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ENVIRONMENTAL–ENERGY POLICIES AND AUTOMOTIVE POLLUTION

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ABSTRACT

After delineating the areas of potential conflict between environmental conservation and energy conservation policies, this paper examines the air quality implications of alternative environmental/energy policy scenarios with particular reference to five urban regions of New York State. In this analysis it is presumed that energy conservation policies will serve to limit the amount of fuels available for private transportation, while the environmental policies considered are those that serve to roll back Clean Air Act air quality standards beyond 1976. It is shown that due to the interdependent nature of environmental and energy conservation objectives, policies in these two areas of concern should be developed conjointly.

Introduction

The "energy crisis" of 1973 has brought into sharp focus the potential conflicts between environmental and energy conservation policies. Nowhere is the conflict more apparent than it is in transportation, a sector which consumes enormous quantities of fuel (energy) and which is at the same time a major contributor to pollution.

Environmental-wise, amendments to the Clean Air Act of 1970 stipulate that emissions of hydrocarbons (HC), carbon monoxide (CO) and nitrous oxides (NO_X) from automotive sources must be reduced and largely eliminated by 1975. In an effort to meet the requisite deadlines the automotive industry (i.e., motor vehicle manufacturers and their suppliers) has devoted considerable effort toward the development of suitable emissions-control technologies. In view of the short lead times it is quite probable that some of the major

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emissions-control devices presently under development will result in increased fuel consumption per vehicle mile [1].

Energy-wise, the recent fuels shortage served as a stark reminder of the need to conserve energy as much as possible. Although a National energy policy has not yet been formulated, in its final form it seems sure to call for fuel conservation in the transportation sector. Among other conservation measures further development of and financial assistance to mass transit, encouragement of carpooling, and special driving or gasoline taxes have all been seriously considered at one time or another. It is clear that the price of fuels will be higher–closer to the world price–and this phenomenon alone should act as a natural driving deterrent. But from all indications, most Americans are currently in the inelastic portions of their gasoline demand curves and the increase in average price per gallon of gasoline from about 39¢ to about 52¢ over six months did not seem to curtail driving activity to any significant degree. So, it seems likely that some of these additional conservation measures will need to be adopted, at least in the short term.

The conflicts between energy and environmental concerns are already surfacing. Most prominently, as part of a fuels conservation policy, several public interest groups have clamored for a relaxation of the stringent environmental goals exemplified by the Clean Air Act of 1970. A major decision confronting government is whether to relax air quality standards and thereby free additional fuels for general (transportation and nontransportation) consumption or to insist that 1975 standards be met at the expense of the incurrence of a substantial fuels penalty. Some concessions have been made already–e.g., the 1975 standards have recently been rolled back to 1976 (see Table 1)–and others are likely to follow. For example, further rollbacks might be contemplated in order to give the automotive industry sufficient lead time with which to develop alternate power technologies which have promise of having desirable fuel consumption as well as emissions characteristics. Many of these technologies–e.g., the stratified charge engine–are currently being investigated but have not yet been shown to be commercially feasible [2, 3].

Table 1. EPA Automobile Emissions Standards, May, 1974 [2]

	Hydrocarbons (HC)		*Carbon Monoxide (CO)*		*Nitrous Oxides (NO_x)*[a]	
Year	*g/mi.*	*% reduction*	*g/mi.*	*% reduction*	*g/mi.*	*% reduction*
pre-1968	8.70	–	87.0	–	5.38	–
1970-71	4.10	53	34.0	61	6.76	–26
1975	0.41	95	3.4	96	3.10	43
1976	0.41	95	3.4	96	0.40	93

[a] Prud 'homme, R. K., "Automobile Emissions Abatement and Fuels Policy," *American Scientist*, 62, 1974, pps. 191-199.

In assessing alternative ways of jointly managing environmental and energy resources, decisionmakers need to be able to assess the joint implications of alternative policies that may be considered.[1] That is, if air quality standards were to be rolled back further, how much fuel would be saved and what would be the cost in terms of air quality? Or, what would be the environmental implications of alternative energy policies ranging, say, from a laissez-faire policy of no or minimal fuels conservation to the more drastic policy calling for fuels rationing? In each of these cases, the relevant trade-offs are between improving air quality at the expense of fuels availability or between fuels conservation at the expense of air quality deterioration. Ideally, we would like to attach "prices" to these factors (e.g., the social value of one "unit" of either air quality or fuel availability) but unfortunately at the present time this is not possible. The best we can hope for is to register the gains and losses in physical terms. In this regard, informed policy decisions would seem to rest on how well we can make the requisite estimates.

This paper looks at one side of this question: the environmental implications of alternative environmental/energy policies which affect fuel availability and prices. With slight extensions, energy implications of alternative environmental policies could be handled as well. The analysis is performed with reference to five urban regions of New York State. The methodology employed is general enough so that it can be applied to any other similar regions in the United States. However, limiting discussion to these five areas is especially meaningful as pointed out in a subsequent section.

Some Basic Concepts

With a little thought, one can readily envision that environmental/energy policies have both direct and indirect effects on transportation and the environment. The effects are direct to the extent that pollutant emissions are reduced as a result of (a) reductions in total vehicle miles of driving due either to higher vehicle and fuel prices or to the general unavailability of fuels and (b) amelioration of highway congestion. The effects are indirect to the extent that fuel penalties due to emission control devices or fuels unavailability due

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[1] Since this paper was written, several major national developments have occurred which probably should be mentioned here. The President's recent State of the Union message advocates further extensions of the Clean Air Act Amendments emissions-control compliance standards under speculation in this paper. At this time it is not possible to be definitive about the final outcome of the President's proposal, as there is sure to be considerable debate on the matter.

Also, it is beginning to appear that some emissions-control devices (most notably the catalytic converter) formerly thought to result in fuel penalties, will, by virtue of the extra 'degree of freedom' provided, actually permit fuel economy. Although this possibility must be kept in mind by readers of this paper, it does not invalidate the findings reported here.

to shortages lead to significant changes in automotive technologies and on consumer preferences for small, economical vehicles. It is likely that over the next decade there will be some of both kinds of effects taking place [4]. The problem is to isolate these two areas of impacts and to estimate the implications of alternative scenarios which would give rise to either the changing of driving habits or of vehicle characteristics.

The direct effects mentioned above are experienced in the short term, while indirect effects occur in the longer term. This paper focuses primarily on short-term effects and further discussion of these is in order.

A subtle yet critical feature of these short-term direct effects is that changes in emissions or in air quality are not necessarily proportional to changes in the number of vehicle miles driven. That is, a 5 per cent or 10 per cent reduction in vehicle miles does not usually lead to a concomitant 5 per cent or 10 per cent reduction in total emissions–in most cases, there will be a more-than-proportional change in emissions. It is important to examine why this is so.

First, we note that emissions per vehicle mile for conventional internal combustion systems vary nonlinearly with vehicle speed. Figures 1, 2 and 3 are pollutant emissions functions which relate outputs of pollutants in pounds per vehicle mile to vehicle speed in miles per hour. These functions were developed from composite data collected from six sources [5-10]. Figure 1 presents the function developed for carbon monoxide; Figure 2 is the emissions function for hydrocarbons; Figure 3 is the nitrous oxides function. It is seen that emissions per vehicle mile of CO and HC decrease with an increase in vehicle speed while emissions of NO_X increase (beyond a threshold) with speed. Next, vehicle speed, at least in urban areas, is greatly conditioned by the number of vehicles on the road. On a congested highway the average vehicle speed would be less than it would be if the highway were not congested [11]. Therefore, if fuels shortages impact drivers such that fewer total vehicle miles are registered it would follow that congestion on roadways decreases while the average speed of travel increases. Consequently, emissions of CO and HC would decrease while those of NO_X might increase. And, as indicated by the shape of the emissions functions of Figures 1, 2 and 3 the changes in emissions would not necessarily be proportional to the changes in congestion levels.

So, to the extent that roadways in urban areas are not congested changes in total emissions could be proportional to changes in the number of vehicle miles driven. But to the extent that the reduction in vehicle miles serves to ameliorate congestion on roadways, then additional changes in emissions are experienced. Hence, in most of our urban areas we can expect changes in emissions which are more-than-proportional to changes in the number of vehicle miles driven.

It is clear that a transportation-related environmental policy, even if it

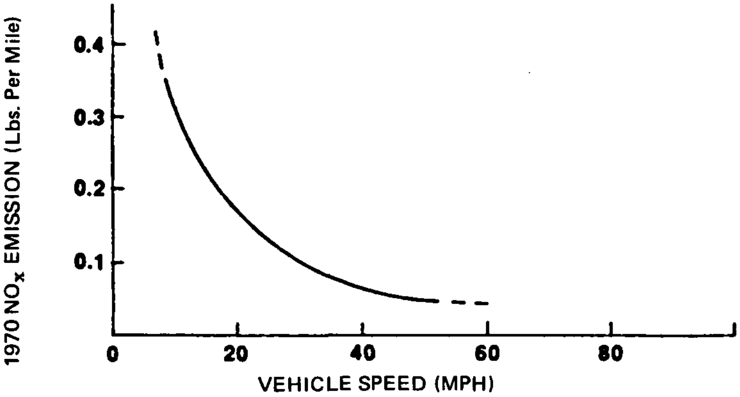

Figure 1. Emissions function for CO [7, 9, 15].

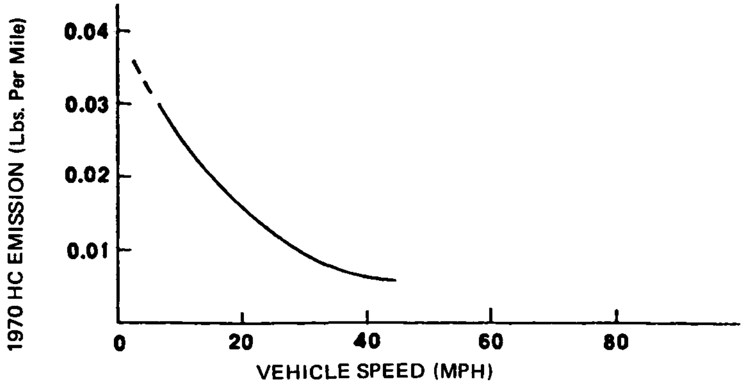

Figure 2. Emissions function for HC [7, 9, 15].

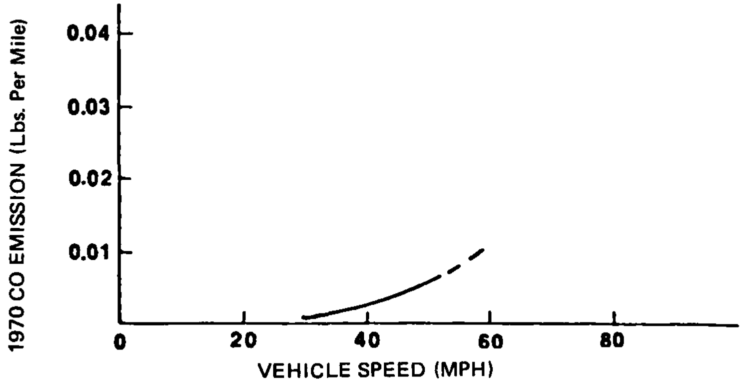

Figure 3. Emissions function for NO_x [7, 9, 15].

is only partially successful, will lead to an overall improvement in air quality. A principal thesis here is that policies designed to conserve fuels will likely have the same effect. In either case the extent to which air quality is improved in any area is highly sensitive to local conditions and thus the effects must be examined on an area-by-area basis. Before analyzing the five New York State regions chosen for examination, it is helpful to present the basic elements of the model.

The Model

The environmental model employed in this analysis is an adaptation of the one presented by Cesario [12]. It provides estimates of the automotive emissions of HC, CO and NO_x (ignoring interactions between pollutants) in a region under a wide variety of assumptions on the spatial arrangements of human and economic activity within the region. It is designed to be used in conjunction with other models that, first, supply relevant traffic volume estimates as input and, second, utilize the output for assessing the air quality implications of a given emissions pattern. That is, it is presumed that travel forecasts are available exogenously and that some dispersion model capable of translating emissions quantities into air quality is available. The most appealing feature of the model is its simplicity. Unlike other, more elaborate procedures developed or advocated elsewhere [5, 13-15] the model employed here is easy and inexpensive to develop and to operate.

Using as input actual or projected traffic volumes over each link in a regional highway network for a time period specified by the user, the model provides as output estimates of pollutant emissions for each subarea of the region. The model is depicted schematically in Figure 4. It is assumed that the user has at his disposal a detailed specification of the highway network to be studied in the form of a map of highway links and intersections in a particular region. It is also assumed that the user has subdivided the region into a set of mutually exclusive and contiguous subareas for which emissions estimates are to be provided.

To summarize the calculation procedure, for each road type (primary and secondary) in each subarea exogenous estimates are made of the total vehicle miles driven during an average day. Travel on each road type is assumed to take place at an effective speed which is the speed limit for the road type (i.e., free flow speed) adjusted downward for delays due to congestion, stoplights and other deterring factors. Emissions per vehicle mile of CO, NO_x, and HC are then estimated by referring to emissions functions which relate emission rates to effective speed of travel for the vintage of vehicle under consideration. Then the emissions of each pollutant per vehicle mile are multiplied by total vehicle miles to yield total emissions in each subarea for both the primary and secondary networks. The mathematics of the model are available elsewhere and need not be repeated here [12].

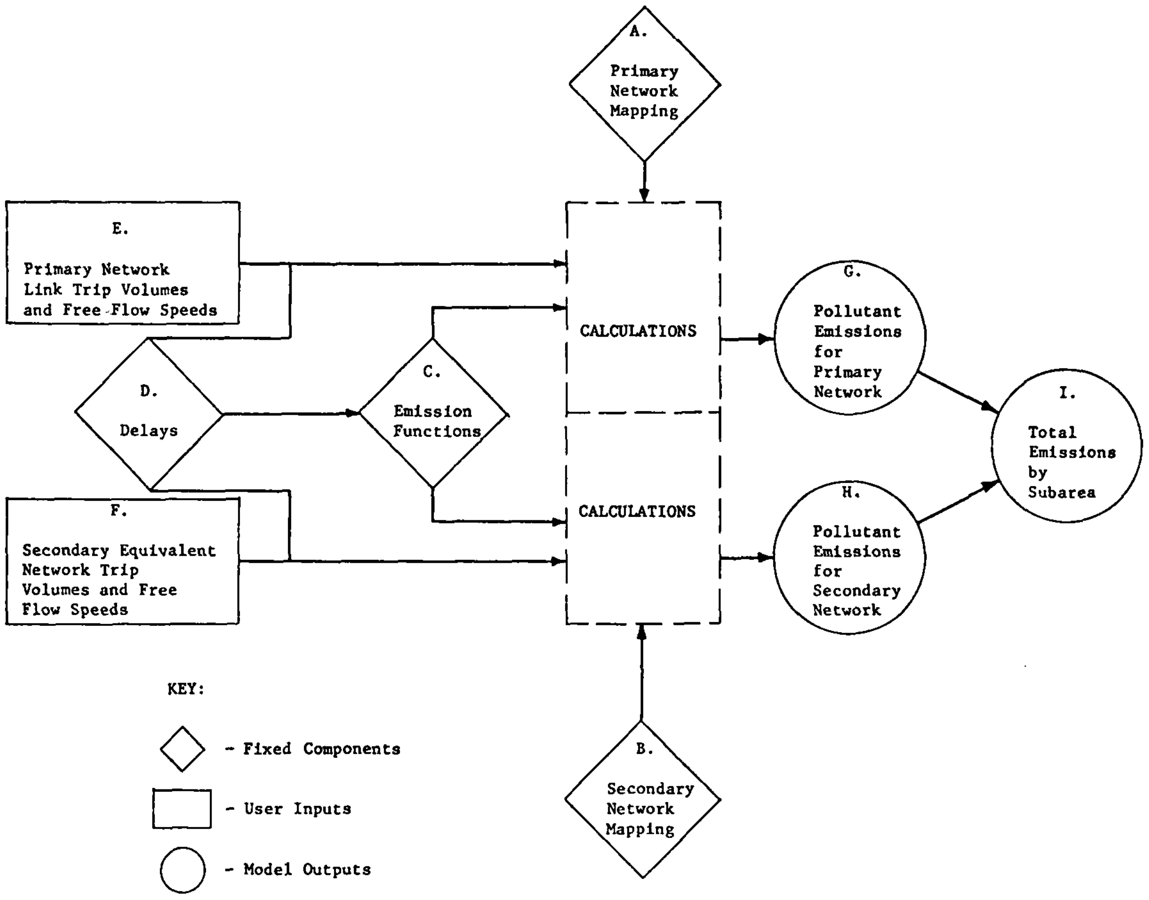

Figure 4. Environmental model schematic [12].

The pollution functions of Figures 1, 2 and 3 form the basis for estimating emissions under any particular set of driving conditions. It should be noted that these functions are relevant only for the year 1970 and apply only to the internal combustion engine. Adjustments of these functions to account for the effects of emission-control devices are made by assuming appropriate uniform percentage reductions of emissions (the vertical axis) at each point on the horizontal axis representing speed—see Table 3.1.1-1 in *Compilation of Air Pollutant Emission Factors* [7] for relevant data with which to calculate these adjustments. Emissions data for alternative power technologies were obtained from Ayres and McKenna [2] and Prud'homme [1].

In making applications to any particular region it is necessary to employ a "travel demand" framework which is sensitive to fuel prices and availability. To this author's knowledge no such model exists. Again, instead of adapting a complicated model (e.g. [15-17]) for making the required estimates a simplified procedure was developed. The procedure involves essentially using base-year data (obtained from survey data) as a starting point and then making certain assumptions as to how the base-year travel patterns would change under different environmental/energy policies.

Applications

THE URBAN REGIONS

The direct and indirect environmental implications of selected environmental/energy policies were examined with particular reference to five urban regions in New York State: (1) the Buffalo SMSA, (2) the Rochester SMSA, (3) the Syracuse SMSA, (4) the Utica-Rome SMSA, and (5) Jefferson County with the city of Watertown at its center (designated the Watertown region). Some relevant data describing these regions are given in Table 2. Detailed examination of this table reveals the considerable diversification represented by this particular set of cities. Of particular interest is the range of population sizes covered.

It is important to point out that all of these regions, with the exception of Watertown, are included in the set of 76 urban regions examined by Berry, et al. in a recent study [18]. Using factor-analytic techniques, Berry developed a pollution-sensitive typology of his regions. A total of 11 different groups were formed. It turned out that Buffalo (along with Baltimore, Indianapolis, Los Angeles and Washington) is in the class of city heavily afflicted with air pollution relative to other types of pollution. Rochester (along with Akron, Allentown-Bethlehem, Canton, Youngstown and York) is in a class of city with less severe air pollution problems. Syracuse (along with Cincinnati, Jersey City, Kansas City, San Bernadino, and Wilmington) is in a class of city having severe water pollution problems relative to other types of pollutants. Utica-

Rome (along with Birmingham, Charleston, Chattanooga, Dayton, Des Moines, Gary-Hammond, Johnstown, Nashville, Omaha, Reading, and Worcester) is in a class having a rather balanced pollution load—that is, no one pollutant type seems to dominate the others.[2]

Table 2. Selected Urban Region Characteristics, 1970 [6] (b)

Characteristics	*Buffalo SMSA*	*Rochester SMSA*	*Syracuse SMSA*	*Utica—Rome SMSA*	*Jefferson County*
(1) Population (thousands)	1349	883	637	341	88
(2) Density (persons/sq. mi.)	848	381	263	128	68
(3) SMSA Median Population Age (years)	28.5	27.3	25.8	29.0	28.7
(4) Median Family Income ($/yr.)	10430	11969	10450	3926	9726
(5) Employed in Manufacturing (%)	34.0	41.6	27.9	35.2	n.a.
(6) Land Area (sq. mi.)	1591	2316	2419	2658	1294
(7) SMSA Property Values ($000's)	3842	4398	3172	1119	n.a.
(8) SO_2, Mean (ug/m^3)	15	32	12	8	n.a.
(9) SO_2, Max. (ug/m^3)	82	227	46	48	n.a.
(10) Particulates, Mean (ug/m^3)	99	111	95	85	n.a.
(11) Particulates, Max. (ug/m^3)	309	213	220	307	n.a.
(12) Water Pollution (PI_1)(a)	11.8	8.1	n.a.	1.8	n.a.
(13) Water Pollution (PI_2)(a)	7.8	3.5	n.a.	0.8	n.a.
(14) Water Pollution (PI_3)(a)	0.9	0.6	n.a.	0.7	n.a.
(15) Water Pollution (PI_4)(a)	6.8	4.1	n.a.	1.1	n.a.
(16) Solid Waste, Dwellings (1000 tons/yr.)	2815	1843	1329	711	n.a.
(17) Solid Waste, Commercial (1000 tons/yr.)	862	564	407	218	n.a.
(18) Solid Waste, Manufacturing (1000 tons/yr.)	1339	1107	518	326	n.a.
(19) Solid Waste, Construction (1000 tons/yr.)	337	221	159	85	n.a.

(a) Expressed in indexes. PI_1 = Drinking use; PI_2 = Recreation use; PI_3 = Industrial use; PI_4 = Average index.

(b) Berry, B. J. L. et al, *Land Use, Urban Form & Environmental Combustion Engine,* Research Paper No. 155, Dept. of Geography, University of Chicago, 1973.

Berry shows that while widely different pollution characteristics are exhibited *between* these city groups, the cities *within* each group are in some sense homogeneous with respect to pollution. Thus, we conclude that not only do the New York State urban regions span a wide size range but also they span a wide range

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[2] Jefferson County (Watertown) was not included in the Berry data set. However, it is judged to be a meaningful addition since it is representative of the small urban area class ignored by Berry.

of pollution-related phenomena. At one extreme we have Buffalo with major air pollution problems; at the other extreme we have Syracuse with heavy water pollution problems. Two cities—Rochester and Utica-Rome—are somewhere in between these two extremes. Since each New York city can be taken as being representative of a large number of other similar cities, it can be said, then, that this set of cities is a representative sample of city types studied by Berry when extended to cover small urban areas.

Berry concluded that the core-oriented city with radial transportation arteries and a steep population density gradient in general displays greater land use intensity, lower percentages of residential and commercial land use, and more open space. As a consequence of this land-use mix, this type of city in general possesses superior air and water quality. At the other extreme, the dispersed city with a circumferential transportation network and uniformly low population densities displays urban sprawl with higher percentages of residential and commercial land uses. As a consequence, this type of city seems to possess inferior air and water quality. Thus, the worst possible combination from a pollution point of view is a large dispersed manufacturing region, while the best combination is a small high-income nonmanufacturing core-oriented region. These results support those of Voorhees and Associates [19].

Since the five New York urban regions span a wide range of characteristics and since pollution patterns and intensification depend on the spatial configurations of activities we suspect that different environmental implications would be forthcoming from a specific set of environmental and/or energy restrictions. The empirical results support this assertion.

THE ANALYSES

Two kinds of analyses were conducted. First for each of the urban regions the environmental effects of alternative levels of assumed reductions in vehicle miles of driving—5 per cent, 10 per cent, 25 per cent and 50 per cent—were examined. We do not presume to specify the particular policies or conditions which will give rise to these particular reductions. Merely, the analysis examines what would happen if such reductions were to be achieved. Second, it is assumed that there will exist sufficient public pressure so that Clean Air Act air quality standards are further relaxed from 1976 to 1980 and beyond. It is assumed that fuel would then be in plentiful supply and, further, that driving is virtually price-inelastic with respect to fuel.

The outputs of the analyses are expressed in terms of emissions quantities rather than in more meaningful measures of air quality per se. Results are presented in this way because Clean Air Act standards are expressed in terms of emissions quantities and the most relevant analyses therefore involve comparing overall emissions reductions under different assumptions to those that would be achieved by strict conformance to Clean Air Act standards. Further, in order to translate emissions quantities into air quality measures one needs to develop dispersion or transformation functions for the particular regions under study. The models that are available for this purpose require substantial amounts of meteorological and other data which are typically unavailable even under the best of circumstances and the models themselves are not widely trusted in general (despite the considerable work recently done in this area).

Table 3 provides results for the alternative assumed reductions in vehicle miles in each urban region. (In Table 3 urban regions are specified from left to right in order of decreasing population.) The reference year is 1974. Against this background it is seen that different results obtain for each urban region. The assertion presented at the outset of this paper—that emissions quantities change more-than-proportionally to changes in vehicle miles—seems to be supported and, as suspected, the major distortions take place in the heavily populated areas vis-a-vis the more lightly populated areas. For example, with an assumed reduction in vehicle miles of 10 per cent in the Buffalo region, emissions changed on the average of 17 per cent while in the Watertown region the corresponding change was only about 11 per cent. This discrepancy is explained by the fact that the Watertown region is far less congested than the Buffalo region and emissions changes in Buffalo come about as a result of

Table 3. Environmental Implications Of Alternative Reductions In Vehicle Miles, 1974[a]

		Urban Region				
Vehicle Mile Reduction	*Pollutants*	*Buffalo*	*Rochester*	*Syracuse*	*Utica-Rome*	*Watertown*
0%	HC	1.00	1.00	1.00	1.00	1.00
	CO	1.00	1.00	1.00	1.00	1.00
	NO_x	1.00	1.00	1.00	1.00	1.00
5%	HC	0.92	0.92	0.94	0.94	0.95
	CO	0.88	0.90	0.92	0.94	0.94
	NO_x	1.07	1.08	1.08	1.07	1.06
10%	HC	0.86	0.86	0.88	0.88	0.89
	CO	0.80	0.82	0.87	0.88	0.90
	NO_x	1.18	1.18	1.17	1.15	1.12
25%	HC	0.65	0.67	0.72	0.72	0.74
	CO	0.60	0.62	0.68	0.72	0.73
	NO_x	1.42	1.39	1.32	1.30	1.28
50%	HC	0.22	0.31	0.37	0.42	0.47
	CO	0.10	0.20	0.31	0.40	0.47
	NO_x	1.82	1.75	1.65	1.62	1.54

[a] Entries in this table are expressed as ratios of the emissions generated under a particular condition (say, a 10 per cent vehicle mile reduction) to the emissions generated under normal driving behavior (i.e., at 0 per cent vehicle mile reduction) for the urban region in question.

both the fewer vehicle miles driven and the alleviation of congestion while in Watertown the changes are mainly due only to the reduced vehicle miles. Similar results for other regions can be noted throughout the table.

Table 4 contains results for the second kind of analysis where it was assumed that Clean Air Act air quality standards were rolled back to 1980 and beyond. It was also assumed that the relative populations of these

Table 4. Environmental Implications of Rollbacks of Air Quality Standards to 1980 and to 2000

			Urban Region				
Year	*Assumption*	*Pollutants*	*Buffalo*	*Rochester*	*Syracuse*	*Utica-Rome*	*Watertown*
1976	0[a]	HC	1.00	1.00	1.00	1.00	1.00
		CO	1.00	1.00	1.00	1.00	1.00
		NO_x	1.00	1.00	1.00	1.00	1.00
	1[b]	HC	10.53	10.14	8.92	7.87	7.53
		CO	11.72	12.13	8.11	8.15	7.53
		NO_x	9.31	8.90	7.94	6.53	6.72
	2[c]	HC	10.53	10.14	8.92	7.87	7.53
		CO	11.72	12.13	8.11	8.15	7.53
		NO_x	9.31	8.90	7.94	6.53	6.72
1980	0	HC	1.00	1.00	1.00	1.00	1.00
		CO	1.00	1.00	1.00	1.00	1.00
		NO_x	1.00	1.00	1.00	1.00	1.00
	1	HC	0.92	0.90	0.89	0.88	0.88
		CO	0.88	0.91	0.89	0.90	0.90
		NO_x	0.75	0.77	0.78	0.72	0.72
	2	HC	5.51	5.24	5.30	5.14	5.07
		CO	6.19	6.04	5.94	5.97	5.81
		NO_x	5.43	5.51	5.55	5.41	5.27
2000	0	HC	1.00	1.00	1.00	1.00	1.00
		CO	1.00	1.00	1.00	1.00	1.00
		NO_x	1.00	1.00	1.00	1.00	1.00
	1	HC	0.72	0.68	0.69	0.65	0.66
		CO	0.69	0.68	0.69	0.67	0.62
		NO_x	0.58	0.59	0.52	0.58	0.57
	2	HC	0.33	0.28	0.29	0.27	0.27
		CO	0.31	0.32	0.30	0.30	0.31
		NO_x	0.28	0.29	0.28	0.27	0.27

[a] Assumption 0: Standards of Table 1 achieved on schedule.

[b] Assumption 1: Rollback of 1976 standards to 1980

[c] Assumption 2: Rollback of 197

urban regions would remain stable over the time period. Along with these assumptions it was presumed that the automotive industry will delay or postpone development work on catalytic converters to a certain extent and instead become heavily involved in the development of alternative power technologies which will have desirable emissions characteristics as well as fuel economy by the year 1980. However, in the interim, it was assumed that existing technology is employed. In Table 4 the basis of reference employed is the set of 1976 Clean Air Act standards as depicted in Table 1. Each entry in the table is an index number which reflects the relationship of the emissions of an alternative policy to that of the reference emissions. For example, an index number of 1.5 implies an emissions level which is 50 per cent higher than it would be if the 1976 standards were in effect.

We can see from this table that under the assumptions of this analysis air quality is sacrificed in the short term for the sake of longer-term gains. For example, under the assumption that emissions standards are rolled back to 1980 it is seen that substantially more emissions are forecasted between 1970 and 1979 for each of the urban areas than would be the case if the air quality standards were to be achieved in 1976. However, beyond 1980 major improvements in emissions quantities are achieved due to the assumed new technologies which will tend to offset the initial environmental losses. Ideally one would in some sense discount those future gains (under the premise that a gain of one unit in air quality today is worth more than a gain of one unit tomorrow) but for all practical purposes we can ignore this detail and simply add up over the entire period the annual gains and losses. If one does this, it becomes immediately apparent that the short-term sacrifices are substantial. However, it is necessary to point out that in order to fully evaluate the results from a public policy viewpoint–that is, to examine the tradeoffs discussed earlier–it is necessary to have on hand estimates of the fuels implications of this scenario. That is, it must be presumed that a substantial savings in fuels would accrue and this aggregate savings must be balanced against the environmental losses.

Although the above analyses were carried out separately we note that it is possible to combine the two kinds of results. For example, one might want to examine the impacts on the environment of a reduction in driving on the order of, say, 10 per cent coupled with a relaxation of the Clean Air Act standards to, say, 1980. If it were possible to assign probabilities to each of these events occurring then it would be possible to construct a probability distribution of environmental impacts based on the two sets of results.

Conclusions

From the results of the analyses displayed in Tables 3 and 4, it may be inferred that under different assumptions on fuel supplies and prices as well as on alternative automotive technologies it is possible to estimate the emissions changes that will ensue under a given scenario. It was seen that direct and indirect environmental implications under a given set of conditions differ between regions having different population and other characteristics. A subtle but important illustration that, due to road congestion, emissions changes (increases or decreases) vary nonlinearly with changes in vehicle miles of driving was pointed out.

It is learned from this analysis that decisions in the environmental and energy areas cannot be made haphazardly or in vacuo as there are many interactions involved which are not immediately apparent that must be taken into consideration. For example, it might be concluded from the preceding analyses (based on admittedly simplified assumptions) that there might be a basis for extending the deadlines for conformance to Clean Air Act air quality standards *when one takes into consideration the fuels savings that would accrue*. On the basis of solely environmental considerations one would not likely reach the same conclusion. In sum, informed National and regional policy explicitly recognizes the tradeoffs between clean air and less fuel or more fuel and dirty air, even though it is difficult if not impossible to attach social values to these resources.

It must be recognized that the analyses in this paper ignored uncertainties with respect to future conditions and policies, and until these uncertainties are explicitly introduced into the analysis it is difficult to make truly informed statements. For example, we know that catalytic converters are technologically and commercially feasible at the present time and while it is suspected that alternative power technologies can be developed that are operationally as well as commercially feasible, this has yet to be determined. If the air quality standards were to be in fact rolled back and the new technologies were not forthcoming then a substantial social cost is incurred. And, we do not know what form a National energy policy will take or what the real effects of alternative policies and restrictions on car-buying and driving behavior will be. Yet, even though there are a great many of these uncertainties associated with market conditions and of government policies in the energy and environmental areas, it is clear that there will be some changes in emissions as a result of environmental/energy policy decisions, and we have attempted to speculate on some of these changes in this paper.

Thus, the analysis was indeed speculative since it looks into the future with reference to a period of time during which much ambiguity about environmental/energy policies prevails. Many assumptions had to be made which under close examination may prove to be invalid. Nevertheless, it is useful to speculate even though such crystal-ball gazing is fraught with many hazards. It therefore behooves us to strive for the development of improved methodologies with which to make improved estimates.

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