

PRODUCT PROFILE

Ethylene Oxide: A Techno-Commercial Profile

Ethylene oxide (EO) is a versatile intermediate used in the production of surfactants and other derivatives such as glycol ethers, polyethylene glycol, polyether polyols, dye intermediates, drug intermediates and ethanolamines. EO is produced by oxidation of ethylene. In India, cracking of naphtha/ natural gas fractions produces the bulk of ethylene. A small quantity of ethylene is also produced through the alcohol route, from ethyl alcohol.

EO is a highly reactive chemical due to the ease of opening of its highly strained three-membered ring, the bond being weaker than ether and the molecule less stable. It is a colourless gas at room temperature, turns liquid below 12°C, soluble in organic solvents and miscible with water in all proportions. It is highly flammable, with a flammable limit in air of 3-100%, toxic, irritating to skin and eyes with tolerance limit of 10-ppm in air. The Indian Standard, as adopted by Bureau of Indian Standards (BIS), for ethylene oxide is IS-5573-1984 and the code of safety is IS-6269-1971.

EO is used in the production of ethylene glycol, surfactants, acrylonitrile, ethanolamines, petroleum demulsifiers, fumigants, rocket propellants, industrial sterilants, polymer modifiers and pesticides.

Ethylene glycol

Monoethylene glycol (MEG) (at times referred to as ethylene glycol), diethylene glycol (DEG) and triethylene glycol (TEG) are clear, colourless syrupy liquids with sweet taste. They are hygroscopic and relatively non-volatile, soluble in water, alcohol and acetone. They are combustible, with auto-ignition temperature ranging

between 228°C to 412°C. Glycols are toxic by ingestion and inhalation with lethal dose reported to be 100-cc and tolerance limit of about 50-ppm in air.

The BIS standard for MEG is IS 5295-1985 and for DEG is IS:7918-1975. There is no standard for TEG.

MEG is used in the manufacture of polyester fibre and film, asphalt-emulsion paints, heat transfer agents, low pressure laminates, brake fluids, low freezing dynamites, solvents, cosmetics, alkyd resins, textiles, ballpoint pens, foam stabilizers, as an ingredient in processing tobacco, in deicing fluid for airport runways, as a substitute for glycerine in explosive manufacture etc.

DEG and TEG are used in the manufacture of unsaturated polyester resins, textile softeners, plasticisers etc.

Process of manufacture Ethylene oxide

EO is produced from polyethylene grade ethylene. The latter is produced from feedstock like natural gas fractions, naphtha and ethyl alcohol. The modern EO manufacturing process is based on a patent of T.E. Lefort using silver based catalyst and oxygen or air as oxidant at 15-30 Kg/cm²g pressure and 200-300°C temperature.

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The process of manufacture of ethylene oxide consists of four steps.

1. Vapour phase reactions of ethylene and oxygen/air in the presence of silver catalyst at elevated temperature and pressure;
2. EO recovery by absorption in water;
3. EO purification by stripping; and
4. Carbon dioxide removal by absorption in hot potassium carbonate solution, followed by desorption and recovery of carbon dioxide.

Pure polythene grade ethylene (99.9% vol.) and oxygen (99.8% vol.) are mixed using a special mixing device and taken in the reactor at elevated temperature and pressure. The reactor tubes are filled with Ag-based catalyst having selectivity close to 80%. The conversion per pass is low (9-13 mol). A large quantity of gas is recycled back after separating the same from EO produced and after stripping carbon dioxide. This EO undergoes further purification.

Relatively impure EO, along with water used for EO stripping, is taken to an ethylene glycol reactor. For cooling the EO reactor, boiling water, kerosene or mobiltherm is used as a coolant.

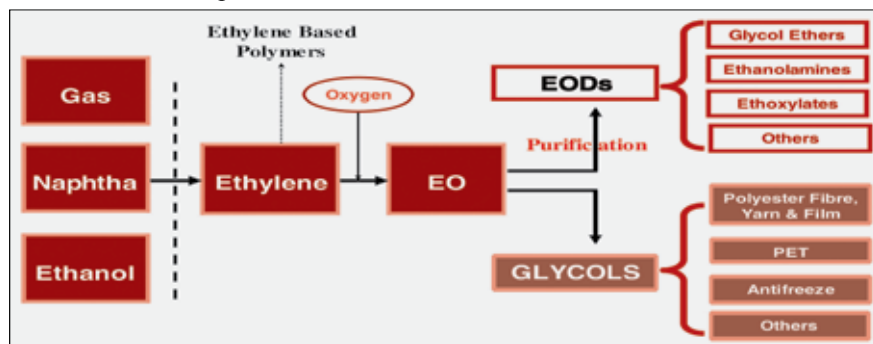


Figure 1: Ethylene oxide manufacture and use

Steam generated in the EO process is used in ethylene glycol plant and also for driving various drives. For the above reasons, ethylene oxide and ethylene glycol plants are integrated.

Ethylene glycol

Commercially ethylene glycol or monoethylene glycol (MEG) is produced by non-catalytic hydration of EO and water (process-condensate) at elevated temperature and pressure. The reaction is exothermic and is carried out in pipeline or baffled column reactor. During MEG manufacture, small quantities of DEG and TEG are produced, besides some polyglycols.

The process of manufacture of the main product MEG consists of three steps.

1. EO reaction with water to form ethylene glycol;
2. Ethylene glycol dewatering; and
3. Ethylene glycol purification to separate MEG, DEG, TEG and other heavier glycols.

EO and pure water are taken into a reactor. The reactor is either a pipeline or a baffled column. EO hydration reaction is non-catalytic and effected at higher temperature and pressure. The conversion is reported to be above 95%. Ethylene glycol so produced is dewatered in multiple-effect evaporators, using steam (from EO plant) as the heating medium. Ethylene glycol so produced is purified in purification columns to separate mono-, di- and triethylene glycols, meeting the product specifications.

For an identical capacity, oxygen-based EO plant is reported to be less capital intensive. Most of the modern plants for EO are based on oxygen as oxidant.

Commercial processes

The main suppliers of EO and glycol technologies include:

1. Dow which offers its *Meteor* (Most effective technology for ethylene oxide reactions) EO/MEG process;
2. Scientific Design Company (acquired jointly by Saudi Basic Industries Corporation, Sabic and Sud-Chemie in 2003) developed its EO/MEG process and started manufacture of EO catalysts in the 1950s. Scientific Design is a major licensor of EO/EG technology;
3. Shell Global Solutions, which offers two processes for the production of EO/MEG – the *Master* and the *Omega* processes.

Applications of EO derivatives

Textile processing

Ethoxylates are used at various stages of textile processing as such or in various formulations. The products used include:

- Alkyl phenol ethoxylates (wetting & scouring);
- Fatty alcohol ethoxylates (scouring);
- Castor oil ethoxylates (dye levelling agents);
- Polyethylene glycols (lubricating additives); and
- Fatty amine ethoxylates (printing & dyeing, also as wetting agent).

Agrochemicals

Ethoxylates are used to formulate emulsifiers, which are required in pesticide formulations, such as emulsifiable concentrates (EC), as well as eco-friendly ones such as water dispersible powders (WDP), suspension concentrates (SC) etc.

The range of ethoxylates used is also broad and includes:

- Alkyl phenol ethoxylates
- Castor oil ethoxylates
- Decyl alcohol ethoxylates; and
- Styrenated phenol ethoxylates

Paints & coatings

Mainly alkyl phenol ethoxylates based products are used as emulsifiers in products whose shelf-life is critical.

Paper

The range of products based on EO which are used include:

- Polyethylene glycols (anti-curling agents, softening agents);
- Lauryl alcohol ethoxylates (resin removal from wood pulp); and
- Alkylphenol ethoxylates (deinking).

Personal care

Products based on EO used in the personal care industry include:

- Polyethylene glycols as stable solubiliser and for moisture balance (in oral care);
- Fatty alcohol ethoxylates used as cream base (skin care); and
- Hydrogenated castor oil ethoxylates (solubiliser).

Detergents

Fatty alcohol ethoxylates are used in detergents as such or as blends with other anionic/nonionic surfactant systems.

Automotive

Polyethylene glycols are used as brake fluids in the automotive industry.

Pharmaceuticals

Polyethylene glycols are used in ointment and in syrups as bases.

Global supply scenario

Global EO capacity is estimated at 24.5-mtpa (2009) and capacity utilization

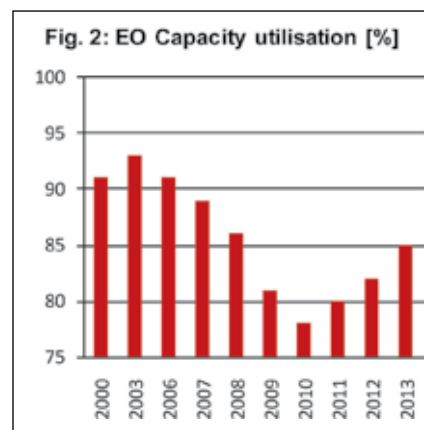


Table 1: Application of glycol ethers

Segment	Application
Automotive	Hydraulic brake fluids: major component (40-60%) due to its high boiling points & stability at high temperatures
Paints & coatings	Excellent solubilising properties aiding in slow & even drying of paints
Others	Printing inks, dye manufacture, perfumery industry etc.

Table 2: Application of ethanolamines

Segment	Application
Oil & gas and fertiliser	Treatment of natural and refinery gases to absorb carbon dioxide and hydrogen sulphide
Agrochemicals	Synthesis of glyphosate
Detergents & personal care	Production of surface active agents, which are used in detergents and personal care products such as ethanolamides, ethanolamine salts and ethanolamine soaps.
Others	As corrosion inhibitor in metal working and oilfield chemicals As intermediate in cement milling

tion approximately 82%, which implies a production of an estimated 20-mt.

Region-wise, Asia is the largest production centre with 47% of capacity, followed by the US (20%), Europe (18%) and Middle East and Africa (MEA) (15%). Capacity utilization was 91% in 2000, which increased to 93% in 2003, but started declining gradually to 86% in 2008 and to 82% in 2009. Significant capacity expansion is likely to take place during the 2009-2011 period, and much of this is likely to be absorbed for MEG production. This will serve to keep operating rates low.

Major producers

Shell, Dow, Shell, NanYa, Sinopec, BASF, Ineos, Honam and Reliance are the leading producers of EO globally. These top nine producers combined constitute 67% of total EO capacity.

Dow, BASF, Ineos and Shell are the major producers of refined EO.

Most of them are located in the US and Europe.

Global demand scenario

Glycols account for more than 74% of EO usage and EO capacities are primarily created to meet MEG demand. The balance 26% is consumed by derivatives of EO.

Global EO demand is understood to have expanded from 16.6-mt in 2004 to 20-mt in 2009, while demand for refined EO expanded from 4.64-mt in

Table 3: Major global producers of EO & refined EO

Producers	[Million tons]	
	EO	Refined EO
Sabir	4.4	
Dow/ME Global	3.2	1.2
Shell	1.9	0.5
NanYa	1.7	
Sinopec	1.4	0.3
BASF	1.2	0.7
Ineos	1.0	0.6
Honam	0.9	0.1
Reliance	0.7	0.1
Total [incl. others]	24.5	5.5

Table 4: World EO capacity by region

	[Million tons]		
	2005	2009	2013
N. America	5.5	5.5	5.1
S. America	0.4	0.4	0.5
Europe	4.0	4.2	3.5
ME & Africa	2.4	5.9	7.4
Asia	5.7	8.2	12.0
Total	18.0	24.2	28.5

2004 to 5.6-mt in 2008. In 2009, demand is estimated to have declined to about 5.2-mt.

Total EO demand registered a growth rate of 5.6% per annum during the period 2005 to 2009 and is projected to grow at 5.7% per annum during 2009 to 2013, thanks in part to improved availability.

Asian countries will be primarily responsible for the growth in demand for MEG and EO in coming years. Consequently, the growth in Asian markets will be a key factor governing demand growth rate worldwide. While the share of Asian demand for MEG may rise from 47% to nearly 70%, that of the US, which has come down from 28%

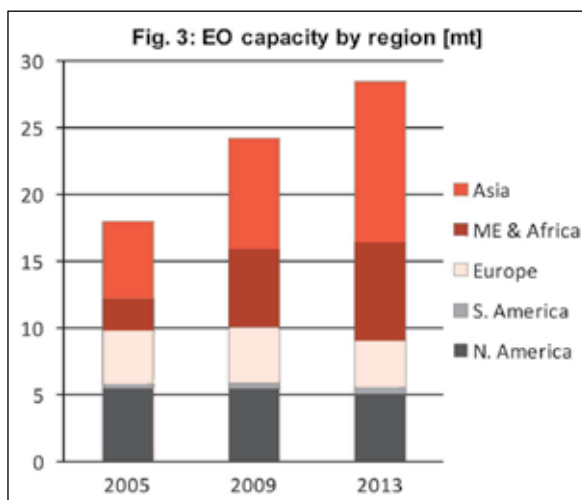


Table 5: Global supply and demand position for EO

	Capacity	Production	Demand [Million tons]	
			for glycols	for EODs
2007	22.6	20.0	14.4	5.6
2008	23.7	20.5	14.9	5.6
2009	24.5	20.0	14.8	5.2
2010	27.1	21.1	15.7	5.4
2011	27.8	22.3	16.6	5.8
2012	28.6	23.5	17.5	6.0
2013	29.0	24.5	18.2	6.3

2010 to 2013 data are estimates

to 20% in last two-three years due to closure of some units, may drop further.

Table 6: Growth in global EO demand by use

	2005 to 2009	2009 to 2013
Total EO	5.6	5.7
For glycols	6.0	5.8
For EODs	4.3	5.5

Global market outlook

EO based products will witness growth rate of nearly 6% p.a. – both in glycols and EODs. In view of high crude oil price scenario, there would be rationalization and shift of world EO consumption & production to regions blessed with cheaper feedstock in Middle East and East Asia. Much of this build-up in capacity will be aimed at providing MEG required for polyester. The Middle East will continue to remain as the supplier of choice, based on costs.

Surplus EO capacities in coming years will result in:

- Lowering of prices and reduction in operating rates;
- Collapse in MEG margins to 'bottom of cycle' economics; and
- Creation of new refined EO & derivatives capacities.

Thus, the Middle East, currently with no presence, can emerge as a major force in EODs. USA and Europe could also focus more on refined EO for EODs production, in view of better margins, and find it more viable to source MEG. Demand growth for EO will be highest in China and India in the coming years, because of better economic growth and improving lifestyles.

Indian supply scenario

In India, EO is produced by Reliance Industries Ltd (RIL), and India Glycols Ltd. (IGL). While RIL sells its entire refined EO produced in the merchant

market, IGL captively consumes all the refined EO produced for production of surfactants and glycol ethers.

The current effective capacity of EO is 830-ktpa, and that of refined EO is 180-ktpa.

Production of re-

Table 7: Global refined EO demand – product-wise

Sector	[Million tons]		
	2005	2009	2013
Ethoxylates & PEGs	2.5	2.6	3.0
Ethanol-amines	1.2	1.2	1.4
Glycol ethers	0.5	0.5	0.6
Others	0.5	0.9	1.2
Total demand	4.7	5.2	6.2

Table 8: EO derivative use - by segment

Sector	Demand share [%]
Agrochemicals	7
Oilfield chemicals	10
Detergents	25
Textile	35
Personal care	10
Pharmaceuticals	8
Others	5
Total [2009]	5.2-mt

finer EO has increased from 69-kt in 2001-02 to 103-kt in 2006-07 and to 120-kt in 2008-09, registering a annual compounded growth of 8.3%. Capacity utilization has been very low – the average capacity utilization during last six years has been 66% – due excess capacity over demand.

Indian consumption pattern

Glycols account for more than 85% of EO usage and capacities are primarily created to meet MEG demand. During 2003-04, MEG accounted for 88% of EO use, while in 2008-09 it accounted for 87%.

Consumption of refined EO increased from 65-kt in 2001-02 to 125-kt in 2008-09, registering an annual compounded growth of 9.7%.

Refined EO is used in making

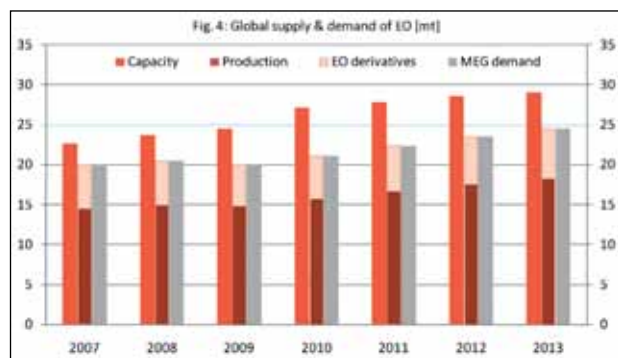


Table 9: EO capacity in India

	EO	Refined EO	[Kilotons] For MEG
Reliance Industries Ltd.	650	100	550
Indian Glycols Ltd.	180	80	100
Total	830	180	650

Table 10: Trend in production and capacity utilisation

Years	Capacity [ktpa]	Production [kt]	[Kilotons] Capacity Utilisation [%]
2001-02	97	69	71
2002-03	107	72	67
2003-04	112	71	63
2004-05	117	79	68
2005-06	140	88	63
2006-07	140	107	76
2007-08	140	117	84
2008-09	180	120	67

Table 11: Indian MEG demand – by use

Sector	2006	2009	2013	[Kilotons]
Polyester	825	942	1300	
PET resin	70	192	271	
PET film	60	91	133	
Others	45	35	51	
Total demand	1000	1260	1755	

Table 12: Refined EO demand in India – product-wise

Sector	Demand share [%]
Ethoxylates & PEGs	50
Ethanolamines	6
Glycol ethers & acetates	28
Vinyl sulphone	12
Others	4
Total demand [2009]	125-kt

ethoxylates, ethanolamines, glycol ethers and vinyl sulphone, besides some other smaller uses.

Table 13: Indian EO derivative use – by segment

Segment	Demand share [%]
Textiles	51
Brake fluids	12
Oil field chemicals	7
Pharmaceuticals	7
Personal care	4
Fertilisers	4
Agrochemicals	3
Detergents	1
Others	11
Total	100

These EO derivatives are used in variety of end-use segments covering agrochemicals, oilfield chemicals, textiles, detergents, pharmaceuticals, personal care products etc.

The textiles industry is the major consumer of EO derivatives, accounting for little over 50 per cent of derivatives produced. Initiation in the detergents is expected to take place in

the coming years, which can give a tremendous boost to demand for EO derivatives.

Demand forecast

During the period 2009 to 2013 growth in demand for EO derivatives is expected to be higher than in the past at 6.3% per annum.

Consequently, demand for refined EO is projected to go up from the current level of 125-kt to 160-kt in 2012-13. The existing capacity of 180-kt will be sufficient to meet this projected demand.

However, some additional EO capacity is being planned by petrochemical majors:

- Reliance Industries has plans for 50-ktpa EO plant at Jamnagar;
- Indian Oil Corporation (IOC), which is also setting up a naphtha cracker along with downstream products at Panipat, could also invest in refined EO capacity.

If these investments fructify, they would only exacerbate the already surplus capacity, leading to lower capacity utilization.

CONCLUSIONS

Overall growth for EO demand in India could reach around 10% per annum, as the economy moves into high gear. Industry segments that could drive growth are paints & coatings, automotive, detergents, textiles, personal care and oil exploration.

A new opportunity for the EO derivatives industry is outsourcing of derivatives. This will obviously hinge on competitive pricing of EO and other chemical raw materials.

REFERENCE

1. Presentation by India Glycols at 9th Asia Surfactants Conference, Shanghai, Sep. 2009.