THE ECONOMIC BENEFITS OF ETHYLENE OXIDE

And the potential cost of deselection

Economics & Statistics Department
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Executive Summary

A versatile and valuable building block of chemistry, ethylene oxide (EO) and its derivatives help make many of the products we use every day, such as plastics, household cleaners, polyurethanes and ointments. A small but important use of ethylene oxide is in the sterilization of medical supplies and devices and healthcare products such as bandages.

The American Chemistry Council's Economics and Statistics Department conducted research to highlight the socioeconomic benefits of ethylene oxide in the United States. This report presents the findings of that research and describes the essential role that EO has in supporting the U.S. economy.

The economic contributions, including output and employment, of EO are substantial and extensive. In 2018, the value of EO produced in the U.S. was $3.5 billion. In addition, the production of primary chemical products derived from EO ("derivatives" or "downstream products") was valued at $5.4 billion. In total, the combined value of EO and immediate derivatives production is $8.9 billion. This production directly generated more than 5,300 U.S. jobs and $475 million in payroll in 2018.

The full economic impact of the industry goes well beyond the direct jobs and output. Businesses in the EO and immediate derivatives industry purchase raw materials, services and other products throughout the supply chain. These purchases, in turn, support nearly 21,000 additional indirect jobs. The wages earned by workers in the EO and immediate derivatives industry and throughout the supply chain are spent on household purchases and taxes, generating an additional 18,800 payroll-induced jobs. *All told, the $8.9 billion in EO and immediate derivatives output supports a total of $21.5 billion in output and more than 45,000 jobs with a payroll of $2.3 billion.*

What is Ethylene Oxide?

A versatile and valuable building block of chemistry, ethylene oxide (EO) is primarily used as an intermediate in the production of other useful chemicals. These products are then, in turn, used to help make many of the products we use every day, such as certain plastics, antifreeze, household cleaners, safety glass, adhesives, textiles, and detergents.

Also known as oxirane, EO is a colorless gas at room temperature and liquefies at about 12 degrees Celsius (53 degrees Fahrenheit). It is highly flammable, soluble in organic solvents, and miscible (can be mixed) with water. EO belongs to the epoxides family and is highly reactive.

Production of Ethylene Oxide

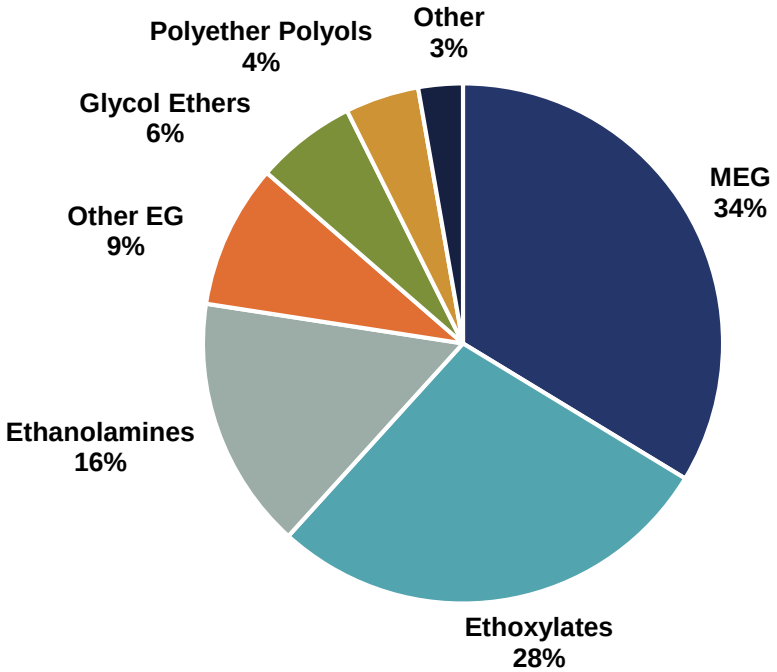
In the U.S., ethylene oxide is produced by catalytic oxidation of ethylene. In 2018, 2.92 million metric tons of ethylene oxide was produced in the United States. The value of this output is $3.49 billion. There are nine U.S. producers of EO, operating 15 facilities in 11 locations in two states: Texas (59%) and Louisiana (41%).

Consumption of Ethylene Oxide

Major Uses

Ethylene oxide is primarily consumed as an intermediate chemical in the production of other chemicals and materials ("derivatives"). The largest end-use (more than one-third) is the production of monoethylene glycol (MEG), which is primarily used to produce polyethylene terephthalate (PET) resin (used to make water bottles and other food and beverage containers) and antifreeze.

Figure 1: U.S. Consumption of Ethylene Oxide



Other major end uses include: ethoxylates, which are used to make a variety of surfactants, a large portion of which is used in household detergents; ethanolamines, which are used to produce herbicides, surfactants for personal care products and detergents, gas purification and as intermediates that are used in the production of other chemicals; other ethylene glycols (including diethylene, triethylene, and polyethylene glycols) which are used to produce unsaturated polyester resins, polyurethanes, solvents, antifreeze, and other products; glycol ethers, which are used as solvents in paints and coatings; and polyether polyols, which are used in the production of polyurethanes and adhesives.

Other Uses

Although the "Other" category represents only a fraction of total EO consumption, its use can be vital to those industries:

- *Medical sterilization* - EO is an essential chemical used in the sterilization of medical and surgical devices and supplies, including devices used in heart surgery, knee replacements, surgical procedure kits, catheters, syringes, and other life-saving products. The Ethylene Oxide Sterilization Association (EOSA) estimates that more than 20 billion medical devices are sterilized using EO each year.
- *Microbial reduction in spices* – In the U.S., spices are often treated with EO to eliminate contaminants such as *Salmonella* and *E.coli*. The American Spice Trade Association (ASTA) recommends the use of "validated microbial reduction techniques," such as EO and estimates that "less than 50% of spices in the U.S. are treated with [EO] each year."[1]
- *Corn refining* - EO is used in corn refining to produce industrial starches, used in applications such as paper coatings, adhesives and pastes.

Trade

Due to its high reactivity, ethylene oxide is generally consumed where it is produced. There is no overseas trade of EO, and minimal trade between countries in North America. A small volume of EO consumed for ethoxylates for surfactants is transported to ethoxylate production facilities via specially designed tank cars and cylinders. There are approximately 1,500 rail tank cars designed to safely carry EO shipments over rail lines.

There is, however, substantial trade of EO derivatives. Exports of MEG, for example, accounted for nearly one-third of U.S. production in 2018. The U.S. is the world's largest producer of both ethoxylates and ethanolamines, accounting for 30% and 33% of global exports, respectively.

[1] American Spice Trade Association. (2017). *Clean, Safe Spices*.

The Economic Impact of the Ethylene Oxide Industry

When considering the economic impact of the ethylene oxide industry, the analysis looks at the benefits from EO, as well as those derived from the production of primary chemical products produced using EO. The combined value of EO and immediate derivatives production is $8.9 billion. There are at least 90 process plants across 12 states and the industry employs more than 5,300 people with a payroll of $475 million.

Table 1
U.S. Production of Ethylene Oxide and Derivatives, 2018

Product	Process Plants	Output (Million $)
Ethylene Oxide	15	$3,492
MEG	13	1,571
Other Ethylene Glycols	34	436
Ethanolamines	5	982
Glycol Ethers	11	154
Polyether Polyols	12	1,078
Other		1,188
Total	**90+**	**$8,901**

The economic contributions of the U.S. ethylene oxide industry are numerous, though often overlooked in traditional analyses that consider only the direct jobs and output of the industry. In addition to the jobs created directly by the industry, additional jobs are supported by the EO industry and by the subsequent expenditure-induced activity ("upstream impact"). The EO industry pays its employees' wages and salaries and purchases supplies and services (including transportation, contract workers, warehousing, maintenance, accounting, etc.). These supplier businesses, in turn, make purchases and pay their employees. Thus, the EO industry generates several rounds of economic spending and re-spending. These indirect and induced effects on other sectors of the economy can also be quantified.

The economic impact of an industry is generally manifested through four channels:

- *Direct impacts* - employment, output and fiscal contributions generated by the sector itself
- *Indirect impacts* - employment and output supported by the sector via purchases from its supply chain
- *Payroll-induced impacts* - employment and output supported by the spending of those employed directly or indirectly by the sector
- *Spillover (or catalytic) impacts* - the extent to which the activities of the relevant sector contribute to improved productivity and performance in other sectors of the economy

This report presents the economic contributions related to the first three channels. Spillover (or catalytic) effects do occur from EO chemistry, but these positive externalities are difficult to quantify and thus were not examined in the analysis.

Methodology

To estimate the economic impacts of the U.S. EO industry, the IMPLAN model was used.[2] The IMPLAN model is an input-output model based on a social accounting matrix that incorporates all flows within an economy. The IMPLAN model includes detailed flow information for 440 industries. As a result, it is possible to estimate the economic impact of a change in final demand for an industry at a relatively fine level of granularity. For a single change in final demand (i.e., change in industry spending), IMPLAN can generate estimates of the direct, indirect and induced economic impacts. Direct impacts refer to the response of the economy to the change in the final demand of a given industry to those directly involved in the activity. Indirect impacts (or supplier impacts) refer to the response of the economy to the change in the final demand of the industries that are dependent on the direct spending industries for their input. Induced impacts refer to the response of the economy to changes in household expenditure as a result of labor income generated by the direct and indirect effects.

Table 2
U.S. Economic Impact of the Ethylene Oxide Industry

Impact Type	Employment	Payroll (Million $)	Output (Million $)
Direct	5,349	$475	$8,901
Indirect	20,912	$1,162	$9,459
Payroll-Induced	18,780	$682	$3,108
Total	**45,041**	**$2,319**	**$21,468**

While the output and employment generated by the EO industry is significant—the $8.9 billion industry directly generated 5,349 jobs and $475 million in payroll in 2018—the full economic impact of the industry goes well beyond the direct jobs and output. Businesses in the EO and immediate derivatives industry purchase raw materials, services, and other products throughout the supply chain, supporting an additional 20,912 indirect jobs. Finally, the wages earned by workers in the EO industry (and throughout the supply chain) are spent on household purchases and taxes, generating an additional 18,780 payroll-induced jobs. *All told, the $8.9 billion in EO and immediate derivatives output generates a total of $21.5 billion in output and 45,041 jobs with a payroll of $2.3 billion.* Appendix I includes information on the economic impacts of ethylene oxide and derivative manufacturing for the 12 states that produce EO and its primary derivatives.

New Investments

In addition to existing capacity (current U.S. EO capacity is about 3.5 million metric tons), there are several new investment projects underway to expand EO and derivatives capacity. Since ethylene oxide is derived from ethylene, access to inexpensive ethane (the key raw material of ethylene) derived from shale gas has made the U.S. an attractive investment location for new capacity. The renewed competitiveness of the EO industry is expected to increase U.S. capacity by more than 50% (1.8 million metric tons) by 2023.

[2] IMPLAN Group LLC, 16905 Norcross Drive, Suite 120 | Huntersville, NC 28078 | www.implan.com

Deselection of Ethylene Oxide

Due to its high flammability, and potential impacts of direct exposure, several government agencies regulate and monitor the use, exposure and transport of EO. The Occupational Safety and Health Administration (OSHA) regulates EO exposure limits for employees and the U.S. Environmental Protection Agency (EPA) regulates the use of EO as a sterilizing agent and fumigant. Furthermore, the U.S. Department of Transportation regulates EO tank car standards and handling.

In 2016, EPA updated its risk value of ethylene oxide, deeming the chemical to be "carcinogenic to humans."[3] As such, the EPA is undertaking multiple efforts to address EO emissions, review existing regulations and gather additional information. Additionally, similar efforts are underway at the state level.[4]

As an intermediate chemical used to make other products, almost all of the EO is reacted with other substances to form new products. Potential exposure, if any, to the general public from EO manufacturing emissions rules is likely to be negligible. However, when there is a concern regarding human exposure, agencies must consider all options in order to ensure the safety of the general public. One of these options could be the deselection—or complete elimination of production and use—of EO.

For purposes of this analysis, it was assumed that if EO were to be deselected, all U.S. production, transportation and consumption of EO would cease. Without access to the key raw material, production of immediate derivatives would also not be possible. Thus, plant closures would occur among producers in this industry. In addition to the established plants, any projects currently under construction would have to be abandoned. The cost of cancelling these projects would be significant but not knowing the stage of completion nearly impossible to estimate. *A total shutdown of EO production facilities in the United States would have manifold impacts on downstream production of EO derivatives and on trade.*

Deselection and the Impact on the Trade Deficit

In recent years, trade deficits have played a large role in economic policy debates. Although very little EO is traded internationally, for many immediate derivatives, trade is essential. For some derivatives, such as ethanolamines and glycol ethers, exports account for a large share of the value of output; for others, such as ethylene glycols, imports play a large role in meeting U.S. demand.

In 2018, the United States exported $724 million (831,000 metric tons) of immediate EO derivatives. During the same period, the U.S. imported $955 million (1.2 million metric tons) of immediate EO derivatives. Thus, the U.S. ran a trade deficit of $231 million.

If EO was no longer available to domestic producers of immediate EO derivatives, production of those derivatives would cease. In order to meet domestic demand, suppliers would have no choice but to look to foreign sources. Therefore, 100% of domestic demand (or consumption) would be imported, increasing the trade deficit from $231 million to $5.6 billion.

[3] U.S. Environmental Protection Agency. (2016). *Evaluation of the Inhalation Carcinogenicity of Ethylene Oxide*. Washington DC.
[4] https://www.epa.gov/hazardous-air-pollutants-ethylene-oxide

The Special Case of Medical Sterilization

Ethylene oxide is the most universal sterilization technology available today: the Ethylene Oxide Sterilization Association (EOSA) estimates that EO is used to sterilize more than 50% of all medical devices annually. The use of EO in sterilizing medical devices protects millions of patients by killing bacteria, viruses, and fungi that could cause life-threatening infections. According to the EOSA, "ethylene oxide is highly compatible with a wide variety of medical device materials of construction, enabling medical device companies to manufacture many devices that would not be possible without EO. The high level of performance and effectiveness of medical devices when sterilized by EO is well understood…. Elimination of this sterilization technology would introduce the real risks of increased morbidity and mortality." [5]

Other sterilization technologies exist, including hydrogen peroxide, heat sterilization, and radiation (gamma, electron beam [e-beam] and x-ray). These alternative technologies, however, are incompatible with some materials, including plastics and other heat sensitive materials, used in medical devices. The deselection of EO would mean that this important technology would no longer be available, resulting in a significant detrimental impact on U.S. healthcare. According to the Centers for Disease Control, 1.7 million hospital acquired infections occur each year, resulting in 99,000 deaths and an estimated $20 billion in healthcare costs. Without the effective sterilization provided by EO, these figures could increase exponentially.

In addition, the deselection of EO would have a significant impact on businesses in the medical sterilization industry. The medical and surgical instrument and appliance manufacturing industry is a $76 billion industry which employs more than 200,000. A significant portion of this industry is supported by the use of EO sterilization technologies. In fact, EO is used at 70 contract sterilizers registered with the FDA (see Appendix II for the number of facilities by state).

The Special Case of Corn Refining

Ethylene oxide is also used in the corn refining industry to produce industrial starches (hydroxyethyl starches). Industrial starches are a versatile input used in many industries including adhesive and binding applications and paper making (printing and coating). Industrial starch can also be used in laundry starch. According to the Corn Refiners Association, corn refining is a $22-billion industry that directly contributes 8,308 jobs and $1.0 billion in annual wages to the U.S. economy.[6] The economic contributions of these downstream industrial industries, where EO is a key part of the refining process, would be significant but virtually impossible to assess.

[5] Ethylene Oxide Sterilization Association, Inc. (9/18/18). *Flawed Science and Modeling by EPA Result in Inappropriate Conclusions That Could Have Disastrous Adverse Public Health Impacts*.
[6] Corn Refiners Association. (2017). *Economic Impact of U.S. Corn Refining*.

Conclusion

Ethylene oxide has a significant role in supporting the U.S. economy. The economic contributions of EO and derivatives are substantial and extensive. Should EO be deselected, the economic impact would be significant.

The $8.9 billion industry directly generates more than 5,300 jobs and $475 million in payroll. An additional 21,000 indirect jobs are supported by industry purchases of raw materials, services, and other products throughout the supply chain. Additionally, wages earned by workers in the EO and industry and throughout the supply chain are spent on household purchases and taxes, generating an additional 18,800 payroll-induced jobs. All told, the $8.9 billion in EO and immediate derivatives output supports a total of $21.5 billion in output and more than 45,000 jobs with a payroll of $2.3 billion.

Beyond the ethylene oxide and derivatives industry, numerous industries—from food and beverage packaging to automotive to healthcare—rely ethylene oxide and derivative products. Without access to this essential chemistry, the economic impact on these downstream industries would be immeasurable.

Appendix I – State Impacts (Ranked in Order from Highest to Lowest Output)

Texas

Impact Type	Employment	Payroll (Million $)	Output (Million $)
Direct	2,887	$384	$5,049
Indirect	6,117	$382	$2,289
Payroll-Induced	4,677	$188	$692
Total	13,681	$954	$8,029

Louisiana

Impact Type	Employment	Payroll (Million $)	Output (Million $)
Direct	1,696	$205	$2,921
Indirect	2,324	$106	$563
Payroll-Induced	1,632	$52	$209
Total	5,652	$363	$3,692

West Virginia

Impact Type	Employment	Payroll (Million $)	Output (Million $)
Direct	125	$12	$203
Indirect	305	$10	$45
Payroll-Induced	146	$4	$18
Total	576	$25	$267

South Carolina

Impact Type	Employment	Payroll (Million $)	Output (Million $)
Direct	99	$9	$159
Indirect	250	$14	$46
Payroll-Induced	150	$7	$21
Total	498	$31	$226

Pennsylvania

Impact Type	Employment	Payroll (Million $)	Output (Million $)
Direct	87	$7	$141
Indirect	211	$11	$45
Payroll-Induced	155	$6	$22
Total	453	$24	$209

Kentucky

Impact Type	Employment	Payroll (Million $)	Output (Million $)
Direct	61	$5	$98
Indirect	156	$6	$24
Payroll-Induced	81	$3	$11
Total	298	$14	$133

North Carolina

Impact Type	Employment	Payroll (Million $)	Output (Million $)
Direct	44	$4	$74
Indirect	106	$5	$19
Payroll-Induced	69	$2	$9
Total	219	$11	$103

Kansas

Impact Type	Employment	Payroll (Million $)	Output (Million $)
Direct	43	$2.9	$70
Indirect	102	$3.4	$22
Payroll-Induced	67	$1.4	$9
Total	212	$7.7	$101

Delaware

Impact Type	Employment	Payroll (Million $)	Output (Million $)
Direct	42	$5.3	$70
Indirect	80	$4.6	$17
Payroll-Induced	62	$2.4	$9
Total	184	$12.3	$96

Tennessee

Impact Type	Employment	Payroll (Million $)	Output (Million $)
Direct	16	$1.3	$26
Indirect	41	$1.9	$8
Payroll-Induced	25	$1.0	$3
Total	81	$4.1	$37

Michigan

Impact Type	Employment	Payroll (Million $)	Output (Million $)
Direct	11	$0.9	$18
Indirect	28	$1.4	$5
Payroll-Induced	18	$0.6	$2
Total	58	$2.9	$26

Illinois

Impact Type	Employment	Payroll (Million $)	Output (Million $)
Direct	7	$0.7	$12
Indirect	17	$1.0	$4
Payroll-Induced	14	$0.5	$2
Total	38	$2.2	$18

Appendix II – Number of Contract Sterilizers using Ethylene Oxide by State

	Number of Facilities
Arizona	3
Arkansas	1
California	5
Colorado	1
Connecticut	1
Florida	6
Georgia	5
Illinois	2
Indiana	1
Iowa	1
Maryland	1
Massachusetts	2
Michigan	2
Minnesota	1
Missouri	1
Montana	1
Nebraska	1
New Jersey	2
New Mexico	1
New York	2
North Carolina	4
Ohio	1
Oklahoma	1
Pennsylvania	3
Puerto Rico	4
Rhode Island	1
South Carolina	1
Tennessee	2
Texas	8
Utah	2
Virginia	1
West Virginia	1
Wisconsin	1
Total U.S.	70

Source: Food and Drug Administration

The Ethylene Oxide Panel

The Ethylene Oxide Panel of the American Chemistry Council (ACC) is a leading source of product stewardship and regulatory information on ethylene oxide. The panel was created to promote the principles of Responsible Care® with respect to the safe handling and use of ethylene oxide. The Panel is actively involved in communicating on advocacy issues, current research, as well as educating government agencies and the public on health, safety and environmental issues arising from the production, use, storage, transportation and disposal of ethylene oxide.

Economics and Statistics Department

The Economics & Statistics Department provides a full range of statistical and economic advice and services for ACC and its members and other partners. The group works to improve overall ACC advocacy impact by providing statistics on American Chemistry as well as preparing information about the economic value and contributions of American Chemistry to our economy and society. They function as an in-house consultant, providing survey, economic analysis and other statistical expertise, as well as monitoring business conditions and changing industry dynamics. The group also offers extensive industry knowledge, a network of leading academic organizations and think tanks, and a dedication to making analysis relevant and comprehensible to a wide audience. Dr. Swift and Ms. Moore were the primary authors of this report.

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