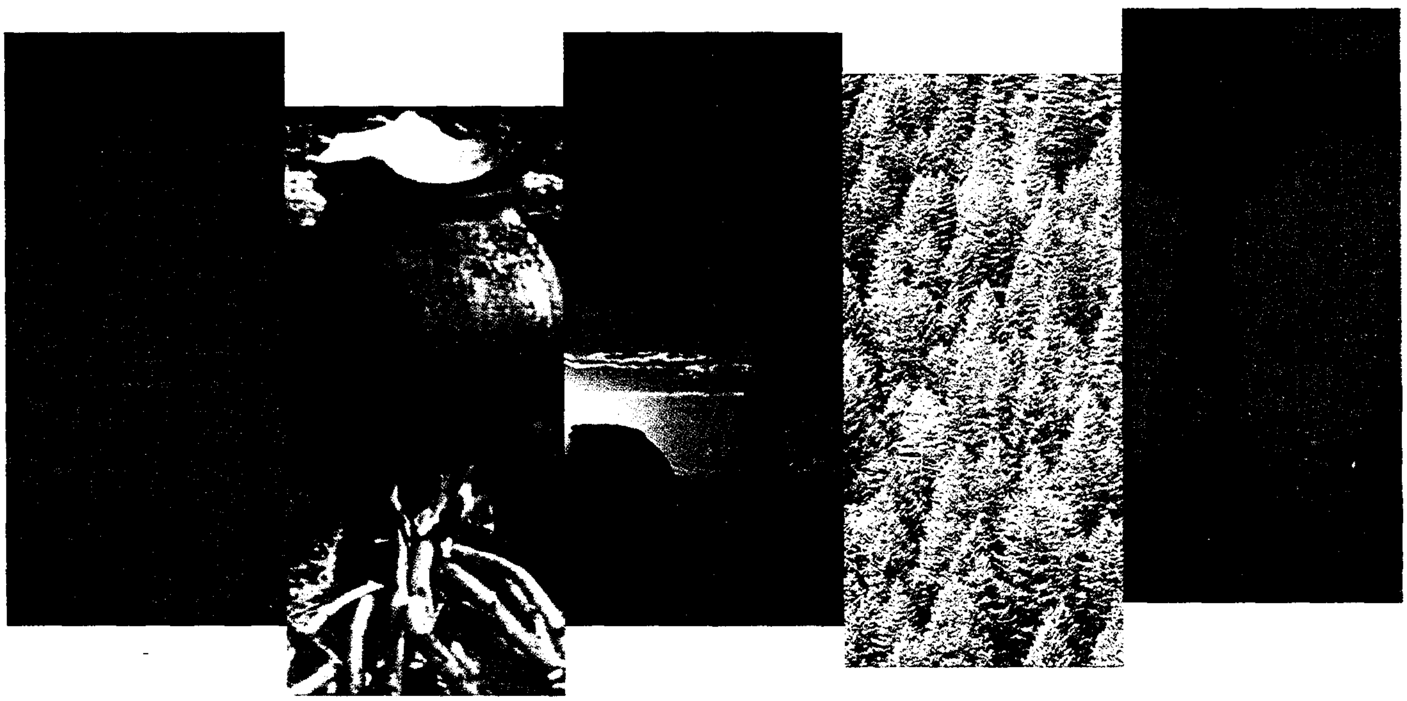
ESM224

Energy, Transportation and Environment: Policy Options for Environmental Improvement



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PURPOSE

The Joint UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP) is a special global technical assistance program run as part of the World Bank's Energy, Mining and Telecommunications Department. ESMAP provides advice to governments on sustainable energy development. Established with the support of UNDP and bilateral official donors in 1983, it focuses on the role of energy in the development process with the objective of contributing to poverty alleviation, improving living conditions and preserving the environment in developing countries and transition economies. ESMAP centers its interventions on three priority areas: sector reform and restructuring; access to modern energy for the poorest; and promotion of sustainable energy practices.

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Energy, Transportation and Environment: Policy Options for Environmental Improvement

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Resources for the Future

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(ESMAP)

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Foreword

It is readily apparent to anyone living in or visiting cities in developing countries that air quality is generally bad and getting worse. While fuel use in industries and households is a major contributor to air pollution, the most rapidly growing form of pollution is from motor vehicles including cars, buses, and two- and three-wheeled motor cycles. As national and household incomes rise, the demand for transportation for commercial and personal use increases causing accelerated deterioration of air quality.

Even a cursory review of the environmental problems associated with energy use to provide transportation services, reveals that there is no quick fix. Although the use of fuel by motor vehicles is the obvious source of pollution, the optimum means of reducing this pollution and of improving urban air quality while at the same time meeting the rapidly growing demand for transportation is far less apparent. Although significant contributions to reducing the environmental impact of transportation can be made from within the energy sector, major complementary actions are required in the transportation and urban sectors.

The present study was undertaken under the Energy Sector Management Assistance Programme (ESMAP). Because energy, environment and transportation issues form such an important nexus with major implications on overall strategy for energy and the environment. Work on this paper was undertaken in conjunction with the preparation of the World Bank Strategy Paper entitled *Fuel for Thought: A New Environmental Strategy for the World Bank.*

This paper was written by Winston Harrington and Alan Krupnick of Resources for the Future with inputs from staff of the Energy, Environment and Transport Departments of the World Bank and participants at the ESMAP/World Bank Energy Donors' Roundtable in April 1997, where an earlier draft was presented and discussed. The authors wish to acknowledge the especially helpful comments on the draft paper from Gunnar Eskeland, Charles Feinstein, John Flora, Chris Hoban, Kenneth Gwilliam, Masami Kojima, Magda Lovei, Eleodoro Mayorga-Alba, Zmarak Shalizi, Debu Talukdar, Lou Thompson. Joseph Gilling initially was the Task Manager followed by Richard Spencer. Dean Girdis, Consultant guided the project from start to finish.

Abbreviations and Acronyms

AAMA	American Automotive Manufacturers Association
API	American Petroleum Institute
ARIC	Atmospheric Research and Information Center
BHP	Brake Horsepower
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
EDF	Environmental Defense Fund
HC	Hydro Carbon
g	gram
IC	Internal Combustion
I&M	Inspection and Maintenance
LPG	Liquefied Petroleum Gas
km	kilometer
MMT	Methylcyclopentadienyl Manganese Tricarbonyl
MTBE	Methyl Tertiary Butyl Ether
NOx	Oxides of Nitrogen
PM	Particulate Matter
ppm	parts per million
RFG	Reformulated Gasoline
RVP	Reid Vapor Pressure
SO_2	Sulfur Dioxide
SOx	Oxides of Sulfur
USEPA	United States Environmental Protection Agency
USGS	United Sates Geological Survey
VOC	Volatile Organic Compound
VKT	Vehicle Kilometers Traveled

Executive Summary

1. This paper explores the role of energy policy in reducing the environmental consequences of transportation in developing countries.

2. By far the most important intersection of environment, transport and energy is air quality, the decline of which is an unfortunate but seemingly inevitable by-product of the rapid urbanization and economic growth experienced in developing countries. Already, a number of the more advanced newly industrializing countries are experiencing congestion levels far in excess of anything found in OECD countries, and some of the worst air quality in the world is found in the mega-cities of developing countries. This situation can only become worse with income growth unless appropriate government policies are adapted to address the issues.

3. Local and national governments in developing countries *have* begun to respond to these challenges, but like the developed countries before them they are finding the task of controlling mobile source pollution to be quite difficult. It is often difficult to know what to control because of complex and nonlinear relationships between air quality and pollutant emissions, be they from large point sources such as industries and power plants or small mobile sources such as motor vehicles. In addition, there are major technical and administrative difficulties in monitoring the very large numbers of emitters, leading to difficulties in enforcing emission reductions from these sources. Enforcement difficulties are largely the reason that in almost every country the most important and effective mobile-source emission policy has been emission standards for new cars. Still, with so many possible points of intervention to reduce emissions — including the fuel, the vehicle, and the driver – it is important to explore which points can be most effective in which circumstances.

4. The energy sector presents opportunities for policy choices that deal with fuel prices, fuel quality, and the potential introduction of new fuels. While policies in these areas may lack the theoretical efficiency of more precisely targeted policies, they are often more feasible and cost effective to enforce. Such policies cannot and should not be the only instruments for promoting environmentally sound transport, but they have a potentially important role to play and need to be coordinated with policies relating to the environment, transportation, land use, and the overall urban economy.

5. Fuel pricing policy is an example of a "blunt instrument" that can have a broad impact on the use of fuel and ultimately the level of air pollution. Fuel prices are at once relatively easy to monitor, fuel use is easily measured and is closely linked with the generation of pollution externalities and will have an impact on the type of vehicle and its use by consumers. Its effectiveness for this purpose depends on the price elasticity of travel and the relationship between vehicle fuel economy and vehicle emissions. Unlike many policies that target emissions directly, higher fuel prices for private vehicles can encourage car-pooling, help preserve markets for collective urban transit bus and rail systems, and in general help avoid the atrophy of these systems as riders seek faster and more comfortable transportation.

6. Particular care must by taken with fuel pricing policies in the transportation sector so that a diversion of fuels (which are subsidized in other sectors of the economy) does not occur. Such diversion for use in motor vehicles, such as kerosene as a substitute for diesel fuel, will not only reduce the effectiveness of the policy, but could even exacerbate environmental problems, since these other fuels often have a higher pollution potential. This issue invokes a standard message: there may be limited scope for using price adjustments to induce socially responsible behavior when some markets are controlled and others are not.

7. Policies affecting fuel quality, whether employing price signals or direct regulation, can be cost-effective, depending on refinery capabilities and the costs of modifications. Fuel quality improvement measures can be targeted by season and (to some extent) geographical area; they affect the entire vehicle fleet (rather than only new cars); and they require little institutional capacity for policy implementation. Efforts to remove or reduce lead in gasoline are the most advanced and important (from a public health perspective) of the fuel quality changes. Despite slightly higher costs of producing unleaded gasoline, it is generally cost effective to tax unleaded fuel at a lower rate than leaded fuel to discourage misfueling. Lowering the sulfur content of diesel fuel would be desirable, but concern about economic effects on commercial trucking is a barrier if standards are set too tightly, leading to high costs of sulfur removal.

8. Alternate fuels, particularly compressed natural gas (CNG) and liquefied petroleum gas (LPG), are penetrating into the bus and fleet vehicle market, sometimes without government prodding. Even in this area, better vehicle maintenance can perhaps be more cost-effective than fuel switching. Significant penetration of alternate-fueled vehicles, except in specific situations, such as in Brazil with ethanol and in Tehran with CNG, will, and should, await further reductions in the cost differentials with conventional fuels.

9. With regard to policies in the transportation sector, a key issue is how to develop viable transit options to slow the switch from walking, bicycles and transit to personal vehicles as incomes grow. The lessons from experience with transit systems in developing countries are: (i) increasing competition, rather than privatization, is what lowers prices and improves service; (ii) government has a role in promoting competition; and (iii) transit subsidies as a means of avoiding fare increasess often starve transit systems of much-needed revenue without appreciably affecting ridership.

10. With respect to environmental policies, it is particularly promising to target high use vehicle classes — taxis, buses, and commercial vehicles — for emissions reduction programs, such as inspection and maintenance programs, both because of their high mileage and therefore high emissions, but also because these are fleet vehicles, making enforcement easier. Retrofitting high use and inherently dirty vehicles is also found to be a promising strategy, in particular vehicles with standard two-cycle engines. Indeed, technologies for retrofitting these engines are relatively inexpensive and improve fuel economy, raising the possibility that the change can pay for itself with fuel economy benefits alone.

11. Success in implementing the approaches to reducing air pollution from transportation as summarized above will require leadership from within each of the sectors and from institutions having the primary responsibility and competence to assume the leadership role. While many activities will require joint efforts, donor agencies and national institutions will need to ensure that their interventions are well targeted and coordinated across sectors. From within the energy sector, activities should be focussed primarily in the areas of (1) fuel pricing, (2) improving fuel quality, (3) phasing out lead from gasoline and (4) promoting the use of less polluting alternative fuels where economic.

12. The World Bank's Energy and Environment Strategy has recommended that Energy and Environment Reviews be undertaken on an "as needed basis" in countries where the related issues need early attention. Such reviews are now starting to be undertaken as ESMAP activities. They should provide an excellent opportunity to assess the issues and options related to energy, transportation, and the environment and to identify a program of measures to be carried out with the support of development institutions.

1

Introduction

1.1 Growth in personal and commercial travel is a necessary ingredient to economic development, but such growth, and the growth in transport infrastructure, vehicle ownership and the use it entails, can carry a high environmental price[1]. Many analysts have examined policies to reduce the environmental impact of transportation. Cost-effective pollution reduction policies are clearly needed and to a large extent must rely on the price system to send appropriate signals to internalize environmental externalities. Although transportation creates other higher cost negative externalities besides air pollution, such as congestion, accidents, noise, and urban sprawl, this paper focuses on air pollution to examine what can be done directly from within the energy sector to reduce pollution from transport in a cost-effective manner.

1.2 Our central thesis is that although the potential impact of energy policies on transport emissions is limited, at least compared to the potential of policies aimed directly at emissions, their ease of administration and enforcement make them attractive complements to other, better targeted, policies. In addition, to a considerable extent the policies we examine –at least those that attempt to alter relative prices – are generally consistent with the kinds of sectoral adjustment policies recommended by the World Bank to promote economic growth. The formulation of energy policies to meet environment objectives in the transport sector requires careful and active coordination with other policy interventions if the gains from any of these policies are to be fully realized. That is, policies designed to modify fuel quality should be coordinated with policies affecting vehicle design. And policies that attempt to alter transport demand through the price mechanism should take into account the potential for "leakage" of lower-priced fuels into transportation fuel markets.

1.3 The environmental effects associated with transportation stand at the end of a number of long and complex causal chains that reach back, ultimately, to the behavioral decisions of individuals, households, firms and governments. The aggregate of these decisions regarding trip purposes, schedules, destinations, and modes translates into temporal and spatial patterns of airborne vehicle emissions, which in turn affect patterns

[1] See Sustainable Transport: Priorities for Policy Reform, the World Bank, 1996.

of ambient air quality. In the long run these decisions affect, and are affected by, the location of homes and workplaces and the availability and cost of transportation alternatives. Note also that because of our focus on medium and short-term policy interventions, we ignore in our review policies that would act directly on land use decisions.

1.4 The complexity of the relationships between transport, the economy and the environment means that there are many policies, affecting many different activities in a variety of ways, that have implications for transport emissions. Potential targets for policies to improve air quality include vehicle emission rates, fuel composition, transport mode, age and type of vehicles, traffic flow, and amount of travel. Each of these targets, moreover, can be affected by a multitude of policies.

1.5 Other things being equal, of course, the most effective and usually most efficient target is the one most closely related to the cause of the environmental problem. Thus, targeting emission rates of existing vehicles may have more promise than those of new vehicles (because there are so many more of the former, with much higher emissions); targeting emission rates may be more effective than targeting vehicular travel (especially if most emissions come from a relatively small number of vehicles). However, other things are rarely equal. Policies efficiently targeting emissions of vehicles in use have proven unexpectedly difficult to implement. And the policy that hitherto has had by far the greatest effect at reducing the air-quality impacts of transport – emission limits on new vehicles – has about exhausted its potential, at least in developed countries. Although many developing countries may still enjoy cost-effective opportunities for more stringent new-vehicle standards, there is every likelihood that those opportunities will also be exhausted without meeting air quality goals. It is fortunate, therefore, that there are so many candidate policies and policy targets available.

1.6 On the other hand, the surfeit of available options does not exactly make the job of policy formation and evaluation any easier. With many alternative policies available, it is a major task to choose the "best" policy or set of policies, as well as the appropriate way to sequence those policies. With many policy targets available it is possible to enact multiple policies simultaneously: not only the new-vehicle emission policies, but policies attacking emissions from existing vehicles, policies discouraging vehicle use, fuel composition and pricing policies, and others. Some policy combinations may be incompatible in the sense that they target the same emissions; others may require coordination among several different government sectors.

1.7 Energy policies, in particular, have some powerful advantages. They can be applied differentially over time, space, and fuels, and can affect the entire vehicle fleet immediately rather than just new vehicles. In addition, their ease of administration and enforcement contrasts sharply with the problems in these areas for environmental policies, even implemented in developed countries.

1.8 Fuel pricing policies are especially of interest, because these can often be made consistent with the economic restructuring policies many of these countries are undertaking or should undertake. In many countries energy subsidies have kept prices artificially low and contributed both to the economic and environmental problems.

1.9 In no case, though, is it possible to achieve environmental objectives through the use of energy policies alone. Our goal is to delineate what energy policy can and cannot do. This will require us to consider not only the energy policies of interest but environmental or transport policies that may be competitive with or complementary to policies in the energy sector.

2

Energy, Transport and Environmental Quality

2.1 Of the many ways that transportation activities can affect the environment, one of the most important for developing countries is air pollution resulting from fuel combustion. In addition, construction and operation of transportation facilities can often cause major environmental disturbances. Major highways, canals and pipelines can destroy or change the character of wetlands, partition ecosystems into smaller and less sustainable units, or join previously isolated ecosystems. By directly affecting the composition and prices of fuels available, energy policies have a large potential role to play in environmental policy, not just with respect to transportation but with respect to other economic sectors. Energy policies can also indirectly affect other environmental consequences of transportation, since changes in demands for transportation services will affect the demand for new transportation infrastructure. It is unlikely, however, that energy policy will be a significant tool for controlling the environmental effects of transportation infrastructure projects other than air quality, hence; this paper is focuses on emissions and air quality in the nexus of energy, transport, and environmental issues.

Transport, Emissions and Air Quality

2.2 Table 2.1 provides some indication of the magnitude of air quality problems in a number of the world's largest cities. As shown, only a few of these cities have air quality that WHO judges as not "serious" for any of the listed pollutants (London, New York and possibly Buenos Aires). Of the remainder, only Los Angeles and Tokyo are not in a developing or transitional economy. Evidently the most troublesome pollutant is suspended particulates, which has been linked to elevated mortality levels in both developing and developed countries and which is considered a serious problem in over half of the selected cities. Air quality appears to be especially bad in Mexico City, which has serious pollution problems for four of the six pollutants, and moderate to heavy pollution in two others.

2.3 The transport sector is an important contributor of emissions in the cities of developing countries, and not just of pollutants most frequently associated with motor vehicles in wealthy countries (HC, CO, NOx and lead). As shown in Table 2.2, motor vehicles are also important sources of SO_2 and fine particulates, a circumstance probably owing to poorer fuel quality and the greater importance of diesel and two-cycle engines in these countries.

Table 2.1 Air Pollution Levels in Selected World Megacities

	Population[a]	SO_2	*SPM*	*Lead*	*CO*	NO_2	O_3
Bangkok	10.3	*	***	**	*	*	*
Beijing	11.5	***	***	*	---	*	**
Bombay	15.4	*	***	*	---	*	**
Buenos Aires	13.0	---	**	*	---	---	---
Cairo	11.8	---	***	***	**	---	---
Calcutta	15.9	*	***	*	---	*	---
Delhi	12.8	*	***	*	*	*	---
Jakarta	13.2	*	***	**	**	*	**
Karachi	11.6	*	***	***	---	---	---
London	10.8	*	*	*	**	*	*
Los Angeles	10.9	*	**	*	**	**	***
Manila	11.5	*	***	**	---	---	---
Mexico City	24.4	***	***	**	***	**	***
Moscow	10.1	---	**	*	**	**	---
New York	16.1	*	*	*	**	*	**
Rio de Janeiro	13.0	**	**	*	*	---	---
Seoul	13.0	***	***	*	*	*	*
Shanghai	14.7	**	***	---	---	---	---
Tokyo	21.3	*	*	---	*	*	***

Source: Atmospheric Research and Information Center, 1996

Key:

--- Inadequate data

* Low pollution, WHO guidelines are normally met (but short-term guidelines may be exceeded occasionally).

** Moderate to heavy pollution, WHO guidelines exceeded by up to a factor of two (Short term guidelines exceeded on a regular basis at certain locations).

*** Serious problem, WHO guidelines exceeded by more than a factor of two.

SPM Suspended particular material

SO_2 Sulfur Dioxide

CO Carbon monoxide

NO_2 Nitrogen Dioxide

O_3 Ozone

[a] Estimated population in 2000 in millions

Table 2.2 Contribution of Motor Vehicles to Urban Air Pollution

	SO_2	*TSP*	*CO*	*HC*	*NOx*
	(Percent of total air emissions)				
Bangkok	39	22	NA	NA	76
Beijing	-	-	39	75	76
Bombay	5	24	-	-	52
Budapest	12	-	81	75	57
Cochin, India	-	-	70	95	77
Colombo, Sri Lanka	94	88	100	100	82
Delhi	13	37	90	85	59
Lagos, Nigeria	27	69	91	20	62
Mexico City	22	35	97	53	75
Santiago	14	11	95	69	85
Sao Paulo	64	39	94	89	92

Source: World Resources Institute, 1997.

2.4 To fashion effective policies the basic science of air pollution from mobile sources needs to be understood. Some pollutants (CO, some particulates, and lead) are of importance because of their direct impacts on human health. Other pollutants of concern are created in the atmosphere from precursor emissions. Ozone is created from volatile organic compounds (VOCs), a category that includes hydrocarbons (HC) and Nitrogen Oxides (NOx) in the presence of sunlight in areas where airflow can stagnate. This process is highly nonlinear and depends on the ratio of VOCs to NOx in the air. When the ratio is high, VOC reductions are unproductive relative to NOx reductions, and the region is termed NOx-limited. Regions are considered VOC-limited otherwise. Particulate matter concentrations (PM) are created from direct particulate emissions (from diesel fuel) and from transformations of SO_2 into sulfates and NO_2 into nitrates (and to a lesser extent from HC into secondary organic aerosols).

2.5 Which of these characteristics deserve focus depends on the particular problems faced by the area in question, which implies that no one policy instrument suits all conditions. Working backwards from effects to concentrations to emissions helps to narrow the problem. If ozone concentrations are deemed the major problem and the area is found to be VOC-limited, then reductions in gasoline vehicle emissions would be called for, because emissions from diesel engines are very low in VOCs. However, if the area were found to be NOx-limited, reductions in emissions from all types of vehicles are potentially effective because all types of vehicles emit NOx. If particulate concentrations are the major problem, then diesel and two-stroke motorcycle emissions may be the best target. In addition, dusty cities may need to address vehicle use or road materials if road dust is a high fraction of the particulate load.[2] Finally, the literature on health effects

[2] There is still considerable uncertainty about the effects of road dust on health; in particular, whether road dust can be treated as equally potent as directly "emitted" particulates or secondary particulates.

suggests additional policy design considerations. Fine particulates (less than 2.5 microns), which are directly emitted in far larger quantities by diesel engines than gasoline engines, have been linked to more (and more severe) health effects than those caused by VOCs and NOx emissions as ozone precursors.

Development, Transport and Energy Use

2.6 Transportation is one of the most important users of energy. In OECD countries the transport sectors account for a range of about 24 percent of total energy use (in Sweden) to about 36 percent (in the U.S.). In developing countries and economies in transition, the fraction of total energy use devoted to transport is similar, though somewhat more variable – for example, only 15 percent in Poland vs. 65 percent in Nigeria (Fraser et al., 1995).

2.7 The most important trend regarding transportation is the growing relative importance of highway travel: motorcycles and , increasingly, automobiles for personal travel and trucks for commercial transport. The unparalleled convenience and personal mobility of the automobile are so highly valued that every developed country in the world has very high levels of personal automobile ownership. Developing countries have much lower levels of auto use at present, but at low per-capita income levels the income elasticity of auto ownership is extremely high.[3] Development will very likely bring an explosion of automobile ownership and use in these countries. This is at any rate what happened in the "Asian Tigers" and in Central and Eastern Europe after 1988.

2.8 Table 2.3 compares growth rates of rail and truck transport for selected countries around the world. As shown, railroads have steadily lost market share relative to trucking in most of the countries listed, and in many countries rail has experienced an absolute decline. The choice, from a narrow perspective, between trucking and rail involves a tradeoff of the superior energy efficiency of rail (whose energy use per ton-mile is less than half that of trucking) and the better service of trucking. Rail tends to be preferred as the energy-cost component of total costs increase – as cargoes get bulkier or hauls get longer. However, the low price of fuels in recent years has reduced the importance of price as a determinant of mode choice in freight transport. Fuel now accounts for only 6 and 12 percent of rail and truck operating costs, respectively (Fraser et al., 1995).

2.9 Other factors besides low energy prices have contributed to the historically declining relative share of commercial traffic carried by railroads. One factor is the growing adoption of "just-in-time" inventory control systems, which put a premium on speed and service in delivery. In addition, railroads worldwide tend to be state-owned or state-regulated monopolies and are not as efficient or well managed as the firms in the

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3 Income elasticity of ownership is much lower in the developed countries. In the United States, which has very nearly reached the level of one private vehicle per licensed driver (Pisarski, 1994), the response to increasing income tends to be acquisition of better-quality vehicles, rather than greater numbers of them.

highly competitive trucking industry. Both industries are heavily subsidized by government provision of infrastructure that is not covered by the taxes, but the key difference appears to be the effects of competition.

Table 2.3 Annual Growth Rates of Commercial Rail and Truck Traffic

	Rail[a]	*Truck*[b]	*Year 1980-1991 (except where indicated)*
Algeria	0.9%	5.9%	
Bangladesh	-2.3%	9.6%	
Bolivia	0.5%	1.8%	
Cameroon	0.9%	-0.3%	
Chile	2.8%	5.1%	'81-93
Congo	-2.8%	1.6%	
Czechoslovakia	-3.4%	3.0%	
Egypt	3.4%	11.2%	
El Salvador	-4.1%	-0.9%	
Greece	-2.3%	5.1%	'81-93
Hungary	-7.2%	3.5%	'81-93
India	4.2%	10.7%	'81-91
Iran	7.4%	-0.2%	
Ireland	-0.8%	5.5%	'80-93
Jordan	3.9%	4.4%	'81-93
Kenya	-4.3%	5.5%	'80-93
Malawi	-12.5%	2.6%	
Malaysia	-0.2%	4.4%	'80-93
Mexico	-1.1%	7.2%	'80-93
Morocco	1.1%	3.5%	'80-93
Myanmar	0.6%	2.1%	
Pakistan	-3.3%	8.6%	
Peru	-2.3%	3.8%	'80-93
Philippines	-15.4%	7.4%	'80-93
Poland	-4.2%	5.0%	'80-93
Saudi Arabia	5.7%	3.6%	'81-91
Sri Lanka	-1.6%	5.8%	'80-93
Tunisia	0.6%	3.8%	
Venezuela	1.6%	-3.4%	

[a] Average annual percent growth in ton-km.
[b] Average annual percent growth in number of vehicles.
Source: United Nations, 1996.

2.10 The growth of highway travel is particularly pronounced in urban areas, even in those areas where population growth has slowed. For example, in Bangkok the number of vehicles continues to grow by 9.9 percent per year, even thought population is growing only by about 2 percent per year as shown in Table 2.4. Vehicle growth is also heavily concentrated in private gasoline-powered vehicles, in particular automobiles and light-duty trucks.

Table 2.4 Characteristics of Vehicle Fleet in Bangkok

Metro area population (1992):	9.2 million
Growth rate	2.2 percent per year
Per capita income (PPP)	US$5,000 per year
Growth rate	7.9 percent per year
Vehicles total (1990)	2.0 million (9.9% ann. growth)
Private cars	598,000 (7%)
Private buses	233,000 (7%)
Pickups	269,000 (23%)
Taxis	13,500 (nil)
Tuk-tuks	7,500 (nil)
Motorcycles	728,000 (8.5%)
Buses	21,000 (4.5%)
Fuel prices (recent change) ($/liter)	
Gasoline	US$0.36 (-39%, 1984-90)
Diesel	US$0.32 (nil, 1984-90)

Source: Sayeg, 1992.

Factors Affecting Emissions

2.11 Transport emissions can be thought of as the product of transport usage time pollution intensity. Transport usage is average vehicle kilometers traveled (VKTs) per vehicle times the stock of vehicles. These simple relationships underscore the fact that to reduce pollution policies that are interactive and integrative, and which operate through all these relationships, may be the most effective approach for reducing emissions.

2.12 The types and quantity of pollutants emitted in various transport categories depends first of all on the scale of use – total ton-kilometers for commercial transport and vehicle miles for passenger vehicles. The intensity with which pollutants are discharged – the grams pollutant per unit activity – depend on a great many variables. Passenger-vehicle emission rates, for example, depend on fuel characteristics, engine characteristics, fuel economy, driving behavior, vehicle age, and vehicle maintenance.

2.13 *Engine Characteristics.* Different engine types have very different emission characteristics. Four-cycle internal combustion (IC) engines tend to emit CO, HC and NOx, but levels of particulates are generally quite low. Two-cycle engines have a similar signature, but they are generally much dirtier. Such engines are infrequently used for transportation in the U.S. and Western Europe (except as snowmobiles), but two cycle motor scooters, motorcycles, and three-wheelers are common in developing countries[4] and the countries of East Asia, and a number of two-cycle East-German-made Wartburgs and Trabants are still common in the countries of Eastern Europe. Diesel engines, more common among heavy trucks, tend to have lower levels of CO and HC, but

[4] In India in 1995, 73% of the vehicle stock was two and three-wheelers, and most of these are two-cycle engines (International Road Federation, 1997).

higher levels of NOx. Fine particulate emissions are a particular problem for diesel engines.

2.14 *Vintage.* Emissions also vary greatly by vintage as a result of a variety of technological changes. In the U.S., western Europe and Japan, 30 years of research and development have reduced the emissions of new cars by as much as 95 percent. Inasmuch as the reduction in emissions is driven by regulations, the decline in new car emissions may not be quite as dramatic in developing countries, which generally have less demanding emission standards.

2.15 *Fuel Characteristics.* Motor fuels are very complex products, containing hundreds of compounds, many of which can affect air quality. These compounds may directly generate harmful air contaminants during combustion or storage, or they may affect air quality indirectly by damaging emission control equipment. Variation in fuels may arise from the characteristics of the crude oil feedstock or from refinery characteristics. In addition, chemicals with environmental implications may be added to fuels for various reasons, one of which is the reduction of the environmental impacts of fuel use.

2.16 Sulfur and lead illustrate, respectively, the inadvertent and deliberate presence of harmful constituents in gasoline. Sulfur concentrations in gasoline depend on the sulfur content of the crude oil input and on the ability of the refinery to remove it. These concentrations in gasoline can be high enough to be an important source of SO_2 emissions, and even in low amounts can seriously affect the performance of the catalytic converters used by modern vehicles to reduce emissions of CO, HC and NOx. These effects are reversible, gradually disappearing if low-sulfur fuel is used.

2.17 Lead can be added to gasoline at the refinery as a low-cost octane enhancer. However, its severe environmental consequences caused developed countries to eliminate it years ago, beginning with Japan in 1975. Lead also poisons catalysts very rapidly, and in addition can have very severe health consequences including the reduction of the intelligence quotient (IQ) of children. After a decline in the average lead concentration of gasoline in the U.S. in the early 1980's (mandated to protect catalytic converters, not for health reasons), researchers found a remarkable and unexpected improvement in blood lead concentrations among the nation's children. This result led to a phase-out of all lead in gasoline in the U.S. beginning around 1985. The evidence of health damages induced many other countries to reduce or eliminate lead in gasoline beginning in the mid-to-late 1980s, including Sweden and Brazil. The phase-out was made possible in part by fuel modifications and in part by an evolution of engines more tolerant of low-octane fuel.

2.18 Gasoline can also be modified in numerous ways that may reduce emissions, including lowering fuel volatility to reduce evaporative emissions and adding oxygen-containing compounds (oxygenates) to enhance complete combustion. Both low-volatility fuel and fuel oxygenated with ethanol or MTBE are now in widespread use in the U.S., although the oxygenates have begun to raise some environmental concerns of their own.

2.19 In addition to modifications to gasoline, it is also possible to use different fuels altogether. Compressed natural gas in particular is an attractive fuel environmentally. Its main disadvantages are that it requires specialized fuel delivery systems that are unlikely to be widely available in developing countries; for use in existing vehicles it requires extensive retrofit; and fuel storage requirements are onerous, especially in a small vehicle. For these reasons it seems most useful for commercial vehicle fleets at present.

2.20 *Vehicle Age and Maintenance.* Wear and tear on engine components cause vehicle emission rates to increase with use. In a well-maintained vehicle this increase is quite minor. It is much more rapid if the vehicle is not maintained properly. Poorly maintained vehicles are an important source of emissions in developed countries, where data suggest that perhaps 10 percent of all vehicles produce 50 percent of HC and CO emissions (Stedman et al., 1994). The distribution of NOx emissions is also skewed, but probably somewhat less so. In developing countries, where fewer cars are equipped with catalytic converters, average emissions are likely to be higher, but the distribution may be less skewed. Poorly maintained vehicles without catalytic converters can generate HC and CO emissions four or more times higher than well maintained vehicles (Faiz, Weaver, and Walsh, 1995). Poor maintenance has an even greater effect on maintenance of emissions-controlled vehicles. In addition, experience has shown that once an emission-controlled vehicle becomes a gross emitter it can be quite expensive to repair effectively, largely because it is rather difficult to determine the underlying causes of the poor emission performance.

2.21 *Driving Behavior.* Driving behavior affects emissions, especially in a vehicle equipped with a catalytic converter. Emissions of all pollutants are higher when the vehicle is under a heavy or rapidly-changing load. When acceleration is particularly high, modern vehicles go into "enrichment" mode, during which the greatly enriched fuel mixture overloads the catalyst and produces CO emissions at a rate 100 or more times normal and of HC of ten or more times. Average vehicle emissions can thus be greatly affected by the frequency of these enrichment episodes, which in turn depend primarily on driver characteristics (Ross et al., 1995). Trip-making behavior can also affect emissions, primarily of HC. Until the engine and catalyst heats up, HC removal in cars with catalytic converters is inefficient, leading to high "cold start" emissions. These considerations have animated efforts to reduce cold-start emissions by such technical approaches as preheating catalysts. In developing countries, where a large fraction of vehicles may not have such abatement devices, cold start emissions may be a much smaller share of total emissions.

2.22 *Fuel Economy.* Generally speaking, trains and buses are perceived to be more energy-efficient than private automobiles, and so they are per *potential* passenger mile. Energy efficiency per actual passenger mile depends on load factors, which tend to be high in developing countries. However, different modes have very different emission characteristics, so a change in modal split may not necessarily improve air quality even if it improves energy efficiency.

2.23 There is also an effect of fuel economy on emissions within transport modes. Improvements in energy efficiency of passenger cars have certainly reduced the environmental impacts, per vehicle-kilometer traveled, in the fuel production and distribution sector (Delucchi, Greene and Wang, 1994). The direct effects on vehicle emissions, however, are considerably more complex. If prices remain stable, fuel economy improvements will reduce the price of a unit of travel, resulting in greater travel demand. In vehicles without catalytic converters, emissions are approximately proportional to fuel use, so that better fuel economy is associated with lower emissions. Whether such a demand increase results in an increase or decrease in vehicle emissions will depend on the effect of fuel economy on vehicle emission rates. In an uncontrolled vehicle, better fuel economy will improve emission rates, which are approximately proportional to fuel use. But the most common kind of vehicle emission regulation breaks this natural link between fuel economy and emissions. This is the regulatory form that requires all vehicles to meet the same emission standard per unit distance. To adhere to such a standard, a vehicle manufacturer must install a relatively larger catalytic converter on vehicles with poor fuel economy, perhaps raising the emission control cost of such vehicles. But once the standard is met, then independence of fuel economy and emission rate can be assumed (Khazzoom, 1995).

2.24 However, the rationale applies only to new vehicles. Empirical analysis of emission data in the U.S. suggests a relationship between fuel economy and emissions that gradually grows stronger as vehicles age, at least for HC and CO emissions. The mechanism producing this result, presumably, is the gradual breakdown of emission control equipment, which allows the pre-regulatory relationship between fuel economy and vehicle emissions to reemerge. The effect is fairly substantial: a 10-year old vehicle in 1991 getting 8.5 kilometers per liter (km/l) had average HC emissions of 1.53 g/km, compared to emissions of 0.94 g/km for a 17 km/l vehicle of the same age. This effect also seems to be slowly disappearing as emissions of all vehicles improve. Analysis of emission data from 1996 shows that a 10-year-old, 8.5 km/l car now averages HC emissions of 1.03 g/km compared to emissions of 0.72 g/km for a 17 km/l car (Harrington, 1997).

3

Policies

Policy Context

3.1 In identifying options for reducing vehicular emissions in developing countries, one cannot refer immediately to the conceptual literature on instrument choice or experience, because much of literature and experience are dominated by developed countries. The special conditions in developing countries that may influence instrument choice – and the ultimate success of the instruments chosen — need to be identified. Many of these conditions, obviously, will be specific to the country or region in question. However, there are also some relevant "stylized facts" that seem to apply to most if not all developing countries, and others that apply to broad groups of them (e.g. Latin America or the transitional economies of Central and Eastern Europe).

- *Developing countries are catching up with developed ones in transportation activity levels.* Vehicle ownership and kilometers traveled per capita is far higher in developed countries than in developing countries (Kenworthy, et al., 1997) but the gap is narrowing, with "rest of world" road fuel use projected to overtake use in the OECD countries of Europe and the Pacific after 2000 (Cadwallader and Donovan, 1995).

3.2 Although VKTs for personal vehicles continue to increase at a few percent per year in developed countries they are increasing at a greater rate in developing countries, particularly ones with a high rate of income growth. Thailand, for instance, had an annual average rate of growth in VKTs for cars and taxis of over 17 percent between 1982 and 1990 (World Bank, 1994). Pakistan's demand for diesel and gasoline is projected to increase 14 percent and 10 percent per year, respectively, out to 2008 (Masud, 1992). In Indonesia, demand for transportation fuel is expected to double by 2005 (Gunawan, 1992) As noted above, in developing countries generally, commercial truck ton-kilometers are growing rapidly, while rail ton-kilometers are generally flat.

- *Transportation fuel quality is lower and less consistent in developing countries, but it is improving.* Many countries have reduced or are planning to reduce the lead content of gasoline, if not eliminate lead altogether. But sulfur in gasoline and diesel, high vapor pressure, and especially the abundance of high carbon chain products in diesel fuel are problematic. Diesel fuels sold in some developing countries have more pollution causing characteristics than those sold in most developed countries. The main problem is that by setting the boiling point of the fuel too high to enhance refinery yields, an excess of aromatics and particulates is produced.

- *Market distortions in energy pricing, tariff barriers, state monopolies, and materials subsidies are widespread.* In many countries, both gasoline and diesel fuels are subsidized, which encourages overuse of these fuels, and only recently have tariff barriers for imported cars been coming down. Protective tariffs and/or non-tariff barriers for India's and Thailand's two-stroke engine industry are particularly problematic for the environment. Yet, tariff barriers are not unambiguously problematic for transport emissions. Tariffs may keep transport prices high and discourage growth in vehicle ownership (Shalizi and Carbajo, 1994).

3.3 Mass transit is typically subsidized in both the developed and developing world. However, in the latter, artificially low fares coupled with inadequate subsidies starve transit authorities in their maintenance and asset building programs, leading to frequent mechanical breakdowns and high pollution from an aging capital stock. As noted above, subsidies also characterize commercial rail and trucking.

- *Capital is scarce relative to other inputs and commodities; incomes are low.* The relatively high cost of capital means that specialized equipment, such as that for testing vehicle emissions and purchasing new vehicles, will be particularly dear for a developing country. Combined with low incomes, the high price of capital leads to the expectation that the vehicle stock will be old. In Bogota, for instance, 36 percent of the buses are 19 years or older, while 43 percent of the personal vehicles are 12 years or older, with 21 percent older than 19 years. In contrast, only 25 percent and 3 percent of U.S. cars are 12 years and older and 19 years and older, respectively (AAMA, 1995).

- *Few pollution controls are in place.* Although marginal costs of air pollution control generally grow with increasing pollution reductions, developing countries may still be at the lower end of their marginal abatement cost function. This is particularly true for vehicle emissions abatement devices less sophisticated than catalytic converters and fuel quality improvements.

- *Most mobile source pollution is caused by trucks and buses rather than personal vehicles.* This is due to the lower rate of private vehicle ownership and use, exacerbated by the lower quality of diesel fuel, as mentioned above.

- *Travel speeds typically are lower and more travel takes place in very congested stop-and-go conditions.* Commercial vehicles, moreover, tend to be overloaded. Operation of vehicles under these conditions can raise emissions per mile over what they would be with better roads and at lighter loads.

- *Public institutions are weak and lack data and expertise.* Public institutions, including courts and bureaucratic agencies, are generally poorly funded compared with their counterparts in developed countries. Environmental agencies often lack statutory authority and expertise appropriate to their mission. The difficulty and expense of monitoring make it difficult to enforce emission regulations for both stationary and mobile sources in developing countries, while the insufficient quantity and poor quality of ambient data plague evaluation of the success of programs or even the identification of the most important problems.

3.4 The economic and social conditions found in developing countries affect thinking about policy choice in several ways.

3.5 First, the lack of expertise in government policymaking circles favors the use of simple policies that do not require monitoring of emissions of vehicles in use. Such policies include the enforcement of emission standards on new or imported vehicles, gasoline taxes, and removal of fuel subsidies, and use of registration fees based on age or certification emissions.

3.6 Second, the relatively low market penetration of personal vehicles may make it easier to put in place policies that, by raising the cost or increasing the inconvenience of private vehicle use and ownership, preserve public transit systems, cycling or pedestrian options with more benign environmental impacts. Such policies become much more difficult to implement once the automobile drives out other alternatives. Likewise, the relatively greater importance of emissions from commercial vehicles, including not only rail and heavy truck but taxis and buses, increases the relative effectiveness of policies directed at vehicle fleets and that do not involve the public directly.

3.7 Third, low incomes and capital scarcity in developing countries, coupled with pervasive subsidies, both explicit and implicit, mean that considerations of cost-effectiveness and economic efficiency are, if anything, even more important to good policymaking in developing countries than in the industrialized world. This implies that "getting the prices right," in the sense that they reflect marginal social costs, is both more important and harder in developing countries. The numerous distortions in markets for capital, energy, labor and other important inputs make it all the more difficult to determine the social costs or benefits of proposed policies, since market prices are not good indicators of opportunity cost. Other things equal, economic incentive policies may be more favored in developing than developed countries, because the former have more to lose from resource misallocation (Shalizi and Carbajo, 1994).

3.8 Fourth, the greater average age of vehicles, together with the slower stock turnover, increases the payoff to policies that encourage the cleaning up of dirtier vehicles and reduces the payoff of policies that impose stringent standards on new vehicles. Indeed, new car standards on new or late-model vehicles, whether domestically produced or imported, may widen the price differential between new cars and old cars, thereby further slowing the rate of vehicle stock turnover. One way to avoid this so-called "new-source bias" is to accompany the new-car emission standards by a policy that encourages the scrappage of older vehicles, such as old-car buyback programs or age-based emission fees both of which would be difficult to implement in developing countries. [5]

3.9 Fifth, policies to improve fuel quality and consistency are likely to be useful. Particular examples include lead reductions and the reduction in the sulfur content of diesel. Where environmentally "good" and "bad" fuel are sold side by side (such as may occur during a transition to unleaded fuel), it is important to employ a differential tax to ensure that the bad fuel costs at least as much as the good.

3.10 Finally, conditions in many developing countries are changing rapidly, including income levels, vehicle ownership rates, commercial trucking ton-kilometers and the degree of sophistication of government institutions. Policies that appear impossible to implement now will not always be so, and conversely, policies that appear politically feasible now may become more difficult to implement as incomes increase and vehicle ownership becomes more widespread. Thus care should be taken that the policies undertaken now do not foreclose opportunities in the future. Likewise, environmental authorities should be prepared to take steps as soon as the institutional and technological setting allows.

Policy Options

3.11 In a perfect world it would be necessary to have only one vehicle emission reduction policy, as long as that policy required vehicle users to pay the social costs of each trip. Considering the great variation in the air quality impacts of emissions at different times, as well as the great differences in the health, material and aesthetic damages of the same ambient air quality in different locations, such a perfect policy is unattainable. In its absence, a very large number of policies are being used or are under consideration for reducing motor vehicle emissions. There are regulations on fuel composition, on emissions of new vehicles, on emissions of existing vehicles; there are policies to encourage the retirement of older vehicles; there are restrictions on the construction of new highways in regions that do not meet air quality standards; there are transit subsidies and programs to encourage or require firms to have ride-share programs for their employees. And a host of others.

3.12 Despite this multitude of policy options, the progress that has been made since 1970 in reducing emissions from motor vehicles has almost entirely been the result of a single policy: the application of increasingly stringent emission standards for new vehicles. This process is most developed in the U.S., where emissions of new cars have been reduced by about 97 percent since 1968 (Table 3.1). One of the most interesting aspects of new car emissions standard is that most of the reduction in new-car emissions occurs upstream of the catalytic converter, a result of other vehicle improvements, such as electronic fuel injection, and changes in fuels, such as oxygenated gasoline. Although some of the improvements achieved in emissions reductions prior to the mandatory use of

[5] The vehicle buy-back approach, however, was successfully used in Los Angeles to reduce vehicle emissions.

catalytic converters (pre-catalyst emissions) is quite costly, large reductions can be achieved at relatively modest cost (Faiz, Weaver and Walsh, 1996) This point is of particular relevance for developing countries, which may find it more cost-effective to adopt, at least in the near term, emission standards that are much less stringent than are currently required in OECD countries.

Table 3.1 Progress in reducing vehicle HC emissions in the U.S.

(new cars)	*Pre-catalyst emissions (g/km)*	*Tailpipe emissions (g/km)*
Uncontrolled vehicle	5.6	5.6
1992 Honda Civic	1.4 (-75%)	0.088 (-98%)
1993 Toyota Camry	1.3 (-77%)	0.17 (-97%)

Source: Ross et al. (1994) and Marc Ross, personal communication, November 1996.

3.13 Improvements in *total* vehicle emissions have lagged well behind the new vehicle improvements. Although estimates are subject to large errors, we estimate total annual emissions in the U.S. in 1991 to be about half the total emissions in 1970 and about a quarter of what they would have been had there been no change in vehicle emission rates.[6]

3.14 In the next two sections we discuss briefly the many vehicle emission-reduction policies that either have been adopted or that are under active consideration by policymakers somewhere in the world. There is a multitude of such policies, which we classify according to the causal distance from what is being regulated to the end result, emissions. Those categories are:

- *Energy policies.* Energy is such an important input to transportation that policies here can strongly affect both the demand for travel (mainly fuel pricing policies) and its environmental impact (fuel content or fuel quality regulations).
- *Transportation policies.* Transportation policies attempt to encourage reductions in travel, or to encourage shifts into modes that are inherently less polluting, such as high-density transit, or to encourage shifts in travel scheduling that result in less pollution or pollution at times less damaging to air quality.

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6 This estimate was made applying the historical vintage-specific emission estimates in MOBILE5b, EPA's current emission factor model, to annual estimates of vehicle travel from AAMA (1994).

- *Environmental policies.* These policies attempt to encourage the use of emission reduction technology, such as new car emission standards, or discourage use of high-pollution technology (such as accelerated scrappage programs).

4

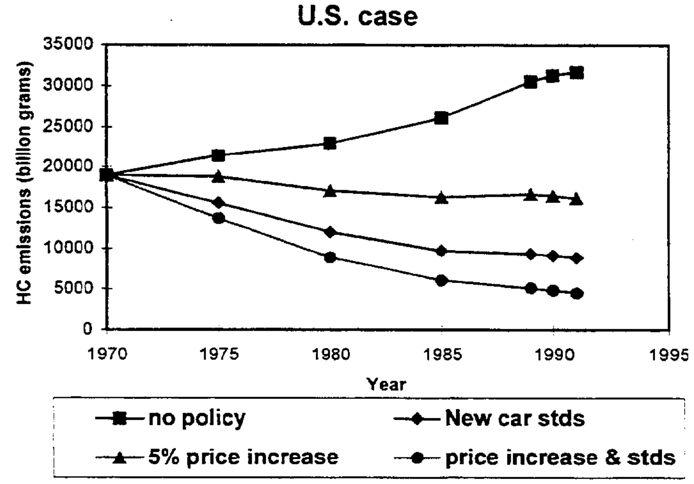
Instruments Applied Directly Within the Energy Sector

Fuel Use Taxation

4.1 Of various policies affecting fuel use, fuel taxes are the most ubiquitous. Although most if not all existing fuel taxes were enacted for revenue purposes, their potential for pollution reduction is becoming apparent. Fuel taxes are attractive because they are simple to administer and easy to enforce; furthermore the administrative apparatus is already in place. These characteristics permit this instrument to be targeted geographically and seasonally. Just as important, fuel use (or fuel composition) policies can affect the entire vehicle fleet, in contrast to policies targeted to new vehicles.

Figure 1

Emission standards vs. fuel price increases: U.S. case



Source: Authors' estimates.

4.3 Several authors have recently suggested that gasoline taxation might be a useful emission reduction policy (Krupnick and Walls, 1992; Eskeland, and Devarjan, 1996), reducing emissions entirely by reducing travel. The effectiveness of fuel taxation as an environmental policy thus depends on the sensitivity of fuel use to changes in price. Higher fuel taxes can affect fuel use in two ways. First, by raising the cost of travel, they encourage motorists to drive less. In addition, an increase in fuel prices encourage the shift in use from vehicles with poor fuel economy to vehicles with better fuel economy. Part of this shift could happen quickly, as commercial fleet operators and multiple-vehicle households shift use among the vehicles at their disposal. Some of the shift could occur over time, as fuel-inefficient vehicles are retired and replaced with more efficient ones.

4.4 Although policy-makers and (especially) the general public are generally skeptical, there is plenty of evidence that fuel use is reasonably sensitive to price, especially in the long run. Fuel price elasticity is one of the most extensively studied of all micro-economic phenomena. A recent review of studies of fuel price elasticity (Dahl and Sterner, 1991) found over a hundred studies, with over three hundred separate elasticity estimates using a wide variety of econometric approaches and data sources and representing over twenty countries. Many of these were dynamic models, allowing estimation of both a short-run and long-run elasticity. The estimates are quite variable, but the authors suggest a range of -0.24 to -0.41 for short-run elasticity and assert that long-run price elasticity is more elastic than -0.77. The difference in estimates cited by Dahl and Sterner seem to depend more on estimating technique and length of sample than on the country or countries studied.

4.5 Even among those who accept the proposition that fuel use responds to price, it is often argued that the kind of fuel price increases that would be necessary to make an environmental difference are politically impossible because they would cause major economic dislocations. As pointed out in the World Bank report *Sustainable Transport* (World Bank, 1996), however, gradual price increases applied over a long period of time can achieve substantial reductions with little dislocation. This proposition is illustrated in Figure 1 which compares the emission reductions actually achieved in the U.S. between 1970 and 1991 by the new vehicle standards with the (simulated) reductions that would have been achieved simply by raising fuel prices by 5 percent per year in real terms. Such a pattern of fuel price increases would have reduced per capita travel by about half and, as shown in the figure, achieved about half the emission reductions achieved by the policy of new-car emission standards. This projection assumes a short-run fuel price elasticity of -0.3 and a long-run elasticity of -0.7, which is about the mean of the studies cited by Dahl and Sterner (1991), and assumes emission factors of all cars as they were in 1970.

4.6 Over the course of this projection, the price of fuel is allowed to rise from \$0.31/liter (in 1996 dollars) to \$0.49 in 1980 to \$0.85 in 1991. The former is close to the real price of fuel in the U.S. in 1970 and the last is similar to prices found today in many European countries. The 50 percent reduction in per capita vehicle use also approximates the difference between European countries and the U.S. in per capita use (Nivola and Crandall, 1995).

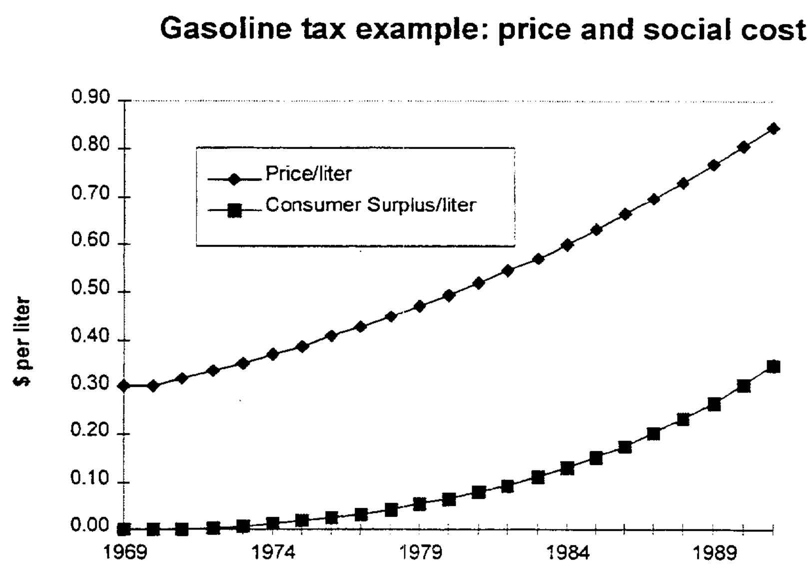
4.7 Figure 2 traces the fuel price per liter and the estimated social cost of emission reductions per liter over the period. Taxes are transfers to the government, so the measure of their social cost is not the total tax collected but the value of the distortions introduced into the purchasing decisions of consumers and firms. This social cost is estimated by the deadweight loss, or the change in consumers surplus that occurs when consumers buy less after a price increase. The deadweight loss is a rapidly increasing function of the disparity between the price of gasoline and its cost, and thus depends not only on the size of the new tax but also on the size of the existing tax on gasoline.

4.8 As shown, the consumer surplus cost would remain low for about a decade and then begins to increase rapidly from \$.06 per liter in 1980 to over \$0.30 per liter in 1990. The reduction expressed in terms of pollutant removed depends on the mean emission rate of vehicles. For typical uncontrolled vehicles in the U.S. in 1970, each cent per liter translates to about \$150 per tonne HC. Thus the cost effectiveness of this policy would only have been less than \$1,000 per tonne in 1980, but would have been about \$4,600 per tonne in 1990. Thus the cost effectiveness of fuel policy depends critically on the level of prices applied.

4.9 The cost-effectiveness also depends on the initial cleanliness of the vehicle fleet. If the base emission rate is taken to be the pre-catalyst emission rate of the Honda and Toyota shown in Table 5 (rather than the uncontrolled emissions of a 1970 vehicle), each penny per liter of tax translates into about \$600 per tonne HC. Thus, the cost-effectiveness of fuel prices as environmental policy is about \$4,000 per tonne HC after 10 years of raising prices and about \$18,000 per ton after raising prices for twenty years.

4.10 The simple comparison of fuel taxes to vehicle emission standards leaves out a few important considerations, of course. One is that the benefits of fuel taxation may extend beyond the reduction in emissions. By making vehicular travel more expensive, fuel taxation may help prevent the deterioration in mass transit and may help promote urban development which is more accommodating to pedestrians and the use of bicycles. In addition, while reducing emissions of conventional pollutants, fuel taxation also encourages the reduction in greenhouse gas emissions. In contrast, a policy of vehicle emission standards can achieve only a reduction in emissions of conventional pollutants. None of these other beneficial effects is achieved through setting tougher emission standards.

Figure 2



4.11 On the other hand, fuel use is probably laden with more uncertainty than emission standards. The most important and obvious of these is of course the uncertainty about price elasticity. Another uncertainty involves interfuel and intermodal substitution. Unless taxes cut across all fuels (generally gasoline, diesel, oil-gas mixtures for two strokes, etc.) proportionally, substitutions to cheaper fuels or cheaper modes may occur. An increase in the gasoline tax alone, for instance, could induce interest in diesel-powered vehicles and motor scooters and even in blending diesel into gasoline. A shift to diesel vehicles would mean lower emissions of HC and CO but could increase SO_2, NOx and fine particulate emissions. Motor scooters tend to have fairly rudimentary emission control systems; even though they are quite fuel-efficient, the emissions per unit distance can be quite high. This is particularly true for scooters with two-cycle engines, which are notorious polluters.[7] Blending diesel fuel with gasoline could have dramatic effects both in lowering performance and increasing emissions.

4.12 The effectiveness of fuel taxes as an environmental policy may also be seriously limited by non-transport fuel use. This is an important consideration for gasoline, which is used in farm equipment and other off-road vehicles, and an even more important one for diesel fuel, also used in off-road vehicles and for which kerosene and some home heating oils are possible substitutes. If the tax is limited to fuels used in transportation, the resulting tax differential will provide a strong incentive to divert into the transport sector fuels nominally purchased for other uses. While such diversion is

[7] Uncontrolled hydrocarbons per kilometer were found to be five times larger in a two-stroke Thai motorcycle than in a four-stroke (14.6 versus 2.9 g/km) (Chan and Weaver, 1994).

also a problem with existing fuel taxes, the incentive to divert fuel would be greatly exacerbated by the higher taxes necessary to make a difference environmentally. Such diversion can be seen now in Sub-Saharan Africa, where kerosene, which is subsidized for household use to discourage fuelwood consumption, is mixed with oil or gasoline or used as a diesel fuel. The high price differential in this region also encourages substantial smuggling from oil-producing Nigeria into neighboring countries. It may be impossible to maintain high fuel price differentials in small open economies unless neighboring countries adopt the same policy. Thus multi-country policy coordination may be required to implement fuel pricing policies whether for revenue-raising or other purposes (Heggie, 1996).

4.13 The only way to avoid the resulting enforcement problems is to tax all fuels regardless of use. Unfortunately, broadening the tax in this way greatly increases its social cost and raises equity concerns, without necessarily improving its environmental effectiveness.[8] These consequences could be avoided by tax rebates for fuel purchased for non-transport uses, which, however, would raise the same enforcement issues encountered in a transport fuel tax.

Fuel Quality

4.14 Improvements in fuel quality can be one of the most cost-effective ways to reduce air pollution. Such improvements can apply to the entire vehicle fleet or a large share of the vehicle fleet and can cause immediate reductions in emissions to be realized. In addition, improved fuel can, within limits, be targeted to the areas, e.g., large cities, where air pollution is worse and to the times, e.g., summer, where air pollution is worse. Contrast this flexibility to another popular policy: emissions standards on new vehicles. The latter reduce emissions only to the extent that new cars enter the fleet, and the added costs of the new vehicles equipped to meet emissions standards may discourage their purchase, further slowing their penetration. Also, temporal or spatial targeting of new vehicle standards would face major implementation hurdles.

4.15 Of course, the costs (and therefore the cost-effectiveness) of fuel quality improvements depend a great deal on the initial fuel quality and on the degree of improvement desired. At a given refinery, incremental costs are generally increasing along a single fuel characteristic; for example, gasoline sulfur concentration can be reduced from uncontrolled levels (typically 300-700 ppm) to 160 ppm for $3.50-$5.70/1000 gal., but to reduce it further to 50 ppm would cost $14.50-$18.60/1000 gal. (Walsh, 1997).

4.16 However, policymakers need to be aware that the costs of improving fuel quality can also differ considerably from one refinery to another, because of differences in installed equipment, crude oil feedstocks and fuel output characteristics. For this reason the most successful policies to affect fuel quality are not likely to be those that

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8 For instance, if residential use of a newly taxed fuel decreased in favor of a dirtier but now cheaper fuel, the environmental effects could be worse.

detail specific limits for the many constituents of gasoline. It is a more promising idea to put standards on fuel performance characteristics, such as volatility, rather than on the specific constituents that affect volatility. There are often many ways to achieve fuel with given characteristics, and the most cost-effective may depend on the qualities of the crude oil feedstock and the capabilities of the refinery. Developing countries in particular should be wary of adopting specific standards of fuel composition simply because those fuels are what are in use in developed countries.[9] The large cost variability across refineries is also a reason to consider economic incentive approaches to fuel quality, inasmuch as well-designed economic incentive policies can target emission reductions on the refineries where the incremental costs are the least.

4.17 In this discussion, we examine policies addressing four of the most promising types of fuel quality improvements: removing or reducing lead in gasoline, reducing sulfur in diesel and gasoline, and gasoline and diesel reformulations.

4.18 *Lead.* As shown in Table 4.1, many countries have instituted programs to reduce or eliminate lead in gasoline and more countries are on track to do this, including some the world's most populated. However, relatively high levels of lead per liter are still the rule in some of the poorest regions of the world and in Romania (where 0.6 g/l) is the standard) and the former Soviet Union (with the exception of Moscow and St. Petersburg). On a per capita basis, the lead burden is highest, surprisingly, in Australia and New Zealand, which have relatively high lead levels paired with high VKTs per capita. Of the developing countries, the average per capita burden is highest in countries in South America, the Middle East, and Africa.

4.19 This worldwide focus on "getting the lead out" is well placed. Except for a few areas near lead smelters, gasoline is the major exposure pathway for this pollutant. Sales of leaded gasoline in cities has been found to be highly correlated with blood lead levels. Children in cities where leaded gasoline is sold are more likely to have blood lead levels exceeding U.S. action levels of 100 μg/l, as well as having levels needing costly medical intervention (over 250 μg/l). High blood lead levels have been associated with lower IQ scores in children and higher risks of hypertension, increased risks of heart attacks and increased mortality risks in adults.

4.20 Technically, lead removal requires alterations in the fuel to replace the octane boost obtained by adding the lead. Equivalent octane enhancement can be achieved by blending other very high octane components that add from 0.5 to 3.0 cents per liter to the cost of the fuel. This may require refinery modifications, especially in older refineries. Countries with a large refining capacity for domestic use may develop programs to encourage or require refiners to eliminate or reduce lead. Countries with small, old, or no refineries may find it cheaper to import unleaded gasoline.

9 For a contaminant like lead, obviously, these two approaches amount to the same thing, since there is no alternative to lead removal that achieves the same performance objective.

Table 4.1 World-Wide Use of Lead in Gasoline (Selected countries)

Maximum Allowed Lead Content	*Market Share of Leaded*		
	Low (0-30%)	*Medium (30-70%)*	*High (70-100%)*
Low (<0.15g/1)	Bulgaria, Greece, Ireland, Israel, Italy, Malaysia, Philippines, Poland, Portugal, Spain, Turkey	Belgium, France, Hungary, Iceland, Norway, Singapore, Switzerland, Taiwan, U.K.	*Argentina, Austria, Brazil, Canada, Colombia, Costa Rica, Denmark, El Salvador, Finland,* Germany, *Honduras, Japan,* Netherlands, *Nicaragua, Slovak Republic, Sweden, Thailand, U.S.*
Medium (0.15-0.4 g/l)	Egypt, Iran, Ivory Coast, Kenya, Russian Federation, Saudi Arabia, Sri Lanka, South Africa, Uruguay, Vietnam	Australia, Ecuador, Mexico	—
High (>0.4 g/l)	Algeria, Angola, Bangladesh, Botswana, Burundi, Cameroon, Chad, China, Cuba, Ethiopia, Gabon, Ghana, India, Jamaica, Kuwait, Libya, Mali, New Zealand, Niger, Nigeria, Pakistan, Peru, Romania, Senegal, Yemen, Venezuela, Zimbabwe	—	—

Source: Based on Lovei (1996). 1993-95 data. Countries in Italics have 100% unleaded. The relative number of countries listed in the cells is not meant to represent proportions of countries with the above characteristics.

4.21 The policy issues are therefore how fast and how completely to remove the lead. A policy of banning leaded fuel outright has been adopted by countries without indigenous refining capacity. Elsewhere a strategy of phased lead reduction may be more practical and cheaper, although the policies required to implement phased reduction are more complicated. For one thing, they require transport and storage systems that permit fuel separation and a system of fuel labeling. In addition, phased reduction of lead raises the question of how to allocate the lead reductions to refineries during the phase-in period. During the phase-in period, furthermore, both leaded and unleaded fuel will be sold, raising the possibility of misfueling problems.

4.22 Most countries have used command and control (C&C) policies to achieve phased lead reductions. With its many oil companies, it made sense for the U.S. to employ a permit/banking system that allowed refineries to trade lead reductions to achieve the targeted overall reductions in the most cost effective ways. (Kerr and Maré, 1997). By 1986 the lead in U.S. gasoline had been reduced by 99 percent (Lovei, 1996). Such a program may be neither necessary, if there is only one refining company in a country, or feasible, if a country lacks the institutional capacity, for developing countries. A negotiated settlement with the refinery monopolist or the controlling state agency if a state monopoly may be a better option. For instance, Mexico negotiated a coexistence strategy with its refinery monopoly, Pemex, with the capital cost of refinery modification to produce unleaded fuel estimated to be US$ 1 - 2 billion (Faiz, 1990), with a phase-in period of thirteen years (ending in 1999).

4.23 The misfueling problem arises when vehicles with catalytic converters are introduced into the fleet before the lead phase-out is completed. (Leaded fuel rapidly ruins catalytic converters. In fact protection of catalysts, not health, was the justification for the removal of lead from gasoline in the U.S.) Left to their own devices, gasoline suppliers tend to charge slightly higher prices for unleaded gasoline, reflecting the greater cost at the refinery. In a survey of 14 countries in Latin America and the Caribbean where both leaded and unleaded fuel were sold, misfueling was found to be a problem in six countries (Alconsult, 1996). None of these countries had a strategy to prevent misfueling.

4.24 To prevent misfueling the U.S. required inlet restrictors on gasoline tanks of catalyst-equipped vehicles, but these were easily tampered with and not terribly effective. The most successful policies for discouraging misfueling have been taxation to ensure that leaded fuel is at least as expensive as unleaded. Differential fuel taxation has been used during the phase-in period in numerous countries, including Germany, Netherlands, Switzerland, Thailand, and the U.K. The use of taxes to create price differentials is far from universal, however.

4.25 Finally, countries may be faced with the issue of low lead versus no lead. Low lead gasoline has the advantage of being cheaper and takes advantage of the fact that most octane is gained in the first small addition of lead. Leaded fuel typically has lead content of around 0.15-0.2 g/l. Lead can be reduced to 0.1 g/l without much loss in octane. Unleaded fuel, however, requires lead levels down to 0.013 g/l. The disadvantage of a low lead strategy is again the misfueling problem, where even 0.1 g/l of lead poisons the catalyst of a new car. Thus, the relative merits of the low lead and no lead strategies depend on the tradeoff between cost savings with some remaining lead health problems versus misfueling problems and additional air pollution of NOx, VOCs, and CO.

4.26 *Sulfur*. Reducing the sulfur content of diesel (and more recently, gasoline) has been the target of regulations because this naturally occurring substance results in sulfur dioxide emissions and, more important from a health standpoint, fine particle concentrations. Both SO_2 and fine particulates have been linked to a wide range of morbidity effects in the general population and premature mortality in older people with compromised health. Sulfur also can reduce the efficiency of catalytic converters, although unlike with lead, this effect is reversible. High concentrations of sulfur can also increase direct particle emissions from diesel fuel.

4.27 Many developed countries have established restrictions on the sulfur content of diesel, although few developing countries have taken this step (Table 4.2). Gasoline is just recently being scrutinized in developed countries for sulfur reductions. The focus on diesel is appropriate because typical diesel fuel has from 1.0 to 0.05 percent sulfur while sulfur concentrations in gasoline are an order of magnitude lower (0.15 to 0.01 percent). Costs per pound removed are an order of magnitude lower for reducing sulfur in diesel as well. At the same time, because sulfur poisons the catalysts used in gasoline vehicles, reductions may be warranted in gasoline in situations where ozone (and carbon monoxide) concentrations are of concern.

4.28 The sulfur content of crude oil can vary widely, and it can be expected to influence crude oil prices, along with other factors. Thus, the importation of low sulfur crude may be a viable strategy depending on transportation cost differentials and other requirements a country places on its oil imports.

Table 4.2 Standards for Sulfur in Diesel in Selected Countries/Regions

Country	*Standard (% fuel sulfur content)*	*Date*	*Notes*
United States	0.05	1993	
European Union	0.05	1996	0.03 by 2000 expected
Finland and Sweden	0.001-0.005	1994	
Japan	0.02	1997	
Thailand	0.25	1996	0.05 by 2000 planned
India, Pakistan, Philippines, Sri Lanka	0.5	1996	Initially in metropolitan areas

4.29 These are several issues to consider in developing a sulfur reduction strategy applied to diesel. The first is the appropriate degree of reduction. The marginal costs of sulfur reductions are highly non-linear in the large refineries. Thus, the level at which a standard should be set is critical. Even small reductions may be infeasible for small and old refineries.

4.30 Another issue is the existing pricing structure. Diesel fuel is often subsidized in developing countries because of the desire to reduce commercial transport costs. Financing changes in refining through price increases or importing low sulfur diesel may conflict with the low-price diesel policy. We would argue, however. that this highly polluting fuel should be priced at its social cost, a large share of which is attributable to health damage.

4.31 Diesel fuels have also been regulated because of their sulfur content. During the 1990s most OECD countries have implemented a maximum sulfur concentration of 0.05 percent by weight. Developing countries are also taking action, but somewhat later and with somewhat less stringency. Mexico, as part of its refinery upgrade process, is moving to adopt a 0.1 percent by weight sulfur level in diesel fuel. Brazil is also looking toward reducing sulfur levels in diesel, hoping to reach 0.5 percent by late in the decade. Cost is a major consideration for the pace of sulfur upgrades. Petrobras, the major Brazilian fuel producer, has begun delivering fuel at 0.3 percent sulfur, a first payoff from its recent $1 billion investment at five refineries. A World Bank study (1992) finds that the investment cost of reducing the sulfur content of diesel from 1 percent to 0.25 percent is $4.21/bbl, or $1800/ton particulates (as sulfates) and $2250/ton SO_2.[10]

4.32 Some countries have used an economic incentive approach to sulfur in diesel fuel. Until recently Sweden used a diesel fuel with higher sulfur and aromatic content. A differential tax on sulfur content of fuels has been quite effective – in fact much more effective than anticipated – and sulfur emissions in Sweden have dropped by about 75 percent in just a few years at costs that were lower than originally projected. The policy was designed to be revenue-neutral, but because so many refineries converted to produce the lower taxed fuels, tax revenues have been reduced.

4.33 Because of the critical importance of reducing sulfur in diesel fuel and its relatively low cost of removal, it may be warranted to permit higher levels of aromatics, olefins, or other fuel characteristics in return for greater reductions in sulfur content.

4.34 *Low Volatility Fuel.* Reducing the volatility of gasoline is a particularly effective way to reduce evaporative VOC emissions.[11] In part this effectiveness derives from the high sensitivity of evaporative emissions to volatility; an increase in fuel volatility by 33 percent (from a Reid vapor pressure (RVP) of 9 to 12) approximately doubles VOC emissions in all vehicles, whether they have evaporative emission controls or not. Vehicle refueling emissions are also disproportionately sensitive, with a 15 percent increase in RVP resulting in a 30 percent increase in refueling emissions. (Walsh 1997). Seasonal standards on maximum gasoline volatility can be flexible and cost-effective policies for encouraging use of low-volatility gasoline. However, if volatility is reduced too far then some vehicles begin to experience problems with drive-ability, so a volatility standard is another policy that has to be carefully coordinated with the capabilities of the existing fleet.

4.35 *Other Fuel Reformulation.* Motor fuels are subject to continuous innovation as oil companies try to obtain an edge over their competitors in fuel

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10 In contrast, the cost of reducing sulfur in gasoline in the U.S. was estimated to be 0.1 cent/liter for a change from 360 ppm to 160 ppm, 0.4 to 0.7 cent/liter from 160 to 50 ppm, and 0.5 to 0.8 from 50 ppm to 20 ppm (Faiz, Weaver, and Walsh, 1996).

11 Harrington et al (1995) reach this conclusion after comparing the costs per ton VOC reduction for a wide variety of emission-reducing approaches

performance or cost. Some fuel innovations also claim to improve the environmental characteristics of fuels. The policy issues here are to identify those innovations that reduce vehicle emissions and to make sure that all fuel improvements do not have unintended adverse consequences. In these matters developing countries will no doubt take their cue from the developed world, but they need to be aware that all innovation has risk associated with it. In the case of fuel innovations, the risks involve long-term environmental damage or excess engine wear, leading to damaged vehicles and higher emissions.

4.36 These problems are well illustrated by two recent innovations with environmental implications. The first is the addition of oxygenates to fuel to provide a source of oxygen in order to promote more complete combustion of fuel. The U.S. recently mandated use of oxygenated fuel or "reformulated gasoline" (RFG) containing on average 2.0 percent oxygen by weight in areas with high ambient ozone. The average oxygen requirement could be met by adding ethanol or methyl tertiary butyl ether (MTBE), and now 30 percent of all U.S. gasoline sold contains one of these two oxygenates (API, 1996). MTBE has been found to reduce emissions of VOC and CO by about 21 and 18 percent, respectively, compared to use of conventional gasoline (Kirchstetter et al., 1996).[12] In Brazil as well, ethanol has also been blended with gasoline, both for environmental reasons and to reduce dependence on imported oil.

4.37 MTBE has also raised fears of contamination of groundwater, however. MTBE is much more mobile in soil and groundwater than conventional gasoline, and more resistant to biodegradation then some other dangerous constituents (such as benzene). In groundwater surveys conducted by the US Geological Survey, it was one of the two most common volatile organic compounds found (USGS, 1995). Nearly half the municipal drinking water supply in Santa Monica, California was shut down in late 1996 after discovery of high levels of MTBE in city wells, apparently contaminated by leaks from a nearby gas station.[13] At present the seriousness of the long-term threat of MBTE to groundwater and surface water resources is unclear.

4.38 The second case is concerned with the methylcyclopentadienyl manganese tricarbonyl compound, (MMT), which was developed by the Ethyl Corporation as a low-cost octane enhancer. Late in 1995 the USEPA was unable to prevent the introduction of MMT into gasoline despite unresolved concerns about health effects and reports from Canada (where it has been used for the past two decades) of damage to spark plugs, catalysts and oxygen sensors. Although the major oil companies have announced that they have no plans to introduce MMT despite its legality, it is possible that its use by others will force them to do likewise. Fearing a groundswell of consumer dissatisfaction, some vehicle manufacturers have begun to include in owners manuals statements warning against use of fuel containing MMT. Ironically, one year after its introduction in the U.S., a bill effectively banning MMT use was passed in the House of Commons in the

[12] This study also found a large decrease in some HC species harmful to health, such as benzene, but an increase in others, such as formaldehyde.

[13] See *U.S. Water News Online*, July 1996.

Parliament of Canada.[14] It has been speculated that Ethyl sought the introduction of MMT into gasoline in the U.S. not to increase its U.S. sales but to get the imprimatur of the USEPA to use in marketing campaigns abroad.

4.39 *Other Diesel Options*. The potential exists for using organic additives as a cost-effective means to reduce diesel smoke. These additives, which keep fuel injectors clean, were shown in one study to reduce particulate emissions by 40 to 60 percent (Faiz, Weaver and Walsh, 1996). Once again, though, considering the past experiences with lead and the questions now being raised about oxygenates and MMT, all such additives need careful review before mandating their use.

Alternative Fuel Vehicles

4.40 This set of strategies focuses on the penetration of new vehicles running on other than gasoline and diesel or of vehicles retrofitted for using alternate fuels in the fleet. Alternative-fueled vehicles could be hybrid vehicles, such as those that can run on either methanol or gasoline, or dedicated vehicles, including those running on compressed natural gas (CNG), ethanol, methanol, propane, liquefied petroleum gas (LPG), electricity, solar, and hydrogen fuel cells.[15] Severe air quality problems, combined with the increasing popularity and availability of private passenger vehicles, has encouraged a good deal of small-scale experimentation with various alternative fuels and several large-scale programs. Many developing countries are taking the lead in the use of some of these technologies for high use segments of their fleets, such as buses, trucks and taxis. In this section, we consider new vehicle issues. See section 5.2.2 for a discussion of vehicle retrofit issues.

4.41 A key issue in policy design is whether one or more types of alternative-fueled vehicles should be especially encouraged for its potential to reduce pollution. The major argument for policy intervention is that such fuels and vehicles require infrastructure that private markets either cannot or will not provide. These arguments are largely irrelevant for fleet vehicles and buses, where compressed natural gas (CNG) use is on the rise without much government prodding. These arguments have not been resolved for personal vehicles, except to the extent that mandates for the introduction of such vehicles will stimulate interest and provide entrepreneurial opportunities in developing and marketing such vehicles. Beyond this market stimulus, sentiment in the U.S. has been to create a "level playing field" for all alternative vehicle/fuel technologies then to rely on market forces to determine technology choices relating to performance, price, and emissions characteristics. It should come as no surprise that there is much disagreement over the definition of "level playing field."

4.42 If particular types of alternative-fueled vehicles are to be promoted, their relative cost-effectiveness is a key issue. Cost-effectiveness will vary by the

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14 See "Auto industry leery of MMT gasoline additive," *Wards Engine Update* v. 22, no. 3, February 1, 1996.

15 Solar and fuel cells and, in a developing country context, electric four-wheel vehicles, are too far beyond the horizon for our consideration here.

4.42 If particular types of alternative-fueled vehicles are to be promoted, their relative cost-effectiveness is a key issue. Cost-effectiveness will vary by the effectiveness of the fuel in limiting emissions, of course, and also by country and region depending on fuel availability and price. On an energy-equivalent basis, CNG costs range from below that of gasoline to twice the price. Where natural gas in plentiful and even "free" in the sense that it is being flared, such as in Tehran, Iran, a CNG strategy may make far more sense than in other countries Methanol is far more expensive than CNG, and ethanol from biomass would be prohibitive in most countries without government subsidies (such as in Brazil and in the U.S.).

4.43 One of the more interesting experiments in the cost-effectiveness of alternate fuels took place in Santiago, Chile from 1989 to 1990. The performance of 12 buses was compared over a six month period. These buses included diesel (the fuel in use at the time), gasoline, LPG, CNG, and methanol. Diesel buses were by far the cheapest to run, and when the buses were well maintained and overhauled routinely, emissions were cut from 66 percent to 85 percent below what they were in a typical Santiago diesel bus. The CNG bus was close to being competitive with diesel, followed by gasoline, with LPG and methanol a distant third. After the experiment Santiago implemented a CNG bus conversion program and a diesel bus maintenance program.

4.44 A program to examine the effectiveness of CNG was implemented in Buenos Aires between 1985 and 1994. Special tax exemptions were granted by the government for trucks, buses and taxis that converted to CNG. By 1994, 65 percent of the diesel taxis had converted to CNG, primarily because fuel costs were one-third lower and the vehicle itself was 30-35 percent cheaper than its diesel counterpart. However, only two percent of the buses converted, primarily because of the long refueling time and a higher initial vehicle cost. This program resulted in a 12 percent substitution of CNG for diesel fuel in Buenos Aires and a six percent reduction in direct diesel particulate emissions. Natural gas conversions are being considered in Chile and Mexico and other countries as well.

4.45 LPG is another fuel being considered by several countries for fleet conversions. Its environmental properties, however, are not quite as good as those of natural gas. Mexico has a small surplus of LPG and could import some from the Gulf states of the U.S. Transportation costs for LPG are high, however, ruling this option out for countries which do not have easy access to LPG sources.

4.46 Brazil, which experienced major problems with its policy to convert automobiles to ethanol, is now focusing on converting diesel buses to natural gas because of their large, inexpensive supplies of gas. Sao Paulo has a 10 year plan to convert 10,000 buses to natural gas over the next 10 years. CNG buses have lower HC, CO, particulates and noise compared to diesel, but NOx emissions are about 15 percent higher (Walsh, 1993).

4.47 Katmandu, Nepal, which has a major smog problem, is taking steps to improve its air by relying on electric two and three wheelers. Of the 100,000 vehicles in Katmandu, 3,500 three-wheelers support public transportation in the city, all running on diesel, and responsible for some 25 percent of total vehicle-kilometers traveled, and a larger share of emissions. Eight electric vehicles were introduced into Katmandu for a six month period of testing, during which time they logged 200,000 trips and 175,000 VKTs.

4.48 As a result of the success of this pilot program, Nepal plans to reduce trade barriers to both the import of vehicles and components to world levels (from 150 percent to 10 percent on vehicles). In addition, private companies are looking to cash in on the profits they feel will be made in the future.

5

Other Instruments

Transportation Policies

Vehicle Use Restrictions and Disincentives

5.1 Recently, significant attention is being paid to reducing vehicle use as a means of reducing both congestion and emissions. Simulation studies show that reducing distance traveled (VKTs) and congestion can reduce pollution as well, but if pollution reductions are the main goal, policies targeted directly to achieve this goal can be more effective (Deakin and Harvey, 1995).

5.2 A variety of countries and cities (France, Mexico City) have used command and control methods to help reduce congestion in city streets, with environmental benefits sometimes an ancillary concern. In Mexico, for example, the "Hoy no Circula," or "day without a car" program, which ran from 1989 through at least 1991 restricted private vehicle use according to license plate number from operating one day of the work week, so one fifth of the fleet would be idle on any given weekday. In contrast to the economic incentive approaches identified below, in which highly valued travel can proceed at a price, this flat prohibition approach is, on its face, inefficient.

5.3 Even so, such a program could be beneficial if pollution and congestion reductions were large enough. It turned out, however, that vehicle use was only reduced for a very short time. A World Bank study (1992) found that gasoline consumption (a useful if imperfect surrogate for congestion and pollution) dropped precipitously after the program began but then resumed its upward trend. A statistical analysis of gasoline demand with and without the program indicated that after the first six months of the program, gasoline consumption exceeded the "no regulation" estimates. Further analysis revealed a sharp increase in used vehicle registrations, and a survey found that 39 percent of vehicle owners had purchased an additional vehicle (many of them old but having an appropriate license plate) to circumvent the restriction. Thus, the day without a car program may have had perverse effects on pollution and congestion. In Latin America Chile has tried this program as well, and in Europe France recently announced a similar license plate scheme to address growing air pollution problems in Paris.

5.4 Another potentially counterproductive idea comes from Bangkok, where the government proposed banning the driving of *new* vehicles during rush hours as a congestion reduction measure (Automotive News, 1996). Such a policy is likely to result in substitution of older vehicles for new vehicles, resulting in increased pollution and fuel consumption. Presumably, this perverse outcome could probably be avoided if licenses were allowed to be bought and sold. Even if they were handed out to older vehicles, many would find their way into the hands of owners of new cars. (Of course, as is usual for these sorts of permit markets, the supply of licenses must be fixed.) A policy very similar to this has been tried in Singapore, which began in 1990 to set quotas for new vehicles and auction permits to the highest bidders. In late 1992 the escalation of prices lead the authorities to make the permits nontransferable, and speculators reduced their demands, accordingly. With or without the transferability, these quotas are not an economic incentive to drive or pollute less, but a tax on owning a vehicle.

5.5 Policies that use economic incentives to ration road access have been a bit more successful, but in most cases they could be sharpened in their application. Most such schemes fall into two categories: road access fees and zone access fees. An example of the latter is Singapore's Area Licensing Scheme, instituted in 1975. This policy requires purchase of a sticker to enter the city during the morning rush hour (in 1975, at a price of US$1.70/day). Parking fees in the city and establishment of a park and ride service complemented the sticker plan. The result, based on the first year of data, was a 75 percent decrease in vehicles entering the area during the morning rush-hour, a 20 percent increase in bus commuters, a doubling of car pools (Wilson, 1988), and a "substantial" reduction in downtown air pollution (UN, 1989). However, the evening rush-hour showed little improvement and travel times for a sizable minority increased (partly due to an increase in *unregulated* truck traffic). Wilson estimates that social welfare (not counting environmental effects and commercial traffic) actually fell because the fees were too high, resulting in under-utilization of roads and over-utilization of buses.[16] The Singapore experience does demonstrate that motorists are responsive to changes in roadway prices. It also suggests that it may be a mistake to exempt commercial traffic. In fact, arguably at least some commercial traffic would find it comparatively easy to shift to off-peak periods and thus may be most responsive to fees.[17]

5.6 Use of road access fees to limit congestion has received a recent boost by the development of advanced electronic toll collection technologies that make it possible to collect tolls without toll booths. Toll authorities in developed countries are just beginning to use these technologies to implement time-of-day pricing. In Orange County, California, State Road 91 opened in late 1995 using time-of-day pricing and offering free passage for 3-person carpools. This road was built with private funds on public lands (in the median of an existing freeway), and is to be operated as a regulated public utility. Toronto has opened a new freeway, Route 407, which has been designed from the ground

16 An earlier assessment by Behbehani et al (1984) was inconclusive.

17 Analysis of more recent experience with the ALS is complicated by the vehicle quota system implemented in Singapore in 1990 (Koh and Lee, 1994).

up for electronic fee collection and uses time-of-day pricing for all vehicles, including commercial vehicles. Admittedly, these examples put time-of-day pricing on new roads only, and in effect reduce congestion by increasing capacity, thus encouraging rather than discouraging vehicle use. It has become clear, however, that about the only viable way to introduce time of day road pricing is on a newly-constructed road, and the hope is that these experiments will be so successful that they will pave the way for more widespread use on existing roads. This is a hope that is predicated on the assumption that much of the opposition to congestion pricing arises out of uncertainty about the impacts.

5.7 Governments in southern California are now testing public support for a congestion fee proposal that would apply to selected freeways, with tolls collected electronically and varying by congestion level. To increase support for the idea and to address equity concerns, at least some of the revenues would be returned to the public as rebates, in such a way as to not distort driving disincentives.[18] Also being considered are "hot lanes," a single lane on an existing freeway that would become a toll lane, while other lanes remain "free" (REACH, 1996).

Mass Transit Improvements

5.8 Mass transit vehicles are generally more polluting than personal vehicles on a per-kilometer basis, but can have lower emissions on a *per-passenger-kilometer* basis if enough passengers are riding — the norm in cities in developing countries. While in developed countries, the debate is about how to switch people from cars to mass transit, in developing countries, the debate is more about how to develop viable transit options to keep riders from switching to car travel as income grows.

5.9 For several reasons policies to promote mass transit (whether public, private, or mixed ownership) must be chosen carefully. First, the most prevalent policy followed by developing countries to provide transportation options to their people — through direct or indirect subsidization — may be ineffective. Low fares leave transit companies cash-starved and forced to cut back on service and maintenance. Further, the low fares do not necessarily increase ridership. One study of travel mode substitution in Sao Paulo, Brazil found that the impact of reduced transit fares on transit use was very low (Swait and Eskeland,1995), with new ridership from lower fares attracted mainly from car pools and walking and even very low fares not large enough to attract the truly poor. Thus, instead of using low fares to attract business, bus companies or mass transit agencies must provide high levels of service, including choices of routes, effective lane segregation to reduce travel times, park and ride and improved bus characteristics.

5.10 Second, more ambitious forms of mass transit, such as urban rail transit, have been found to be exceedingly costly on a per trip basis, particularly when lines and stations are underground. For instance, one study of Washington, D.C.'s subway system concludes that riders pay only a fraction of the annualized cost of their trips, with subsidies of over $6 per trip. (Mills and Hamilton (1994), p.303). The Washington case

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18 See Hau, 1992;p. 13-15 for this idea as well.

also suggests that even when heavily subsidized transit attracts riders, it does not appreciably reduce auto use or improve air quality.

5.11 Policies to improve transit have been implemented in a number of countries. Bogota, for instance, has created special bus lanes downtown, although the buses still become mired in congestion on the outskirts of the city. In Mexico City, many improvements to the bus system are under way (World Bank, 1992). There have been regulatory changes, such as stricter requirements for bus registration due to the problem of illegal buses, route restructuring because previous regulations did not allow the route policy to adapt to customer demand, and additions of park and ride facilities.

5.12 One of the major messages delivered over many years to developing countries wishing to improve their bus service was to deregulate and privatize. Mass transit systems have always been private in some Latin American and Asian cities, although they may operate with a heavy dose of public regulation. Conversion to private or mixed systems (many still retaining public control over fares) has occurred in Buenos Aires, Argentina; Ibadan, Nigeria; Kingston, Jamaica; Santiago, Chile; and Colombo, Sri Lanka; among other places (Meyer and Gomez-Ibanez, 1993). Subsidy reduction or elimination has often followed such conversions, along with some fare increases and increased ridership (for instance, in Colombo and in Santiago). However, some cross-subsidies have been used to maintain service on unprofitable routes.

5.13 More recently several countries have experimented with "concessioning" of transport systems: retaining ownership while contracting out operations of transit facilities. The concessions are awarded as part of a bidding process that may significantly lower government cost (Shaw et al., 1996).[19]

5.14 The lessons from experience with transit systems in developing countries are: (i) competition rather than privatization leads to lower prices and improved service; (ii) government has a role in promoting competition; (iii) although subsidies should be used as a last resort, they may be needed to offset subsidies to road use and in selected circumstances to achieved warranted outcomes; and (iv) fares should be deregulated to permit fuller operation of market forces in determining prices.

Environmental Policies

New Vehicle Technology Standards

5.15 In a large prosperous country like the U.S., with a large domestic auto industry and a domestic market, national authorities have been able to exert a profound influence on the safety characteristics, the emissions and the fuel economy of new vehicles. That result is rather more difficult to achieve in a small open economy without either a domestic industry or a large market. But although small nations must take largely as given the existing mix of vehicles offered by the world's manufacturers, they can influence the relative import demands for those vehicles either by quantity

[19] See Engel et al (1997) for experiences to the contrary.

restrictions or tariffs applied to vehicles with particular characteristics (Shalizi and Carbajo, 1994). As noted earlier, now that effective emission reduction technologies have been developed, requiring their use can be an inexpensive way to achieve emission reductions.

5.16 *New Gasoline Vehicle Standards.* By far the policies most frequently used around the world are technology-based standards (such as the requirement that all new cars have catalytic converters), and emissions standards. These policies used to be confined primarily to automobiles and light-duty trucks, but recently emission standards have been applied to new heavy-diesel trucks and off-road vehicles as well.

5.17 Progressively more stringent new vehicle emission standards have been the cornerstone of vehicle emission reduction policy in the U.S. since 1970. Current model year vehicles must achieve emission standards that are less than five percent of the emissions of HC and CO emissions of an uncontrolled 1968 vehicle. In addition, there have been stricter regulations imposed by the U.S. Environmental Protection Agency (EPA) on the durability of emissions control equipment. New certification procedures require that emissions controls remain in compliance for 100,000 miles in certification tests. These emissions controls have come at a cost, with estimates of the cost of controls on current new cars of between $500 and $1500 per car compared to what would have been required in the absence of a policy (McConnell et al., 1995).

5.18 One reason these standards initially were so costly was that they were technology-*forcing* standards, as opposed to technology-*following* standards, the distinction referring to whether the standard to be adopted requires technology that has never before been demonstrated in a commercial product (Faiz et al., 1990). Now that the technology has been developed, substantial reductions in new-car emissions can be achieved at only a modest cost.

5.19 The Federal Republic of Germany and the Netherlands have been unique in that they have promoted the introduction of tighter new car standards with an economic incentive policy. They have both adopted a differential fee on new cars, in which the fee varies according the car's emissions standards. In the Netherlands in 1991, cars that met the stricter EU standards that were to become mandatory in 1993, were subject to a lower tax than cars that did not meet that standard. As a result, by 1992, more than 80 percent of new cars sold in the Netherlands met the EU standard even though that standard was not mandatory until 1993 (van Wee, 1995). Germany has had a similar new car differential tax rate in effect for a number of years.

5.20 Many countries have now adopted mandatory new car standards. Among developing countries, Brazil has adopted new car emissions limits. For 1997 model years the standards are 0.3 g/km for hydrocarbons (HC), 0.6 g/km for NOx, and 2 g/km for CO, which are approximately the same as the U.S. standards for HC and NOx for the 1981-93 model years and the 1994 standard for CO. Both Mexico and Chile have introduced emissions standards that for post 1992 model years are comparable to U.S. standards of the mid to late 1980s.

5.21 *Emissions Standards for Diesel-fueled Vehicles.* In the U.S., standards for reducing particulate emissions from heavy duty diesel engines have been in place since the 1988 model year when they were set at 0.6 gram/BHP-hr (brake horsepower per hour. 1 g/BHP-hr is approximately 15 grams per liter of fuel burned). They have been further tightened at 2-3 year intervals, and the 1990 Clean Air Act Amendments have targeted a further tightening of the standards to 0.1 gram/BHP-hr. In addition, the law set a new performance standard for diesel buses. Further, EPA has set NOx standards for new heavy-duty diesel engines of 4.0 g/bhp-hr. to be met by 1998, with plans for a 2.4 g/bhp-hr. standard in 2004.[20] These NOx standards are estimated to be exceedingly cost-effective (e.g., $300/ton of NOx reduced) based on estimates of the future costs of abatement technologies now under development. There are generally no inspection and maintenance programs for diesel trucks, however, their engines are not subject to the same degree of degradation over time as those of light-duty gasoline vehicles.

5.22 Starting in 1994, buses operating more than 70 percent of the time in large urban areas are to reduce particulates emissions by 50 percent compared to conventional heavy duty vehicles (i.e. to .05 grams/BHP-hr). Inspection programs must be put in place to see that the standards are being met (Walsh, 1993). In order to meet these standards, alternative fuels vehicles will most likely have to be introduced. In addition, the USEPA has been directed to study the rebuilding of diesel engines and the impact on emissions.

5.23 A number of other countries have also begun programs to reduce particulate emissions from heavy duty vehicles. Both Canada and the European Union are in the process of adopting the 1988 US standard for heavy duty diesel vehicles of 0.6gr/BHP-hr. Mexico has taken steps to dramatically tighten its vehicle emissions regulations in the last few years but has not yet put in place policies to reduce emissions from heavy duty vehicle engines, except to decrease the sulfur content of diesel fuel (see below). Although Mexico City has considered adopting the 1988 US standards, they have not because the controls do not address the high altitude conditions in Mexico City.

5.24 In South Korea, diesel fueled vehicles are basically uncontrolled. However, the South Koreans are implementing a number of policies to reduce emissions and reduce the number of diesels in the fleet. New bus engines must have higher horsepower because one source of excess emissions was believed to be the overloading of engines; also, smoke standards were tightened in 1990 in the hope that this would encourage better maintenance. Singapore, Hong Kong and Taiwan have also been moving toward additional controls on diesels.

5.25 *Buses.* Emissions reductions for buses are also important. These can result from policies that change or improve engine performance or by improving the maintenance of buses in service. Bus re-engining or replacement were discussed above. Chile has had a stringent diesel bus inspection program in place for a number of years (Weaver et al, 1994).

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[20] This include non-methane hydrocarbons, which are a tiny fraction of the emissions.

Retrofit and Replacement Programs

5.26 A basic issue is the relative merits of policies affecting the use of the existing fleet of vehicles versus those affecting the new car stock. Changes in vehicle use have the potential for immediate and widespread environmental benefits while changes in the stock can have more dramatic, if slower effects. Both can be important components of policy. In our view, mobile source policy should be designed, at least in part, to let the market decide on this emphasis based on the costs and feasibility of the various options. Government certainly has some role in setting temporal priorities and goals and introducing policies that reflect them. And, in some cases, once a path is chosen, other options may become more difficult. For example, to go in the direction of certain vehicle technologies for personal vehicle use, such as compressed natural gas (CNG), requires such an investment in production facilities and infrastructure that other technologies may be foreclosed.

5.27 Vehicle replacement or retrofit programs are beginning to be used in conjunction with policies to tighten new car emissions standards. As the new vehicle fleet becomes cleaner, the share of emissions from the large number of older, uncontrolled vehicles will increase. Vehicle replacement policies have focused on replacement of high use, older vehicles like taxis or vans, and retrofit policies focus more on heavy duty vehicles like trucks and buses because of their long useful lives and because they are designed for the possibility of engine replacement. Retrofit will be more cost-effective if done for whole fleets or vehicles. Some of the possibilities include:

- replacement of gasoline engines with LPG or CNG engines;
- re-engining trucks, buses and minibuses;
- retrofitting and replacement of two-stroke motorbikes and three-wheelers.

5.28 There are a number of both replacement and retrofit policies underway in various countries. The most dramatic example of a vehicle replacement program is the taxi modernization program in place in Mexico City. The Mexican authorities, the taxi association and auto manufacturers are partners in an agreement that will result in replacement of up to 93 percent of all pre-1985 model year taxis. The new vehicles will be provided at agreed upon prices at terms that are below market rates. The project is being funded by $700 million (U.S. dollars) from all of the parties to the agreement. Another $600 million is being used for minibus and van retrofit (Weaver, 1994).There is some controversy over whether the taxis that are retired as taxis should be scrapped, sold outside the high pollution region or resold in the Mexico City region. Allowing vehicles to be resold in the City would seem to be counter to the intent of the policy, though some have argued that these vehicles in private hands would be driven much less than they were as taxis. If such vehicles are required to be registered in jurisdictions which are less polluted and congested, they could still provide economic value to the country but their environmental impact would be reduced.

5.29 Hungary has also had a successful vehicle replacement program in effect for a number of years. Budapest had a large number of old heavily polluting two-cycle engine vehicles, Trabants and Wartburgs, which were contributing a large share of particulate emissions in the city. The Hungarian government banned the use of these vehicles for commercial uses and set up several policies to retire the rest of them. Motorists who turned in their two stroke vehicles could receive either a free transit pass for four years or a reduced price on a new cleaner car. Any subsidy program like this is subject to problems of fraud. In this case, it is not clear how many Trabants and Wartburgs may have been brought in from outside the city to take advantage of the subsidy.

5.30 Retrofitting the existing fleet of vehicles either with improved emissions control systems or a new less polluting engine shows promise of being cost-effective in certain cases. Germany has had a catalytic converter retrofit program in place for a number of years. The program, under which motorists pay lower vehicle taxes if they add a catalytic converter, has been considered a modest success. Sweden has a similar program and Taiwan and Chile are both considering such programs. Hungary has a variant of this program, in which the cost of the added catalytic converter is subsidized (Weaver et al., 1994).

5.31 Retrofitting fleets of heavy duty vehicles is a policy that is in place in some countries and under consideration in others. Conversion of gasoline engines to LPG or CNG is being done in Mexico City (see above, under alternative fuels). Natural gas conversions are more expensive than conversions to LPG, but natural gas has lower fuel and maintenance costs over the life of the vehicle. Re-engining diesel engines, including transit buses is also under consideration in a number of countries. One study has found that this may be a relatively cost-effective alternative for reducing pollution (World Bank, 1992).

5.32 Because of their high pollution per kilometer and rapid growth in developing countries, two-stroke two and three-wheeled vehicles represent a potentially vital area for emissions improvements. Technologies for retrofitting these engines are inexpensive. For $20-$30, engine modifications can reduce HC by 50 percent and improve fuel economy by 10-15 percent, raising the possibility that the change can pay for itself with fuel economy benefits alone. More involved modifications, based on experience in E. Asia can reduce HC by 90 percent and improve fuel economy by 35-50 percent at a cost of only $50-60 per vehicle. Bangkok has a program for retrofitting its three-wheeler "tuk-tuks" to run on LPG.

5.33 An instructive case of motorcycle retrofit and replacement programs is the experience of Vietnam. Prior to opening its economy, Vietnam was importing two-stroke motorbikes from Russia and the Eastern block countries. After the economy was opened, demand soared, particularly for a cheap Japanese four-stroke import, valued for its reliability. More recently demand has turned towards a Japanese two-stroke and several foreign-owned plants making the two-strokes have opened up in Vietnam. Thus, without some form of emissions restrictions on motorcycles, the relatively clean four-strokes which had dominated the motorcycle fleet are in danger of being supplanted by the dirtier two-strokes.

5.34 There are a variety of options for new vehicles. Where two-strokes are entrenched, new direct injection designs promise emission performance of four-stroke engines, at an additional cost of $100 (a large sum in India, for instance, where per capita income is only $340 (WDR, 1997). Four strokes themselves are competitively priced with two-stroke motorcycles in India, although they are at a disadvantage in maintenance costs and in the sales distribution. Electric two and three-wheelers are also being introduced (in Nepal and Taiwan, for instance). Technologies such as the "magic wheel" for electrifying bicycles and scooters could slow the rapid shift from bicycles to two-cycle mopeds and motorcycles and result in dramatically lower emissions from the transportation sector than might otherwise be the case.[21]

Inspection and Maintenance

5.35 In many countries, inspection and maintenance (I&M) policies have complemented the introduction of new car emissions standards and technology. Emissions control technology has not been as durable and immune from human tampering as vehicle producers and regulators had hoped. I&M programs have been initiated: 1) to find and repair vehicles whose emissions control equipment is not working, 2) to deter tampering with emissions control equipment, and 3) to keep vehicles without much emissions control equipment running efficiently with emissions as low as possible.

5.36 A number of developing and newly industrializing countries have implemented limited I&M and other in-use vehicle emission control programs, including Mexico, Singapore, Hong Kong, the Philippines, India, Colombia, South Korea, Taiwan and Thailand,[22] Of particular interest is a program now underway in Mexico, which has made an unusually strong commitment to making I&M work in the Federal District. Nonetheless, at the present time the most ambitious efforts, as well as the majority of the empirical evidence of I&M program performance, have been in the U.S. and Canada. It is in the U.S. where one can best see the potential for – and difficulty of — getting serious emission reductions from I&M programs.

5.37 It is quite clear that I&M policies have plenty of potential. In the U.S., for example, though the VOC standard has been 0.4 grams per mile for nearly 15 years, the average vehicle in the fleet has emissions of almost five times that rate. Most of the excess emissions come from a small fraction of vehicles, so finding and repairing these vehicles would reduce emissions considerably.

5.38 Unfortunately, an amalgam of technical, behavioral and political factors has prevented this potential from being realized in the U.S. To begin with, I&M is one of the few environmental regulatory programs that impinge directly on private citizens, and the necessity of requiring millions of motorists to appear regularly for emission tests is a

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21 Information concerning vehicle improvement programs in E. Asia was presented at a World Bank seminar in March 1997.

22 See Faiz, Weaver and Walsh (1996) and Krupnick and McConnell (1996) for a discussion of experience in developing countries.

formidable administrative challenge. This challenge is exacerbated by recent evidence suggesting that the cost to repair some vehicles is quite high (Cebula, 1992; California I&M Review Committee, 1993), which has given motorists, especially those with dirty vehicles, a strong incentive to evade the regulations, by avoiding the emission tests altogether, by fraudulently passing emission tests, or by failing to make effective repairs. Despite efforts by the USEPA to plug these holes, in particular by encouraging the adoption of more accurate emission tests, few state and local jurisdictions have had the political will to implement a program that would actually require effective repairs, especially inasmuch as the dirtiest cars are likely to belong to the poorest car owners.[23]

5.39 To avoid the kinds of political opposition that has arisen in the U.S., it may make sense to implement I&M in stages. In the initial stage, enforcement of I&M could be limited to large commercial or government vehicle fleets, including taxicabs, buses, rental cars, and large commercial carriers. In a fleet-centered program, the sorts of monitoring and enforcement problems discussed above may not arise, or at least may arise with less force than they do in a program directed at the privately-owned automobile.

5.40 Most importantly, a fleet-centered I&M program reduces the number of parties that must be regulated against. Rather than dealing with each private motorist, fleet enforcement means dealing only with the fleet operator. In addition, vehicles in fleets are often just the ones that it is important to subject to emission inspection. Passenger vehicles in fleets – especially taxis – tend to be among the most frequently used of all passenger vehicles. Also, many heavy-duty gasoline and large diesel vehicles are disproportionately found in fleets. Targeting governmental fleets is especially important. Focus group sessions convened in the U.S to discuss I&M have uncovered a certain amount of resentment against publicly-owned buses, the participants feeling that government should get its own house in order before "harassing" private citizens. (McConnell, Harrington and Alberini 1997).

5.41 The U.S. experience also suggests two policy amendments that at least have a chance of identifying the cost effective repairs and of spreading the cost of repairing vehicles so that it does not fall disproportionately on the owners of older vehicles. Although neither of these approaches has been tried and they appear to share some of the problems identified above of ascertaining actual emission levels, they are theoretically appealing and deserve further consideration. These policies involve the combination of the I&M concept with emission fees or with gasoline taxes, or both.

5.42 *Emissions Fees:* An emission fee could easily be combined with an existing I&M program, simply by requiring the motorist to pay a fee based on the results of the emission test. What makes this policy attractive is the fact that repair costs, in

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23 In a developing country the poorest car owners are still likely to be relatively well off, but they will nonetheless resent programs that appear to fall less on the wealthiest members of society. Note, however, that such people have already "paid" for their emissions control by buying new cars.

addition to being high, are also quite variable.[24] The motorist would have the option of continuing to operate the vehicle as is, scrapping the vehicle and getting a refund of the fee, or repairing the vehicle and getting a partial or full refund based on the result of another emission test. This program is close to an optimal policy, providing motorists with almost all the right incentives to take the lowest cost action to reduce emissions, whether this involves scrapping the old car and buying a new one, maintaining the old car, or just paying the fee. It does not provide an incentive to drive less, but that incentive could be built in if a reliable and non-tamperable way could be found to estimate vehicle use. To address the equity issues that arise when fees fall more heavily on poorer people, the concept could include a revenue distribution feature, where part of the fees are returned to the public through income tax credits or other means, or where collected fees are used to subsidize emission repairs for low-income motorists.[25]

24 That is, repair costs vary tremendously from one vehicle to another for the same emission reduction. For a given vehicle, it is doubtless true that higher spending is associated with greater emission reductions.

25 Simulation results suggest that such policies could be much more cost-effective than command-and-control policies without sacrificing much emission reductions (Harrington, McConnell and Alberini, 1996).

6

Conclusions and Recommendations

6.1 While the transport sector gives rise to a number of environmental externalities, air pollution and deteriorating air quality are the main ones directly associated with the energy sector. It is clear that there no quick fixes in terms of transport modes, vehicle technologies or alternative fuels that will meet transportation needs and improve air quality. Significant improvements in air quality can only be achieved by a series of complementary approaches in related sectors; however, the feasibility and effectiveness of these approaches will depend on the capability of national institutions to assess the situation, evaluate options, develop policies and implement the chosen measures, particularly with regard to the enforcement of standards.

6.2 Complementary approaches need to be pursued from various sectoral perspectives which include:

Macro:

Getting the prices right and seeking market solutions are the preferred approaches for economic development across all sectors. In getting the prices right for transportation and energy, it is also necessary to evaluate the environmental externalities that are involved in the provision and use of transportation. A full accounting of the environmental (especially air pollution) and social costs (e.g. congestion) of transportation in determining user charges would, in most cities, lead to a greater support for collective mass transit which has a lower environmental impact compared with low capacity motorized transport. While full cost pricing including externalities is the preferred approach, subsidies for lower polluting forms of transport (e.g. mass transit) are justified to help reflect externality costs in the relative price of alternative transportation modes.

Urban

Decisions regarding land use and the spatial organization of activities within urban area require a long run perspective. Transportation costs for both infrastructure and operations need to be considered in the urban planning; hence, the macro framework including the reflection of environmental and social externalities involved is an important starting point.

Environment

While motorized transportation is an important contributor to air pollution, it is essential to assess of air quality within an overall airshed before setting standards or targeting measures at individual sources of emissions. The contributions of various sources such as industry, households, and transportation and the evaluation of the health impacts of the various pollutants needs to be evaluated in setting emission standards. For transportation fuels, the principal pollutants to be controlled are particulates and lead followed by NOx, VOCs, CO, and sulfur. In addition to the cost effectiveness of controlling emissions, consideration must be given to the tasks of monitoring and enforcing emissions standards.

Transport

In the short run, the demand for individual motorized transportation tends to be relatively price inelastic; however, modal choices over the long run show higher degrees of price elasticity which means that consumers will tend to choose more environmentally friendly forms of transportation if the relative costs also reflect the environmental externality costs. By and large, governments should refrain from making technology choices through command and control decisions. However, government encouragement of and participation in vehicle fleet related programs for inspection and maintenance, vehicle replacement, and engine conversion or replacement may be effective provided (1) the program can be shown to be cost effective and (2) the institutional capacity is available to administer it. Government clearly has a role in decisions regarding the development of transportation infrastructure because choices here involve long term commitments to different modes of transportation and hence their environmental consequences.

Energy

Fuel pricing policy within the energy sector is the starting point for addressing transport related environmental issues and must be consistent with setting the macro framework above. It is essential that prices reflect the environmental costs of fuel use as well as the resource cost of supply. Attention must be given to ensure that diversion of subsidized cheaper fuels which cause increased pollution (e.g. kerosene substituting for diesel fuel) is avoided. Depending on relative fuel prices, may reveal opportunities to use alternative fuels, especially natural gas if available for use as CNG in vehicle fleets. The greatest opportunities to reduce air pollution which can be pursued from within the energy sector are to improve fuel quality through refinery upgrading and to phase-out lead from gasoline.

6.3 Success in implementing the approaches to reducing air pollution from transportation will require leadership from within each of the sectors or institutions which has the primary responsibility and competence in the areas identified above. While many actives will require joint efforts, donor agencies and national institutions will need to ensure that their interventions are well targeted and coordinated across sectors. From within the energy sector, activities should be focussed primarily in the areas of (1) fuel pricing, (2) improving fuel quality, (3) phasing out lead from gasoline and (4) promoting the use of less polluting alternative fuels where economic.

6.4 The World Bank's Energy and Environment Strategy has recommended that Energy and Environment Reviews be undertaken on an "as needed basis" in countries where the related issues need early attention. These reviews could be undertaken as ESMAP activities and would provide an excellent opportunity to assess the issues and options related to energy, transportation, and the environment and to identify a program of measures to be carried out with the support of development institutions.

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Joint UNDP/World Bank
ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

LIST OF REPORTS ON COMPLETED ACTIVITIES

Region/Country	*Activity/Report Title*	*Date*	*Number*
	SUB-SAHARAN AFRICA (AFR)		
Africa Regional	Anglophone Africa Household Energy Workshop (English)	07/88	085/88
	Regional Power Seminar on Reducing Electric Power System Losses in Africa (English)	08/88	087/88
	Institutional Evaluation of EGL (English)	02/89	098/89
	Biomass Mapping Regional Workshops (English)	05/89	--
	Francophone Household Energy Workshop (French)	08/89	--
	Interafrican Electrical Engineering College: Proposals for Short- and Long-Term Development (English)	03/90	112/90
	Biomass Assessment and Mapping (English)	03/90	--
	Symposium on Power Sector Reform and Efficiency Improvement in Sub-Saharan Africa (English)	06/96	182/96
	Commercialization of Marginal Gas Fields (English)	12/97	201/97
Angola	Energy Assessment (English and Portuguese)	05/89	4708-ANG
	Power Rehabilitation and Technical Assistance (English)	10/91	142/91
Benin	Energy Assessment (English and French)	06/85	5222-BEN
Botswana	Energy Assessment (English)	09/84	4998-BT
	Pump Electrification Prefeasibility Study (English)	01/86	047/86
	Review of Electricity Service Connection Policy (English)	07/87	071/87
	Tuli Block Farms Electrification Study (English)	07/87	072/87
	Household Energy Issues Study (English)	02/88	--
	Urban Household Energy Strategy Study (English)	05/91	132/91
Burkina Faso	Energy Assessment (English and French)	01/86	5730-BUR
	Technical Assistance Program (English)	03/86	052/86
	Urban Household Energy Strategy Study (English and French)	06/91	134/91
Burundi	Energy Assessment (English)	06/82	3778-BU
	Petroleum Supply Management (English)	01/84	012/84
	Status Report (English and French)	02/84	011/84
	Presentation of Energy Projects for the Fourth Five-Year Plan (1983-1987) (English and French)	05/85	036/85
	Improved Charcoal Cookstove Strategy (English and French)	09/85	042/85
	Peat Utilization Project (English)	11/85	046/85
	Energy Assessment (English and French)	01/92	9215-BU
Cape Verde	Energy Assessment (English and Portuguese)	08/84	5073-CV
	Household Energy Strategy Study (English)	02/90	110/90
Central African Republic	Energy Assessement (French)	08/92	9898-CAR
Chad	Elements of Strategy for Urban Household Energy The Case of N'djamena (French)	12/93	160/94
Comoros	Energy Assessment (English and French)	01/88	7104-COM
Congo	Energy Assessment (English)	01/88	6420-COB
	Power Development Plan (English and French)	03/90	106/90
Côte d'Ivoire	Energy Assessment (English and French)	04/85	5250-IVC
	Improved Biomass Utilization (English and French)	04/87	069/87
	Power System Efficiency Study (English)	12/87	--
	Power Sector Efficiency Study (French)	02/92	140/91
	Project of Energy Efficiency in Buildings (English)	09/95	175/95
Ethiopia	Energy Assessment (English)	07/84	4741-ET

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Ethiopia	Power System Efficiency Study (English)	10/85	045/85
	Agricultural Residue Briquetting Pilot Project (English)	12/86	062/86
	Bagasse Study (English)	12/86	063/86
	Cooking Efficiency Project (English)	12/87	--
	Energy Assessment (English)	02/96	179/96
Gabon	Energy Assessment (English)	07/88	6915-GA
The Gambia	Energy Assessment (English)	11/83	4743-GM
	Solar Water Heating Retrofit Project (English)	02/85	030/85
	Solar Photovoltaic Applications (English)	03/85	032/85
	Petroleum Supply Management Assistance (English)	04/85	035/85
Ghana	Energy Assessment (English)	11/86	6234-GH
	Energy Rationalization in the Industrial Sector (English)	06/88	084/88
	Sawmill Residues Utilization Study (English)	11/88	074/87
	Industrial Energy Efficiency (English)	11/92	148/92
Guinea	Energy Assessment (English)	11/86	6137-GUI
	Household Energy Strategy (English and French)	01/94	163/94
Guinea-Bissau	Energy Assessment (English and Portuguese)	08/84	5083-GUB
	Recommended Technical Assistance Projects (English & Portuguese)	04/85	033/85
	Management Options for the Electric Power and Water Supply Subsectors (English)	02/90	100/90
	Power and Water Institutional Restructuring (French)	04/91	118/91
Kenya	Energy Assessment (English)	05/82	3800-KE
	Power System Efficiency Study (English)	03/84	014/84
	Status Report (English)	05/84	016/84
	Coal Conversion Action Plan (English)	02/87	--
	Solar Water Heating Study (English)	02/87	066/87
	Peri-Urban Woodfuel Development (English)	10/87	076/87
	Power Master Plan (English)	11/87	--
	Power Loss Reduction Study (English)	09/96	186/96
Lesotho	Energy Assessment (English)	01/84	4676-LSO
Liberia	Energy Assessment (English)	12/84	5279-LBR
	Recommended Technical Assistance Projects (English)	06/85	038/85
	Power System Efficiency Study (English)	12/87	081/87
Madagascar	Energy Assessment (English)	01/87	5700-MAG
	Power System Efficiency Study (English and French)	12/87	075/87
	Environmental Impact of Woodfuels (French)	10/95	176/95
Malawi	Energy Assessment (English)	08/82	3903-MAL
	Technical Assistance to Improve the Efficiency of Fuelwood Use in the Tobacco Industry (English)	11/83	009/83
	Status Report (English)	01/84	013/84
Mali	Energy Assessment (English and French)	11/91	8423-MLI
	Household Energy Strategy (English and French)	03/92	147/92
Islamic Republic of Mauritania	Energy Assessment (English and French)	04/85	5224-MAU
	Household Energy Strategy Study (English and French)	07/90	123/90
Mauritius	Energy Assessment (English)	12/81	3510-MAS
	Status Report (English)	10/83	008/83
	Power System Efficiency Audit (English)	05/87	070/87
Mauritius	Bagasse Power Potential (English)	10/87	077/87
	Energy Sector Review (English)	12/94	3643-MAS
Mozambique	Energy Assessment (English)	01/87	6128-MOZ

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Mozambique	Household Electricity Utilization Study (English)	03/90	113/90
	Electricity Tariffs Study (English)	06/96	181/96
	Sample Survey of Low Voltage Electricity Customers	06/97	195/97
Namibia	Energy Assessment (English)	03/93	11320-NAM
Niger	Energy Assessment (French)	05/84	4642-NIR
	Status Report (English and French)	02/86	051/86
	Improved Stoves Project (English and French)	12/87	080/87
	Household Energy Conservation and Substitution (English and French)	01/88	082/88
Nigeria	Energy Assessment (English)	08/83	4440-UNI
	Energy Assessment (English)	07/93	11672-UNI
Rwanda	Energy Assessment (English)	06/82	3779-RW
	Status Report (English and French)	05/84	017/84
	Improved Charcoal Cookstove Strategy (English and French)	08/86	059/86
	Improved Charcoal Production Techniques (English and French)	02/87	065/87
	Energy Assessment (English and French)	07/91	8017-RW
	Commercialization of Improved Charcoal Stoves and Carbonization Techniques Mid-Term Progress Report (English and French)	12/91	141/91
SADC	SADC Regional Power Interconnection Study, Vols. I-IV (English)	12/93	--
SADCC	SADCC Regional Sector: Regional Capacity-Building Program for Energy Surveys and Policy Analysis (English)	11/91	--
Sao Tome and Principe	Energy Assessment (English)	10/85	5803-STP
Senegal	Energy Assessment (English)	07/83	4182-SE
	Status Report (English and French)	10/84	025/84
	Industrial Energy Conservation Study (English)	05/85	037/85
	Preparatory Assistance for Donor Meeting (English and French)	04/86	056/86
	Urban Household Energy Strategy (English)	02/89	096/89
	Industrial Energy Conservation Program (English)	05/94	165/94
Seychelles	Energy Assessment (English)	01/84	4693-SEY
	Electric Power System Efficiency Study (English)	08/84	021/84
Sierra Leone	Energy Assessment (English)	10/87	6597-SL
Somalia	Energy Assessment (English)	12/85	5796-SO
South Africa Republic of	Options for the Structure and Regulation of Natural Gas Industry (English)	05/95	172/95
Sudan	Management Assistance to the Ministry of Energy and Mining	05/83	003/83
	Energy Assessment (English)	07/83	4511-SU
	Power System Efficiency Study (English)	06/84	018/84
	Status Report (English)	11/84	026/84
	Wood Energy/Forestry Feasibility (English)	07/87	073/87
Swaziland	Energy Assessment (English)	02/87	6262-SW
	Household Energy Strategy Study	10/97	198/97
Tanzania	Energy Assessment (English)	11/84	4969-TA
	Peri-Urban Woodfuels Feasibility Study (English)	08/88	086/88
	Tobacco Curing Efficiency Study (English)	05/89	102/89
	Remote Sensing and Mapping of Woodlands (English)	06/90	–
	Industrial Energy Efficiency Technical Assistance (English)	08/90	122/90
Tanzania	Power Loss Reduction Volume 1: Transmission and Distribution SystemTechnical Loss Reduction and Network Development (English)	06/98	204A/98
	Power Loss Reduction Volume 2: Reduction of Non-Technical Losses (English)	06/98	204B/98

gion/Country	Activity/Report Title	Date	Number
Togo	Energy Assessment (English)	06/85	5221-TO
	Wood Recovery in the Nangbeto Lake (English and French)	04/86	055/86
	Power Efficiency Improvement (English and French)	12/87	078/87
Uganda	Energy Assessment (English)	07/83	4453-UG
	Status Report (English)	08/84	020/84
	Institutional Review of the Energy Sector (English)	01/85	029/85
	Energy Efficiency in Tobacco Curing Industry (English)	02/86	049/86
	Fuelwood/Forestry Feasibility Study (English)	03/86	053/86
	Power System Efficiency Study (English)	12/88	092/88
	Energy Efficiency Improvement in the Brick and Tile Industry (English)	02/89	097/89
	Tobacco Curing Pilot Project (English)	03/89	UNDP Terminal Report
	Energy Assessment (English)	12/96	193/96
	Rural Electrification Strategy Study	09/99	221/99
Zaire	Energy Assessment (English)	05/86	5837-ZR
Zambia	Energy Assessment (English)	01/83	4110-ZA
	Status Report (English)	08/85	039/85
	Energy Sector Institutional Review (English)	11/86	060/86
	Power Subsector Efficiency Study (English)	02/89	093/88
	Energy Strategy Study (English)	02/89	094/88
	Urban Household Energy Strategy Study (English)	08/90	121/90
Zimbabwe	Energy Assessment (English)	06/82	3765-ZIM
	Power System Efficiency Study (English)	06/83	005/83
	Status Report (English)	08/84	019/84
	Power Sector Management Assistance Project (English)	04/85	034/85
	Power Sector Management Institution Building (English)	09/89	--
	Petroleum Management Assistance (English)	12/89	109/89
	Charcoal Utilization Prefeasibility Study (English)	06/90	119/90
	Integrated Energy Strategy Evaluation (English)	01/92	8768-ZIM
	Energy Efficiency Technical Assistance Project: Strategic Framework for a National Energy Efficiency Improvement Program (English)	04/94	--
	Capacity Building for the National Energy Efficiency Improvement Programme (NEEIP) (English)	12/94	--

EAST ASIA AND PACIFIC (EAP)

Asia Regional	Pacific Household and Rural Energy Seminar (English)	11/90	--
China	County-Level Rural Energy Assessments (English)	05/89	101/89
	Fuelwood Forestry Preinvestment Study (English)	12/89	105/89
	Strategic Options for Power Sector Reform in China (English)	07/93	156/93
	Energy Efficiency and Pollution Control in Township and Village Enterprises (TVE) Industry (English)	11/94	168/94
	Energy for Rural Development in China: An Assessment Based on a Joint Chinese/ESMAP Study in Six Counties (English)	06/96	183/96
	Improving the Technical Efficiency of Decentralized Power Companies	09/99	222/999
Fiji	Energy Assessment (English)	06/83	4462-FIJ
Indonesia	Energy Assessment (English)	11/81	3543-IND
	Status Report (English)	09/84	022/84

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Indonesia	Power Generation Efficiency Study (English)	02/86	050/86
	Energy Efficiency in the Brick, Tile and Lime Industries (English)	04/87	067/87
	Diesel Generating Plant Efficiency Study (English)	12/88	095/88
	Urban Household Energy Strategy Study (English)	02/90	107/90
	Biomass Gasifier Preinvestment Study Vols. I & II (English)	12/90	124/90
	Prospects for Biomass Power Generation with Emphasis on Palm Oil, Sugar, Rubberwood and Plywood Residues (English)	11/94	167/94
Lao PDR	Urban Electricity Demand Assessment Study (English)	03/93	154/93
	Institutional Development for Off-Grid Electrification	06/99	215/99
Malaysia	Sabah Power System Efficiency Study (English)	03/87	068/87
	Gas Utilization Study (English)	09/91	9645-MA
Myanmar	Energy Assessment (English)	06/85	5416-BA
Papua New Guinea	Energy Assessment (English)	06/82	3882-PNG
	Status Report (English)	07/83	006/83
	Energy Strategy Paper (English)	--	--
	Institutional Review in the Energy Sector (English)	10/84	023/84
	Power Tariff Study (English)	10/84	024/84
Philippines	Commercial Potential for Power Production from Agricultural Residues (English)	12/93	157/93
	Energy Conservation Study (English)	08/94	--
Solomon Islands	Energy Assessment (English)	06/83	4404-SOL
	Energy Assessment (English)	01/92	979-SOL
South Pacific	Petroleum Transport in the South Pacific (English)	05/86	--
Thailand	Energy Assessment (English)	09/85	5793-TH
	Rural Energy Issues and Options (English)	09/85	044/85
	Accelerated Dissemination of Improved Stoves and Charcoal Kilns (English)	09/87	079/87
	Northeast Region Village Forestry and Woodfuels Preinvestment Study (English)	02/88	083/88
	Impact of Lower Oil Prices (English)	08/88	--
	Coal Development and Utilization Study (English)	10/89	--
Tonga	Energy Assessment (English)	06/85	5498-TON
Vanuatu	Energy Assessment (English)	06/85	5577-VA
Vietnam	Rural and Household Energy-Issues and Options (English)	01/94	161/94
	Power Sector Reform and Restructuring in Vietnam: Final Report to the Steering Committee (English and Vietnamese)	09/95	174/95
	Household Energy Technical Assistance: Improved Coal Briquetting and Commercialized Dissemination of Higher Efficiency Biomass and Coal Stoves (English)	01/96	178/96
Western Samoa	Energy Assessment (English)	06/85	5497-WSO

SOUTH ASIA (SAS)

Bangladesh	Energy Assessment (English)	10/82	3873-BD
	Priority Investment Program (English)	05/83	002/83
	Status Report (English)	04/84	015/84
	Power System Efficiency Study (English)	02/85	031/85
	Small Scale Uses of Gas Prefeasibility Study (English)	12/88	--

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India	Opportunities for Commercialization of Nonconventional Energy Systems (English)	11/88	091/88
	Maharashtra Bagasse Energy Efficiency Project (English)	07/90	120/90
	Mini-Hydro Development on Irrigation Dams and Canal Drops Vols. I, II and III (English)	07/91	139/91
	WindFarm Pre-Investment Study (English)	12/92	150/92
	Power Sector Reform Seminar (English)	04/94	166/94
	Environmental Issues in the Power Sector (English)	06/98	205/98
	Environmental Issues in the Power Sector: Manual for Environmental Decision Making (English)	06/99	213/99
	Household Energy Strategies for Urban India: The Case of Hyderabad	06/99	214/99
Nepal	Energy Assessment (English)	08/83	4474-NEP
	Status Report (English)	01/85	028/84
	Energy Efficiency & Fuel Substitution in Industries (English)	06/93	158/93
Pakistan	Household Energy Assessment (English)	05/88	--
	Assessment of Photovoltaic Programs, Applications, and Markets (English)	10/89	103/89
	National Household Energy Survey and Strategy Formulation Study: Project Terminal Report (English)	03/94	--
	Managing the Energy Transition (English)	10/94	--
	Lighting Efficiency Improvement Program Phase 1: Commercial Buildings Five Year Plan (English)	10/94	--
Sri Lanka	Energy Assessment (English)	05/82	3792-CE
	Power System Loss Reduction Study (English)	07/83	007/83
	Status Report (English)	01/84	010/84
	Industrial Energy Conservation Study (English)	03/86	054/86

EUROPE AND CENTRAL ASIA (ECA)

Bulgaria	Natural Gas Policies and Issues (English)	10/96	188/96
Central and Eastern Europe	Power Sector Reform in Selected Countries	07/97	196/97
Eastern Europe	The Future of Natural Gas in Eastern Europe (English)	08/92	149/92
Kazakhstan	Natural Gas Investment Study, Volumes 1, 2 & 3	12/97	199/97
Kazakhstan & Kyrgyzstan	Opportunities for Renewable Energy Development	11/97	16855-KAZ
Poland	Energy Sector Restructuring Program Vols. I-V (English)	01/93	153/93
	Natural Gas Upstream Policy (English and Polish)	08/98	206/98
	Energy Sector Restructuring Program: Establishing the Energy Regulation Authority	10/98	208/98
Portugal	Energy Assessment (English)	04/84	4824-PO
Romania	Natural Gas Development Strategy (English)	12/96	192/96
Slovenia	Workshop on Private Participation in the Power Sector (English)	02/99	211/99
Turkey	Energy Assessment (English)	03/83	3877-TU

MIDDLE EAST AND NORTH AFRICA (MNA)

Arab Republic of Egypt	Energy Assessment (English)	10/96	189/96

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Arab Republic of Egypt	Energy Assessment (English and French)	03/84	4157-MOR
	Status Report (English and French)	01/86	048/86
Morocco	Energy Sector Institutional Development Study (English and French)	07/95	173/95
	Natural Gas Pricing Study (French)	10/98	209/98
	Gas Development Plan Phase II (French)	02/99	210/99
Syria	Energy Assessment (English)	05/86	5822-SYR
	Electric Power Efficiency Study (English)	09/88	089/88
	Energy Efficiency Improvement in the Cement Sector (English)	04/89	099/89
Syria	Energy Efficiency Improvement in the Fertilizer Sector (English)	06/90	115/90
Tunisia	Fuel Substitution (English and French)	03/90	--
	Power Efficiency Study (English and French)	02/92	136/91
	Energy Management Strategy in the Residential and Tertiary Sectors (English)	04/92	146/92
	Renewable Energy Strategy Study, Volume I (French)	11/96	190A/96
	Renewable Energy Strategy Study, Volume II (French)	11/96	190B/96
Yemen	Energy Assessment (English)	12/84	4892-YAR
	Energy Investment Priorities (English)	02/87	6376-YAR
	Household Energy Strategy Study Phase I (English)	03/91	126/91

LATIN AMERICA AND THE CARIBBEAN (LAC)

LAC Regional	Regional Seminar on Electric Power System Loss Reduction in the Caribbean (English)	07/89	--
	Elimination of Lead in Gasoline in Latin America and the Caribbean (English and Spanish)	04/97	194/97
	Elimination of Lead in Gasoline in Latin America and the Caribbean - Status Report (English and Spanish)	12/97	200/97
	Harmonization of Fuels Specifications in Latin America and the Caribbean (English and Spanish)	06/98	203/98
Bolivia	Energy Assessment (English)	04/83	4213-BO
	National Energy Plan (English)	12/87	--
	La Paz Private Power Technical Assistance (English)	11/90	111/90
	Prefeasibility Evaluation Rural Electrification and Demand Assessment (English and Spanish)	04/91	129/91
	National Energy Plan (Spanish)	08/91	131/91
	Private Power Generation and Transmission (English)	01/92	137/91
	Natural Gas Distribution: Economics and Regulation (English)	03/92	125/92
	Natural Gas Sector Policies and Issues (English and Spanish)	12/93	164/93
	Household Rural Energy Strategy (English and Spanish)	01/94	162/94
	Preparation of Capitalization of the Hydrocarbon Sector	12/96	191/96
Brazil	Energy Efficiency & Conservation: Strategic Partnership for Energy Efficiency in Brazil (English)	01/95	170/95
	Hydro and Thermal Power Sector Study	09/97	197/97
Chile	Energy Sector Review (English)	08/88	7129-CH
Colombia	Energy Strategy Paper (English)	12/86	--
	Power Sector Restructuring (English)	11/94	169/94
	Energy Efficiency Report for the Commercial and Public Sector (English)	06/96	184/96
Costa Rica	Energy Assessment (English and Spanish)	01/84	4655-CR
	Recommended Technical Assistance Projects (English)	11/84	027/84

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Costa Rica	Forest Residues Utilization Study (English and Spanish)	02/90	108/90
Dominican Republic	Energy Assessment (English)	05/91	8234-DO
Ecuador	Energy Assessment (Spanish)	12/85	5865-EC
	Energy Strategy Phase I (Spanish)	07/88	--
	Energy Strategy (English)	04/91	--
	Private Minihydropower Development Study (English)	11/92	--
	Energy Pricing Subsidies and Interfuel Substitution (English)	08/94	11798-EC
	Energy Pricing, Poverty and Social Mitigation (English)	08/94	12831-EC
Guatemala	Issues and Options in the Energy Sector (English)	09/93	12160-GU
Ha...	Energy Assessment (English and French)	06/82	3672-HA
	Status Report (English and French)	08/85	041/85
	Household Energy Strategy (English and French)	12/91	143/91
Honduras	Energy Assessment (English)	08/87	6476-HO
	Petroleum Supply Management (English)	03/91	128/91
Jamaica	Energy Assessment (English)	04/85	5466-JM
	Petroleum Procurement, Refining, and Distribution Study (English)	11/86	061/86
	Energy Efficiency Building Code Phase I (English)	03/88	--
	Energy Efficiency Standards and Labels Phase I (English)	03/88	--
	Management Information System Phase I (English)	03/88	--
	Charcoal Production Project (English)	09/88	090/88
	FIDCO Sawmill Residues Utilization Study (English)	09/88	088/88
	Energy Sector Strategy and Investment Planning Study (English)	07/92	135/92
Mexico	Improved Charcoal Production Within Forest Management for the State of Veracruz (English and Spanish)	08/91	138/91
	Energy Efficiency Management Technical Assistance to the Comision Nacional para el Ahorro de Energia (CONAE) (English)	04/96	180/96
Panama	Power System Efficiency Study (English)	06/83	004/83
Paraguay	Energy Assessment (English)	10/84	5145-PA
	Recommended Technical Assistance Projects (English)	09/85	--
	Status Report (English and Spanish)	09/85	043/85
. eru	Energy Assessment (English)	01/84	4677-PE
	Status Report (English)	08/85	040/85
	Proposal for a Stove Dissemination Program in the Sierra (English and Spanish)	02/87	064/87
	Energy Strategy (English and Spanish)	12/90	--
	Study of Energy Taxation and Liberalization of the Hydrocarbons Sector (English and Spanish)	120/93	159/93
	Reform and Privatization in the Hydrocarbon Sector (English and Spanish)	07/99	216/99
Saint Lucia	Energy Assessment (English)	09/84	5111-SLU
St. Vincent and the Grenadines	Energy Assessment (English)	09/84	5103-STV
Sub Andean	Environmental and Social Regulation of Oil and Gas Operations in Sensitive Areas of the Sub-Andean Basin (English and Spanish)	07/99	217/99
Trinidad and Tobago	Energy Assessment (English)	12/85	5930-TR

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	GLOBAL		
	Energy End Use Efficiency: Research and Strategy (English)	11/89	--
	Women and Energy--A Resource Guide The International Network: Policies and Experience (English)	04/90	--
	Guidelines for Utility Customer Management and Metering (English and Spanish)	07/91	--
	Assessment of Personal Computer Models for Energy Planning in Developing Countries (English)	10/91	--
	Long-Term Gas Contracts Principles and Applications (English)	02/93	152/93
	Comparative Behavior of Firms Under Public and Private Ownership (English)	05/93	155/93
	Development of Regional Electric Power Networks (English)	10/94	--
	Roundtable on Energy Efficiency (English)	02/95	171/95
	Assessing Pollution Abatement Policies with a Case Study of Ankara (English)	11/95	177/95
	A Synopsis of the Third Annual Roundtable on Independent Power Projects: Rhetoric and Reality (English)	08/96	187/96
	Rural Energy and Development Roundtable (English)	05/98	202/98
	A Synopsis of the Second Roundtable on Energy Efficiency: Institutional and Financial Delivery Mechanisms (English)	09/98	207/98
	The Effect of a Shadow Price on Carbon Emission in the Energy Portfolio of the World Bank: A Carbon Backcasting Exercise (English)	02/99	212/99
	Increasing the Efficiency of Gas Distribution Phase 1: Case Studies and Thematic Data Sheets	07/99	218/99
	Global Energy Sector Reform in Developing Countries: A Scorecard	07/99	219/99
	Global Lighting Services for the Poor Phase II: Text Marketing of Small "Solar" Batteries for Rural Electrification Purposes	08/99	220/99
	A Review of the Renewable Energy Activities of the UNDP/ World Bank Energy Sector Management Assistance Programme 1993 to 1998	11/99	223/99
	Energy, Transportation and Environment: Policy Options for Environmental Improvement	12/99	224/99

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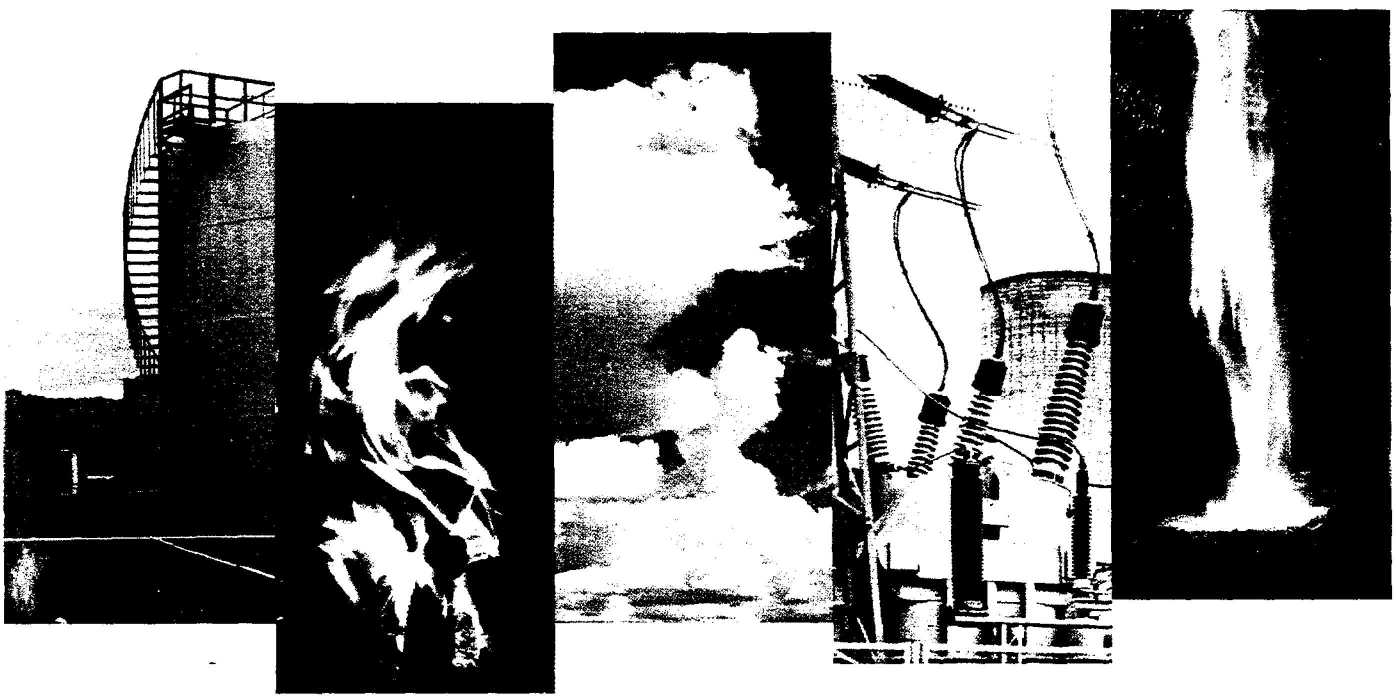

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