Green Chemistry and the Phaseout of Leaded Fuel

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Green Chemistry in Higher Education Symposium
U.C Berkeley
October 26, 2010

Abstract: **The phaseout of leaded fuel provides a dramatic example of the economic benefits from green chemistry. Using the technique of GDP extrapolation applied to published literature, the global benefits range from $1- $6 trillion/year, with a best estimate of $2.45 trillion/year. These benefits may also be expressed as 4% of global GDP. Opponents of green chemistry who rely on economic arguments should be reminded of the enormous economic impact of green chemistry. Green chemistry should not require detailed economic justification, since the economic evidence is likely to emerge long after initial actions are taken. Nevertheless, as economic evidence does become available, the technique of global GDP extrapolation can provide powerful support for sustainable approaches in chemical synthesis.**

Objectives:

Leaded fuel has been phased out in all but a small number of countries. As scientific and economic data have accumulated, it is possible to estimate the global benefits from the phaseout of leaded fuel. These estimates are increasingly important in justifying research and policies in green chemistry and environmental health. This study extends previous estimates to the global level and incorporates the latest scientific and economic research on societal effects from lead.

Methods:

Starting with detailed studies in the U.S., we argue that extrapolation based on the ratio of US GDP to world GDP is the most accurate method at this time. We refine the estimate by drawing from the most accurate studies on an extensive range of known health effects.

Results:

Global benefits from GDP extrapolation range from $1- $6 trillion/year, and our best estimate is **$2.45 trillion/year**. These benefits may also be expressed as 4% of GDP.

Testing GDP extrapolation:

Does GDP extrapolation predict benefits across countries? To test this idea, we took simultaneous estimates of benefits from the phaseout of leaded fuel in Canada and the U.S (*1*). Using the known GDP values for the two countries during the time of the study (expressed in billions of US Dollars), we determined that 1999 Benefits/GDP were consistent with each other, thus supporting GDP extrapolation:

1999 Benefits/GDP: Canada = 20.7/651 = 3.2%
US = 275 / 9216 (low) = 2.98%
327 / 9216 (high) = 3.55%

Additional support comes from a study on leaded fuel phaseout in Lebanon (2) that relied on US to Lebanon per capita GDP disparity (2). Yet another study on the global costs of dementia relied on the per capita disparity of GDP between developed and developing economies (3).

Key assumptions:

Using different studies in the U.S. on the benefits of phasing out lead, the ability to express global benefits in 2010 dollars depends on three key assumptions:

- Inflation Rate (to express values from different studies in 2010 dollars) = 1.25%
- Blood Lead Level (BLL) = reduction in BLL from phaseout of leaded gasoline
  = 15.1 µg/dL BLL (*4*)
- GDP Extrapolation Factor = GDP of World / GDP of U.S. = 4.27

Components of the Global Benefits:

Individual health benefits for children and adults (*5*) are:

$$12{,}492{,}000{,}000 * (1.0125)^{23} * 15.1 * 4.27 = \textbf{\$1.07 trillion}$$

Using the same strategy of adjusting by interest rate, blood lead levels, and GDP extrapolation factor, the benefits from preventing a 3 IQ point degradation (*1*) are:

$5.7 billion (low birth rate)
$40.3 billion (male incarceration)
$25 billion (residual contribution to GDP)

Similarly, benefits from children preventing IQ decrement (*4*) are:

$1.03 trillion (discounted earnings per cohort of children)

Finally, benefits for children and adults from societal and individual effects (*6*) are:

$154.7 billion (tax revenue forgone)
$890 million (ADHD)
$119.5 billion (lead linked crimes)

Global Benefits in $USD from Phaseout of Leaded Fuel:

Summing the previous components (in billions):

1070 + 5.7 + 40.3 + 25 + 1030 + 154.7 + 0.89 + 119.5 =

$2.45 trillion / year

Disaggregating by GDP:

$2.45 trillion/$60 trillion = 4% of global GDP

Applying 4% to the known GDP of developing and developed nations:

Developing Nations: 4% GDP = $702 billion / year
Developed Nations: 4% GDP = $1.74 trillion / year

Uncertainties:

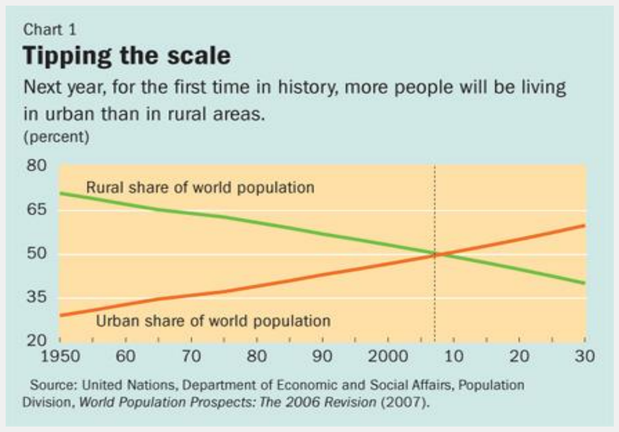
Clearly there are uncertainties with these estimates, and it is natural to question whether extrapolation from U.S. values overestimates global values due to such factors as the relatively high cost of U.S. health care. However, GDP does account for wealth disparities, and there are at least three major reasons why global values may even be underestimated.

1. Unknown Effects: Many effects from lead have not yet been quantified as costs:

- Hearing
- Cancer
- Reduced growth rate and stature
- Pain and suffering from medical treatment
- Limited activity after heart attack and stroke

2. Emerging information economies: As information is becoming more easily accessed (e.g., broadband access to the internet), the ability to process and apply information through cognitive (IQ) and non-cognitive (ADHD) means is basic to economic growth. This is difficult to quantify, but we know that the phaseout of leaded fuel and its associated effects on IQ and ADHD must increase these benefits.

3. The Urbanization Effect:



Exposure to leaded fuel is predominantly an urban phenomenon. Thus, as the world's population becomes increasingly urbanized, the global benefits from phasing out leaded fuel would be expected to increase over time.

Conclusions:

- The phaseout of leaded fuel promotes economic as well as human health. The benefit to cost ratio for the phaseout of leaded fuel is at least 10 to 1 (*7*). Our analysis extends that understanding by demonstrating that the phaseout can have significant effects on GDP: the global benefits are on the order of trillions of dollars per year.
- Scientific as well as economic research should continue to refine our estimates of benefits. As recent studies have shown, lead not only affects individuals but society as a whole. With the introduction of each generation, we expect the cumulative benefits to grow well beyond our original estimates.
- The techniques employed in this study may be applied to other environmental agents. Indeed, they already have been employed with such conditions as dementia. While there are inevitable uncertainties with such studies, the magnitude of the benefits underscores the critical role of these studies in helping to shape appropriate policies and provide stronger advocacy for continued scientific research in green chemistry and environmental health.

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Acknowledgments: **We recognize the following reviewers for their helpful comments:**

Scott Grosse, Centers for Disease Control and Prevention
Richard Jackson, UCLA Department of Environmental Health Sciences
Phillip Landrigan, Mount Sinai School of Medicine

This study was supported by a grant from:

the United Nations Environment Programme

through the

Partnership for Clean Fuels and Vehicles (PCFV)

We also thank our symposium sponsors:

The California Department of Toxic Substances Control

and

The Berkeley Center for Green Chemistry

California State University Northridge

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