Economic Primer on Formaldehyde

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March 2006

People benefit from products that contain formaldehyde every day. This chemical is a critical and commercially valuable basic building block of our modern society. One of formaldehyde's earliest and best-known uses – embalming -- took advantage of its preservative properties. Today, this application represents less than 1% of formaldehyde consumption. On the other hand, products derived from formaldehyde have an extremely broad role in the economy, even though the fact that these myriad products rely on formaldehyde is largely invisible to the public. This primer is intended to bring formaldehyde's important and unique societal values to light by:

- Describing how the products of formaldehyde chemistry permeate our world;
- Quantifying and comparing the economic importance of formaldehyde with other leading chemical products;
- Summarizing the results of Global Insight, Inc.'s recent original research on the economic importance of formaldehyde.

THE FORMALDEHYDE PROCESS CHAIN

Formaldehyde is produced from methanol (a natural gas derivative) using a catalytic oxidation process. Thirteen companies in the United States and six companies in Canada produce formaldehyde; three companies (Hexion, Celanese, and Dynea) have formaldehyde plants in both the United States and Canada. At the end of 2003, there were a total of 40 formaldehyde production sites in the United States and 11 in Canada. Formaldehyde plants typically are located close to where the chemical is consumed in order to reduce transportation costs. Thus, it is common to find these plants in all parts of the country and, indeed, the world.

Production of formaldehyde in the United States in 2003 amounted to 4.33 million metric tons; production in Canada amounted to 775,000 metric tons. Formaldehyde is classified as an "organic chemical intermediate." We compare formaldehyde production with other organic chemical intermediates to put these production figures into perspective. As such, formaldehyde ranks as the fifth largest volume product in this class in the United States, according to statistics compiled by the United States International Trade Commission and American Chemistry Council. Using the market price of formaldehyde in 2003 as a yardstick, the U.S. value of formaldehyde production was $1.5 billion. Of course, this simple measure does not account for the considerable and diverse value-added products that are derived from formaldehyde.

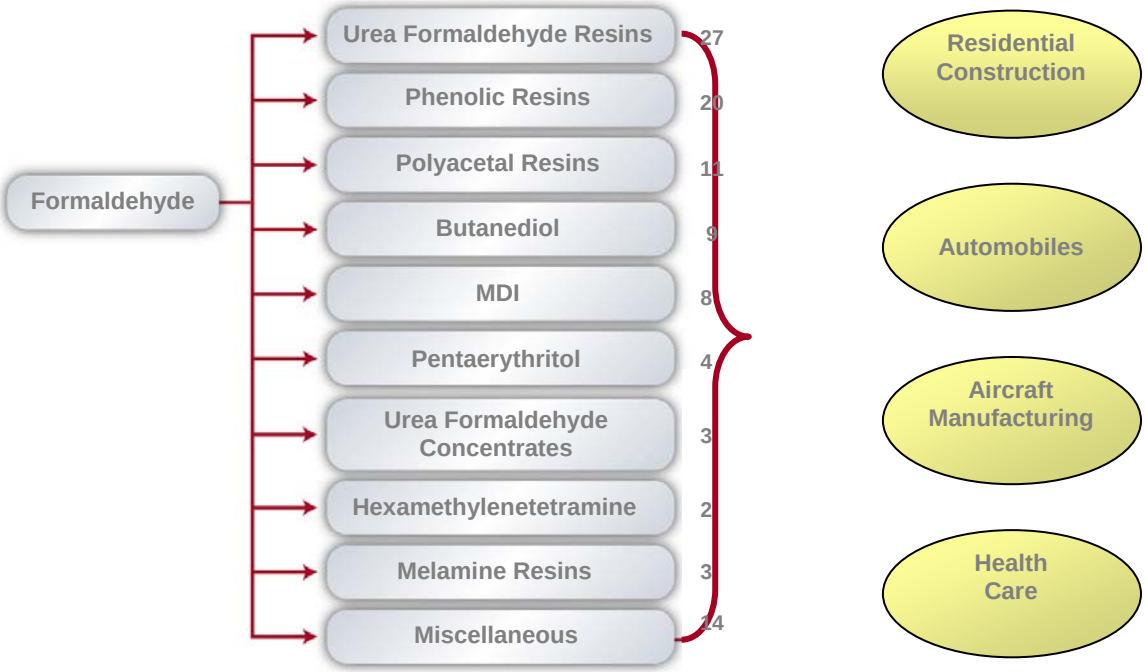
Table 1
U.S. Organic Intermediate Chemical Production, 2003

	Units	Amount	Major End Uses
Ethylene Dichloride	'000 MT	9,952	PVC plastics
MTBE	'000 MT	7,375	Gasoline additive
Ethylbenzene	'000 MT	5,575	Styrene manufacture
Styrene	'000 MT	5,239	Polystyrene plastics
Formaldehyde	**'000 MT**	**4,325**	**Thermoset resins and other chemicals**

Source: United States International Trade Commission, American Chemistry Council, and SRI International.

Of the five leading organic intermediate chemicals listed above, formaldehyde is by far the most versatile building block. Its major uses include ***thermoset resin applications*** (e.g., urea-formaldehyde, phenol-formaldehyde, and melamine-formaldehyde), as an ***intermediate raw material*** in synthesizing other chemicals (e.g. polyacetal resins, 1,4-butanediol, methylenebis (4-phenyl isocyanate) or MDI, and pentaerythritol), and in ***direct uses*** such as preservation and disinfection. The percent formaldehyde consumption by end use is shown below in the formaldehyde "product tree."

Figure 1
Product Tree for Formaldehyde, 2003



To understand the economic importance of formaldehyde, we must trace each of these derivatives to their ultimate end use in the economy. This is a complicated and detailed process. We summarize below how four major sectors of the economy depend on the products of formaldehyde chemistry.

- ***Residential construction***: These products include the crucial adhesives used for making products like plywood, sheathing and cladding, asphalt shingles, cabinets and cabinet doors, floors, furniture and paneling; other applications include laminated countertops and flooring systems, plumbing mechanisms, paints and varnishes, electrical boxes and outlets, and bedding;

- ***Automobiles***: These products can be found in molded under-the-hood components due to their ability to withstand high temperatures, in exterior primer and clear coat paints for their durability and gloss retention, in tire cord adhesives, in brake pads, and in critical fuel system components;

- ***Civilian and military aircraft***: These products can be found in landing gear components, lubricants that can withstand both extreme hot and cold temperatures, brake pads, and door and window insulation, and

- ***Health care applications***: These products are used widely for vaccine manufacturing, as an active ingredient in anti-infective drugs, for hard-gel capsule manufacturing, in pharmaceutical research (especially proteomics and genomics research), and as a denaturant for ribonucleic acid analysis.

ECONOMIC IMPORTANCE OF THE FORMALDEHYDE CHAIN

Global Insight analyzed the formaldehyde product tree and traced each product to the ultimate point of consumption. Here are highlights of the major findings for economic contributions of the formaldehyde industry to the U.S. and Canadian economies in 2003, using a narrow definition of the industry:

Value of Sales.

The value of sales of formaldehyde and derivative products amounted to $145 billion-plus. This represents 1.2% of the Gross Domestic Product (GDP) of the United States and Canada.

Employment.

The total number of workers in the United States and Canada who depend on the formaldehyde industry is four million-plus. This includes direct employment in the industry and the indirect employment of those whose livelihoods depend on this industry. This represents nearly 3.4% of employment in private, nonfarm establishments in the United States and Canada.

Wages.

Total wages for all of these workers amounted to nearly $130 billion, or 1.9% of the compensation of all U.S. and Canadian employees.

Value of Business Fixed Investment.

Formaldehyde and derivatives production was carried out in facilities with an aggregate investment value of nearly $90 billion in the United States and Canada, representing 4.2% of the net stock of private fixed assets in the manufacturing sector.

Number of Plants:

There are approximately 11,900 formaldehyde and derivative plants operating in the United States and Canada, with nearly all states and provinces represented.

Table 2
United States Economic Highlights, 2003

	Units	Formaldehyde Industry	United States Economy	Share of Total
Value of Sales	$Billion/Year	$127.3	$11,000[1]	1.2%
Total Employment	Million Workers	3.6	108[2]	3.3%
Total Wages	$Billion/Year	$112.1	$6,300[3]	1.8%
Fixed Investment	$Billion	$77.4	$1,832[4]	4.2%

Source: Global Insight, Inc.
[1] Gross domestic product in nominal dollars.
[2] Employment in private, nonfarm establishments.
[3] Compensation of employees in nominal dollars.
[4] Current-cost net stock of private fixed assets in manufacturing.

Table 3
Canadian Economic Highlights, 2003

	Units	Formaldehyde Industry	Canadian Economy	Share of Total
Value of Sales	$Billion/Year	$19.3	$870[1]	2.2%
Total Employment	Million Workers	0.6	16[2]	3.8%
Total Wages	$Billion/Year	$16.8	$440[3]	3.8%
Fixed Investment	$Billion	$10.7	$170[4]	6.3%

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Source: Global Insight, Inc.
[1] Gross domestic product in nominal dollars.
[2] Employment in private, nonfarm establishments.
[3] Compensation of employees in nominal dollars.
[4] Current-cost net stock of private fixed assets in manufacturing.

SUBSTITUTION ECONOMICS OF THE FORMALDEHYDE CHAIN

Global Insight investigated the unique and specific physical and chemical properties of formaldehyde and the qualities that it imparts to major categories of products that benefit from it. While there are some applications where other materials could replace formaldehyde with only a small incremental cost or performance penalty, in most instances the use of substitutes would entail significant cost increases or performance losses. Here are highlights of the major findings of benefits to consumers:

- Consumers would have to spend an additional $17 billion per year (the equivalent of nearly $3,500 per metric ton of formaldehyde currently consumed) if formaldehyde-based products were replaced by substitute materials. Nearly 60% of the estimated benefits are attributed to three major applications: urea formaldehyde resins, phenol formaldehyde resins, and methylenebis(4-phenyl isocyanate) or MDI. In most cases, substitution in these end uses is very imperfect; consumers would suffer large losses in utility using alternative materials, and large new capital investments would be required to produce or utilize the substitutes.

- Urea formaldehyde (UF) resin is one of the mainstays in the building and construction industry. Nearly 95% of UF resins are used as binders or adhesives in particleboard and medium-density fiberboard for composite panels, roofing tiles, hardwood plywood, and coatings. Wood products made using UF resins have predominant market shares in their main applications. Without UF resins, consumers would be forced to use more expensive, less versatile, and less durable materials, or else switch to entirely different construction methods. In most cases, switching to different construction methods is a significantly more costly alternative.

- Phenol formaldehyde (PF) resin is another mainstay in the building and construction industry. Nearly 75% of PF resins are used to make structural panels, insulation binder and laminates. Other significant end uses include automobile applications (e.g. friction materials) and foundry binders. Like UF resins, PF resins have predominant market shares in major applications. Without PF resins, consumers would be forced to use more expensive, less desirable, and less versatile materials, or switch to alternative construction methods.

- The majority of MDI is used in the manufacture of rigid polyurethane foams. These products' superior insulating and mechanical properties benefit their numerous construction applications. Other MDI rigid foam applications include appliances (e.g., refrigerators, freezers, and air conditioners), packaging for high-end electronics, and transportation. In the absence of MDI, consumers would be forced to use less effective materials and would experience significant losses of utility (e.g. inferior insulation properties, increased breakage or spoilage).

Table 4
Economic Benefits of Formaldehyde

	Economic Value in 2003 ($ billion per year)
Formaldehyde End Use	
Urea formaldehyde resin (UF)	$3.41
Phenol formaldehyde resin (PF)	$4.64
Polyacetal resin	$0.22
1,4-Butanediol (BDO)	$0.14
MDI	$2.33
Pentaerythritol	$0.14
Controlled Release Fertilizers	$0.11
Melamine formaldehyde resin (MF)	$0.37
All other products & derivative benefits	$5.85
Total benefits to consumers	**$17.22**

Source: Global Insight, Inc.
Note: These economic values are additive. Totals may not add due to rounding.

To summarize Global Insight's findings:

- Production of formaldehyde and its derivatives generates a substantial volume of sales, provides a sizable number of jobs, and contributes to the local economies in countless visible and not-so-visible ways.

- We find that nearly all U.S. industries consume the products of the formaldehyde industry, and that four major sectors are critically dependent on formaldehyde; they are residential construction, automobiles, aircraft manufacturing, and health care.

- Our analysis demonstrates that products derived from formaldehyde provide a very large range of economic benefits to consumers. Substitution costs are extremely high in some cases and modest in others.

- Products that benefit from formaldehyde are pervasive in our society, and their value is increased substantially by how difficult it would be to find suitable replacements for them, not how much formaldehyde is used to produce them.

FORMALDEHYDE: A NATURAL PART OF OUR WORLD[1]

Formaldehyde is a natural constituent of all living systems, from bacteria and fish to rodents and humans. In fact, it is one of the most abundant organic compounds in the universe. In outer space, measurements of methyl formate – a product of alcohol and formaldehyde – in the swirling dust clouds of the Milky Way suggest that if the gas condensed into liquid form, a typical dust cloud would contain a thousand trillion trillion (1 with 27 zeros after it) gallons of formaldehyde.

As life evolved on earth, formaldehyde became an important part of the process because it is one of the simplest biological forms of carbon. Even the most primitive organisms relied on formaldehyde as a building block for the synthesis of more complex molecules. Due to its importance in various metabolic processes, formaldehyde is naturally present in the human body with concentrations of approximately one to two parts per million in blood.

Because it is volatile, formaldehyde is exhaled in human breath. And because it has existed since the beginning of life, the evolutionary process had to include a way to ensure that formaldehyde's inherent toxicity could be controlled. Certain enzymes evolved as the control system. They convert formaldehyde formed continuously in various biological processes to formate, which is less reactive and, therefore, less toxic than formaldehyde. Their role is simple – to keep formaldehyde from reaching concentrations that are toxic to cells.

[1] For more information, request the backgrounder entitled "Formaldehyde and Human Health" from the Formaldehyde Council, Inc., 703-741-5750, or visit www.formaldehyde.org.