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Office of the Clerk
Illinois Pollution Control Board
100 West Randolph
Chicago, IL 60601

August 17, 2006

Re: Comments on Proposed New 35 ILL. ADM. CODE 225, Control of Emissions from Large Combustion Sources (Mercury); R06-25

Ladies & gentlemen:

I am writing on behalf of the Center for Energy & Economic Development, Inc. (CEED) regarding the proposed rule for controlling mercury emissions from coal-fueled powerplants in Illinois.

CEED is a national membership organization representing major U.S. railroads, coal producers, electric generating firms and numerous other industrial interests. CEED members have direct and substantial interests in the generation of electricity and the production and transportation of coal used for electric generation throughout Illinois.

On March 14, 2006, the Illinois Environmental Protection Agency (IEPA) filed a proposed rule with the Illinois Pollution Control Board requiring coal-fired electric generating units (EGUs) to reduce mercury emissions through a state-specific program. The IEPA proposed rule contains emission limitations more stringent than the U.S. Environmental Protection Agency's (EPA) Clean Air Mercury Rule (CAMR), to be achieved on a timetable inconsistent both with CAMR and EPA's companion Clean Air Interstate Rule (CAIR) for reducing emissions of sulfur dioxide (SO_2) and nitrogen oxides (NOx).

CEED strongly supports state implementation of U.S. EPA's CAMR and CAIR as the most cost-effective approach to reducing EGU emissions of mercury, SO_2 and NOx. The restructured Illinois electric generation industry requires a level playing field to compete effectively against firms in nearby states - such as Iowa, Kentucky, Missouri, Indiana and Ohio - that plan to implement CAIR and CAMR. For the reasons discussed below, CEED respectfully recommends that the Pollution Control Board reject the proposed IEPA rule, and recommend adoption of CAMR in its place.

Summary of CEED's Objections to the IEPA Mercury Rule

CEED has four basic objections to the proposed IEPA mercury rule:

1) The proposed rule would increase electric generation costs and reduce the competitiveness of Illinois electric generators with no demonstrable environmental or public health benefits relative to implementation of U.S. EPA's CAIR and CAMR.

2) Increasing energy costs for consumers and industries would discourage job creation and retention at new and existing industries throughout Illinois, to the detriment of the state economy and public health, forcing households to make increasingly difficult budget choices between energy and other essential goods and services such as nutrition, health care, and education.

3) The proposed rule incorporates unrealistic deadlines and inflexible, plant-by-plant emission mandates. Unlike IEPA's rule, EPA's CAMR is designed to take advantage of the "co-benefit" mercury reductions resulting from implementation of CAIR, with a national emissions trading program to further reduce the costs of mercury reductions.

4) If implemented as proposed, the Illinois mercury rule could jeopardize electric system reliability by causing the premature shutdown of older and smaller coal-fueled generating units that could no longer provide competitively-priced electricity.

The proposed rule would reduce the competitiveness of Illinois electric generators

This rulemaking record demonstrates that the proposed IEPA rule would increase the costs of electric generation well above the costs of compliance with EPA's CAMR. There is no corresponding evidence that the rule would provide demonstrable environmental or public health benefits beyond those provided by CAIR and CAMR.

We first look to IEPA's own economic impact evaluation of its proposed rule. A study by ICF Resources[1] conducted for IEPA shows that the proposed mercury rule would:

- Decrease generation from coal-fueled EGUs in Illinois by 15 percent in 2015;
- Substantially reduce Illinois' electricity exports; and
- Increase overall consumer electric costs by $271 million in the year 2015 relative to CAIR/CAMR.

A study conducted by James Marchetti and Ed Cichanowicz for this rulemaking finds that implementation of the proposed IEPA rule would increase electric generation costs in Illinois by $2.0 billion over the period 2009-2018, compared to the costs of compliance with EPA's CAIR and CAMR. A summary of their findings appears below:

Cumulative Annualized Compliance Costs for SO_2, NOx and Mercury Controls in Illinois, 2009-2018 (in billions of 2006 $)

Rules	SO_2	NOx	Hg	Total
CAIR/CAMR	**1.91**	**0.65**	**0.54**	**3.10**
CAIR/IL Rule	**1.85**	**0.62**	**2.63**	**5.10**
Differential Cost	**-0.06**	**-0.03**	**2.09**	**2.00**

Source: Prefiled testimony of James Marchetti, July 28, 2006, Table 4.

[1] ICF Resources, "Analysis of the Proposed Illinois Mercury Rule," March 10, 2006 (prepared under contract to the Lake Michigan Air Directors Consortium.)

Increasing power production costs by $2 billion over the period 2009 to 2018 - or roughly $200 million per year - would harm the competitiveness of Illinois electric generators, as well as the overall state economy. IEPA's finding that its rule would reduce Illinois coal-based electric generation by 15% should be sufficient, in itself, to raise serious concerns about the proposed mercury rule.

Increased energy costs would harm Illinois consumers and public health

The projected economic impacts of the IEPA rule are significant for the Illinois economy. Like other Midwest states, Illinois is struggling to cope with rapidly escalating energy costs and the loss of well-paying industrial jobs. Since 1990, Illinois has lost more than 220,000 highly-paid manufacturing jobs.[2] In the past six years, the median household income in Illinois has dropped by $6,000, a 12% decline.[3]

IEPA's economic analysis reveals that average household electric rates would increase by $1.50 per month in 2015, compared to the costs associated with U.S. EPA's CAIR and CAMR.[4] This is, in effect, a "mercury tax" of $1.50 per month levied on every household in Illinois. With declining wage rates and a shrinking industrial base, imposing costs of this magnitude on Illinois households is simply unsupportable, without a demonstration of significant environmental and public health benefits to the state's workers and consumers.

CEED recommends that the Board consider the potential adverse public health consequences of the rule's impacts on consumer energy costs and employment. The attached article[5] by M. Harvey Brenner, Professor of Public Health at Johns Hopkins University and Senior Professor of Epidemiology at the Berlin Institute of Technology, points out the strong statistical association between U.S. mortality trends and changes in real per

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[2] Northern Illinois University and Center for Tax and Budget Accountability, "State of Working Illinois," (November 2005).
[3] *Id*.
[4] ICF Resources, op. cit., p. 8.
[5] See Attachment 1, M. Harvey Brenner, Ph.D., "Health Benefits of Low-Cost Energy Supplies," Environmental Manager, November 2005 (calculating potential increased premature mortality of 150,000 lives annually for implementation of the McCain-Lieberman climate bill, SA 2028).

capita GDP, personal income, and unemployment rates. Policies that lead to increased unemployment can induce premature mortality. In Dr. Brenner's case study of proposed climate change legislation, an estimated 150,000 premature deaths could result from the adverse income and employment consequences of large-scale decreases in coal-based electric generation in favor of higher-cost generation alternatives.

CEED is not asserting that premature mortality effects of this magnitude could flow from IEPA's proposed mercury rule. The purpose of Dr. Brenner's case study is to highlight the other side of the "environmental externality" equation, namely, the need for careful assessment of the potential adverse public health consequences of policies that increase energy costs and risk increased unemployment.

The proposed rule offers no demonstrable environmental benefits

CEED urges the Pollution Control Board to scrutinize any claims of environmental or public health benefits associated with the IEPA rule. Mercury deposition modeling[6] conducted by U.S. EPA for its CAIR and CAMR rules indicates that, by 2020, these two rules will virtually eliminate mercury deposition in Illinois from electric generating facilities (see Figures 1 and 2, below). The rulemaking record, as discussed below, does not show that the IEPA rule will provide measurable public health or environmental benefits in excess of those provided by U.S. EPA's CAIR and CAMR.

[6] Figures 1 and 2 are from U.S. EPA, Region III.

Figure 1

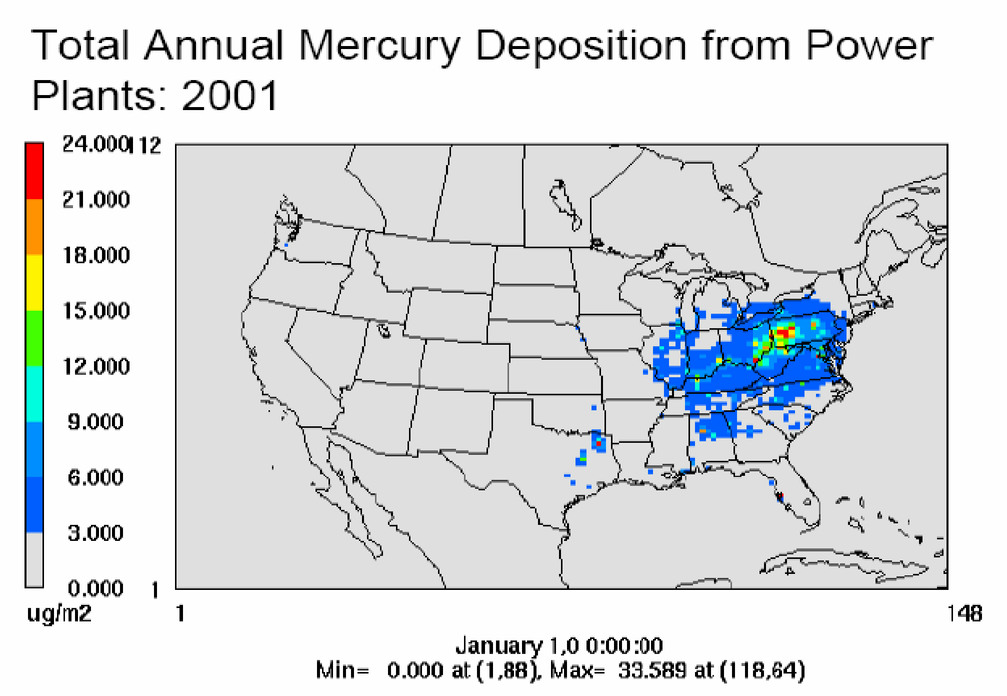
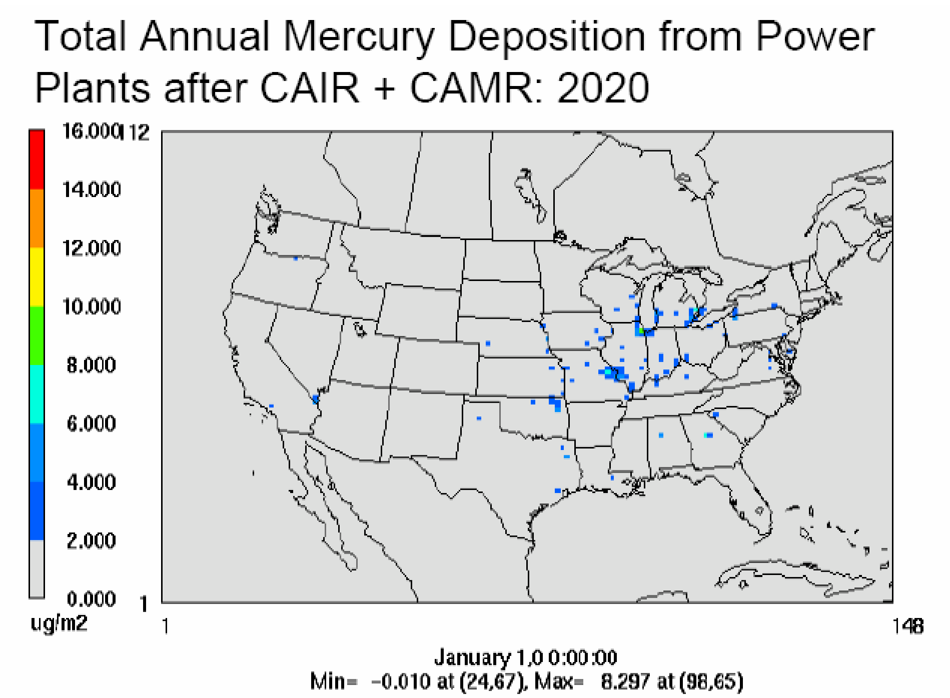


Figure 2



The rulemaking record contains an intensive examination of the sources of mercury exposure in Illinois, and the environmental rationale for the proposed IEPA rule. The testimony of Peter M. Chapman, Ph.D., an international expert in aquatic ecology and ecotoxicology, addresses a central question: whether the proposed rule "will ensure that impairment restrictions can be lifted for water bodies where fish have elevated mercury concentrations?"[7] Dr. Chapman's conclusion - considering among other facts that the proposed rule would result in only a 4% reduction in mercury deposition in Illinois relative to CAMR[8] - is simply "no."[9]

The testimony of Gail Charnley, Ph.D., a toxicologist and expert in environmental risk assessments, analyzes the relationship between reductions of mercury emissions and changes in mercury concentrations in fish tissue. Dr. Charnley's conclusion underscores the lack of credible scientific evidence supporting the imposition of IEPA's rule in lieu of U.S. EPA's CAIR and CAMR:

> "I do not dispute the desirability of limiting mercury emissions from coal-based power plants as a means of limiting its contribution to fish methylmercury levels in places where it may be significant. I do dispute the simplistic notion that limiting power plant mercury emissions in Illinois is going to have a direct and noticeable impact on Illinois fish methylmercury levels, on Illinois methylmercury exposures, or on public health in Illinois. A tremendous amount of uncertainty remains regarding the relationship between power plant mercury emissions and fish methylmercury levels and toxicity, but the weight of the scientific evidence does not suggest that they are simply and directly related. The public health benefits of limiting Illinois mercury emissions are being oversold and the benefits of limiting mercury emissions deeper and faster than is required by US EPA are political only."[10]

[7] Prefiled testimony of Peter M. Chapman, Ph.D., (July 28, 2006), p. 2.
[8] *Id.*, citing prefiled testimony of K. Vijayaraghavan at p. 7 (see p. 10 of prefiled testimony).
[9] *Id.*, p. 14.
[10] Prefiled testimony of Gail Charnley, Ph.D., (July 28, 2006), p. 20.

The proposed rule jeopardizes electric reliability in Illinois

Illinois has many older, smaller coal-based generating units that are at risk of retirement if the IEPA mercury rule were implemented. Units more than 40 years of age and smaller than 200 megawatts generating capacity generally do not offer cost-effective opportunities for emission controls due to their relatively low capacity factors, the lack of "economies of scale" in control technology installations, and limited remaining lifetimes for the recovery of capital investments.

Many of these older generating units perform critical tasks as "load-following" units helping to meet high demand conditions, and providing system stability. The analysis presented by James Marchetti and Ed Chicanowicz outlines the risks that the inflexible IEPA rule poses for older generating units:

> "An important technology deployment presumption is that units older than 50 years at the time a compliance decision is required *do not* receive any control technology. The rationale for the 50 year old rule on technology deployment is that … industry is unlikely to make major capital investments on older units, which could result in one trying to recover capital on units that may be in excess of 65 years old at the end of the recovery period. The IL Rule is so stringent that the averaging provisions that are included in the Rule are not sufficient to allow companies to avoid controlling the older units, and the prohibition of trading precludes their buying allowances if they are not able to comply. …
>
> Another potential implication … is the uncertainty of whether IL generators would be able to recover the $1.77 billion they would need to invest in the mercury control equipment before July 1, 2009. If generators are unable to recover their investment, it may force them to retire or shutdown some older/ uneconomical units that are required to install mercury control technologies under the IL Rule. A potential casualty could be some or all of the … 3,093 MW of capacity that would be

> greater than 50 years old in 2009 and required to install mercury control technology."[11]

The risk of premature retirements of generating capacity due to stringent state mercury regulations is substantial and imminent. State mercury regulations are cited by PJM as a factor supporting its application to the U.S. Department of Energy for the designation of several new "National Interest Transmission Corridors" to facilitate increased electric transmission capability between the Midwest and Mid-Atlantic states:

> "The risk of more retirements is very real. Nearly 90,000 MW of the approximately 164,000 MW of existing generating capacity in PJM are from fossil steam generating units. More than 75% of that capacity is from units that are at least 30 years old; more than 20% is from units that are 50 or more years old. New limits on mercury emissions from coal-fired power plants now under consideration in Pennsylvania, New Jersey and Maryland, among other states, may prove to be an important factor in potential future retirements. PJM has been closely monitoring the states' deliberations on these requirements; its analyses indicate that, should the current proposed requirements be adopted, as much as 4,000 MW of older, coal-fired generation capacity potentially could be retired because the investment needed at such units to meet the new emission limits would be deemed uneconomic."[12]

In view of these concerns, CEED recommends that the Pollution Control Board seek appropriate consultation with - or input from - PJM and the Illinois Commerce Commission to assess the nature and magnitude of reliability risks posed by the IEPA rule. Recent power shortages and outages across the eastern U.S. demonstrate our critical dependence upon safe, reliable, and affordable electricity. The citizens of Illinois can ill afford new threats to the reliability of their electric supplies from costly, ineffective state mercury regulations.

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[11] Prefiled testimony of James Marchetti, at pp. 3, 9.

[12] Request of PJM Interconnection, L.L.C. for Early Designation of National Interest Electric Transmission Corridors (submitted to U.S. Department of Energy, March 6, 2006), p. 30.

CAMR provides a superior alternative

U.S. EPA's Clean Air Mercury Rule offers a more balanced, cost-effective approach to reducing mercury emissions than IEPA's plant-by-plant control regime. CAMR is based on the successful federal "cap-and-trade" program developed to reduce acid rain. By infusing market forces within a firm emissions cap, CAMR offers several key advantages:

- Plants that over-control mercury emissions are rewarded by earning tradable mercury allowances, potentially offsetting some of the costs incurred for installing and operating pollution controls.
- Provisions for "banking" of emission reductions in excess of annual emission limits create an incentive for early reduction of emissions, with no adverse effect on the environment.
- Market-based trading assures power generators the ability to demonstrate compliance with mercury emission control requirements, critical to their ability to finance pollution control investments.

U.S. EPA developed CAMR as a separate but closely related companion to its CAIR rule for reducing emissions of SO_2 and NO_x. CAMR builds upon the mercury "cobenefits" resulting from compliance with CAIR, achieved by the installation of scrubbers and selective catalytic reduction systems at utilities throughout the eastern United States.

By linking these two major rules together, on similar compliance timelines, EPA's approach maximizes the cost-effectiveness of achieving an overall 70% national reduction in mercury emissions from EGUs. State mercury rules that use different compliance timetables than CAMR, or that impose plant-by-plant control limits, essentially discard the mercury "cobenefits" of CAIR. The high compliance costs projected for IEPA's rule, cited above, reflect the inherent inefficiency of command-and-control regulation compared to market-based alternatives.

For the foregoing reasons, CEED respectfully requests the Pollution Control Board to reject the proposed IEPA mercury rule.

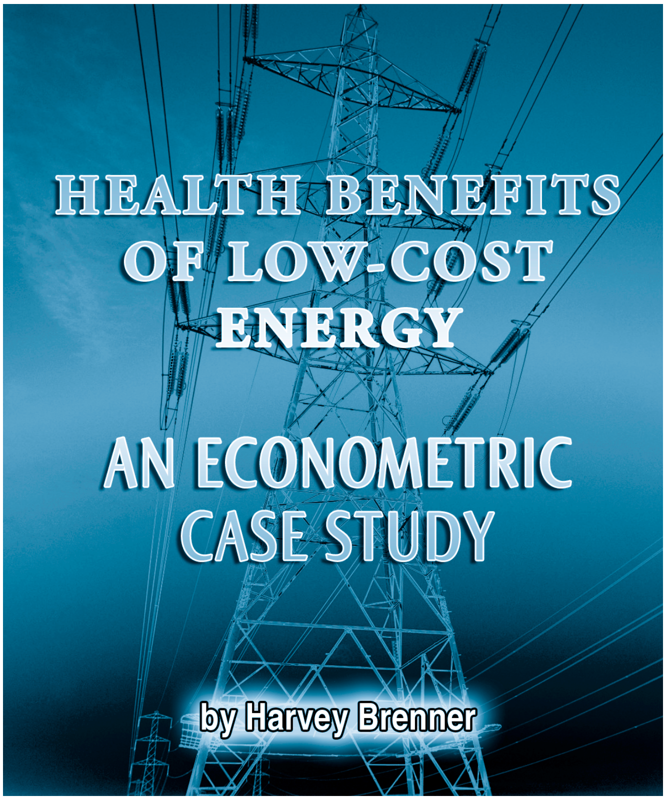
CEED appreciates the opportunity to submit these comments.

Sincerely,

/s/

Scott Wiseman
Vice President
CEED Midwest Region

Attachment



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Numerous studies conducted in the past 10–15 years have indicated that economic factors, such as income, employment, and socioeconomic status, affect disease and death.[1] The case study research described in this article shows how a large-scale econometric model—the application of statistical methods to the study of economic data and problems—can accurately predict long-term U.S. mortality trends based on variables such as per-capita income and unemployment rates (see Figure 1). In addition, it demonstrates that even short-term, year-to-year fluctuations in economic indicators can accurately predict year-to-year fluctuations in population mortality rates (see Figure 2). These results leave little doubt that the statistically significant relationships between socioeconomic indicators and population mortality rates identify principal risk factors to a population's health.

AN ECONOMETRIC MODEL

An econometric model was applied to a hypothetical regulatory case study, whereby U.S. coal was replaced by alternative higher-cost fuels such as natural gas for the purpose of electricity generation. The model was used to estimate the premature mortality associated with increased unemployment and reduced personal income. The adverse impacts on household income and unemployment due to the substitution of higher-cost energy sources were estimated to result in 195,000 additional premature deaths annually (see Table 1).

The results from this hypothetical case study may be scaled to apply to specific policy initiatives affecting the U.S. coal-based electricity generation sector. For example, the U.S. Department of Energy's Energy Information Administration (EIA) estimates that climate change bills currently before the U.S. Congress—such as Senate Amendment No. 2028, rejected by the Senate in 2003 and again in June 2005—could result in the displacement of up to 78% of U.S. coal-based electricity generation with higher-cost energy sources.[2] The methodology employed here suggests that, absent any direct mitigation measures to offset expected decreases in employment and income,[3] implementation of such measures could result in an annual increase of premature mortality rates by more than 150,000.

Governmental programs intended to protect public health and the environment should take into account potential income and employment effects of required compliance measures.

These predicted mortality trends are an order of magnitude greater than recent estimates of the premature mortality benefits associated with implementation of the U.S. Environmental Protection Agency's 8-hr ozone standard (approximately 1000–3000 premature deaths avoided annually)[4] and fine particulate ($PM_{2.5}$) standard (approximately 15,000 premature deaths avoided annually).[5] In this context, a major implication of this research is that governmental programs intended to protect public health should take into account potential income and employment effects of required compliance measures. By increasing the costs of goods and services such as energy, and decreasing disposable incomes, regulation can inadvertently harm the socioeconomic status of individuals and, thereby, contribute to poor health and premature death.

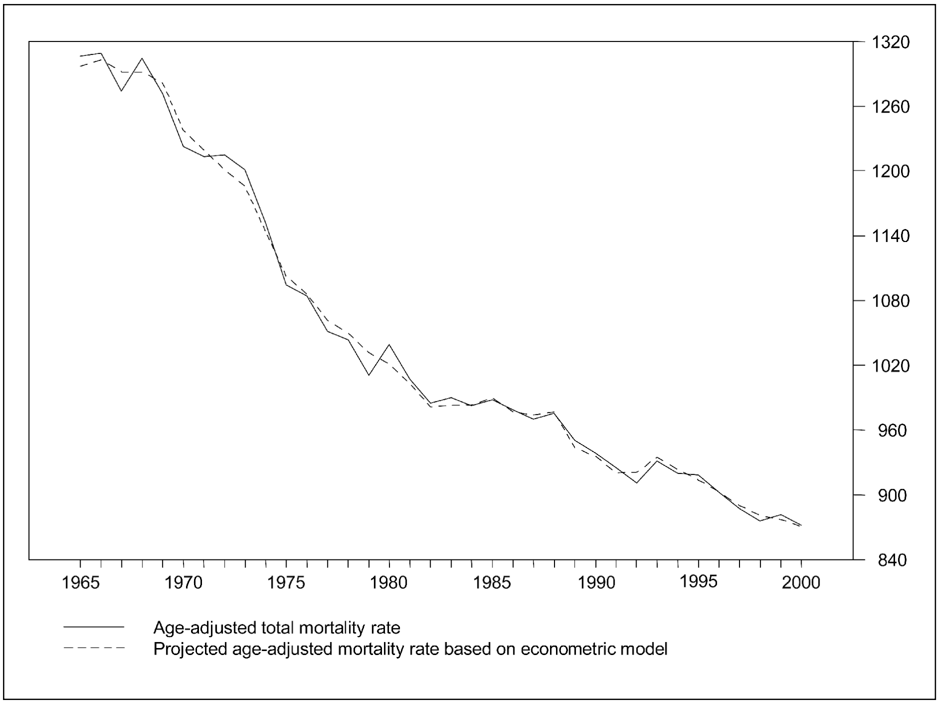

Figure 1. U.S. total mortality rate, real and projected, 1965–2000 (Level model; age-adjusted per 100,000 population).

ENERGY AND HEALTH

Energy is among the most indispensable ingredients of human existence. Like most advanced industrial economies, the United States depends primarily on carbon-based (and carbon-emitting) energy. In 2003, U.S. energy users consumed a total of 98 quadrillion British Thermal Units (quads) of energy, including 39 quads of petroleum, 23 quads of natural gas, and 23 quads of coal. Nuclear, hydro, and other non-carbon-emitting energy sources supplied the remaining 14 quads, or 15% of total energy consumption.[6] Emissions from coal-based electricity generation plants alone represented one-third of U.S. carbon dioxide (CO_2) emissions in 2002.[7]

A substantial body of literature has developed examining the potential impacts of proposed restrictions on greenhouse gas emissions on the national gross domestic product (GDP), energy prices, income, and employment.[8] It has been estimated, for example, that global climate change initiatives requiring expanded use of high-cost, lower-carbon energy alternatives such as natural gas would increase the cost of energy to the point that per-capita income and employment rates would decrease in a quantitatively predictable manner. Assuming these estimates to be approximately correct, and given the epidemiological findings on socioeconomic status and health,[1,3,9-11] it follows that these proposed policies might, in effect, bring about a net increase in population mortality.

LINKS BETWEEN HEALTH AND INCOME

The socioeconomic-status findings show that changes in the economic status of individuals produce subsequent changes in the health and life span of those individuals. Unfortunately, traditional epidemiological literature has not dealt with the issue of change in socioeconomic status in relation to changes in health status. However, another body of research shows that decreased real income per capita and increased unemployment have consequences that lead to increased mortality in U.S. and European populations.[3,9-11] This literature uses econometric analyses of time-series data to measure the relationship between changes in the economy and changes in health outcomes.

The econometric approach to health impact assessments was developed initially in two studies for the Joint Economic Committee (JEC) of the U.S. Congress in 1979[9] and 1984.[10]

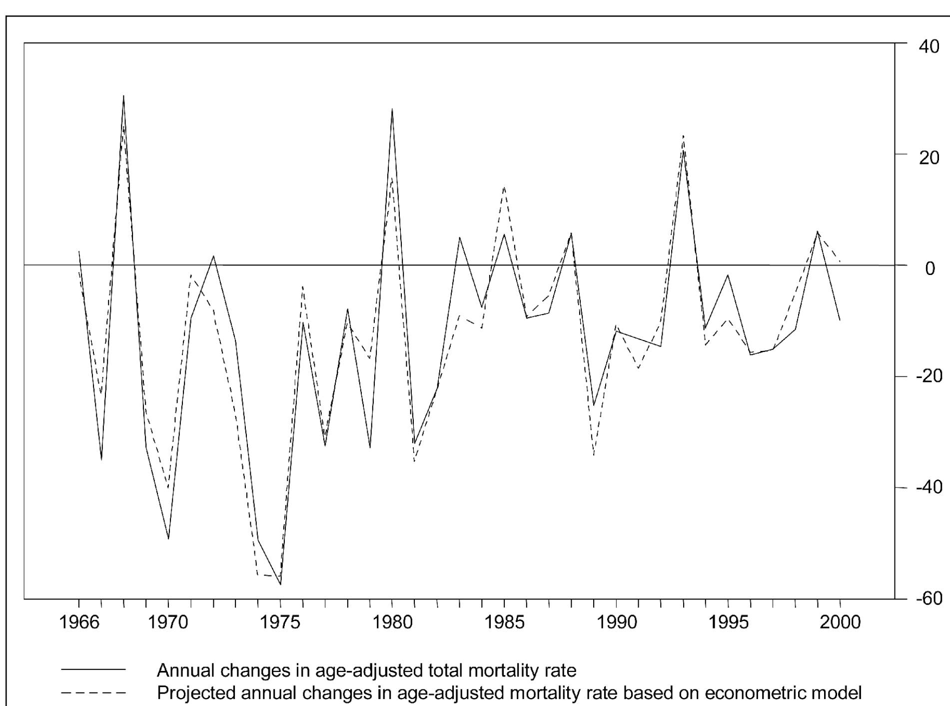

Figure 2. Annual changes of U.S. total mortality rate, real and projected, 1966–2000 (First difference model using error correction method [ECM]; age-adjusted per 100,000 population).

Table 1. Estimates of premature mortality impacts in 2010 of hypothesized elimination of coal utilization for electricity generation.

Year	U.S. Population	Annual Growth
2000	282,125,000	
2010	310,013,000	0.95%

Model Types		Base (2010)	Mortality Rates[a] Final	Delta	Base	Final	Number of Deaths Low SD (95% confidence)[b]	Delta	High SD (95% confidence)[b]	Delta Growth (%)[c]
Model 1 – Unemployment Rate (UR)	Level model	797	852	55	2,470,804	2,641,311	166,505	170,507	174,510	6.9
	First difference model	811	870	59	2,514,205	2,697,113	178,282	182,908	187,533	7.3
Model 2 – Employment Rate (ER)	Level model	885	947	62	2,743,615	2,935,823	188,555	192,208	195,861	7
	First difference model	915	976	61	2,836,619	3,025,727	185,620	189,108	192,596	6.7
Model 3 – GDP per capita (GDPP)	Level model	1392	1,504	112	4,315,381	4,662,596	342,597	347,215	351,832	8
	First difference model	1463	1,582	119	4,535,490	4,904,406	364,252	368,915	373,579	8.1
Model 4 – Model # 3 level with Model #2 first difference	First difference model	1406	1469	63	4,358,783	4,554,091	193,181	195,308	197,435	4.5
Average		**1096**	**1171**	**76**	**3,396,414**	**3,631,581**	**231,285**	**235,167**	**239,049**	**6.9**

Model Type	Mortality Rate	Weights[d]	Number of Deaths
Model 4	**Delta**		
First difference model	195,308		
UR		0.246	48,079
ER		0.266	52,037
GDPP		0.487	95,192
Total		**1.000**	**195,308**

[a]Base = 2010 forecast; Final = 2010 forecast with coal utilization impact. The impact on UR is the average of the DRI[14] and Rose and Yang[15] estimates for job loss % change from the 4% assumed 2010 base level. The impact on ER is assumed to be a minus 2% change from the 2010 base level. The impact on GDPP is the average of the DRI[14] and Rose and Yang[15] estimates for personal income % change the 2010 base level; Delta = 2010 forecast, no population assumption needed. [b]Error forecast standard deviation (SD). [c]Delta mortality rate divided by the 2010 base forecast. [d]Weights calculation = Step 1: GDPP weight is estimated as 1 minus Delta from Model 2 first difference divided by Delta from Model 3 first difference; Step 2: UR weight is estimated as 1 minus GDPP weight divided by 2 multiplied by Delta from Model 1 first difference divided by Delta from Model 2 first difference; Step 3: ER weight is estimated as 1 minus GDPP weight minus UR weight; by definition weights sum to 1.

These studies demonstrated that declines in real income per capita and increases in unemployment led to elevated mortality rates over a subsequent period of six years. For example, the 1984 JEC study found that a one-percentage-point increase in the unemployment rate (e.g., from 5% to 6%) would lead to a 2% increase in the age-adjusted mortality rate. The growth of real income per capita also showed a significant correlation to decreases in mortality rates (except for suicide and homicide), mental hospitalization, and property crimes. Over the past four years, the European Commission has supported similar research showing comparable results throughout the European Union.[11]

UPDATED MODEL RESULTS

The research described in this article updates the 1984 JEC analysis. U.S. data for the period 1965–2000 were employed to estimate mortality rates and other health effects of changes in economic conditions. The econometric model combined four predictive factors in the explanation of U.S. mortality trends and fluctuations:

1. real GDP per capita (beneficial impact on mortality);
2. employment ratio (beneficial impact);
3. unemployment rate (harmful impact); and
4. the interaction between GDP and unemployment as coincident and lagging business-cycle indicators (harmful impact).

At the national level, the findings confirmed that the hypothesized benefits of real income per capita and employment were strong and statistically significant, while the damaging effects of increased unemployment and acute business-cycle disturbances were similarly robust and statistically significant. Figure 1 demonstrates the model's projection of U.S. mortality rates.

As in the 1984 JEC study, the upward trends in real income per capita represented the most important factor in decreased U.S. mortality rates since the 1960s. Also, the unemployment rate continued to bear a significant correlation to increased mortality rates, such that an increase of 1% in the unemployment rate eventuates in an approximately 2% increase in the age-adjusted mortality rate, estimated cumulatively over at least the subsequent decade.

> In sum, growth in real income per capita is the backbone of decreases in the U.S. mortality rate.

In sum, growth in real income per capita is the backbone of decreases in the U.S. mortality rate. There are several reasons for this. First, with respect to physical health, economic growth is fundamental in meeting basic population needs, such as nutrition, housing, health insurance,[12] medical care, sanitation, electricity, transportation, and climate control. In addition, economic growth enables increased industrial investment in pollution control technologies and safer work environments, with minimal adverse workplace exposures to chemicals, noise, and unsanitary conditions.

Year-to-year fluctuations in mortality rates are largely explained by annual changes in the behavior of variables in the model (see Figure 2). This means that a decline in the mortality rate from one year to the next (e.g., between 1981 and 1982) is related to increased real income per capita and declining unemployment rates during that same year's change (1981–1982) and the (approximately) 10 years prior to that same year's mortality decline.

State and Regional Analyses

If the economic model explaining mortality changes in the overall United States applied to all of its regions, or to a large number of states, then it would necessarily follow that the historical pattern of mortality rate changes in the regions and states would resemble one another. If true, this would be remarkable, in that there is no existing literature indicating that the trends and fluctuations in mortality rates are similar among the major regions of the United States.

Regional and state modeling to test the robustness of the national model constituted a major effort of the present analysis.

The U.S. national-level model was applied to the explanation of mortality rate changes in five populous and geographically diverse states: California, Texas, New York, Florida, and Illinois. The results were remarkably similar in that the overall U.S. model applied quite precisely to each of those five states. The model's principal predictive variables all showed statistically robust relations to the age-adjusted mortality rate. It should be pointed out that the coefficients, representing the extent of change in mortality related to changes in the economic variables, were not identical from state to state. Nevertheless, it is important to note that the same economic model described historical changes in mortality rates of states thousands of miles from one another, with vastly different economies, patterns of urbanization, and a host of lifestyle, social, and environmental factors. Similar findings resulted from application of the model to regional data for the United States.

All statistical tests traditionally used in time-series analysis, as well as the forecasting capacity of the model, demonstrate that each of the variables in the model plays a highly significant role and that the entire model is of great statistical significance. The overall results, prevalent throughout the United States, demonstrate (1) long-term declining mortality rates related to patterns of economic growth, and (2) short-term fluctuations in mortality rates associated with recessions, structural unemployment rates, and the lag of unemployment rates behind changes in real GDP per capita (a standard feature of the business cycle).

CASE STUDY: MORTALITY EFFECTS OF ENERGY SUPPLY CHANGES

The national econometric model was applied to a case study to quantify the increased mortality rate that could result from potential decreased real income per capita and increased unemployment rates due to regulatory constraints on U.S. coal utilization. Numerous policy proposals to reduce greenhouse gas emissions have called for restrictions of carbon emissions by the U.S. electricity-generating sector.[13]

Under the hypothetical scenario that coal production and related electricity generation were eliminated in favor of lower-carbon, higher-cost alternatives such as natural gas combined-cycle generation, an additional 195,000 premature deaths were estimated to occur by the year 2010 (see Table 1). This is a conservative estimate based on a tight construction of the assumptions of the future behavior of the study variables (e.g., real income per capita, unemployment rates) to 2010.

The case study used inputs from two analyses of the impacts of reduced coal utilization on U.S. income and employment data, each offering disaggregated state-level estimates of income and employment effects. Standard & Poor's DRI (1998)[14] and Rose and Yang of The Pennsylvania State University (2001)[15] used alternative macroeconomic and input–output models, respectively, to estimate the reductions of income and employment associated with large-scale displacement of coal use. The findings from these studies were scaled to approximate the effects of a hypothetical 100% replacement of coal. Thus adjusted, the estimated increased unemployment in 2010 ranged from 3.2 million (Rose and Yang) to 4.6 million jobs (DRI). The reduction in household income was estimated in a range of $166 billion (Rose and Yang, 1999$) to $363 billion (DRI, 1992$).

This upward scaling provided the basis for an assessment of policy proposals that could result in specific energy supply changes. For example, in a recent study, EIA estimates that the climate change proposals currently before the U.S. Congress could lead to the displacement of 59–78% of U.S. coal-based electricity generation by higher-cost natural gas and other alternative generation sources.[2]

The results from this hypothetical case study demonstrate that increased mortality rates would result from decreased household income and increased unemployment associated with a shift to higher cost energy supply options, absent any direct mitigation programs that effectively prevented or offset these effects. The estimated increased mortality in the year 2010, based on four different variations of the econometric model, ranges from an additional 170,507 to 368,915 deaths for the displacement of 100% of coal-based generation. A moderately conservative estimate based on an annual change model would be an additional 195,308 deaths. This point estimate has a 95% confidence interval of 193,181–197,435 individual deaths.

Given an estimated potential displacement of 78% of U.S. coal generation based on EIA's study of proposed climate

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Effects of Lagged Relationships

The relationship between change in the economic circumstances of people's lives and their subsequent health status unfolds over time. In the case of sharp stress reactions to financial or employment catastrophes, the reaction patterns may be very rapid, that is, within a single year. This is clearly the case when suicide rates are factored in, as these rates typically rise sharply within several months of increases in national unemployment rates. Chronic diseases such as cardiovascular diseases, on the other hand, are known to respond to many different health risk factors within years, if not decades.

In addition to the potential health effects of income loss and unemployment, one has the problem of judging at what point to begin the estimation of the impact of increased unemployment. The difficulty here is that in classic analyses of business cycles, national income—specifically, GDP per capita—is a "coincident" business cycle indicator, meaning that changes in it tend to coincide with the timing of business cycles. Unemployment rates, on the other hand, are "lagging" business cycle indicators. This means that, despite even robust economic growth, during much of the initial year of recovery from a recession, unemployment rates may still remain high.

If one does not take into account these basic relationships between income and unemployment change on one hand and mortality on the other over at least a decade, it is possible to arrive at the misinterpretation that without lag there might be a negative relation between unemployment and mortality. This could imply that unemployment (in the very short term) is related to decreased mortality.[16] This type of error becomes more likely if one does not control for the usual impact of traditional risk factors on mortality, such as the effects of tobacco and saturated fat consumption on cardiovascular mortality rates over at least a decade.

In virtually all of the studies on unemployment and health, unemployment (especially long-term) is definitively associated with higher illness and mortality rates at the individual level of analysis.[17] But perhaps the most powerful evidence that economic growth is the fundamental source of life-span longevity improvement is that, as shown in the present study, the trends of decline in mortality rates across diverse states and regions of the United States are related to those in real GDP per capita cumulated for at least 10 years.

Influence of Other Health Factors

The model described here was evaluated to determine whether control for principal epidemiological risk factors to health would render the predictive variables insignificant. The result was that, while known risk factors to health, such as high consumption of tobacco, alcohol, and fatty foods, are additionally significant predictors of mortality, they are subordinate to the main economic predictors of the model that routinely influence mortality.

Since the late 1960s, increasing real income per capita in the United States is no longer positively related to consumption of tobacco, alcohol, and fatty foods. Indeed, after 1970, in the United States and much of Europe, these health risk factors ceased to be found more frequently in higher income segments of society and came to be linked instead to the lifestyles of lower socioeconomic groups. Thus, the population groups that generally have benefited least from economic growth and have been most vulnerable to problems of structural and cyclical losses of employment are most likely to suffer from the risks of dietary and addictive "lifestyle" health risks.

CONCLUSIONS

This study demonstrates the fundamental importance of sustained economic growth to health and improved life span for the U.S. population. The technological bases of long-term economic growth continue to involve the harnessing of energy supplies to enable humans to produce more per unit of labor or capital investment. The economic growth that continuously improves human life expectancy requires access to affordable energy. In this fundamental sense, any policy change that reduces growth or raises the level of unemployment should therefore be defined and addressed as a public health issue requiring an economic policy response that limits or offsets these results. The implication of the research described in this article provides an important basis for future studies of energy and health. **em**

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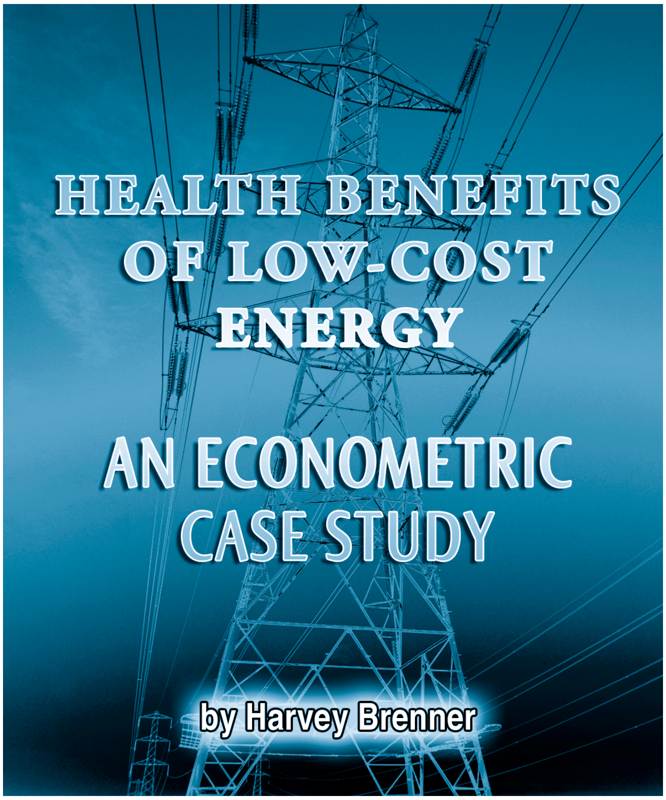

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Disclaimer: The research described in this article was supported by a grant from the Center for Energy & Economic Development Inc. The author accepts sole responsibility for the findings, conclusions, and opinions expressed herein.

Numerous studies conducted in the past 10–15 years have indicated that economic factors, such as income, employment, and socioeconomic status, affect disease and death.[1] The case study research described in this article shows how a large-scale econometric model—the application of statistical methods to the study of economic data and problems—can accurately predict long-term U.S. mortality trends based on variables such as per-capita income and unemployment rates (see Figure 1). In addition, it demonstrates that even short-term, year-to-year fluctuations in economic indicators can accurately predict year-to-year fluctuations in population mortality rates (see Figure 2). These results leave little doubt that the statistically significant relationships between socioeconomic indicators and population mortality rates identify principal risk factors to a population's health.

AN ECONOMETRIC MODEL

An econometric model was applied to a hypothetical regulatory case study, whereby U.S. coal was replaced by alternative higher-cost fuels such as natural gas for the purpose of electricity generation. The model was used to estimate the premature mortality associated with increased unemployment and reduced personal income. The adverse impacts on household income and unemployment due to the substitution of higher-cost energy sources were estimated to result in 195,000 additional premature deaths annually (see Table 1).

The results from this hypothetical case study may be scaled to apply to specific policy initiatives affecting the U.S. coal-based electricity generation sector. For example, the U.S. Department of Energy's Energy Information Administration (EIA) estimates that climate change bills currently before the U.S. Congress—such as Senate Amendment No. 2028, rejected by the Senate in 2003 and again in June 2005—could result in the displacement of up to 78% of U.S. coal-based electricity generation with higher-cost energy sources.[2] The methodology employed here suggests that, absent any direct mitigation measures to offset expected decreases in employment and income,[3] implementation of such measures could result in an annual increase of premature mortality rates by more than 150,000.

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These predicted mortality trends are an order of magnitude greater than recent estimates of the premature mortality benefits associated with implementation of the U.S. Environmental Protection Agency's 8-hr ozone standard (approximately 1000–3000 premature deaths avoided annually)[4] and fine particulate ($PM_{2.5}$) standard (approximately 15,000 premature deaths avoided annually).[5] In this context, a major implication of this research is that governmental programs intended to protect public health should take into account potential income and employment effects of required compliance measures. By increasing the costs of goods and services such as energy, and decreasing disposable incomes, regulation can inadvertently harm the socioeconomic status of individuals and, thereby, contribute to poor health and premature death.

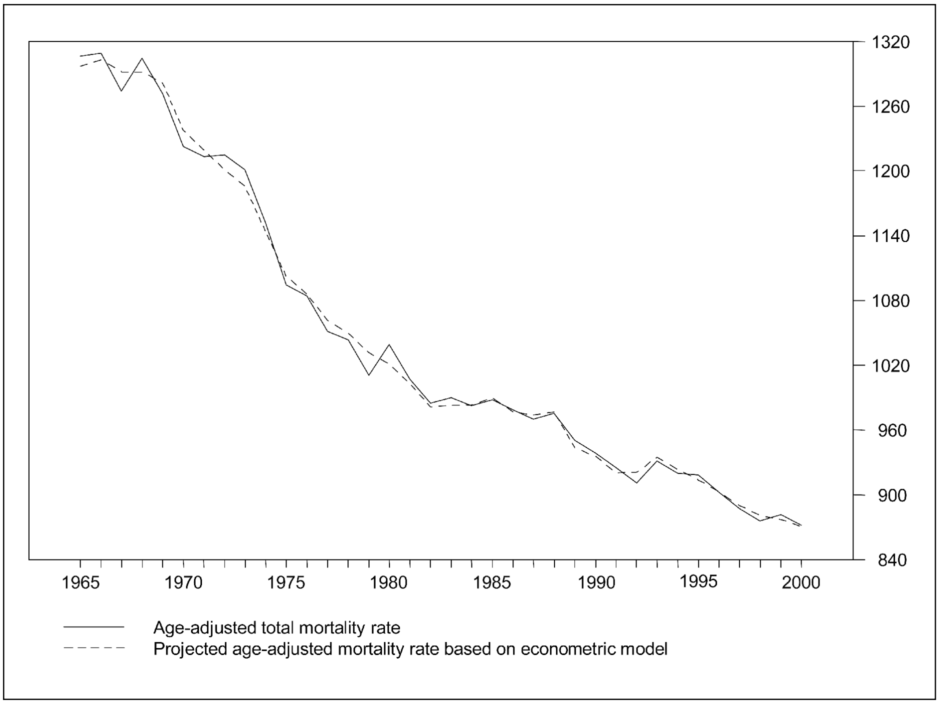

Figure 1. U.S. total mortality rate, real and projected, 1965–2000 (Level model; age-adjusted per 100,000 population).

manner. Assuming these estimates to be approximately correct, and given the epidemiological findings on socioeconomic status and health,[1,3,9-11] it follows that these proposed policies might, in effect, bring about a net increase in population mortality.

LINKS BETWEEN HEALTH AND INCOME

The socioeconomic-status findings show that changes in the economic status of individuals produce subsequent changes in the health and life span of those individuals. Unfortunately, traditional epidemiological literature has not dealt with the issue of change in socioeconomic status in relation to changes in health status. However, another body of research shows that decreased real income per capita and increased unemployment have consequences that lead to increased mortality in U.S. and European populations.[3,9-11] This literature uses econometric analyses of time-series data to measure the relationship between changes in the economy and changes in health outcomes.

The econometric approach to health impact assessments was developed initially in two studies for the Joint Economic Committee (JEC) of the U.S. Congress in 1979[9] and 1984.[10]

ENERGY AND HEALTH

Energy is among the most indispensable ingredients of human existence. Like most advanced industrial economies, the United States depends primarily on carbon-based (and carbon-emitting) energy. In 2003, U.S. energy users consumed a total of 98 quadrillion British Thermal Units (quads) of energy, including 39 quads of petroleum, 23 quads of natural gas, and 23 quads of coal. Nuclear, hydro, and other non-carbon-emitting energy sources supplied the remaining 14 quads, or 15% of total energy consumption.[6] Emissions from coal-based electricity generation plants alone represented one-third of U.S. carbon dioxide (CO_2) emissions in 2002.[7]

A substantial body of literature has developed examining the potential impacts of proposed restrictions on greenhouse gas emissions on the national gross domestic product (GDP), energy prices, income, and employment.[8] It has been estimated, for example, that global climate change initiatives requiring expanded use of high-cost, lower-carbon energy alternatives such as natural gas would increase the cost of energy to the point that per-capita income and employment rates would decrease in a quantitatively predictable

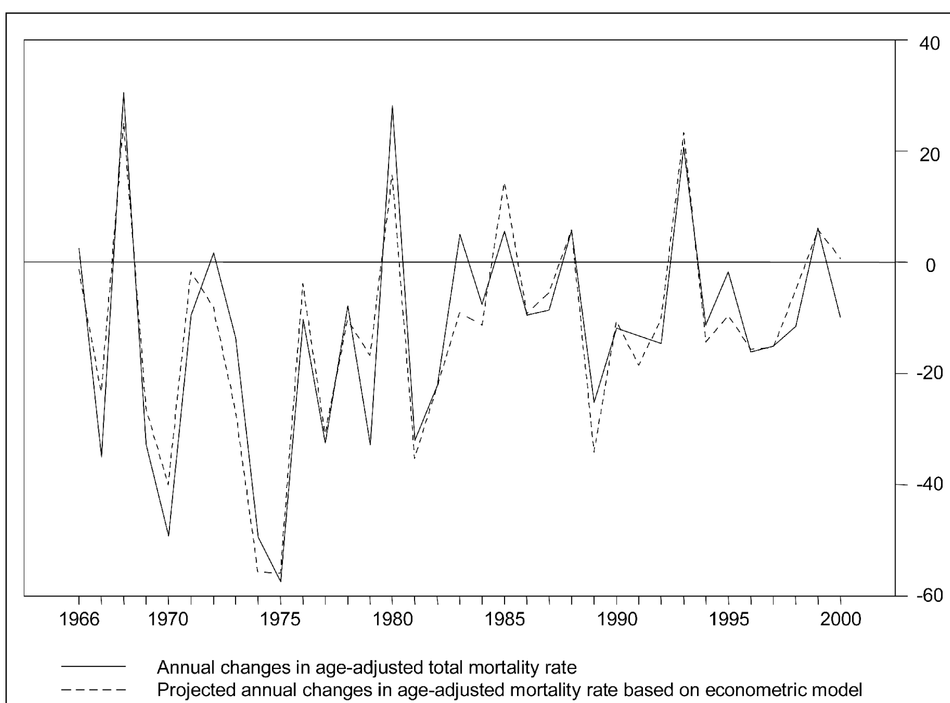

Figure 2. Annual changes of U.S. total mortality rate, real and projected, 1966–2000 (First difference model using error correction method [ECM]; age-adjusted per 100,000 population).

Table 1. Estimates of premature mortality impacts in 2010 of hypothesized elimination of coal utilization for electricity generation.

Year	U.S. Population	Annual Growth
2000	282,125,000	
2010	310,013,000	0.95%

Model Types		Base (2010)	Mortality Rates[a] Final	Delta	Base	Final	Number of Deaths Low SD (95% confidence)[b]	Delta	High SD (95% confidence)[b]	Delta Growth (%)[c]
Model 1 – Unemployment Rate (UR)	Level model	797	852	55	2,470,804	2,641,311	166,505	170,507	174,510	6.9
	First difference model	811	870	59	2,514,205	2,697,113	178,282	182,908	187,533	7.3
Model 2 – Employment Rate (ER)	Level model	885	947	62	2,743,615	2,935,823	188,555	192,208	195,861	7
	First difference model	915	976	61	2,836,619	3,025,727	185,620	189,108	192,596	6.7
Model 3 – GDP per capita (GDPP)	Level model	1392	1,504	112	4,315,381	4,662,596	342,597	347,215	351,832	8
	First difference model	1463	1,582	119	4,535,490	4,904,406	364,252	368,915	373,579	8.1
Model 4 – Model # 3 level with Model #2 first difference	First difference model	1406	1469	63	4,358,783	4,554,091	193,181	195,308	197,435	4.5
Average		**1096**	**1171**	**76**	**3,396,414**	**3,631,581**	**231,285**	**235,167**	**239,049**	**6.9**

Model Type	Mortality Rate	Weights[d]	Number of Deaths
Model 4	**Delta**		
First difference model	195,308		
UR		0.246	48,079
ER		0.266	52,037
GDPP		0.487	95,192
Total		**1.000**	**195,308**

[a]Base = 2010 forecast; Final = 2010 forecast with coal utilization impact. The impact on UR is the average of the DRI[14] and Rose and Yang[15] estimates for job loss % change from the 4% assumed 2010 base level. The impact on ER is assumed to be a minus 2% change from the 2010 base level. The impact on GDPP is the average of the DRI[14] and Rose and Yang[15] estimates for personal income % change the 2010 base level; Delta = 2010 forecast, no population assumption needed. [b]Error forecast standard deviation (SD). [c]Delta mortality rate divided by the 2010 base forecast. [d]Weights calculation = Step 1: GDPP weight is estimated as 1 minus Delta from Model 2 first difference divided by Delta from Model 3 first difference; Step 2: UR weight is estimated as 1 minus GDPP weight divided by 2 multiplied by Delta from Model 1 first difference divided by Delta from Model 2 first difference; Step 3: ER weight is estimated as 1 minus GDPP weight minus UR weight; by definition weights sum to 1.

These studies demonstrated that declines in real income per capita and increases in unemployment led to elevated mortality rates over a subsequent period of six years. For example, the 1984 JEC study found that a one-percentage-point increase in the unemployment rate (e.g., from 5% to 6%) would lead to a 2% increase in the age-adjusted mortality rate. The growth of real income per capita also showed a significant correlation to decreases in mortality rates (except for suicide and homicide), mental hospitalization, and property crimes. Over the past four years, the European Commission has supported similar research showing comparable results throughout the European Union.[11]

UPDATED MODEL RESULTS

The research described in this article updates the 1984 JEC analysis. U.S. data for the period 1965–2000 were employed to estimate mortality rates and other health effects of changes in economic conditions. The econometric model combined four predictive factors in the explanation of U.S. mortality trends and fluctuations:

1. real GDP per capita (beneficial impact on mortality);
2. employment ratio (beneficial impact);
3. unemployment rate (harmful impact); and
4. the interaction between GDP and unemployment as coincident and lagging business-cycle indicators (harmful impact).

At the national level, the findings confirmed that the hypothesized benefits of real income per capita and employment were strong and statistically significant, while the damaging effects of increased unemployment and acute business-cycle disturbances were similarly robust and statistically significant. Figure 1 demonstrates the model's projection of U.S. mortality rates.

As in the 1984 JEC study, the upward trends in real income per capita represented the most important factor in decreased U.S. mortality rates since the 1960s. Also, the unemployment rate continued to bear a significant correlation to increased mortality rates, such that an increase of 1% in the unemployment rate eventuates in an approximately 2% increase in the age-adjusted mortality rate, estimated cumulatively over at least the subsequent decade.

In sum, growth in real income per capita is the backbone of decreases in the U.S. mortality rate.

In sum, growth in real income per capita is the backbone of decreases in the U.S. mortality rate. There are several reasons for this. First, with respect to physical health, economic growth is fundamental in meeting basic population needs, such as nutrition, housing, health insurance,[12] medical care, sanitation, electricity, transportation, and climate control. In addition, economic growth enables increased industrial investment in pollution control technologies and safer work environments, with minimal adverse workplace exposures to chemicals, noise, and unsanitary conditions.

Year-to-year fluctuations in mortality rates are largely explained by annual changes in the behavior of variables in the model (see Figure 2). This means that a decline in the mortality rate from one year to the next (e.g., between 1981 and 1982) is related to increased real income per capita and declining unemployment rates during that same year's change (1981–1982) and the (approximately) 10 years prior to that same year's mortality decline.

State and Regional Analyses

If the economic model explaining mortality changes in the overall United States applied to all of its regions, or to a large number of states, then it would necessarily follow that the historical pattern of mortality rate changes in the regions and states would resemble one another. If true, this would be remarkable, in that there is no existing literature indicating that the trends and fluctuations in mortality rates are similar among the major regions of the United States.

Regional and state modeling to test the robustness of the national model constituted a major effort of the present analysis.

The U.S. national-level model was applied to the explanation of mortality rate changes in five populous and geographically diverse states: California, Texas, New York, Florida, and Illinois. The results were remarkably similar in that the overall U.S. model applied quite precisely to each of those five states. The model's principal predictive variables all showed statistically robust relations to the age-adjusted mortality rate. It should be pointed out that the coefficients, representing the extent of change in mortality related to changes in the economic variables, were not identical from state to state. Nevertheless, it is important to note that the same economic model described historical changes in mortality rates of states thousands of miles from one another, with vastly different economies, patterns of urbanization, and a host of lifestyle, social, and environmental factors. Similar findings resulted from application of the model to regional data for the United States.

All statistical tests traditionally used in time-series analysis, as well as the forecasting capacity of the model, demonstrate that each of the variables in the model plays a highly significant role and that the entire model is of great statistical significance. The overall results, prevalent throughout the United States, demonstrate (1) long-term declining mortality rates related to patterns of economic growth, and (2) short-term fluctuations in mortality rates associated with recessions, structural unemployment rates, and the lag of unemployment rates behind changes in real GDP per capita (a standard feature of the business cycle).

CASE STUDY: MORTALITY EFFECTS OF ENERGY SUPPLY CHANGES

The national econometric model was applied to a case study to quantify the increased mortality rate that could result from potential decreased real income per capita and increased unemployment rates due to regulatory constraints on U.S. coal utilization. Numerous policy proposals to reduce greenhouse gas emissions have called for restrictions of carbon emissions by the U.S. electricity-generating sector. [13]

Under the hypothetical scenario that coal production and related electricity generation were eliminated in favor of lower-carbon, higher-cost alternatives such as natural gas combined-cycle generation, an additional 195,000 premature deaths were estimated to occur by the year 2010 (see Table 1). This is a conservative estimate based on a tight construction of the assumptions of the future behavior of the study variables (e.g., real income per capita, unemployment rates) to 2010.

The case study used inputs from two analyses of the impacts of reduced coal utilization on U.S. income and employment data, each offering disaggregated state-level estimates of income and employment effects. Standard & Poor's DRI (1998)[14] and Rose and Yang of The Pennsylvania State University (2001)[15] used alternative macroeconomic and input–output models, respectively, to estimate the reductions of income and employment associated with large-scale displacement of coal use. The findings from these studies were scaled to approximate the effects of a hypothetical 100% replacement of coal. Thus adjusted, the estimated increased unemployment in 2010 ranged from 3.2 million (Rose and Yang) to 4.6 million jobs (DRI). The reduction in household income was estimated in a range of $166 billion (Rose and Yang, 1999$) to $363 billion (DRI, 1992$).

This upward scaling provided the basis for an assessment of policy proposals that could result in specific energy supply changes. For example, in a recent study, EIA estimates that the climate change proposals currently before the U.S. Congress could lead to the displacement of 59–78% of U.S. coal-based electricity generation by higher-cost natural gas and other alternative generation sources.[2]

The results from this hypothetical case study demonstrate that increased mortality rates would result from decreased household income and increased unemployment associated with a shift to higher cost energy supply options, absent any direct mitigation programs that effectively prevented or offset these effects. The estimated increased mortality in the year 2010, based on four different variations of the econometric model, ranges from an additional 170,507 to 368,915 deaths for the displacement of 100% of coal-based generation. A moderately conservative estimate based on an annual change model would be an additional 195,308 deaths. This point estimate has a 95% confidence interval of 193,181–197,435 individual deaths.

Given an estimated potential displacement of 78% of U.S. coal generation based on EIA's study of proposed climate

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Since the late 1960s, increasing real income per capita in the United States is no longer positively related to consumption of tobacco, alcohol, and fatty foods. Indeed, after 1970, in the United States and much of Europe, these health risk factors ceased to be found more frequently in higher income segments of society and came to be linked instead to the lifestyles of lower socioeconomic groups. Thus, the population groups that generally have benefited least from economic growth and have been most vulnerable to problems of structural and cyclical losses of employment are most likely to suffer from the risks of dietary and addictive "lifestyle" health risks.

CONCLUSIONS

This study demonstrates the fundamental importance of sustained economic growth to health and improved life span for the U.S. population. The technological bases of long-term economic growth continue to involve the harnessing of energy supplies to enable humans to produce more per unit of labor or capital investment. The economic growth that continuously improves human life expectancy requires access to affordable energy. In this fundamental sense, any policy change that reduces growth or raises the level of unemployment should therefore be defined and addressed as a public health issue requiring an economic policy response that limits or offsets these results. The implication of the research described in this article provides an important basis for future studies of energy and health. **em**