National Expenditures, Jobs, and Economic Growth Associated With Indoor Air Quality in the United States

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Abstract **While a number of studies have addressed the economic cost associated with adverse health and productivity effects of poor indoor air quality (IAQ), few have addressed the value of economic expenditures and job creation associated with this industry. This article estimates that the annual sale of IAQ products and services is valued at $18–$30 billion and is associated with approximately 150,000–250,000 current jobs. Compared with other familiar industries, the IAQ market remains relatively small. Given the close association between good IAQ and both job performance of adults and learning performance of children, however, the expenditure to maintain good IAQ in commercial and educational facilities is a useful complement to programs designed to improve education and economic growth.**

Introduction

Public Awareness and Concern for Indoor Air Quality (IAQ)

In 2005, Hal Levin developed the first comprehensive study of national annual expenditures for IAQ goods and services, which he estimated to be $12–$20 billion per year, with a midpoint estimate of $16 billion (Levin, 2005). IAQ has been developing as a new subject of public concern since the 1970s, when in response to the oil embargo of 1973, the U.S. began a concerted effort to reduce energy use, including reducing outdoor air ventilation in buildings. Since ventilation dilutes indoor pollutants from indoor sources, that reduction inadvertently created a significant uptake in incidences of discomfort and illnesses related to indoor pollution. These illnesses, which came to be known as "sick building syndrome" and "building-related illness," attracted attention in the building sector and from public health authorities. Significant events related to the discovery of Legionnaires' disease, exposure to radon in homes, and formaldehyde from insulation and other building materials contributed to this awareness. Further, the scientific community began developing evidence that poor IAQ diminishes occupant health, comfort, and productivity. Also, in 2001, the public became acutely aware of the health consequences of the indoor pollution associated with the terrorist attack on the World Trade Center in New York City. Thus, by the early 2000s, about 95% of the general population reported in surveys by the Chelsea Group that they were concerned about IAQ in their homes (BCC Research, 2012).

Concern About Markets and Jobs

The recent economic recession and concern about the impact of budgetary decisions on the number of jobs in the U.S. have heightened interest in the degree of economic activity and jobs associated with various policy areas of interest. While some studies have estimated the economic cost of poor IAQ in terms of health and productivity (Mudarri, 2010a), few have estimated market expenditures and jobs associated with the IAQ products and services. Levin gave a comprehensive treatment of this subject in 2005, but that study is now out of date. Other studies, while more current, tend to cover one or two aspects of IAQ and are therefore limited in scope (Association of Nonwoven Fabrics Industry, 2008; BCC Research, 2012; Freedonia Custom Research, 2009; Greenguard Environmental Institute, 2011; Kline & Company, 2010; Packaged Facts, 2011). This article updates and broadens the Levin study by incorporating information from more recent market analyses in an attempt to provide useful grounding for policy decision makers concerned with the economic impact of budgetary decisions related to IAQ activities.

Methods Overview

Levin estimated the size of the U.S. market in 2003. Most of the cost and revenue data for that study came from approximately 150 interviews with knowledgeable industry representatives including IAQ mitigation firms, laboratories, trade associations, and manufacturers, plus summaries of industry market research reports and Web sites. The Levin analysis established the following market segments for IAQ:

- consultant services for IAQ problem investigation, diagnosis, and resolution;
- building remediation for IAQ;
- laboratory services pertaining to IAQ diagnostics or related aspects of building design;
- emissions testing for certification/labeling;
- air duct cleaning;

- purchase and use of and improved filtration;
- IAQ litigation and insurance;
- radon mitigation and prevention; and
- asbestos and lead abatement.

This article updates and expands the Levin analysis in three phases. First, the economic growth in the U.S. economy as measured by the real growth rate of the gross domestic product (GDP) and the inflation rate as measured by the consumer price index between 2003 and 2011 was determined. These rates were assumed to be appropriate as default updating factors for any IAQ market segment in Levin for which no evidence was found suggesting that different updating factors would be more appropriate.

Second, an analysis was conducted of trends in IAQ activity using summary reports of more recent market research and from the general literature. This analysis sought to identify (a) market segments identified by Levin whose growth and inflation significantly deviated from the U.S. economy, (b) market segments that were not identified by Levin but had shown considerable activity, and (c) market segments that ought to be redefined to better represent current market realities. Market segments so identified were analyzed to determine appropriate sales volume for 2011.

Levin recognized that many IAQ problem prevention or mitigation activities are also part of standard practice by building professionals and ought not to be attributed specifically to IAQ. Therefore, he defined IAQ expenditures as those "incurred primarily to avoid or mitigate IAQ problems that were not standard practice prior to the early1970s when IAQ first started to be recognized as a national concern." This definition is also used in this current analysis and is used primarily when making professional judgments about expenditures attributable to the IAQ industry. In addition, Levin recognized the significant uncertainty in the estimates and therefore used a range of plus or minus 25% to account for this uncertainty. Estimates in this article reflect activity as of 2011, enumerated in 2011 dollars, and using the same range of uncertainty.

Third, in addition to estimating the size of the IAQ market in terms of annual sales of products and services, this article estimates the total number of jobs associated with the IAQ industry in 2011. To account for all the jobs associated with IAQ products and services, one could possibly trace all of the jobs associated with the sale of final products and services plus those used throughout the supply chain that make up final products and services associated with IAQ. That is, one might try to include jobs in all the products from the raw materials that go into the parts that go into the equipment that are used to make the final product, including the jobs associated with the energy used and the jobs that go into the manufacture of every nut and bolt and wire, as well as the services, and so on. To account for each job or portion of a job associated in this way would not be feasible.

A simpler approach recognizes that the sales value of all final products and services already accounts for the value of all intermediate products throughout their supply chain. This is also true throughout the economy. Thus, if one assumes that the labor intensity of IAQ products and services including the supply chain is similar to the average labor intensity throughout the economy, one could take the ratio of employed persons in the economy to GDP and multiply it by the total annual expenditures for IAQ products and services to approximate the number of jobs associated with IAQ. This is the approach taken in this article.

To put the size of the IAQ market in perspective, the estimates for IAQ sales are compared to retail sales of other retail categories taken from the U.S. Census (2013). In addition, the importance of IAQ in economic growth is assessed in terms of the impact of IAQ on productivity and educational achievement and the relationship of these issues to economic growth and vitality.

Analysis

Growth and Inflation in the U.S. Economy as Default Updating Factors for the IAQ Market

Between 2003 and 2011, the U.S. real GDP (absent inflation) rose by 12.36% (U.S. Department of Agriculture, 2012), while inflation as measured by the consumer price index rose by 22.25% (U.S. Bureau of Labor Statistics, 2012a). Combining the real growth in GDP with inflation yields a growth of 37.36% (1.1236 x 1.2225 = 1.3736). Therefore, this is the default factor used to update those IAQ market segments in Levin for which no evidence was found to indicate that a different updating factor would be more appropriate.

IAQ Market Segments Identified for Special Analysis

Analysis of recent market research on various IAQ market segments revealed that two market segments—emissions testing and certification/labeling and asbestos and lead abatement—deserved more individualized updating factors, and two market segments—IAQ equipment and green cleaning—not included in Levin needed to be added. Further, since some equipment sales were implicitly included by Levin in the building remediation market segment as well as the purchase and use of improved filtration segment, these segments would need to be adjusted to avoid double counting with the new IAQ equipment category. For these market segments, information from market research summary reports was used to determine the best appropriate estimates of IAQ market activity in 2011. A discussion of these market segments follows.

Emission Testing, Certification, and Product Modifications

Expenditures for testing and certification were estimated by Levin to be $0.1 billion in 2003. In November 2003, the Greenguard Environmental Institute, the largest certification organization for indoor product emissions, had listed approximately 1,400 products as having been certified. By August 2011, that number had risen to over 2,000, excluding furniture, plus approximately 8,000 pieces of furniture (Greenguard Environmental Institute, 2011). Excluding furniture, this represents a 43% increase in product certifications over that period, compared to the growth in real GDP of just over 12%. Including each piece of furniture as a separate product, the average annual growth rate would be approximately 700%, but the dominance of furniture in this data suggests that it is overrepresented. It is therefore assumed that product emission testing and certification activity for all products has experienced a real growth rate of approximately 50%, which when added to inflation would bring the 2011 estimate to $0.18 billion.

In addition, Levin did not include expenditures by manufacturers to reduce emissions by modifying their products' design and content. Yet the cost of testing is likely to be minor relative to the cost of redesign and reformulation of products. While such expenditures

would be considerably different for different products or product lines, it is conservatively assumed that the cost of product modification is 10 times the cost of testing, and that such an estimate also accounts for the modifications of products that are not tested or certified by third parties. Accordingly, the estimate for product modification in 2011 is $1.8 billion. These values rounded to the nearest $0.1 billion are presented in Table 1.

IAQ Equipment

Expenditures for IAQ equipment were not included as a separate category in the Levin report though some are implicit in the building remediation and filtration market segments. BCC Research (2012) estimates that the IAQ equipment market was worth $3.0 billion in 2003 and $3.6 billion in 2011, a growth that was slowed considerably by the recent recession. That analysis limits its concern, however, mostly to pollution-oriented portions of IAQ such as filtration, pollutant measurement, and ventilation. Thus, much of the equipment market designed to improve the thermal and moisture aspects of IAQ are not included. Nor does it include new chemical-free cleaning equipment that replaces cleaning chemicals. It is therefore assumed that an added $0.2 billion to the BCC Research 2011 estimate would account for these differences. The estimate for IAQ equipment in 2011 is therefore estimated to be $3.8 billion.

Levin estimated the sales in the "building remediation for IAQ" market segment to be $2.1 billion in 2003. If this estimate were updated to 2011 using the default increase of 37.36%, the 2011 value would be $4.7 billion. It is assumed, however, that $0.5 billion is captured in that portion of building remediation dealing with equipment that is already reflected in the new IAQ equipment category. Therefore, the 2011 value for building remediation is reduced to $4.2 billion. Similarly, if the air cleaning and improved filtration category in Levin were updated to reflect the growth in U.S. GDP and inflation, the 2011 value would be $2.1 billion. It is assumed that all of this is also included in the new IAQ equipment category. These adjustments and estimates are also presented in Table 1.

Asbestos and Lead Abatement

Levin estimated that the asbestos and lead abatement market accounted for approxi-

TABLE **1**

New and Adjusted Estimates for Select Indoor Air Quality (IAQ) Market Segments (2003 and 2011)

Market Segment	2003 (Billions)	2011 (Billions)
Product certification or labeling	$0.1	$0.2
Product modification	—	$1.8
IAQ equipment	—	$3.8
Building remediation for IAQ	$3.4	$4.2
Air cleaning and improved filtration	$1.5	Included in IAQ equipment above
Asbestos and lead abatement	$4.0	$3.0
Green cleaning	—	$0.9

TABLE **2**

Estimated Nationwide Expenditures for Indoor Air Quality (IAQ) in 2003 and 2011

Market Segment	Estimated Expenditure (Billions)*		Comments
	2003	2011	
Consultant services for IAQ problem investigation, diagnosis, and resolution	$2.1	$2.9	Includes consultant investigations and diagnostic services. Does not include in-house diagnostic services or in-house response to or resolution of complaints.
Laboratory services	$0.1	$0.1	Includes testing of mold, lead, asbestos, and volatile organic compounds.
Building remediation for IAQ	$3.4	$4.2	Covers repair and upgrade of controls, ventilation, filtration of HVAC[a] systems, and contaminant removal.
Duct cleaning	$4.0	$5.5	Residential and commercial.
Air cleaning and improved filtration	$1.5	$**	Includes sales of residential units and annual expenditures to operate residential and commercial units.
IAQ equipment	—	$3.8	Encompasses all equipment, including ventilation, filtration, air cleaning, cleaning, and monitoring.
Product certification or labeling	$0.1	$0.2	Includes testing and certification expenditures.
Product modification		$1.8	Modifying products to reduce emissions but excludes green cleaners.
IAQ litigation and insurance	$0.5	$0.7	All litigation and insurance claim payments.
Radon mitigation and prevention	$0.2	$0.3	Radon testing, mitigation, and radon resistant new construction.
Asbestos and lead abatement	$4.0	$3.0	Residential and commercial for asbestos, residential for lead.
Green cleaning for IAQ	—	$0.9	Cleaners but not equipment.
Total estimated expenditures for IAQ	$15.9	$23.4	Range: $12–$20 billion in 2003 and $18–$30 billion in 2011.

[a]HVAC = heating, ventilation, and air conditioning.
*Estimated expenditures in 2011 account for inflation and market growth. 2003 estimates are in 2003 dollars.
**Included in 2011 IAQ equipment estimate.

TABLE **3**

2011 Comparison of Indoor Air Quality (IAQ) Sales With Other Retail Sales Categories

Retail Store	Market Size in Retail Sales* (Millions)	IAQ Market Size as % of Other Retail Markets
New car dealers	$614,000	4%
Supermarket and grocery store	$519,000	4%
Warehouse, club, and super stores	$445,000	5%
Full service restaurants	$212,000	11%
Department stores	$188,000	12%
Furniture stores	$48,000	48%
Beer, wine, and liquor stores	$43,000	53%
Sporting goods stores	$40,000	58%
*Indoor air quality**	$23,000	100%
Shoe stores	$20,000	115%
Office supplies and stationery stores	$20,000	115%
Book stores	$14,000	164%

*Source: U.S. Census, 2013.

mately $4.0 billion in 2003. Indications are that this market has waned since 2003, however, and the cost of asbestos remediation has declined considerably (BCC Research, 2012). Therefore, it is assumed that this market has declined in both real and nominal dollars, from $4.0 billion in 1993 (1993 dollars) to $3.0 billion in 2011. This estimate is included in Table 1.

Green Cleaning Products

Levin did not include green cleaning associated with reducing harmful emissions of cleaning product chemicals as a separate category, and it was not included in the emissions testing category because certification of such products relies on chemical content information rather than emissions testing. In the residential market, the market for green household cleaners in 2009 was $0.34 billion and constituted 60% of the residential green cleaners and laundry product market (Air Quality Services, 2011). In addition, the proportion of all household cleaning and laundry products that are green has expanded significantly over the past decade from 3% in 2008 to an expected 30% in 2013 (Air Quality Services, 2011). Cleaning and laundry products in the commercial and institutional market were valued at $3.6 billion in 2010 and are also experiencing a strong movement toward green (Kline & Company, 2010). If, as with household products, 30% of the commercial and institutional market is also green, and 60% are green cleaners, then the green commercial and institutional market for green cleaners would be valued at approximately $0.65 billion. Adding the residential market would yield a total green cleaning market of $0.99 billion. Not all of green cleaning is related, however, to the toxicity of the chemical cleaners as it relates to the health of users and occupants. Adjusting for this, it is estimated that the IAQ portion of the green cleaning market in 2010 was approximately $0.9 billion. This figure is also used to represent the market in 2011. Since green cleaning products are not generally tested in emission testing chambers, these are not included in the category of emission testing and certification. Further, this does not include green cleaning equipment, which is included in the IAQ equipment category. The value of the green cleaning market portion related to IAQ is presented as the last market segment in Table 1.

Results

Size of the IAQ Sales Market

Table 2 provides the Levin estimates for national expenditures in the IAQ market in 2003 (2003 dollars), as well as the current estimates for 2011 (2011 dollars) based on the analysis above. Accordingly, Table 2 suggests that total national expenditures for IAQ is currently $23 billion per year, or, accounting for uncertainty, between $18 and $30 billion per year.

To put the size of the U.S. market for IAQ products and services in perspective, Table 3 lists the annual sales of various retail enterprise categories as defined by the U.S. Census Bureau (2013) along with the IAQ sales estimate. To facilitate comparison, the IAQ market as a percentage of each of these retail sectors is also included. For example, the size of the IAQ market, as measured by the sale of IAQ products and services, is approximately only 4% of the size of the new car retail sales market, but is 164% larger than the book store sales market.

Jobs Associated With IAQ

One might ask, if there were no IAQ products and services, how many jobs would be lost? Or alternatively, how many jobs are associated directly or indirectly with IAQ? As described in the methods section, this estimate is derived by multiplying the estimated expenditures of IAQ products and services by the ratio of current U.S. employment to GDP. One hundred thirty million persons were employed in 2011 (U.S. Bureau of Labor Statistics, 2012b) while the value of GDP was $15.1 trillion (Kim, Gilmore, & Joliff, 2012), leaving a ratio of employment to GDP of 8.6 x 10^{-6}. Multiplying this ratio by the estimated expenditure for IAQ of $23.4 billion yields an estimate of approximately 200,000 jobs associated with IAQ, or, accounting for uncertainty, between 150,000 and 250,000 jobs.

Discussion

Market Trends in IAQ

The current updated estimate of the national expenditures in the IAQ market reflects changes that have taken place since 2003. Since 2003, public awareness and concern for IAQ has been solidified, partly because of the proliferation of information from sources such as the U.S. Environmental Protection Agency (2014), the Institute of Medicine (2000, 2004), and from many other sources. This awareness plus general advancements in emission testing and certification technol-

ogy appear to have resulted in a substantial increase in concern about the chemical emissions of products. In addition, buoyed by the desire for energy independence and concerns about greenhouse gas emissions, federal policies have mandated the development of new energy building codes that currently call for reduction in natural infiltration in buildings and minimal mechanical ventilation. This places an increased burden on building architects and engineers to ensure adequate IAQ by other means (Mudarri, 2010b). Therefore, considerable interest exists in energy recovery and other energy efficient ventilation solutions (BCC Research, 2012).

Model green building programs and national building codes are beginning to call for mechanical ventilation in residential buildings plus other IAQ protections to accompany tighter building envelopes. Improved IAQ controls, air cleaning devices, moisture control, and monitoring equipment are being introduced to support improved IAQ, as are dedicated outdoor air systems, ventilation monitoring and controls, demand control ventilation, and liquid desiccant cooling for moisture control. Medium-efficiency filters have largely replaced the standard furnace filter, while high-efficiency filtration is now a fast growing filter medium (Association of Nonwovens Fabrics Industry, 2008; Freedonia Custom Research, 2009). In addition, air quality monitors (e.g., carbon dioxide monitors, carbon monoxide monitors, and moisture meters) have become popular for not only consultants and diagnosticians, but also now for building maintenance personnel.

Thus, the product emission control segment of the IAQ market and the IAQ equipment segment have grown faster than other segments. In addition, since 2003, the cleaning industry has greatly accelerated the movement toward "cleaning for health" as opposed to "cleaning for appearance" by introducing low toxicity products and chemical free cleaning equipment that improves IAQ (Mudarri, 2011).

These changes appear to be trends that are likely to continue in the future. Climate change, with its implications for reduced infiltration and ventilation in buildings, will likely promote further interest in energy-efficient ventilation solutions as well as alternative IAQ improvement mechanisms (Environmental News Network, 2008). By contrast, asbestos and lead abatement are on the decline. This can be expected because these substances have been highly restricted for a long time, few currently manufactured products contain them, and many of the past problems have already been mitigated.

The Comparative Size and Importance of the IAQ Market

Despite its relatively small size, the IAQ market is surprisingly important to the economy because of the impact of good IAQ on learning and productivity (Lawrence Berkeley National Laboratory, 2012). An abundance of research shows a close positive relationship between the education level of a country and its GDP. But the research emphasizes that "level of educational achievement" is not only the educational level from which one graduates, but also the level of knowledge and skills acquired while being educated (Hanushek, Woessmann, & Jamison, 2008). With respect to learning, children have been shown to have greater ability to perform mental tasks, to have lower absentee rates, and to have higher test scores with better IAQ (Lawrence Berkeley National Laboratory, 2012). In the adult world, improved IAQ increases productivity and reduces absenteeism at work (Lawrence Berkeley National Laboratory, 2012). These research findings highlight the importance of IAQ to economic growth.

Conclusion

In general, IAQ is estimated to represent approximately $18 billion–$30 billion annually in economic activity, and that activity is associated with approximately 150,000–250,000 jobs. Given the rising public awareness of and sensitivity to IAQ, combined with the increasing emphasis on IAQ protections from energy conservation and climate change activities, the IAQ market should show healthy growth in the future. In the long term, promotion of good IAQ has a strong role to play to ensure robust economic growth and improve both the number and quality of jobs enjoyed by all Americans. This is because of the positive impact of good IAQ on productivity and educational achievement.

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