to gasoline. For example, in both the near term and longer term, natural gas vehicles potentially offer significant CO reductions relative to gasoline or methanol, but in the longer term, the absolute CO savings is much less.

"Tailpipe" standards do not effect electric vehicles. Thus, while EVs can contribute to pollution reduction in congested metropolitan areas, there are regional increases from their power supply sources. The emissions of EVs are set by the marginal generating mix supplying the EV and the stationary source emissions standards governing those facilities.[9] The large improvement seen from the Near Term to the Longer Term scenario is due solely to the different generating supply assumptions (coal in the near term, gas combined cycle in the longer term), and is not connected to any particular standard.

Efficiency Improvements. Improvements in vehicle efficiency, no matter the policy mechanism used to induce them, significantly decrease CO_2, SO_X emissions, as well as all upstream emissions, owing to the reduction in fuel use. Although most transportation air quality discussions, and regulations, have focussed on CO and ozone precursors, *50% or more the externality costs assumed here come from CO_2 alone*[10]. The externality costs of the upstream emissions are often on the same order of magnitude as the direct emissions. Clearly, no matter the fuel being used, increased efficiency has role to play in reducing pollution from transportation.

Within a given set of emissions standards and vehicle efficiency assumptions, the use of fuels other than gasoline can have significant benefits, but these benefits are generally on the same order of magnitude at best as the improvements gained from setting stricter standards and efficiency improvements. Policies encouraging alternative fuels can be effective in reducing emissions, but alternative fuels alone should not be the only vehicle-oriented policy addressing air quality issues.

The Elusive "Level Playing Field." Given our conclusion that alterative fuels have role to play in transportation environmental planning and policy making, the large question becomes which fuel or fuels to support through which policy instruments. The analysis presented here and analyses elsewhere cannot point to a definitive "winner" in all contexts and conditions; differences in underlying conditions (e.g., location) and the uncertainty in many variables (e.g., vehicle mileage) could result in different fuels being least cost. Therefore, one approach, rather cavalierly put, is to "level the playing field," let all the alternative fuels compete, and "may the best fuel win." Of course, the winner may not be a single fuel as different mixes of transportation fuel at different times and in different contexts may evolve.

A difficulty with this approach is that the least-cost solution in the long-term may suffer from a poor starting position. For example, gasoline clearly has huge advantages in its existing infrastructure, and while natural gas has a nearly national transmission/distribution system in place it does not yet have a widespread refuelling system. By letting the market pick the winners, the implementation of options which in the longer term might be superior could be significantly impeded. Thus, focussed policy initiatives to help maintain a level playing field *over the longer term* may be needed.

The electric vehicles in this analysis are a good example. Clearly, a huge amount of research and development are needed before EVs could be expected to make a significant dent in the light vehicle market on economic merits alone. Policy makers at the both the federal and state levels, recognizing the long term potential of EVs, have chosen to support EV research financially, while the California LEV standards have gone as far as to effectively mandate a niche for EVs. Another promising vehicle type, fuel cell vehicles, will likely need a similar publicly supported R&D effort in order to become marketable.

Other Policy Instruments. This discussion so far has centered on technology oriented policy--what can government do to affect the technology in the marketplace, through emissions standards, efficiency improvements or support of less polluting alterative fuels. However the other side of the emissions equation is vehicle miles travelled (VMT). A "clean" vehicle driven a lot could be, on the whole, more polluting than a less clean one driven less. Although promulgating standards and mandating fuels are somewhat easier solutions, policies to reduce VMT, particularly in regions out of Clean Air Act ozone attainment, might be more effective in reducing transportation related emissions.

Pollution and/or fuel taxes may play a role in affecting driving behavior as well as vehicle purchase decisions and fuel choice.[11] Fees and or restrictions on access to parking in urban areas might also play a role, affecting congestion as well as urban air pollution. Incentives to reduce VMT either through trip reduction, van pooling or mode shifting for commuters could also be effective in solving a number of problems at once. Land-use decisions and infrastructure investments are important policy considerations that can interact with the other approaches. Enhanced vehicle inspections and maintenance requirements are being enacted in a number of states as an emission reduction strategy. Although analysis of these policies are beyond the scope of this paper, they should not be ignored when addressing the air pollution impacts of light duty vehicles, no matter the fuel.

CONCLUSIONS

In the near term, new gasoline vehicles will likely have the lowest direct costs, and the lowest societal cost when either set of environmental externalities are included. However, these results assume that gasoline vehicles will soon meet the relatively stringent requirements of the US 1990 Clear Air Act Amendments, which restrict emissions to levels much lower than is typical of cars on the road today.

In the longer-term, we find electricity to have the lowest direct costs and the lowest cost when either set of environmental externalities are included. But the great uncertainty in key assumptions such as externality values, vehicle costs, or electric generation source do not allow for definitive conclusions. Any number of reasonable and plausible changes in the assumptions could tilt the balance in favor of any of the fuels examined here. As noted earlier, however, the balance might ultimately tilt towards a mix of vehicle fuels, depending on the context.

The inclusion of environmental externalities affects the relationship between EVs and the vehicles using internal combustion engines. When the power supplying an EV is generated with existing, relatively dirty, coal power plants, then the externality costs of the sulfur emissions will add significantly to the cost of EVs. If new, clean burning gas combined cycle (or renewable) technology is applied the reduced externality values relative to the internal combustion engine alternatives provide electric vehicles a significant savings.

NOTES

1. Because fuel taxes are used to pay for the necessary road infrastructure, they should ideally be included in a social cost analysis. They were not included here because of state-to-state variations, particularly with respect to the alternative fuels.

2. It can be argued that because large amounts of petroleum refinery capacity is located in highly populated and polluted areas (e.g., New Jersey, Southern California, Houston, Texas), that the congested urban values might be more appropriate.

3. Much of the engine wear in a liquid fuelled engine comes during the cold start, when the fuel condenses and then combusts on the cylinder walls.

4. It should be noted that the Union of Concerned Scientists 1991 assumes a large increase in fuel economy from the present for the larger term scenario-- up to 50 miles per gallon. This aggressive value should not be seen as a prediction, but rather to help serve as a "high end" assumption in the analysis. The impacts on the results of differing efficiency assumptions are addressed in the sensitivity analysis section.

5. Most of the vehicle efficiency enhancements assumed on EVs could be applied to the other vehicles as well. However, in general these enhancements are seen as only justifiable on the EVs because of their particularly poor energy storage capabilities.

6. Ideally, electricity and gas tariffs would send the appropriate market signals reflecting the marginal resource costs.

years.

8. The large impact of SO_X emissions is due to our assumption that the electricity generated for EVs will come from coal. In regions where the marginal baseload fuel is natural gas, hydro or nuclear, the SO_X emissions impacts will be greatly reduced.

9. In addition to point source standards, the system-wide sulphur dioxide limitations embodied in Title IV of the 1990 Clean Air Act Amendments also limits emissions from electric generation, particularly from baseload coal units.

10. This result is a strong function of the CO_2 externality value used in the analysis. The externality value for CO_2 is very uncertain, and dollar per ton estimates have been made which are both significantly high and lower than the one used here.

11. Pay-As-You-Drive-Insurance is one such option that has been suggested, which is designed to be revenue neutral.

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FEEBATES FOR FUEL ECONOMY: Market Incentives for Encouraging Production and Sales of Efficient Vehicles

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Washington, D.C./Berkeley, California

FEEBATES FOR FUEL ECONOMY: Market Incentives for Encouraging Production and Sales of Efficient Vehicles

SUMMARY

This report discusses purchase price incentives for making fuel-efficient vehicles more attractive in the automotive marketplace. ***Feebate*** is a contraction of the words "fee" and "rebate." Applied to motor vehicle fuel efficiency, a feebate is a tax/subsidy system which specifies fees for "guzzlers" (vehicles of relatively lower efficiency) and rebates for "sippers" (vehicles of relatively higher efficiency). In the United States, a federal feebate program can be thought of as an extension of the existing gas guzzler tax. State feebate programs could involve tax surcharges ("fees") and tax credits ("rebates") developed as a modification of existing sales tax or licensing programs. Feebates can be designed to be either revenue neutral or revenue generating.

General principles for formulating feebates are described and a brief review is given of programs which have been recently proposed or enacted. Issues that need to be addressed in developing a workable feebate program are discussed, particularly treatment of light trucks and differential impacts on domestic and foreign manufacturers. Other issues identified include: appropriate magnitudes for fees and rebates; coordination with fuel economy standards; likely impacts on consumer and automaker decision making; potential energy savings; understandability to consumers; revenue impacts; tax equity considerations; coverage of alternatively fueled vehicles; and special considerations for state-level feebate programs.

Incorporating vehicle size into the calculation of feebates is a promising approach in our view. Size-adjusted feebates can avoid specifically favoring manufacturers whose model lines are concentrated on smaller vehicles at the expense of those whose model lines include larger vehicles. Efficient vehicles of any size can qualify for a rebate; likewise, fees are levied on the less efficient vehicles of any size. Detailed analysis is provided for feebates based on fuel consumption (or CO_2 emissions) adjusted by vehicle footprint (wheelbase times track width) or interior volume. We show that, by separating cars from light trucks and chosing an appropriate size-adjusted approach, it is possible to develop a feebate system which would not disadvantage U.S. automakers on the basis of the 1990 fleet mix. Because they are effective in addressing the manufacturer equity issue, we recommend the size-based feebate concepts presented here as a foundation for developing federal and state incentive programs.

Further analysis and implementation experience are needed before the effectiveness of feebates can be fully assessed. However, a strong feebate program would shift consumers' new vehicle purchase decisions toward more efficient vehicles. It would also affect manufacturers' product planning, providing an incentive for efficiency-oriented innovation. This technology forcing role (which is shared by ongoing strengthening of fuel economy standards) is likely to have a greater effect on fleetwide efficiency improvement than shifts in consumer choices alone. Feebates are therefore a promising way to reach long-term national objectives of reducing transportation oil use and its attendant adverse economic and environmental impacts. This report provides a concrete basis for developing specific proposals by presenting a detailed analysis of potential feebate programs and identifying the various issues which need to be addressed.

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An Updated Assessment of the Near-Term Potential for Improving Automotive Fuel Economy

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November 1993

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SUMMARY

Improving the fuel economy of cars and light trucks is the largest step that the United States can take to reduce petroleum use and its adverse economic and environmental impacts. The fuel economy of cars and light trucks (light vehicles) rose dramatically after 1973, peaking in 1987-88. Oil prices plunged in 1986, squelching market interest in fuel economy. Corporate Average Fuel Economy (CAFE) standards helped drive the increase in fuel economy, but standards have not been meaningfully raised since the mid-1980s. By 1993 most older, less efficient vehicles had essentially been replaced, particularly in terms of annual usage. Because fuel economy improvement has ceased, light vehicle fuel use is again growing at the same rate as the amount of driving, which is expected to increase 50% over the next two decades. The United States has sent more than a trillion dollars overseas for oil imports, equal to 70% of the cumulative trade deficit over the past two decades. Light vehicle fuel use accounts for 21% of U.S. carbon dioxide emissions. A major portion of hydrocarbon emissions is also directly related to gasoline use. These problems will continue to grow unless new vehicle fuel economy is substantially improved.

An understanding of the opportunities for cost-effectively improving new car fuel economy underpins the development of balanced policies for controlling light vehicle fuel use. A number of recent studies address this question. Estimates of the potential fuel economy of the new automobile fleet for the year 2001 range from 28 mpg (essentially no improvement over recent levels) to 45 mpg. Disagreements can be traced to divergent assumptions about the benefits, costs, applicability, and marketability of the technologies considered. Published estimates for improvements over the near-term (roughly 10 years) are limited in that only existing technologies are considered. The primary assessments are the studies by Energy and Environmental Analysis, Inc. (EEA), sponsored by federal agencies, and studies by auto industry consultants such as SRI. The National Research Council (NRC) study of 1992 drew mainly on these sources. The technologies included in these data bases are now already five or more years old; newer technologies and further refinements of the existing ones are not fully included.

This analysis considers more widespread use of technologies already in production plus the introduction of emerging technologies. Our review is organized as a menu of options, grouped under major headings representing the engine, transmission, and tractive load aspects of vehicle design. While this discrete approach is convenient for analysis, in reality engineers take a much more integrated approach to design. In fact, the creativity of engineers and designers continually refines and expands the menu of options which can be used to increase vehicles' efficiency and improve them in other ways as well. To both capture the integrated nature of technology refinement and check our results, we also apply an engineering model to perform an integrated analysis of efficiency improvements to a typical vehicle.

We base our assessment on the technology status of the new car fleet in 1990, which is taken as the base year for the analysis. We consider technology improvements that will improve fuel economy while maintaining the same average vehicle size and performance as in 1990. Available cost information is reviewed and technologies are screened according to cost-effectiveness, considering the fuel savings to all consumers over an average vehicle lifetime. We examine contemporary auto industry product cycles, development times, and rates of technology change, obtaining an estimate that 8-11 years of lead time are needed to achieve full penetration of the efficiency improvements. Given the late 1993 timing of this report (model year 1994 has started), this implies that the industry can achieve the estimated degree of fuel economy improvement by model years 2002-2005. There have undoubtedly

been increases in the use of some of the technologies since the 1990 base year assumed here. However, these technology improvements have not been directed toward fleetwide fuel economy improvement. Thus, achieving the vehicle efficiency increases estimated here could involve not only incorporation of new technology but also a redirection of existing technology applications. This suggests that the feasible improvements could actually happen more quickly or at lower cost than estimated here.

The resulting estimates of potential fuel economy improvement are presented in Box S1 (next page). Reflecting the uncertainties surrounding new applications of technology, we present our results at three levels of technical certainty:

> Level 1 includes technologies already in use in at least one mass market vehicle worldwide and which have no technical risk in that they are fully demonstrated and available;
>
> Level 2 incorporates measures which are ready for commercialization and for which there are no engineering constraints (such as emissions control considerations) which inhibit their use in production vehicles but which entail risk in that some "debugging" may be needed because of limited production experience;
>
> Level 3 technologies are those in advanced stages of development but which may face some technical constraints before they can be used in production vehicles.

In this context, technical risk is interpreted as the risk that a technology cannot be put into widespread use within the time horizon identified here at acceptably low cost (full production scale average cost). Allowing more time would lower the risk, but we are unable to say how much longer would be needed before such technologies could be counted on for widespread use at low cost. For options better characterized by degree of design refinement, such as aerodynamic improvements or weight reduction, the certainty levels are interpreted to be successively less conservative regarding the degree of improvement. Table S1 (page ix) lists the technologies through Level 2 and their estimated fuel economy benefits. Level 3 adds lean-burn and two-stroke engines, which must overcome nitrogen oxide emissions limitations before they can see widespread use throughout the fleet. Level 3 also includes further degrees of improvement in tractive load reduction.

In order of increasing technical uncertainty, the resulting estimates of achievable new car fleet average fuel economy are 40 mpg, 46 mpg, and 51 mpg. These values correspond to improvements of 43%, 65%, and 85%, respectively, over the 1990 base year average of 28 mpg. We also performed sensitivity analyses to investigate assumptions regarding fleet average acceleration performance and technology penetration. Increasing performance to the 1993 average lowers projected fuel economy by about 1 mpg; decreasing performance to the 1987 average raises it by about 1.5 mpg. There is a smaller sensitivity to the degree of technology penetration within the range considered. No change in average vehicle size is needed for the technology-based fuel economy improvements analyzed here.

While much judgment is clearly involved in policy development, we believe that our Level 2 estimate--a new fleet fuel economy improvement of 65% by 2002-2005--provides a reasonable target for public policies intended to increase automotive fuel economy. More ambitious targets might be justified under our Level 3 assumptions, since policy guidance can hasten the development and application of advanced technologies which have the potential for widespread commercialization.

Box S1. Achievable New Car Fleet Average Fuel Economy in 2002-2005, Incremental Cost, and Potential Nationwide Gasoline Savings.			
Technology Certainty:	Level 1	Level 2	Level 3
Achievable, Cost-Effective MPG	40	46	51
Average Added Cost per Car (1993$)	590	770	840
Average Cost of Conserved Energy ($/gal)	0.55	0.53	0.51
Potential Savings in 2000 (Mbd)	0.4	0.5	0.6
Potential Savings in 2010 (Mbd)	2.1	2.8	3.2

Fuel economy values are the EPA composite 55% city, 45% highway unadjusted test ratings; note that adjusted (vehicle sticker) MPG ratings are 15% lower on average. Potential nationwide gasoline savings are given in million barrels per day (Mbd); convert to carbon emissions reductions using 50.2 MT_C/yr per Mbd and to hydrocarbon emission reductions using 0.17 MT_{HC}/yr per Mbd.

Two types of checks corroborate the fleet-average technology penetration analysis used to obtain our summary results: simulation analysis of improvements for a typical vehicle and comparison to fuel economy levels actually achieved in a particular car.

Applying an engineering model relating fuel consumption to vehicle tractive loads and engine performance for standard driving cycles enables us to simulate the effect of technologies on a specific vehicle. Taking a 1991 Ford Taurus as an example, we analyze a set of Level 2 technologies applied to reduce vehicle loads and decrease engine friction. Figure S1 illustrates energy losses in the current vehicle (lighter bars) and the reduced losses in the improved vehicle (darker bars). The result is a 43% cut in fuel consumption per mile, implying a 75% improvement in fuel economy. Thus, applying technologies for tractive load reduction, engine specific power enhancement, and optimized transmission control raises the base vehicle's fuel economy from 27 mpg to 47 mpg, an increase just exceeding the fleet average we estimate at Level 2 certainty. Incorporating Level 3 technologies, such as lean-burn or two stroke engines and a greater degree of tractive load reduction, would permit an even greater improvement, to in excess of 50 mpg.

The 1992 Honda Civic VX provides a concrete example of fuel economy levels in the ranges we estimate. The lean-burn version has a composite unadjusted fuel economy of 60 mpg, slightly higher than the 58 mpg obtained by applying our Level 3 estimates to the 1990 subcompact fleet average of 31.5 mpg. The California version of the Civic VX has a fuel economy of 55 mpg, also higher than the 52 mpg average implied for subcompacts by our Level 2 technology estimates (without lean-burn engines). Although the Honda Civic VX is not an average car (as in the modeled Taurus example), it demonstrates substantial fuel economy improvements over a comparable Civic hatchback without reducing size or performance and using only some of the technologies reviewed here. Moreover, its improvements were already achieved, over one 4-year product cycle, while our projections allow 8-11 years of lead time for the fleet as a whole.

Accurately estimating the cost of improving fuel economy is difficult because of limitations in publicly available data and costing methodologies. Our technology cost estimates are derived largely from previously published information, such as studies by Energy and Environmental Analysis (EEA) and other sources. Costs for the Level 2 technologies are listed in Table S1. These estimates represent the incremental costs of improved vehicle technology, assuming the use of a mature technology averaged over a total production period and without premature replacement of production facilities. The resulting average per-car incremental retail price estimates are $590, $770, and $840 (1993$) for technology certainty Levels 1-3, respectively. The applicability of these cost estimates depends on assumptions regarding industry product cycles and other factors which affect the economics of motor vehicle production. In particular, costs are linked to lead time, since we estimated lead time sufficient to validate the assumption of no premature replacement of production facilities.

Given the above caveats, the estimated costs of fuel economy improvement are quite modest, in the range of 3%-5% of the average cost of a new car. These estimates are corroborated by the historical experience of past technology-driven fuel economy improvements, of which retrospective analyses have observed cost increases of roughly 5% of average new car price. While the estimates reported here are affected by industry economic factors which we are not able to address, this larger uncertainty cuts both ways: while it possible that actual costs of making the fuel economy improvements identified here could be higher than estimated, it is also possible that the costs could be lower, particularly as experience is gained and opportunities arise for finding cost savings in the course of product development.

Annual fuel costs for an average new car are roughly $500 per year at current fuel prices which, adjusted for inflation, are as low as they have ever been. Thus, although market interest in fuel economy is low, improving fuel economy is quite cost-effective to consumers, with an average payback time of less than four years. In reporting that the efficiency-related technology improvements identified here are cost-effective, we are not saying that they would necessarily be salable under today's market conditions. Much more efficient vehicles could be sold under changed conditions which might be brought about by various factors, such as national policies (fuel economy regulation, vehicle pricing incentives, or dramatically higher fuel taxes) or international events (wars, oil supply cartel decisions). Thus, policies to encourage or require efficiency improvement would change market conditions so as to lower the risk of applying technologies for efficiency improvement. In this regard, we distinguish the concerns of citizens from the concerns of consumers: citizens can collectively decide that higher fuel economy is needed to address problems of national concern and therefore support policy changes to raise fuel economy above the market level which they (and the auto industry) decide when acting as individual consumers.

The technology benefit, cost, and penetration estimates can be used to construct supply curves of potential fuel economy improvement and gasoline savings, as given in Figure S2 and Table S1. Figure S2(a) plots potential new car fleet average fuel economy against the Cost of Conserved Energy (CCE), expressed in 1993$ per gallon. The CCE is based on the ratio of incremental technology cost to fuel savings discounted with a 5% real rate over a 12-year vehicle life. It is an index of cost-effectiveness from the perspective of consumers in aggregate (all owners over the car lifetime rather than only the new car buyer). Figure S2 gives costs under our Level 2 assumptions; similar curves at other technology certainty levels are presented in Figure 7 of the report.

Each step in Figure S2 represents one of the technologies considered in our analysis, showing its incremental benefit for fuel economy improvement and its marginal cost expressed as an equivalent cost of avoided gasoline consumption. Steps are numbered by technology as listed in Table S1. For example, step 8 is variable valve control (VVC), which offers an efficiency benefit of 12% and would save 580 gallons of gasoline over an average vehicle lifetime. The cost for VVC is equivalent to having to pay only $0.46/gallon for this saved fuel, shown as the CCE level for step 8 in the figure. Technologies are cost-effective if their CCE is lower than the future price of gasoline expected over the life of the improved vehicles, which we assume to be $1.65/gallon (1993$).

The bottom part of Figure S2 shows the nationwide gasoline savings and greenhouse gas emission reductions in 2010 for each increment of new vehicle fuel economy improvement achieved by 2005. This graph assumes proportionate efficiency improvements in light trucks and expresses the CCE as a crude oil price equivalent, adjusting for the differences between oil prices and retail gasoline prices. Thus, savings of 2.8 million barrels per day (Mbd) can be obtained at a cost of just under $33 per barrel, roughly the oil price projected for 2010 by the U.S. Department of Energy. These savings would amount to a one-third cut in U.S. light vehicle fuel consumption, expected to otherwise reach 9 Mbd by 2010.

The corresponding reduction in greenhouse gas emissions would be 27 million metric tons per year (MT_C/yr) in 2000 and 140 MT_C/yr in 2010 (full fuel cycle CO_2-equivalent emissions expressed on a carbon mass basis). Achieving this level of new car fuel economy improvement would thus provide an 8% cut in U.S. CO_2 emissions otherwise expected for 2010, avoiding 38% of the projected growth in U.S. CO_2 emissions over 1990-2010. The cost of CO_2 emissions reduction is zero for fuel economy improvements having a CCE up to the avoided cost of fuel consumption ($33/bbl in 1993$, equivalent to retail gasoline at $1.65/gallon). For modest levels of fuel economy improvement lower than the fully cost-effective level, greenhouse gas emissions reductions can be achieved at net savings.

Of the gasoline consumption and CO_2 emissions reductions estimated here, 60% are from the improvements in passenger car fuel economy specifically analyzed in this report. The remainder are from proportionate improvements in light truck fuel economy, which we believe are similarly feasible and cost-effective although a detailed analysis has not been done by ACEEE.

The report also addresses the relationship between investments needed to improve fuel economy and issues such as market risks and competitive factors in the auto industry. Although not all firms are equally strong in all areas, competition induces ongoing enhancements of every firm's ability to respond to evolving market conditions. To meet changes in market conditions--be they induced by consumers, the world oil market, the government, or their competitors--a firm depends on its ability to develop quality products on a tight schedule, to retool quickly, and to execute flexible, "lean," production processes. An aspect of the advancing production efficiency includes relationships among competitors in the industry, such as joint ventures, product sharing, and outsourcing of components to competitors as well as to specialized suppliers. Thus, the issue of fuel economy improvement is largely one of how the industry's substantial, competition-driven capabilities are directed. In the absence of market signals or government policies to direct advances toward improving fuel economy, the industry's energies have recently been directed toward greater performance, luxury, and product differentiation, some of these coming at the expense of fuel economy.

We find no inherent reason why the industry's capabilities could not otherwise be channeled, with little change in risk or cost, given market signals or government policies pointing toward efficiency improvement. Given adequate lead time and balanced policies that provide equitable treatment of firms in the U.S. market, the 43%-85% improvements in conventional vehicle fuel economy identified here can be reached without added market risk and at modest per-vehicle cost, with overwhelming benefits in terms of fuel savings and avoided oil import and environmental costs over the life of the improved vehicles.

Our study shows that a number of technologies, implemented throughout the fleet to varying degrees, can yield a range of new car fuel economy levels considerably higher than those of today. There is a rich array of technological approaches for improving fuel economy, so that automakers need not count on the availability of only one circumscribed set of engineering options for reaching modest or intermediate levels of new fleet average fuel economy. The potential availability of less certain technologies, e.g., those identified here as Level 3 technologies, reduces the risk for reaching low or intermediate levels of fleet wide fuel economy improvement. Thus, there are multiple ways by which the new car fleet could evolve to reach, say, our Level 2 achievable potential of 46 mpg. Different approaches might, in fact, be taken by different manufacturers.

It is important to emphasize the conservatism of the results presented here, which rely solely on incremental improvement of vehicles based on gasoline-burning internal combustion engines, without radical changes in either design or manufacturing technique. We do not consider the potentially dramatic improvements in fuel efficiency that could be achieved through the use of hybrid drivetrains for efficient power management, net-shaping of composite body structures, along with advanced computer-aided design, manufacturing, and engine/transmission control technologies. The use of such approaches for automotive design has already reached the prototype stage, and could well be used for commercial production within a decade. Policy impetus for achieving improvements in new car fuel economy would do much to stimulate the commercialization of these more advanced technologies.

In summary, our review indicates that there is a wide array of available and near-commercial technologies which can be applied to improve automotive fuel economy over the next decade. Improving new cars to the mid-range (Level 2) estimate of 46 mpg by 2005 and improving new light trucks proportionally would cut U.S. gasoline consumption by 2.8 million barrels per day and reduce oil imports by at least 2 million barrels per day in 2010. There would be corresponding annual cuts of 140 million tons of greenhouse gas emissions and nearly 500,000 tons of hydrocarbon emissions. This degree of fuel economy improvement would add about \$770 to the price of an average new vehicle. The overall annual cost increase in the new vehicle market would gradually rise to as much as \$11 billion. Up-front investment costs by the auto industry will occur sooner but would be only a fraction of the overall retail cost increase. These costs are quite modest compared to annual expenditures of over \$200 billion in new light vehicle purchases. Viewed as a national investment, fuel economy improvement is very cost-effective, with the gasoline cost savings reaching \$70 billion per year by 2010 and continuing to rise thereafter. The enhanced economic growth from re-spending of these gasoline cost savings would increase net U.S. employment by nearly 250,000 jobs by 2010, including nearly 50,000 new jobs in the auto industry. In short, the large benefits to the nation--direct consumer savings, lower oil imports, reduced hydrocarbon and CO_2 emissions, and job creation--indicate that fuel economy improvement is one of the best investments the country can make.

Table S1. List of technologies, fuel economy benefits, and costs for mid-range (Level 2) estimates of technology certainty.

Technology	Average MPG benefit	Est. unit cost	Fleet avg MPG increase	New Car MPG	CCE $/gal	ACE $/gal	Fleet avg cost	Savings in 2010 (Mbd)
1 Compression ratio increase	1.0%	$ 0	1%	28.2	0.00	0.00	$ 0	0.08
2 Lubrication improvements	0.5%	2	2%	28.4	0.11	0.03	2	0.13
3 Lower tire rolling resistance	4.8%	22	7%	29.8	0.12	0.10	24	0.46
4 Continuously variable trans.	6.0%	33	10%	30.6	0.15	0.12	37	0.63
5 Optimized manual transmission	11.0%	66	12%	31.3	0.18	0.13	51	0.77
6 Optimized transmission control	9.0%	66	19%	33.2	0.24	0.17	99	1.14
7 Accessory improvements	1.7%	14	21%	33.8	0.30	0.18	112	1.23
8 Variable valve control	12.0%	140	32%	36.8	0.46	0.26	232	1.71
9 Variable displacement	5.0%	70	34%	37.4	0.61	0.28	260	1.81
10 Overhead cam	3.0%	44	37%	38.0	0.64	0.29	284	1.90
11 Weight reduction	9.9%	160	47%	40.9	0.79	0.37	449	2.29
12 Friction reduction	6.0%	110	53%	42.4	0.97	0.42	536	2.47
13 Four valves per cylinder	6.6%	120	57%	43.9	1.03	0.46	621	2.64
14 Torque converter lockup	3.0%	60	58%	44.0	1.17	0.46	623	2.65
15 5-speed automatic transmission	5.0%	120	60%	44.6	1.42	0.48	667	2.72
16 Aerodynamic improvements	3.8%	100	65%	45.9	1.59	0.53	766	2.85
17 Multipoint fuel injection	3.0%	80	66%	46.2	1.73	0.53	784	2.88
18 Super-/turbo- charging	5.0%	180	70%	47.3	2.27	0.59	903	3.00
19 Idle off	6.0%	290	74%	48.3	3.19	0.67	1046	3.09

Average MPG benefit is for the technology applied to an individual car with Level 2 assumptions, as given in Table 1 of the report.

Estimated unit cost and fleet average cost increase are based on Table 4 but given in 1993$ (using a GDP inflator of 1.10 to update from 1990$ to 1993$).

Fleet average MPG increase is cumulative, based on an average of the High and Full penetration assumptions given in Table 2(b), and reflects an interpolated optimization factor to account for the multiplicative interaction of load reduction and drivetrain measures (based on Table 3).

Marginal (CCE) and average (ACE) cost of conserved energy are based on 5% real discount rate and 12-year, 10,000 mi/yr lifetime; CCE and ACE values would be 30% higher using a 10% discount rate.

Nationwide gasoline savings in million barrels per day (Mbd) in 2010 assume the given percentage MPG increase is achieved in new cars and light trucks by 2005 and are calculated relative to new fleet fuel economy frozen at the 1990 level of 25.2 mpg, using a fuel economy shortfall of 20%, a cost of driving ("rebound") elasticity of 10%, and total light duty Vehicle Miles of Travel (VMT) of 2.748×10^{12} miles/year in 2010.

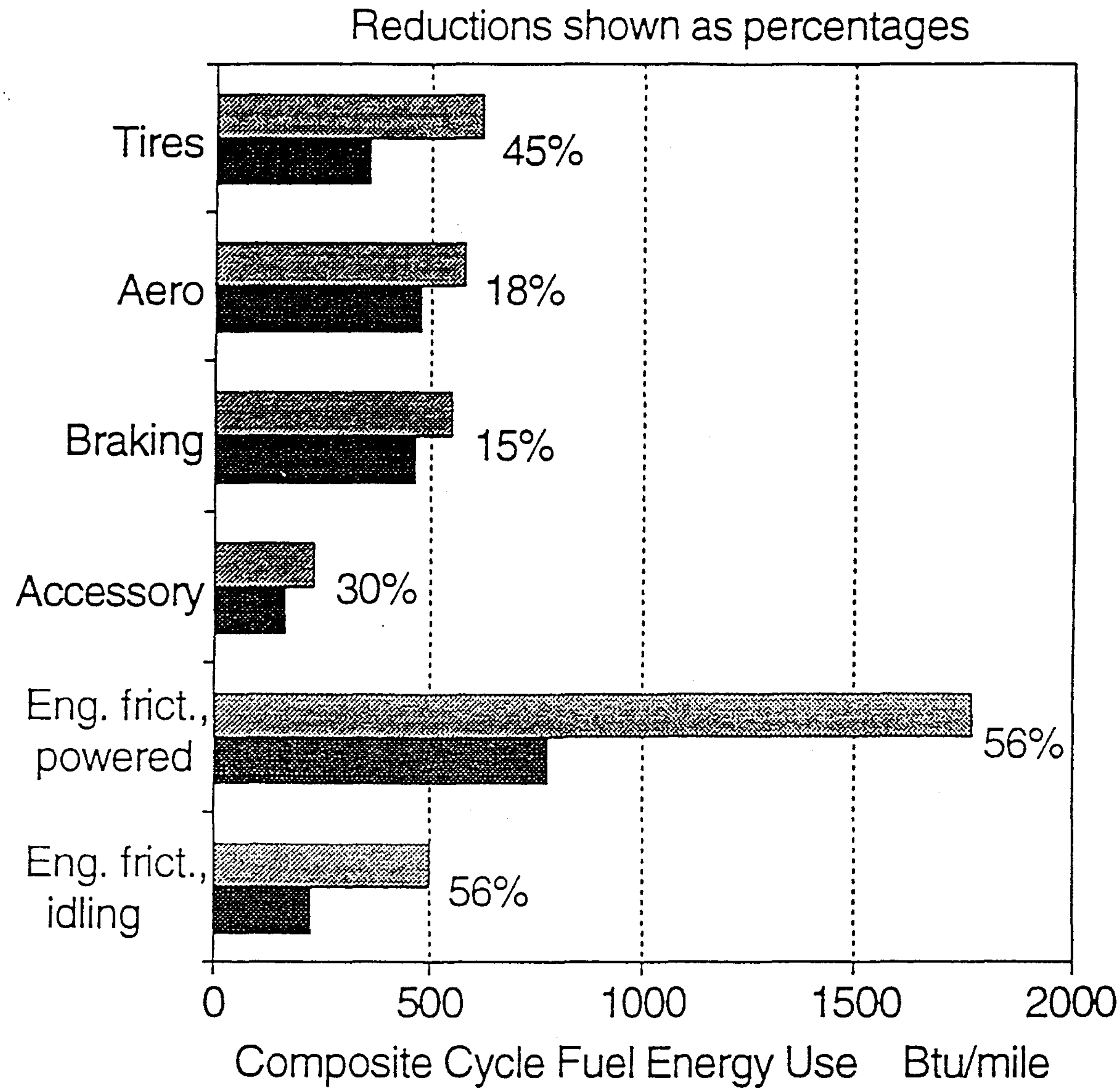

Figure S1. Potential Reductions in Fuel Energy Losses for a Typical Car

Based on application of Level 2 technologies to a 1991 Ford Taurus, resulting in an overall 43 % reduction in composite cycle energy use and a 75 % improvement in fuel economy, from 27 mpg to 47 mpg.

Tire losses reduced through lower rolling resistance and reduced vehicle weight.

Aerodynamic losses reduced through lower drag coefficient.

Braking (inertial) losses reduced through lower weight.

Accessory losses reduced by more efficient vehicle accessories.

Engine friction losses, both while under power and at idle, reduced by using a 4-valve per cylinder, variable valve timing, higher compression engine of reduced displacement with optimized transmission control.

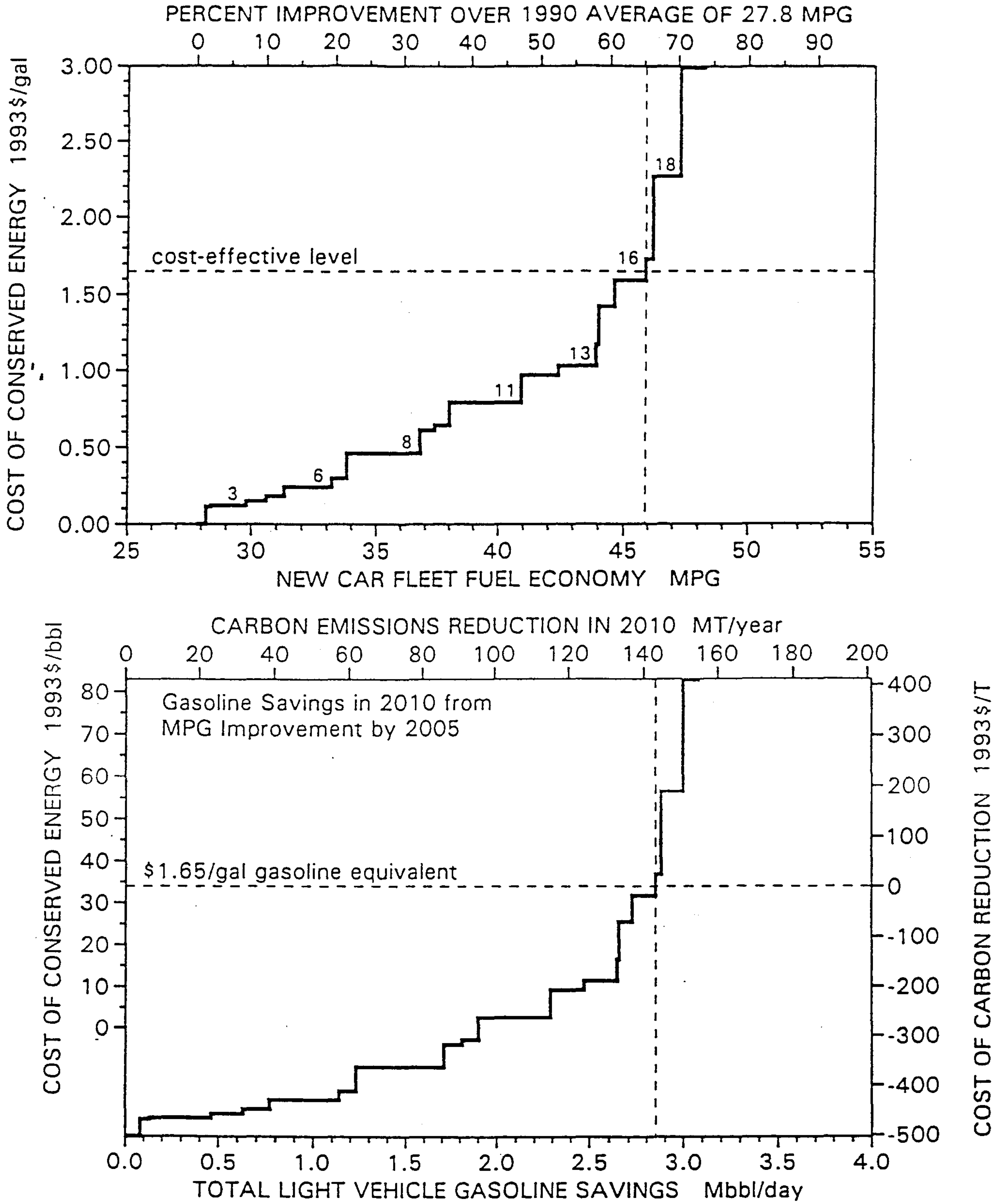

Figure S2. Cost Curves for Fuel Economy Improvement and Gasoline Savings
Results for certainty Level 2 assuming 5% discount rate and 12-year vehicle life, as in Table S1.
Steps: 1=CR inc, 2=Lube, 3=CVT, 4=Tires, 5=OptMT, 6=OptAT, 7=Access, 8=VVC, 9=Vari.D, 10=OHC, 11=Frict, 12=4-valve, 13=Wt red, 14=TCLU, 15=Boost, 16=5spAT, 17=Aero, 18=MPFI, 19=IdlOff.

ACKNOWLEDGEMENTS

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ATTACHMENT E

TELLUS ENERGY AND ENVIRONMENTAL MODELS AND DATABASES

Environmental and Resource Planning Models and Databases Developed at Tellus Institute P1

MODEL	SUMMARY DESCRIPTION	CLIENTS	APPLICATIONS	TRANSFER/ TRAINING
LEAP - Long-range Energy Alternatives Planning system	National and regional energy and environmental accounting and scenario evaluation system. Covers all sectors, fuels and energy conversion processes. Includes biomass/land-use, cost-benefit analysis, and multi-area aggregation modules. Links with EDB (see below) to produce comprehensive energy-environment scenario analyses.	Stockholm Environment Institute, Beijer Institute of the Royal Swedish Academy of Sciences, USAID, Swedish International Development Agency, European development assistance agencies, United Nations, World Bank, Union of Concerned Scientists, Greenpeace International, numerous national and local energy planning agencies and universities.	Energy-environment planning and policy analyses, including IRP and greenhouse gas mitigation. Numerous global, regional, national, and local studies.	Used by over 100 government agencies, NGOs, and research institutes in over 30 developing and industrialized countries. (e.g. Brazil, Ecuador, India, Italy, Philippines, Senegal,Tanzania, U.S. and Zimbabwe)
EDB - Environmental Database	International database of environmental loading factors from energy use and transformation. Can be used together with LEAP model or stand-alone.	United Nations Environment Programme, Stockholm Environment Institute, International Development Research Center, Washington State Energy Office, and others.	Various greenhouse gas studies; transport and environment studies; Vermont DPS environmental analysis; .	Transfers pending to government agencies in Kenya, Hungary and other countries.
G2S2 - Greenhouse Gas Scenario System	Database and assessment tool providing current and historic greenhouse gas accounts, covering all major gases, sources, and reporting at country, regional and global levels. Can reflect policies and projections through the 21st century.	Stockholm Environment Institute, Dutch Ministry of the Environment, Climate Network Europe, ENEA (Italy), University of New Hampshire, Center for Global Change	Used to explore alternative greenhouse gas policy targets and to test the sensitivity to uncertainty in basic driving parameters.	Over a dozen NGOs in Kenya, Bangladesh, and several Eastern European countries.
POLESTAR - An Accounting System for Sustainable Development	An accounting framework and simulation tool for examing alternative development strategies including socio-economic patterns, energy, water and mineral resource flows, agriculture and land-use patterns, and environmental loadings. Under current development by SEI-B.	The *2050 Project* organized by the World Resources Institute, the Brookings Institution, and the Santa Fe Institute.	As part of the POLESTAR project, and the *2050 Project* to analyze.a "transition to sustainability in the next century".	Yet to be diseminated
ECO - Energy Conservation Model	Model analyzes demand-side management (DSM) measures and programs by calculating costs, benefits, resource impacts, and environmental externalities.	Long Island Power Authority; Connecticut Municipal Electric Energy Cooperative; Commonwealth Gas; Consumers Gas (Ontario).	Used for utility conservation program planning. Its predecessor, CONCOST, was used in over 25 utility regulatory proceedings.	Connecticut Municipal Electric Energy Cooperative; Commonwealth Gas; Czech, Romanian, and Slovak agencies.
EXMOD - New York State Externalities Model	Detailed analysis of fuel cycle externalities for site-specific electric facilities. Covers emissions, transport, concentration, exposure, dose-response and monetization based on a damage costing approach. Under current development by Tellus and RCG/Hagler Baily.	Empire State Electric Energy Research Corporation	To be used by regulators and any interested parties; public domain software. Can be adapted to other regions.	Yet to be diseminated
WastePlan - Solid Waste Planning Model	The solid waste system cost mode forecasts growth in individual components of a municipal solid waste stream. This model allows simulation and cost analysis of source reduction, recycling, composting, resource recovery and landfill disposal systems.	Based on work initially done for Congressional Office of Technology Assessment. Enhanced and used by the State of Michigan, New York, California, US nationwide.	Implemented in numerous regions of Michigan, and for New York City. Used in nationwide packaging study. Similar study planned for Mexico.	OTA; Public agencies in Michigan, New York, Illinois, California, Delaware, and Maine.
P2/Finance - Pollution Prevention Financial Analysis & Cost Evaluation System	Provides a framework for preparing a total cost assessment of industrial pollution prevention projects.	U.S. EPA/ Pollution Prevention Division and New Jersey Dept. of Environmental Protection and Energy	Used in the analysis of projects in the pulp and paper, paper coating, metal fabrication, and chemical industries.	New Jersey DEPE staff; Workshops for government and industry are in the planning stage.
WEAP - Water Planning and Evaluation System	The water evaluation and planning system surveys water development planning and policy options, providing a practical new methodology for environmentally sound and cost-effective water development.	Institute of Geography, Soviet Science Academy, US Army Corps of Engineers.	Used in the Aral Sea region of the Soviet Union; Enhanced by US Army Corps of Engineers for potential use in domestic water planning projects.	US Army Corps of Engineers.
Acid Rain Abatement Optimization Model	A linear programming optimization model. Critical loads for acid deposition have been developed for the land area of Europe, based upon geology, soil type, land use and rainfall, serving as the basis for deposition targets which the model tries to satisfy by applying various combinations of emissions abatement in each of 27 European countries.	Stockholm Environment Institute - York, England	Used to explore targeted deposition strategies for acid rain abatement in Europe.	SEI - York, England

MODEL	SUMMARY DESCRIPTION	CLIENTS	APPLICATIONS	TRANSFER/ TRAINING
GasPlan	A recently-developed model that analyzes short and long-term natural gas supply strategies, evaluating them against the standards of reliability, cost, and risk.	Consumers Gas Company, Ontario.	To be used in resource planning to assess reliability criteria, capacity and supply options, and contracting practices.	n/a
FACE - Forecast and Conservation Evaluation System	End-use electricity load forecast model for long-range projections of energy and peak demand. Fossil fuels in residential, commercial and industrial sectors treated within consistent framework.	New York State Dept. of Environmental Conservation	Used in more than 100 forecasts in 25 states, involving 50 utilities.	Alberta Power Ltd; Staff at New York State Dept. of Environmental Conservation; Staff at Dept. of Public Service of Vermont.
DHSM - District Heating Strategy Model	DHSM evaluates district heating systems for cities. Compares and selects from alternative central station plant/urban district heating and cooling supply-demand configurations with respect to cost, fuel savings, emissions, and local air quality.	Argonne National Laboratory	Used in DOE/HUD 28-city evaluation of district heating projects. Used in analysis of district heating and air quality by the Boston Redevelopment Authority.	Staff at Argonne and Oak Ridge National Laboratories.
JOBS	A regional input-output model tracking employment impacts of alternative energy plans which account for inter-industry interactions and re-spending effects of energy cost savings.	Brookhaven National Laboratory; Council on Economic Priorities.	Applied in regional analyses of energy plans: Long Island NY; Springfield MA; State of Ohio; State of New York.	Council on Economic Priorities.
CANS - Cost Assessment of Nuclear Substitution	Utility required revenues model: tracks incremental required revenues of alternative long-range plans (annual and PVRR).	Numerous state agencies and several foundations.	Used in economic analysis of 20 utility systems' capacity plans.	n/a
HOMES	Model for simulating and estimating building space conditioning (heating and cooling) requirements.	Numerous state agencies. Applied to approximately 40 electric utility service territories.	Fuel usage trade-offs for space-conditioning technical/economic analysis.	n/a
SYSGEN/ MEDUSA - Power Production and Costing Reliability Model	The SYSGEN utility dispatch, production costing reliability code was developed at MIT Energy Laboratory for the US DOE. Tellus added input and output routines, enhanced parts of the code, and added MEDUSA to account for fixed costs.	Numerous state agencies.	Used in more than 16 analyses involving about 30 electric utilities.	Vermont Dept. of Public Service, Massachusetts Executive Office of Energy Resources, Energy Facilities Siting.
Cogeneration Rate Impact Model	Model for computing the impact of various levels of cogeneration development upon electricity rates, assuming payments of avoided cost for cogeneration and the impacts of timing.	Massachusetts Office of Energy Resources.	Applied statewide in the context of developing new cogeneration policies and regulations.	n/a
WADES	Regional end-use water demand model.	Public Service Commission of Kentucky.	Applied in Kentucky.	n/a
WASTES - Hazardous Waste Stream Evaluation System	This model produces a disaggregated forecast of more than 40 individual hazardous waste substances, analyzes waste output by region, sector, and disposal category, and examines policy scenarios.	Currently in use in Manitoba Hazardous Waste Management Corporation.	n/a	Manitoba Hazardous Waste Management Corporation.
EMP - Energy Master Planning System	EMP provides a framework for developing current energy accounts, generating detailed and comprehensive supply/demand forecasts, and evaluating cost and resource impacts of alternate scenarios.	n/a	n/a	n/a
CDMQC - Climatological Dispersion Model	A modified version of the EPA code used to estimate air quality impacts of dispersed sources of pollutant emissions.	Argonne National Laboratory; Boston Redevelopment Authority (BRA)	Linked CDMQC to Tellus' District Heating Strategy Model in case studies (Argonne); Boston District Heating Cogeneration Study (Boston Redevel. Authority)	n/a

ATTACHMENT F

TELLUS INSTITUTE BROCHURES

Tellus Institute

Objectives

Tellus Institute is a team of scientists, planners and policy analysts organized into a non-profit research and consulting organization. The Institute applies the best available scientific methods, technical data, and policy analysis to address resource management and environmental issues. Our mission is to design rational and equitable resource and environmental strategies for the public good. We conduct policy research on specific problems and issues with a keen awareness of the larger issues of our time -- the linked problems of economic development, social equity, and environmental sustainability.

Tellus Institute was founded in 1976. The name Tellus refers to the Roman goddess of the earth who attended to the earth's well-being and productivity. Our work includes over 1500 research reports, policy papers, and monographs. Senior staff have testified widely before regulatory and policy-making bodies. Tellus projects are sponsored by foundations, state and federal agencies, international bodies, public interest groups, and private organizations. The research program is organized into four groups:

- ❑ Energy
- ❑ Solid Waste
- ❑ Risk Analysis
- ❑ Stockholm Environment Institute - Boston Center

Energy

The Energy Group provides expertise on the technical, economic, environmental, regulatory and policy aspects of energy. The group is comprised of five programs – Energy and Environment, Electricity, Natural Gas, Demand-Side Management, and Finance & Regulation. Key areas of research include:

- Integrated resource planning for electricity and gas
- Economic and environmental impacts of energy
- Utility financial analyses, ratemaking, regulatory reform
- Energy forecasting / economic modeling
- Renewable energy resources
- Transportation energy
- Conservation assessments and program design

Solid Waste

The Solid Waste Group performs research, planning studies and computer modelling on issues of waste management, materials use, and related economic and environmental impacts. These activities promote the efficient management of natural resources through appropriate solid waste programs and materials policies. Areas of expertise include:

- Materials Policy
- Source Reduction
- WastePlan computer modelling
- Recycling
- Organic Waste Management
- Rate Structures and Pricing
- Forecasting and Measurement

Risk Analysis

The Risk Analysis Group evaluates the environmental, public health, and financial risks of projects and provides policy, regulatory and technical analysis. The group develops analytical methods, conducts policy studies and technical training, and provides expert testimony in several program areas:

- Pollution prevention and toxics use reduction
- Environmental accounting and total cost assessment
- Life-cycle assessment
- Environmental impact review of proposed facilities
- Negotiation/implementation of host community agreements
- Corporate environmental practices
- Environmental communications

Stockholm Environment Institute
Boston Center

Tellus conducts an extensive international program as host to the Stockholm Environment Institute - Boston Center (SEI-B). SEI-B performs research, policy evaluations, and field applications concerned with environmentally sound development. Principal program areas include:

- Energy and environment in developing and industrialized countries
- Greenhouse gas assessments and policy analysis
- Water strategies and development
- Integrated sustainable development strategies

SEI-B develops and applies accessible computer-based methods for exploring scenarios for sustainable development. These include *LEAP*, the Long-range Energy Alternatives Planning system; *WEAP*, the Water Evaluation and Planning system; *G2S2*, the Greenhouse Gas Scenario System; *EDB*, the Environmental Data Base, and *PoleStar*, a tool for exploring global, regional and national sustainable development strategies.

Staff

The Tellus staff of approximately fifty professionals are drawn from a variety of scientific, social science, and engineering backgrounds. Tellus Institute's offices, library and research facilities are located in Boston, Massachusetts. Tellus maintains close contact with other research institutions in the Boston area and elsewhere and collaborates with specialist consultants as needed.

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TELLUS INSTITUTE
for Resource and Environmental Strategies

Stockholm Environment Institute - Boston Center

Tellus Institute is the home of the Boston Center of the Stockholm Environment Institute (SEI), an international organization based in Sweden. Stockholm Environment Institute - Boston (SEI-B) develops and applies methods for sustainable development at the local, national and global levels.

Objectives

The theme of sustainable development is central to SEI-B activities. The program focuses on assessing alternative futures in order to guide policy today. What are the current patterns of economic, resource, and environmental interaction? Where are these patterns leading us? What actions are needed to meet social and economic needs without jeopardizing natural environments? What policies can best stimulate desirable actions?

A powerful tool in answering these questions is scenario analysis. Scenario analysis combines the best available data, information, and simulation methods to paint a picture of current situations and future possibilities. By permitting us to experiment with alternative futures, scenario analysis provides a laboratory for rational decision-making today. SEI-B is at the forefront of developing and applying computer-based methods for scenario analysis. Currently there are five program areas.

Energy

The centerpiece of SEI-B's energy and environmental program is a comprehensive and user-friendly computer system, the *Long-range Energy Alternatives Planning system (LEAP)*. *LEAP* takes into account land use changes and biomass exploitation as well as conventional fuels analysis. *LEAP* includes an environmental impact feature that describes the environmental consequences of alternative actions and investments in the energy sector. For this purpose, *LEAP* is linked to SEI-B's *Environmental Data Base (EDB)*, an easy-to-use microcomputer system that summarizes and documents the coefficients and factors linking energy resource use to emissions and other environmental loadings. *LEAP* has been widely used for twelve years and projects are currently underway in many developing and industrialized countries.

Greenhouse Gases

This project centers around the *Greenhouse Gas Scenario System (G2S2)* abase and software system for estimating current emissions of greenhouse gases (GHG) and projecting emissions under a range of assumptions. *G2S2* is both detailed and comprehensive. It includes emissions of all major greenhouse gases, contributions from all significant human activities with disaggregation by country. *G2S2* is a quick response resource for global-warming analysts and policy makers designed to explore alternative GHG policy targets, and to test the sensitivity to uncertainty in basic driving parameters.

Water

SEI-B has developed a practical new methodology for environmentally sound and cost-effective water development, the *Water Evaluation And Planning (WEAP)* system. *WEAP* is an easy-to-use computer-based tool that can be applied to a wide variety of water planning situations. *WEAP* is an assessment tool for simulating demand and supply under alternative planning assumptions. *WEAP* allows for analysis of the costs and environmental consequences of water development strategies, providing a structured approach for exploring water policy options. *WEAP* is currently being used in applications throughout the world.

PoleStar

PoleStar is a cross-disciplinary project which seeks to develop new concepts, methods and tools for sustainable development planning into the 21st century. The project has three dimensions: research on global change, policy assessment to link long term sustainability considerations to near term decisions, and education to heighten public appreciation of the issues. A centerpiece of the project is a computer-based framework for representing current and future economic, resource and environment patterns under a wide range of assumptions. The *PoleStar* software organizes a vast amount of data pertaining to sustainability in a compact and accessible fashion, quantitatively represents a broad range of conceivable development scenarios, and evaluate scenarios against sustainability indicators, including environmental, resource and human development measures. The software is being applied to sustainable development scenarios at the global level and in selected countries.

Building Institutional Capacity

SEI-B assists developing countries in improving their capacity for integrated resource planning. This program includes the transfer of our computer systems to developing country planning agencies. SEI-B also trains professionals on integrated planning, data development, computer use, and general skills as requested. *LEAP, WEAP, G2S2* and *PoleStar* have been transferred to hundreds of recipients throughout the world including governmental and multilateral agencies, universities, and individual researchers.

Staff

The SEI-B staff is directed by Dr. Paul Raskin, the President of the Tellus Institute. Project teams are supplemented by experts both within and outside of the Tellus Institute.

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TELLUS INSTITUTE
for Resource and Environmental Strategies

Energy Group

Objective

The Energy Group was the original founding group of Tellus Institute. The group provides expertise on the technical, economic, environmental, regulatory and policy aspects of energy planning. Analyses focus on utility resource planning and management, as well as on broader energy planning and policy issues throughout all sectors of the economy. The group communicates its methods and results to external audiences in an effort to promote rational, equitable and environmentally sound energy strategies on both the local and national levels.

Sponsors include: public utility commissions and environmental agencies that regulate energy industries; foundations; consumer and environmental advocates; and state, regional and national agencies that make energy planning and policy decisions.

Research

The Energy Group's research program addresses a broad range of technical and policy issues, and is organized into five specific program areas:

- ❑ Energy and Environment
- ❑ Electricity
- ❑ Natural Gas
- ❑ Demand-Side Management
- ❑ Finance and Regulation

Energy and Environment

The Energy and Environment Program analyzes broad areas of energy planning and policy in state, regional, national and international studies. It examines energy supply and demand, technology choice, economic impacts, and environmental consequences in all sectors of the economy, and considers all fuels. The work aims to inform energy and environmental agencies, utility commissions, legislatures, national policy agencies, and non-governmental organizations that develop policy or make energy and environmental decisions. Principal areas of analysis include:

- integrated energy/environmental planning
- renewable resources
- energy and economic modeling
- energy and pollution taxes
- transportation energy and environment
- economic and environmental impacts of energy

Electricity

The Electricity Program analyzes issues, methods, and resources that impact electric utilities and their customers, and provides sponsors with technical and policy recommendations for sound electric system planning and ratemaking. Integrated resource planning (IRP) is a key organizing concept behind much of this work. Resources such as fossil fuels, renewables, demand-side management (DSM), transmission, distribution and nuclear power are analyzed in the evaluation of utility resource plans. Key areas of research include:

- load forecasting
- supply acquisition, bidding, reliability, risk
- capacity expansion and plant retirement
- environmental impacts / Clean Air Act compliance
- cost of service / rate design / PURPA standards
- avoided costs

Natural Gas

The Natural Gas Program addresses many of the same issues as those in the Electricity Program, evaluating resources specific to the gas industry such as supply contracts, fuel choice and gas DSM, and pipeline, storage and peaking capacity. Gas IRP is an area of increasing interest and serves as a basis for much of the work done in this program. Key areas of research include:

- load forecasting
- supply planning
- cost allocation / rate design
- transportation service rates and tariffs
- recovery of purchased gas costs
- avoided costs

Demand-Side Management

The DSM Program promotes the development, implementation and evaluation of cost-effective DSM programs as a key component in utility planning and regulation. DSM is emphasized within the context of IRP, both as a priority for electric and gas utilities and regulators, and for broader energy planning and policy initiatives. Areas of research include:

- review, design and development of DSM programs
- program implementation planning
- process and impact evaluation
- recovery of DSM program costs

Finance and Regulation

The Finance and Regulation Program focuses on emerging issues of regulatory reform, particularly those addressed in the Energy Policy Act of 1992 and those associated with IRP. The program also analyzes the financial aspects of electric and gas utilities and the evolving structure of the utility industry. Areas of research include:

- decoupling, lost revenue recovery, incentives
- deregulation and competition
- mergers, acquisitions, takeovers, bankruptcy
- regulatory reform
- cost of capital / rate of return
- fuel clause policies

Staff

The Energy Group is directed by Dr. Richard Rosen. It's staff includes scientists, engineers, economists and policy analysts, many with over a decade of energy planning and policy experience.

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Risk Analysis Group

Objectives

Approaching a new century, we face difficult decisions about managing environmental risk for a sustainable future. Tellus Institute's Risk Analysis Group provides technical expertise to evaluate the risks and benefits of alternative environmental policies.

The Risk Analysis Group addresses ecological, public health and socioeconomic risks, from world-wide to local impacts. In doing so the group develops analytical methods, conducts policy studies and technical training, and prepares expert testimony in several program areas:

- **Pollution prevention**
- **Facility impacts**
- **Life-cycle assessment**
- **Environmental Accounting**
- **Environmental Communication**
- **Program on Business and the Environment**

Pollution Prevention

As a leading actor in the shift from "end-of-pipe" regulation to upstream pollution prevention, Tellus assists government and industry in projects to promote source reduction and toxics use reduction and clean technologies. Recent work includes studies of safe substitutes for solvent-based inks, paints and glycol ethers. Staff have participated in a three-year study of how clean technologies are transferred to developing countries by U.S. multinational corporations. We also participate internationally in the U.S. AID Environment and Natural Resources Policy and Training Project (EPAT). Tellus has initiated a major U.S. study of chemical restrictions, looking at impacts on health, the environment, and the economy of New Jersey.

Facility Impacts

With growing concern about health and the environment, effective and fair policies for siting and operating potentially hazardous facilities are needed. The Risk Analysis Group evaluates the health, environmental and socioeconomic impacts of proposed facilities. We provide independent technical review and expert testimony, negotiate on behalf of host communities and coordinate regional environmental planning. We have evaluated facilities for solid waste, hazardous waste, radioactive waste and sludge, as well as transmission lines, power plants and other energy facilities. Tellus staff have worked as advisors to state and local governments and citizen groups in Massachusetts, New York, Pennsylvania, Michigan, North Carolina, Colorado and many other states. We provide expert testimony in areas of active scientific investigation, including health risks of electromagnetic fields (EMF) and air pollutants.

Life-Cycle Assessment

Life-cycle Assessment (LCA) evaluates the environmental and health impacts of a product or material from extraction and transportation of raw materials through conversion into products, and disposal, recycling or reuse. Tellus participates actively in developing LCA methods and research priorities through the Society of Environmental Toxicology and Chemistry (SETAC) and U.S. EPA's LCA Peer Review Group. We provide ongoing support to U.S. EPA's Pollution Prevention Division to incorporate LCA concepts into rule-making. We have also conducted a multi-year study of the environmental impacts of packaging for U.S. EPA, New Jersey and the Council of State Governments.

Environmental Accounting

Environmental accounting includes methods for tracking waste, allocating costs to product lines and production processes, measuring pollution prevention progress, reporting overall environmental performance, and performing investment analyses of environmental projects. With support from U.S. EPA, the State of New Jersey, environmental organizations and industry, we perform environmental audits and develops environmental accounting tools. These include: *P2/FINANCE*, a Total Cost Assessment software system for the financial analysis of pollution prevention investments; and the CERES Report, a standardized disclosure form for reporting environmental performance to the public, investors and industry itself.

Environmental Communication

Effective programs to reduce environmental risk include the public, technical experts, businesses and government. Tellus works to facilitate environmental communication and participation through research on public attitudes and behavior, evaluation of interventions that target behavior change, policies for public participation, and negotiation of conflict. We provide technical assistance to numerous local governments and citizen groups to assure meaningful public participation in environmental decisions. Projects for Massachusetts and New Jersey assess rates of recycling and home composting and evaluate new programs to boost recycling in hard-to-reach multi-family residences and small businesses.

Business and the Environment

Tellus' Program on Business and the Environment is a recent initiative under development with selected leadership firms in the U.S. The program focuses on four areas integral to environmental excellence: environmental performance auditing and disclosure; international technology transfer to overseas facilities; dissemination of accounting tools to encourage pollution prevention; and assessment of management practices to enhance corporate environmental performance.

Staff

Risk Analysis staff combines expertise in resource economics, risk assessment, public health, air and water quality, chemistry, geography, public participation and engineering. Headed by Dr. Allen L. White, the group regularly draws on the expertise of Tellus Institute's professional staff of scientists, engineers, economists and policy analysts in the International, Solid Waste and Energy groups.

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Solid Waste Group

Objectives

The Tellus Institute Solid Waste group performs research, planning studies and computer modelling on issues of waste management, materials use, and related economic and environmental impacts. The goal of these activities is to promote the efficient management of natural resources through appropriate solid waste programs and materials policies.

The Solid Waste group's areas of expertise include:

- **Materials Policy**
- **Source Reduction**
- ***WastePlan* computer modelling**
- **Recycling**
- **Organic Waste Management**
- **Rate Structures and Pricing**
- **Forecasting and Measurement**

Materials Policy

As waste diversion programs generate increasing supplies of secondary materials, there is a need for public policies that address the use of these materials. Tellus research has examined the life cycle environmental impacts of packaging materials, the anticipated supplies of secondary materials from the New York metropolitan area, and the extent of state subsidies for virgin vs. recycled materials in California. Analysis of the economic impacts of waste management has included projection of employment gains from recycling in New York City.

Source Reduction

Tellus is active in quantitative analysis, evaluation and development of solid waste source reduction plans for state, local and private sector agencies. Source reduction plans have been developed for California, the New York metropolitan area, and the communities of Nashua, New Hampshire and Wellesley, Massachusetts. Institutional food waste reduction plans have been developed for New York's Riker's Island jail and for the University of Vermont. Tellus also maintains a library and resource center on source reduction.

WastePlan

WastePlan©, developed by Tellus Institute, is a user-friendly, microcomputer-based model of integrated waste management systems. It allows analysis and forecasting of costs and capacity requirements for waste management, including modelling of waste generation, collection systems, and a full range of processing and disposal systems. First created for the Federal Office of Technology Assessment, *WastePlan* has been licensed by state planners in New York, Illinois, Michigan, Minnesota, Ohio, Tennessee, Delaware, and Maine. Tellus used *WastePlan* extensively in assisting New York City's long-range waste planning and on a World Bank project to develop an environmental master plan for Beijing, China.

Recycling

Tellus staff has been involved with both public and private sector recycling efforts from the development of regional approaches to the utilization of material recovery facilities to decentralized rural strategies such as cooperative marketing. A major focus of Tellus' efforts has been to develop viable plans to insure the highest quality and the appropriate quantity of recyclables so as to meet market requirements. Tellus staff has acted as a third party reviewer of facility/host community agreements, provided critiques of pending market contracts and developed implementation plans for recycling in such diverse situations as Yosemite National Park and Boston's Logan Airport.

Organic Waste

Tellus has broad experience in analysis of organic waste management, including in-depth knowledge of costs, technologies, program options and assessment of compost markets. Major projects include hands-on development of a successful pilot program for low-cost urban waste composting in Jakarta, Indonesia; an ongoing study of composting options at Riker's Island; and analysis of anaerobic digestion options for Rhode Island. Tellus has assisted the states of Massachusetts and Rhode Island in developing comprehensive plans for the organic fraction of the municipal solid waste stream.

Rates and Pricing

Tellus offers a combination of years of experience in energy rate design and pricing analysis, together with detailed knowledge of solid waste management cost issues. A study for West Virginia developed a volume-based rate proposal for the state's rural waste haulers. The WastePlan model includes an analysis of volume-based collection rates. In California, Tellus performed a path-breaking analysis of a proposed advance disposal fee. Many Tellus studies examine market incentives for waste management, including the analysis of state incentives for virgin material production in California.

Forecasting

Drawing on strengths in computer modelling and economic analysis, Tellus has performed analysis and forecasts of waste generation in New York City, the surrounding metropolitan area, Minnesota, and California. Related studies of waste quantification and measurement problems have been done for the states of Massachusetts and Washington.

Staff

The Solid Waste group includes a staff of planners, economists and scientists, and is directed by Dr. John Stutz. The group collaborates closely with other Tellus Institute staff, and with experts at other institutions involved in analysis of waste, risk and materials issues.

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