

MJPhD

INTEGRATION: CRITICAL AT THE START OF
THE CHEMICAL INDUSTRY, *NOT SO MUCH*
Now....



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MJPHD, LLC

5 September 2023



EAST PALESTINE, OHIO



CO-PRODUCT PROCESSES



<https://www.youtube.com/watch?v=YYkj2yYaGtU>



WHAT I HOPE TO LEAVE YOU WITH

- Integration was crucial in the development of the chemical industry but has decreased in importance
- Inorganic chemistry created the chemical industry and remains important, but not particularly valued
- Scale remains the major source of competitive advantage in commodity chemicals

CHEMICAL INDUSTRY TECHNOLOGY WAVES

Inorganic

- mined materials
- electrochemical
- active reagents allow transformations

Functionalization

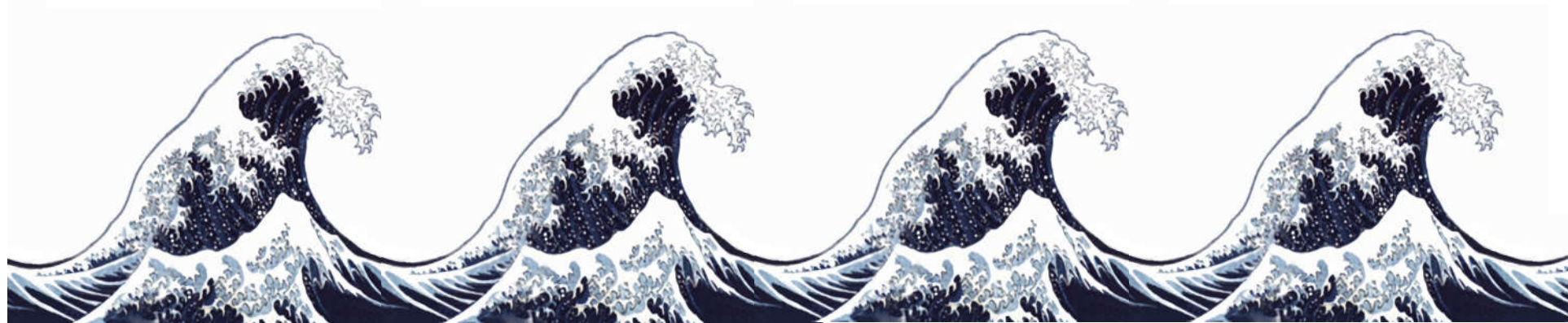
- use inorganics to transform organic substrates
- make dyes, solvents and drugs

Cellulosics

- use inorganics to transform natural materials
- partially synthetic polymers

Polymers

- took off with synthetic rubber
- continues today



1760-1910

rocks



1870-1930

coal
salt



1895-1935

biomass



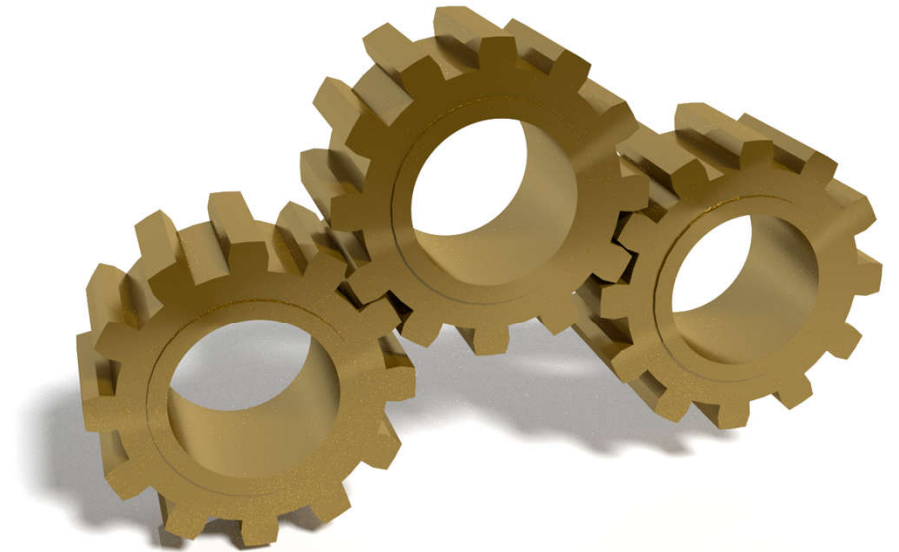
1925-present

petroleum
NGL

WHAT IS INTEGRATION?

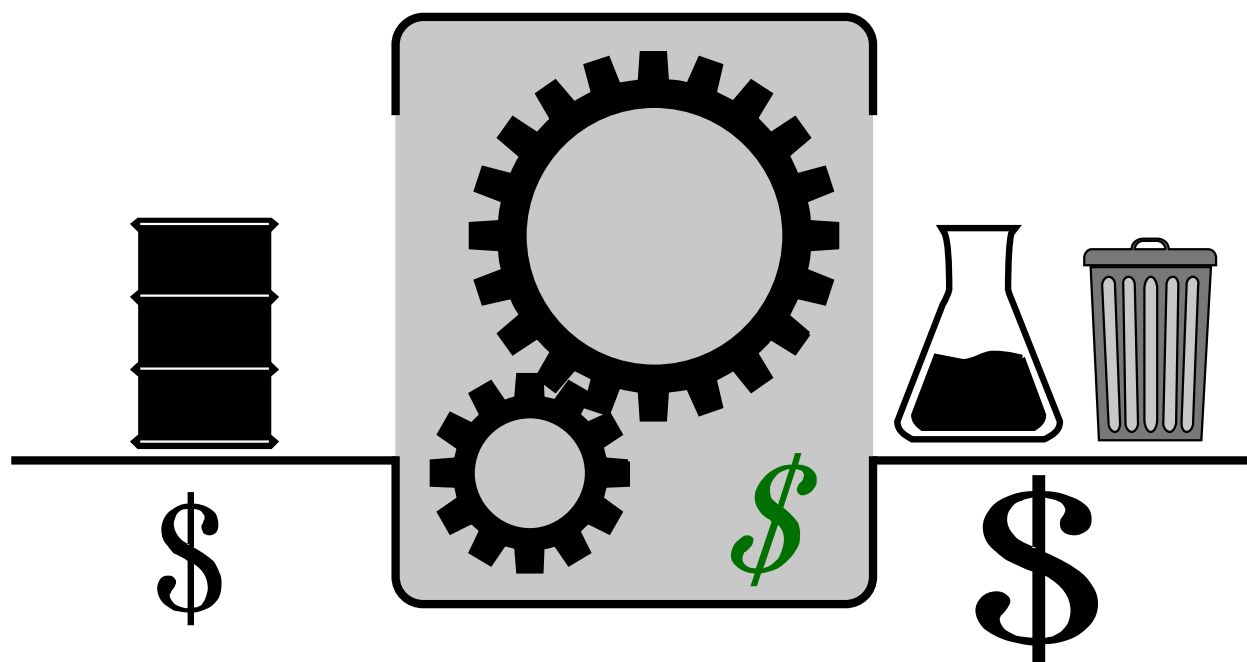


INTEGRATION



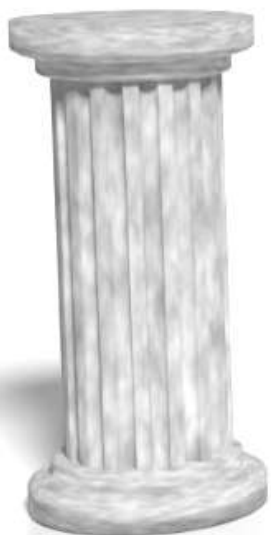
Linkage of mass and energy flows that create a significant advantage.

SIMPLIFIED CHEMICAL INDUSTRY



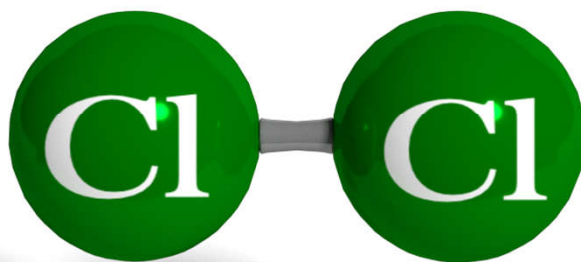
FOUNDATIONAL PILLARS OF THE MODERN CHEMICAL INDUSTRY

Electrochemical Chlor-Alkali



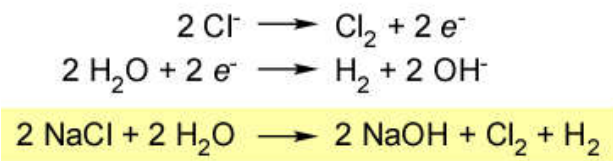
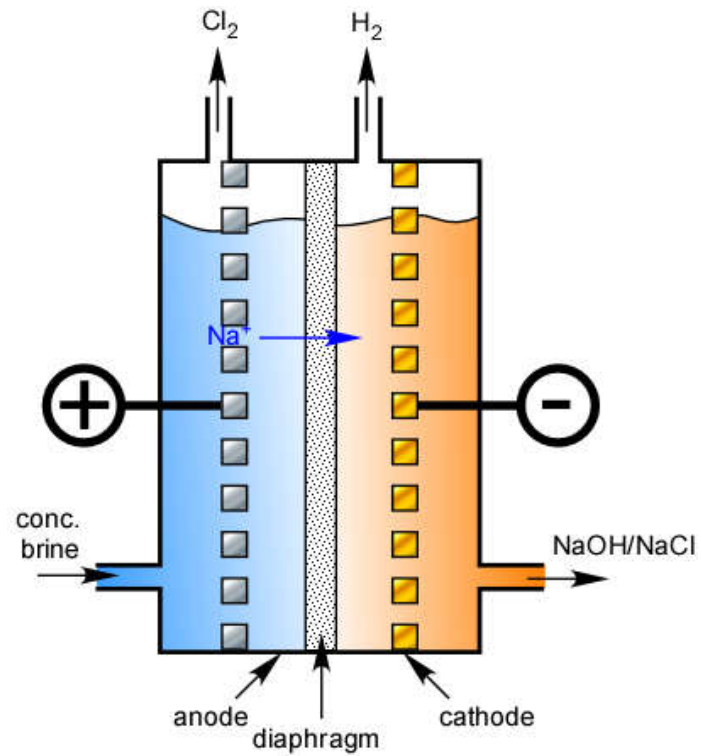
Steam Cracking





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CHLOR-ALKALI

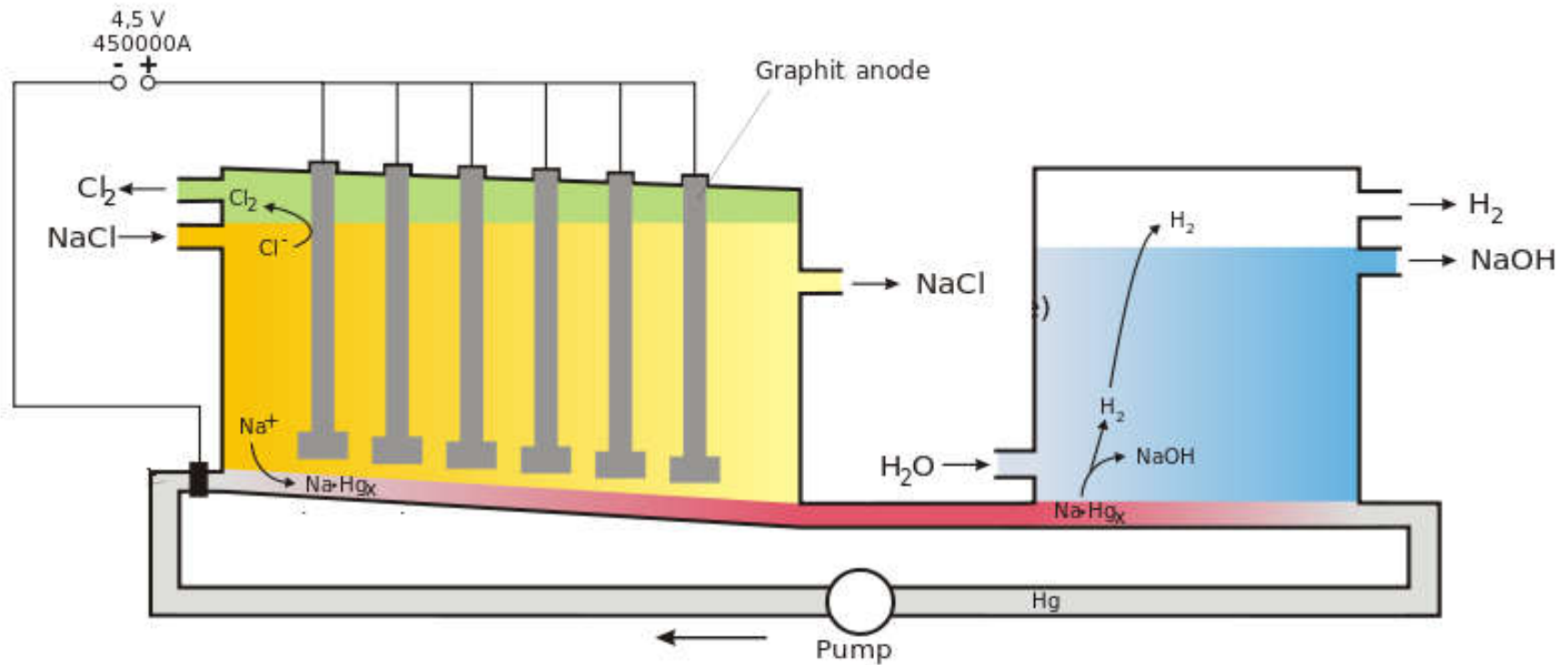


BLEACH WAS THE PRODUCT

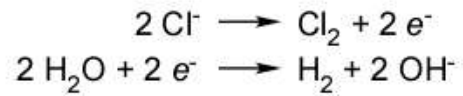
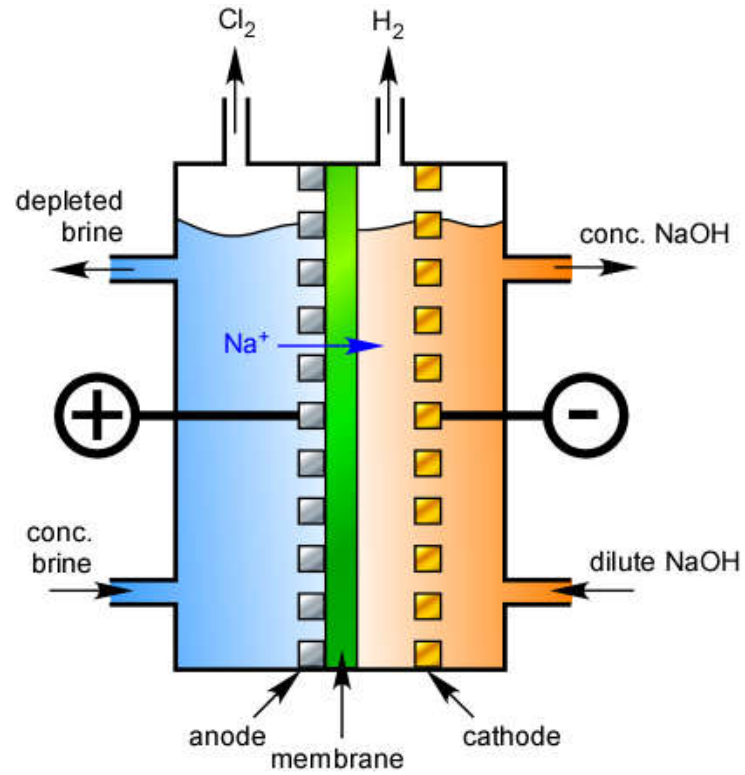


- The oxidizing power of chlorine was what was desired.
- *No net production of alkali*

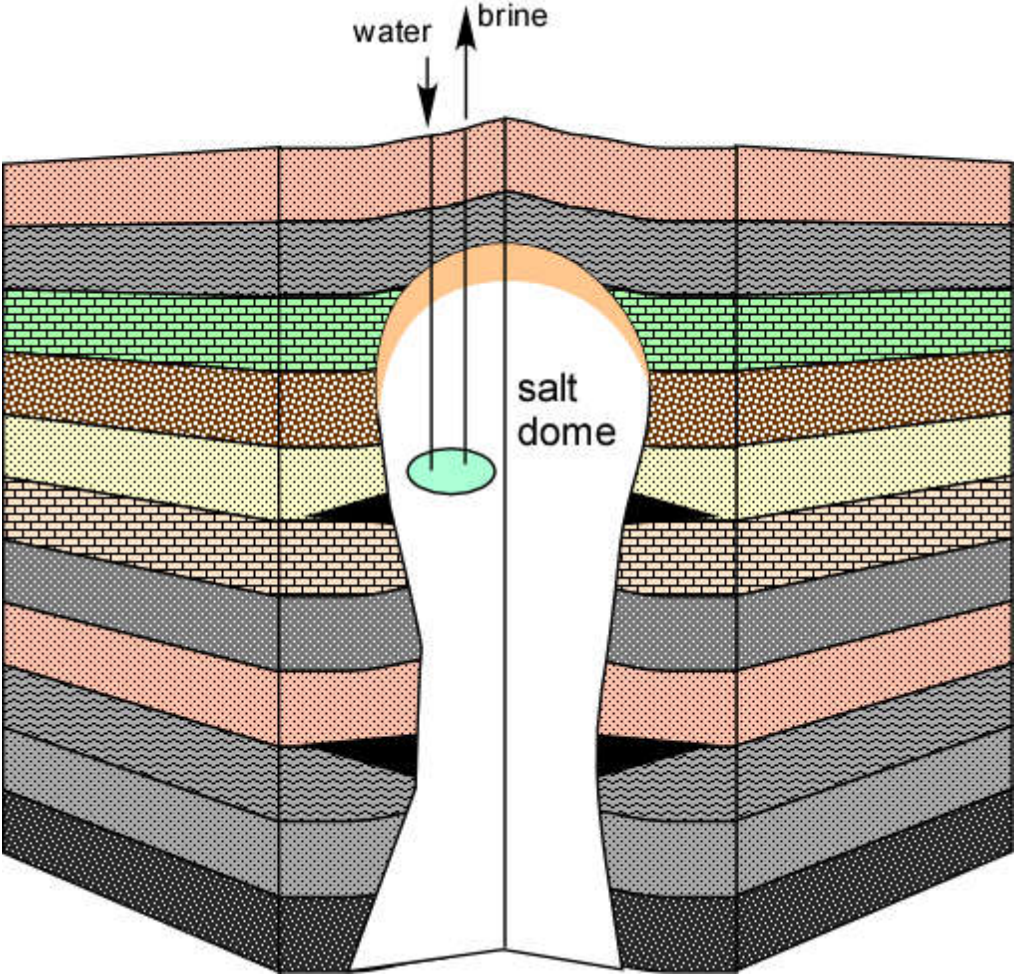
MERCURY CELLS



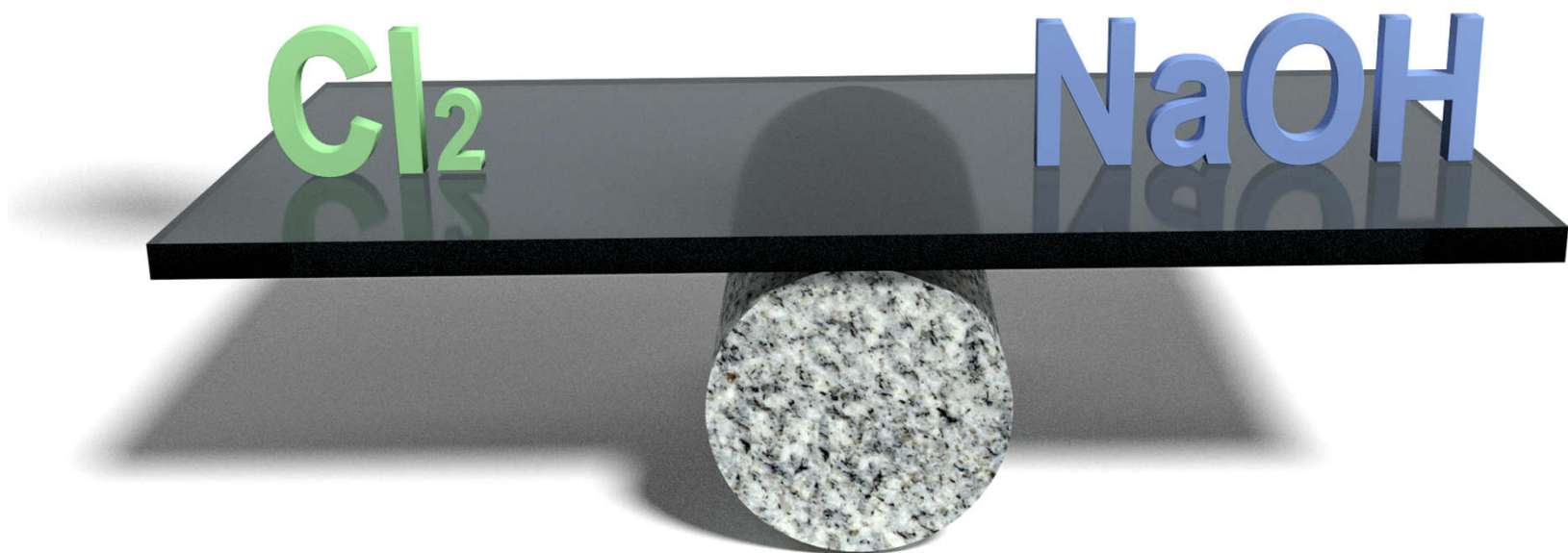
MEMBRANE CELLS



SOLUTION BRINE MINING - AN INVISIBLE MINE



BALANCING THE ECU

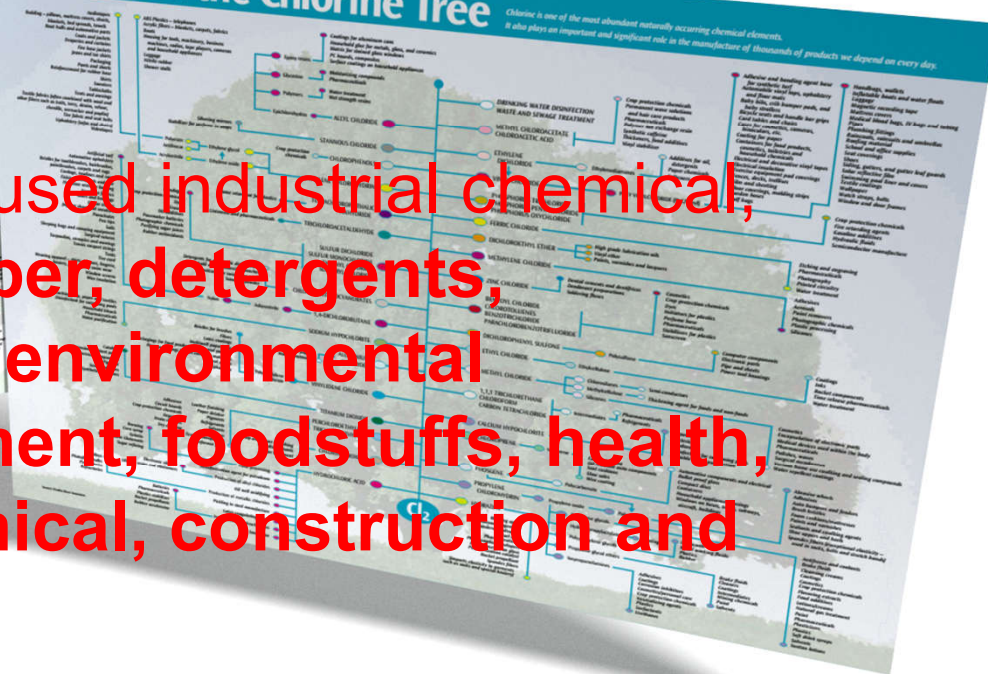


Caustic Soda Chemistry and End Product Uses



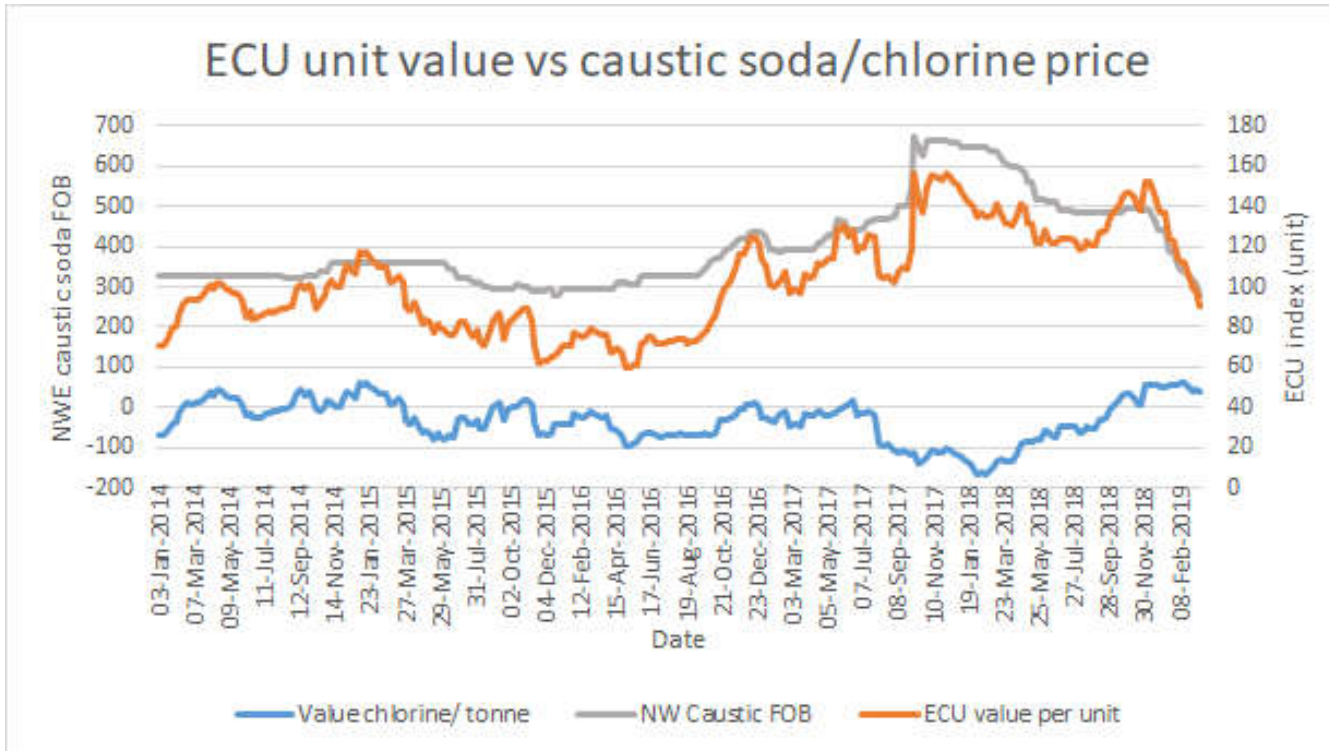
Products of the Chlorine Tree

Chlorine is one of the most abundant naturally occurring chemical elements. It also plays an important and significant role in the manufacture of thousands of products we depend on every day.



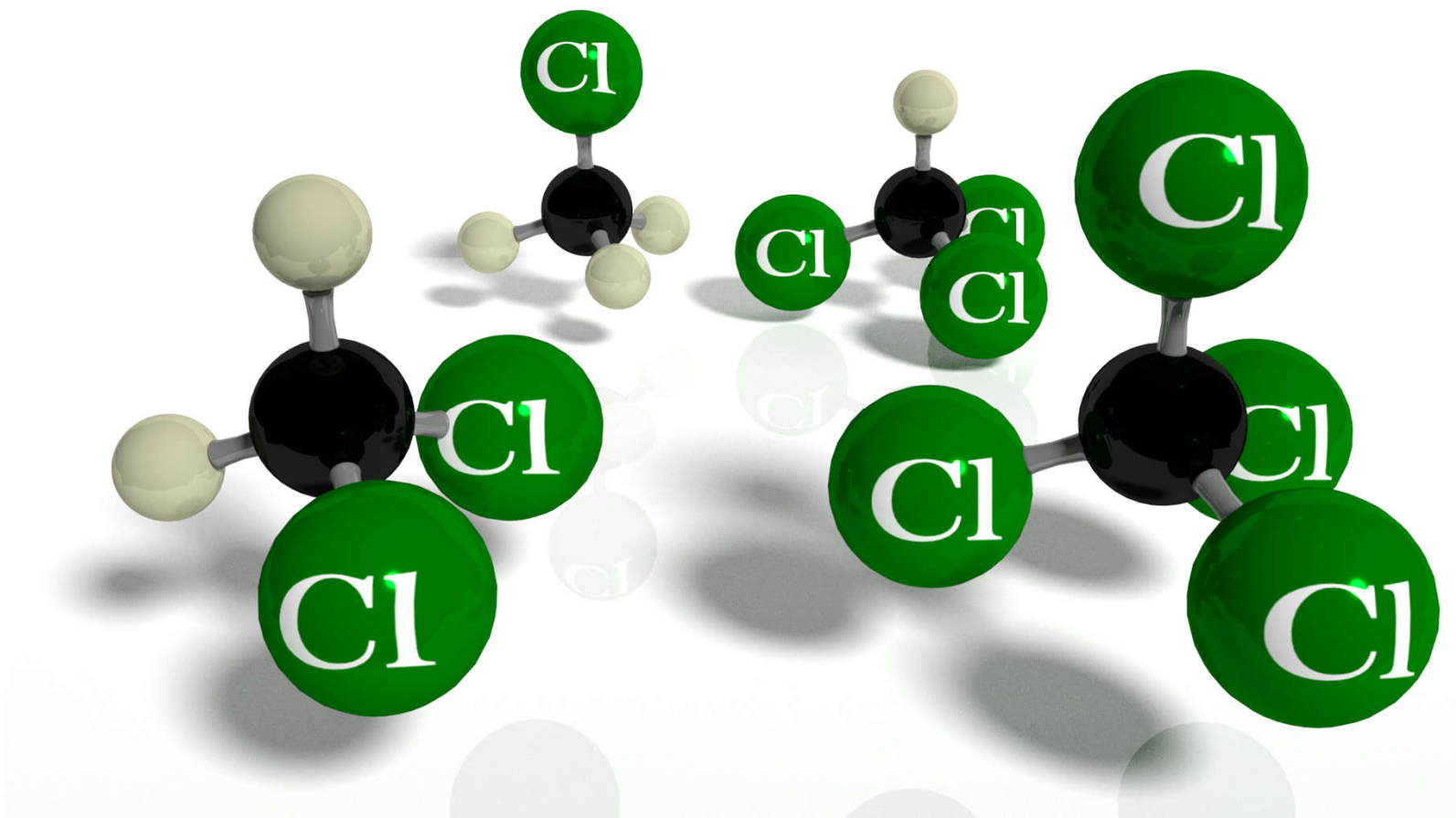
Caustic soda is a widely used industrial chemical, including in pulp and paper, detergents, packaging, agriculture, environmental protection, water treatment, foodstuffs, health, textiles and in the chemical, construction and car industries.

ECU PRICING



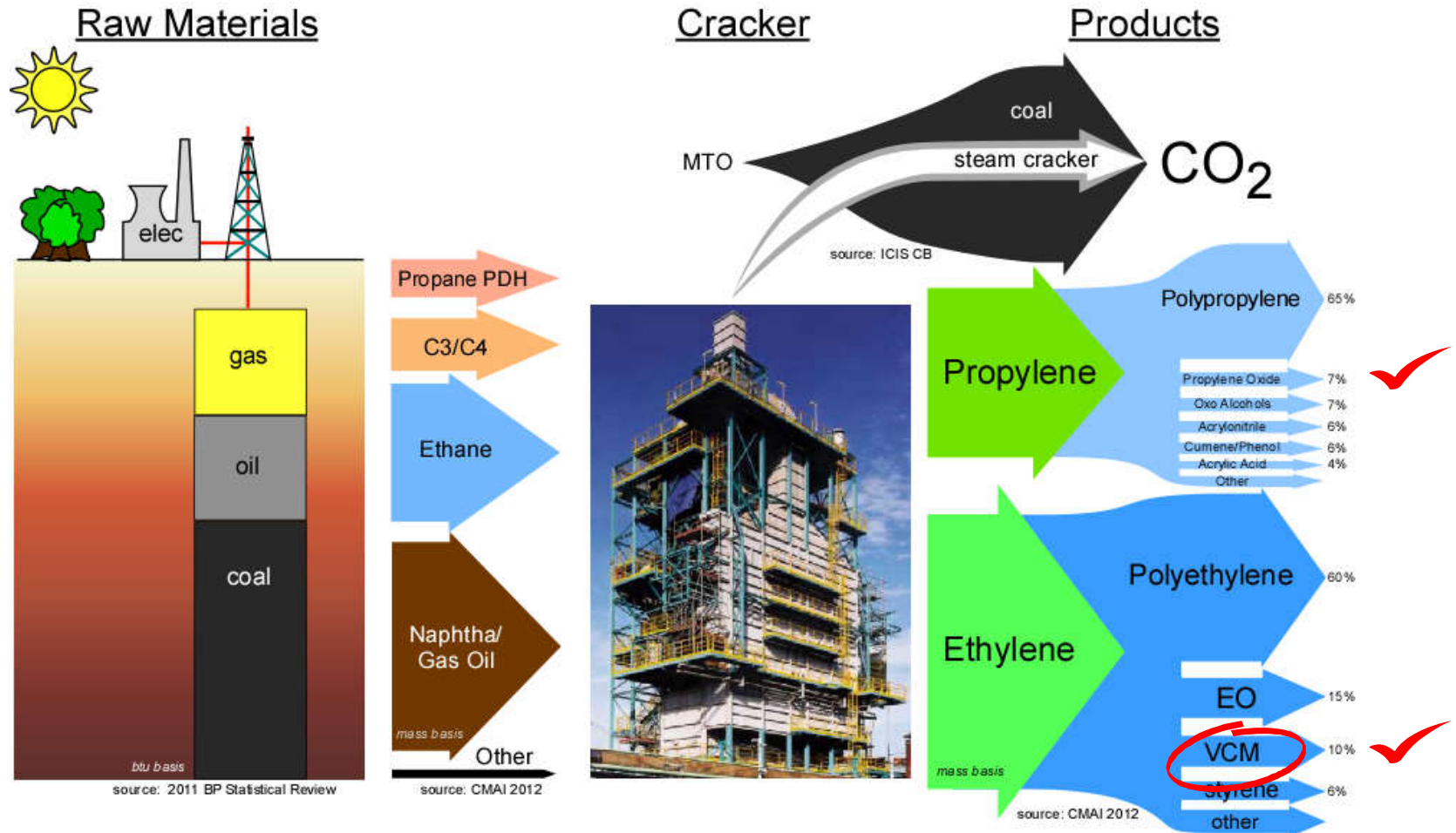
[ics.com/explore/resources/news/2019/03/21/10336962/insight-european-ecu-values-fall-to-the-lowest-level-since-2016/](https://www.ics.com/explore/resources/news/2019/03/21/10336962/insight-european-ecu-values-fall-to-the-lowest-level-since-2016/)

ORGANOCHLORIDES

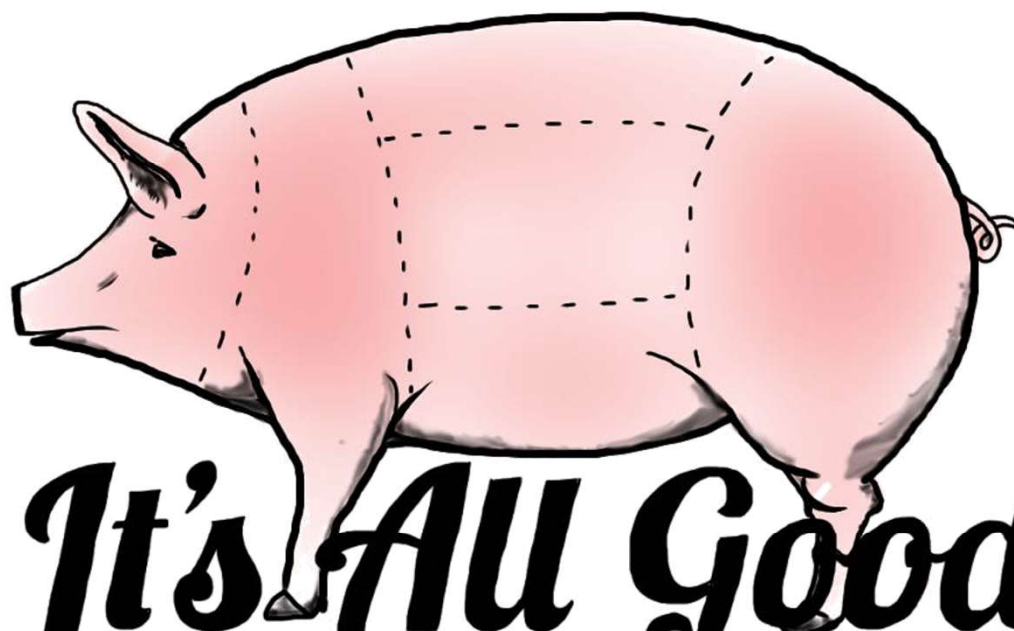




CHEMICAL INDUSTRY SNAPSHOT

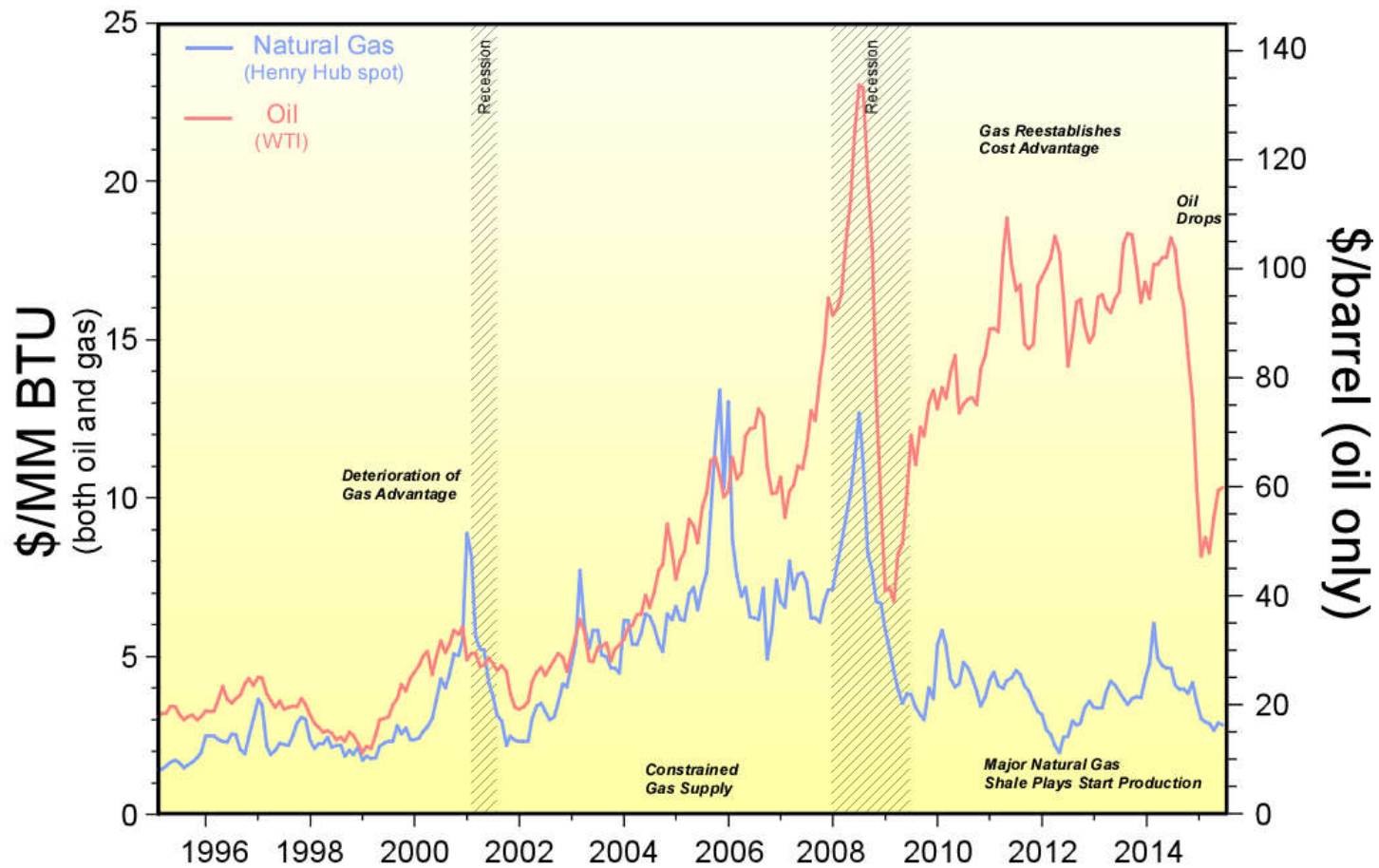


ALL REACTION PRODUCTS FIND USES

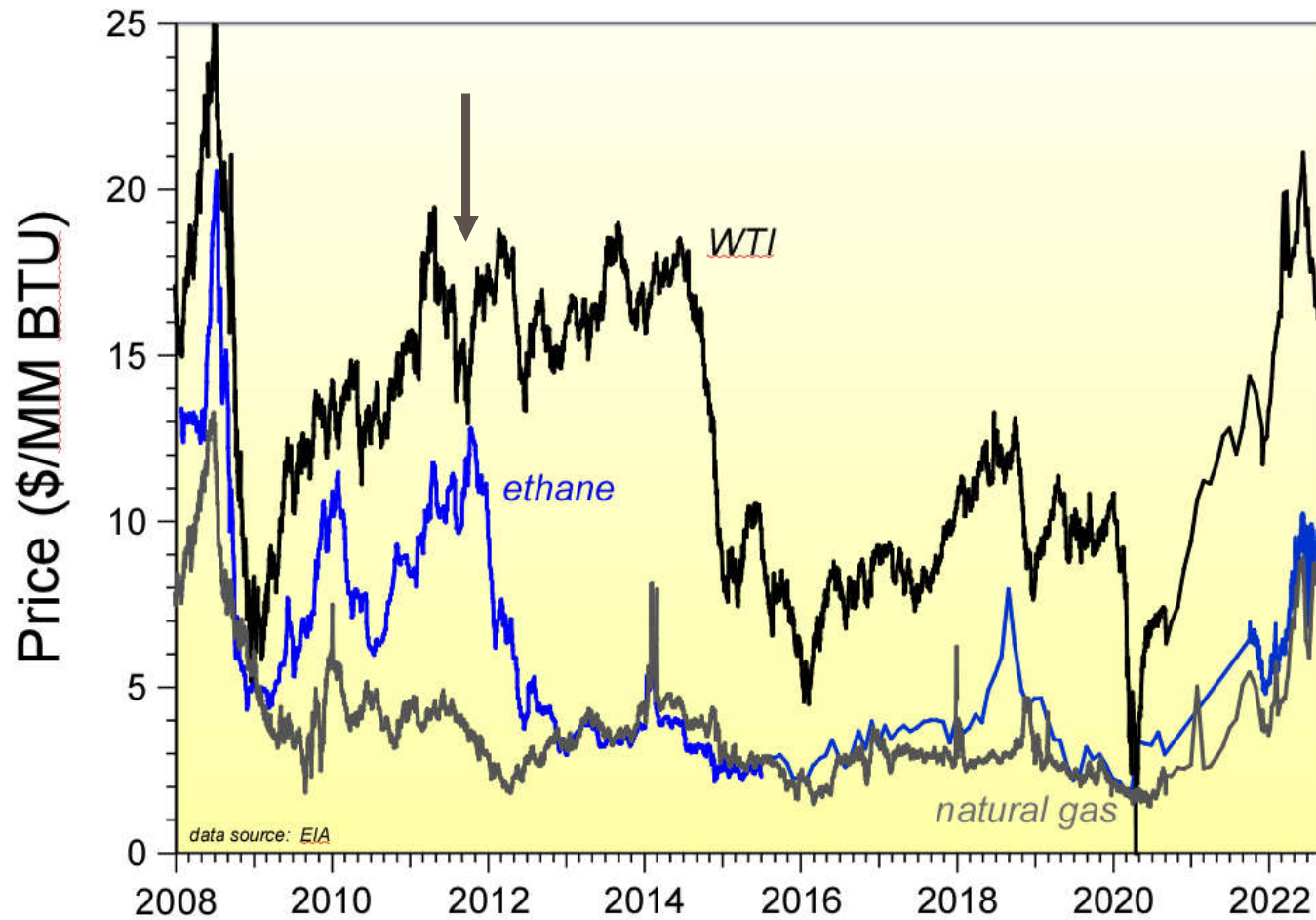


It's All Good!

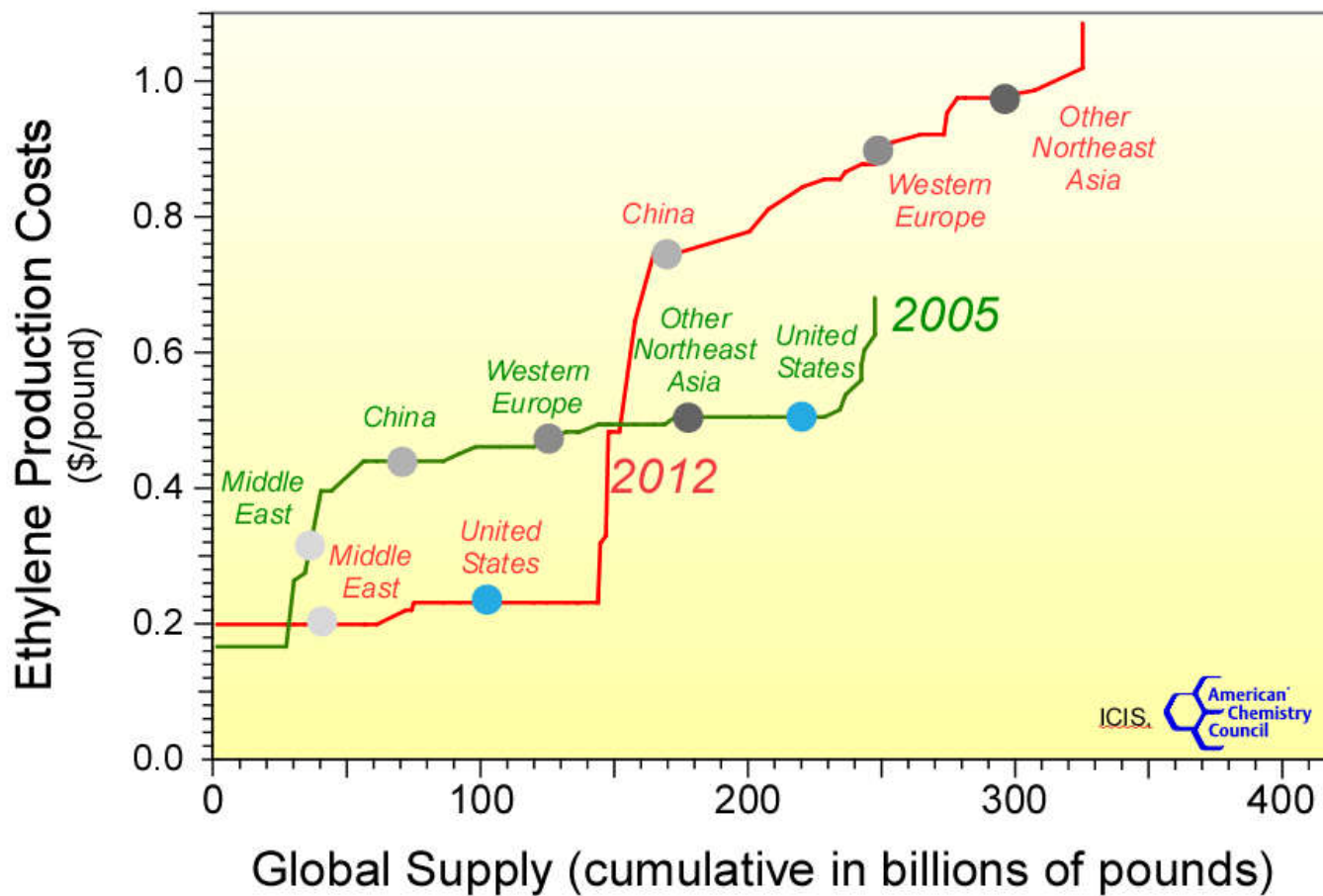
RECENT INDUSTRY HISTORY



ETHANE PRICE NOW TRACKS GAS

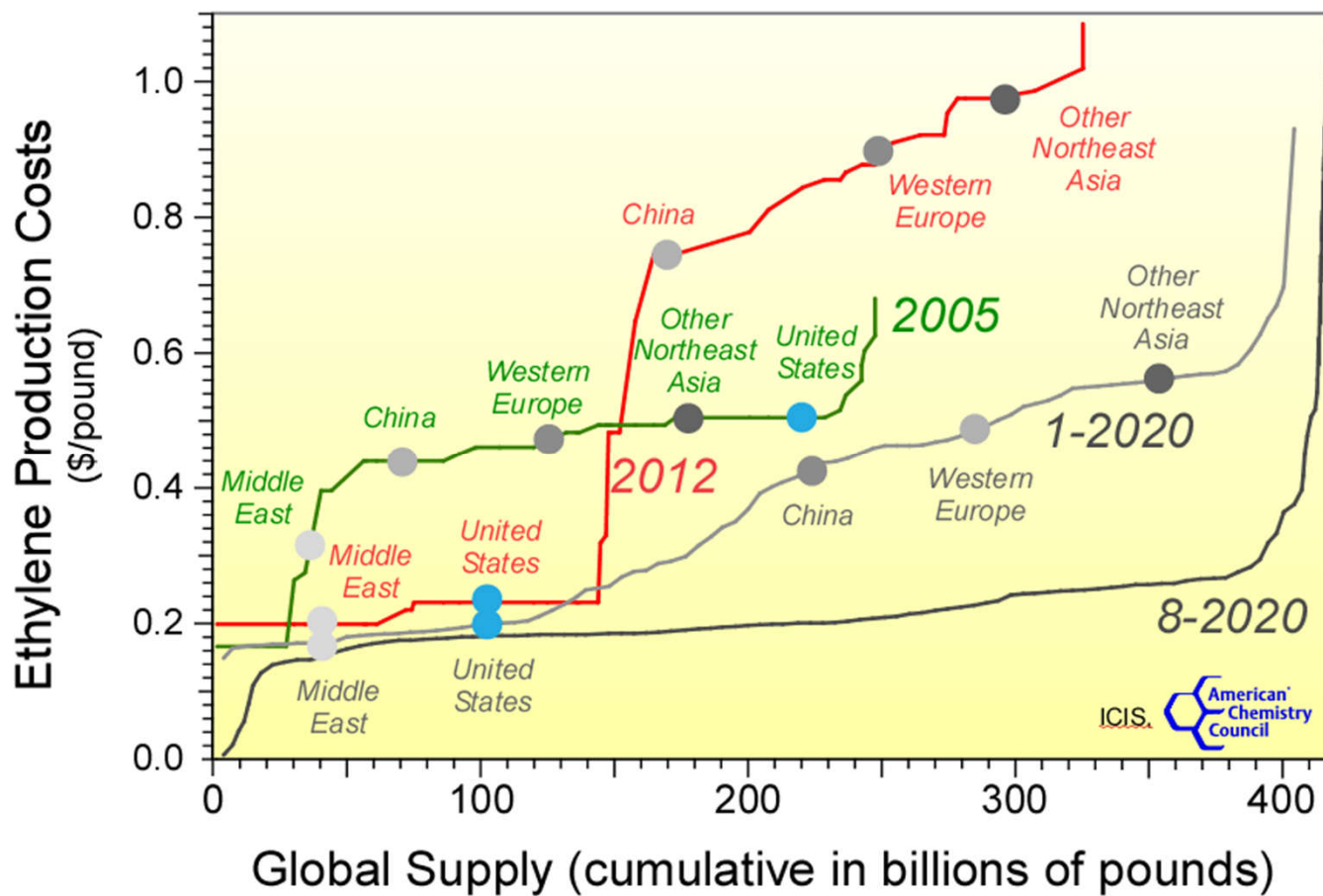


IMPACT OF LOW GAS PRICES

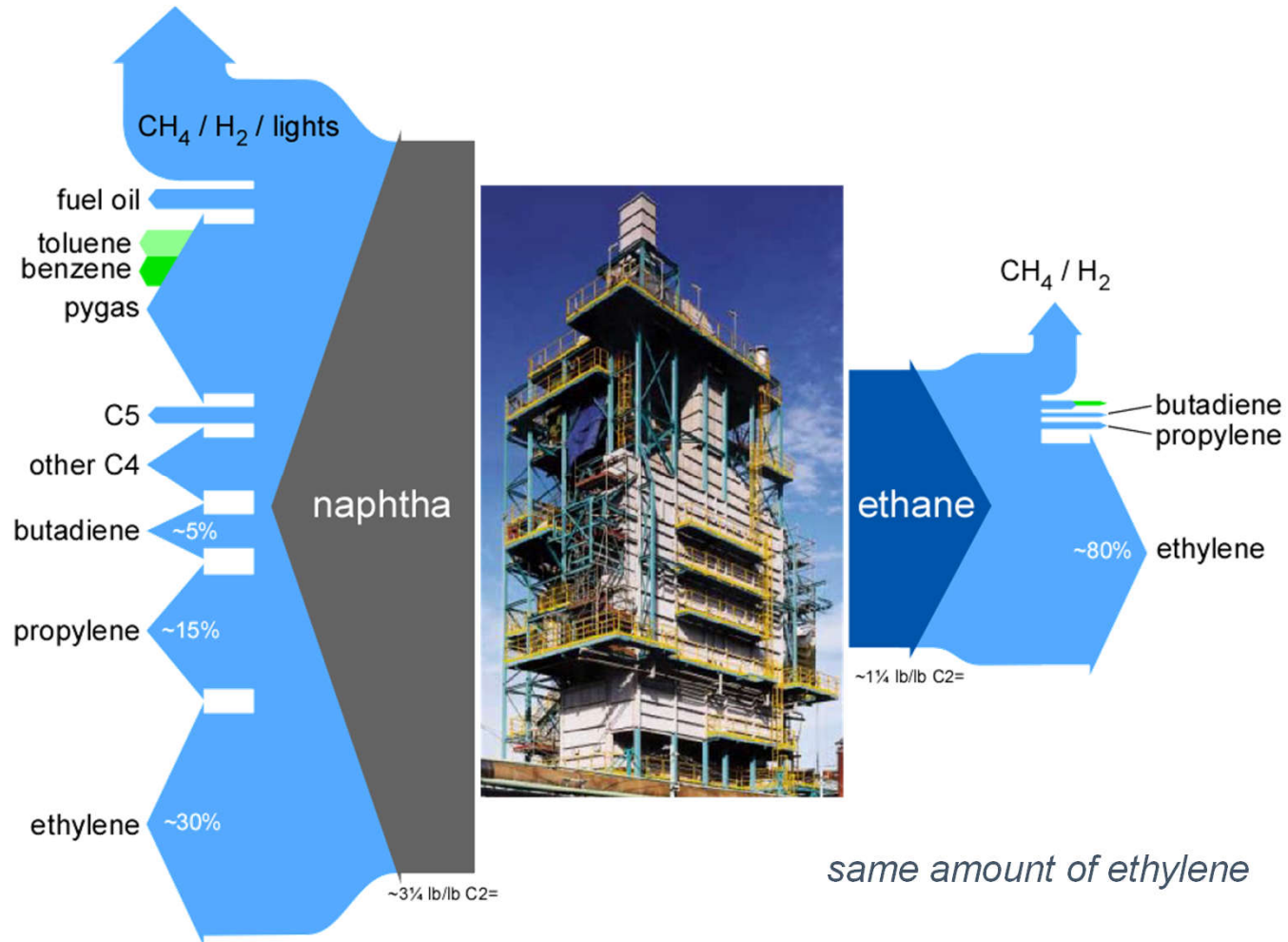


ICIS. American Chemistry Council

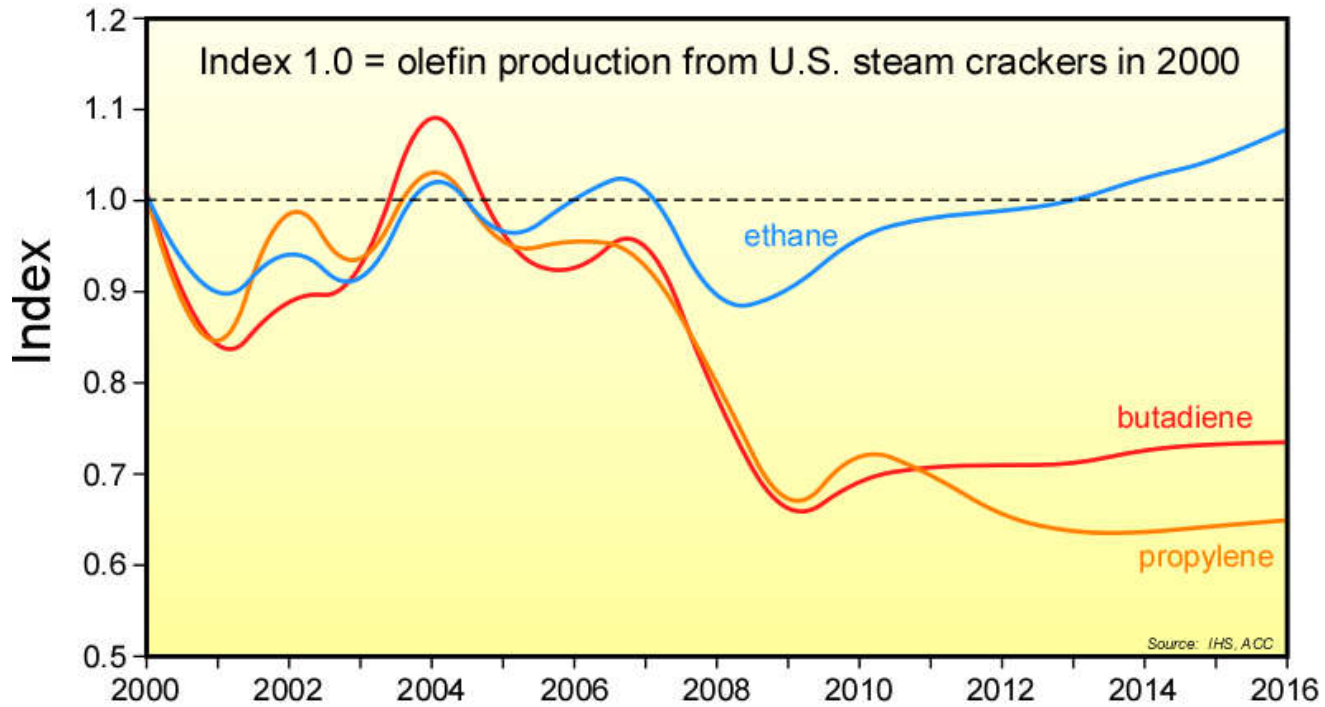
IMPACT OF LOW GAS PRICES



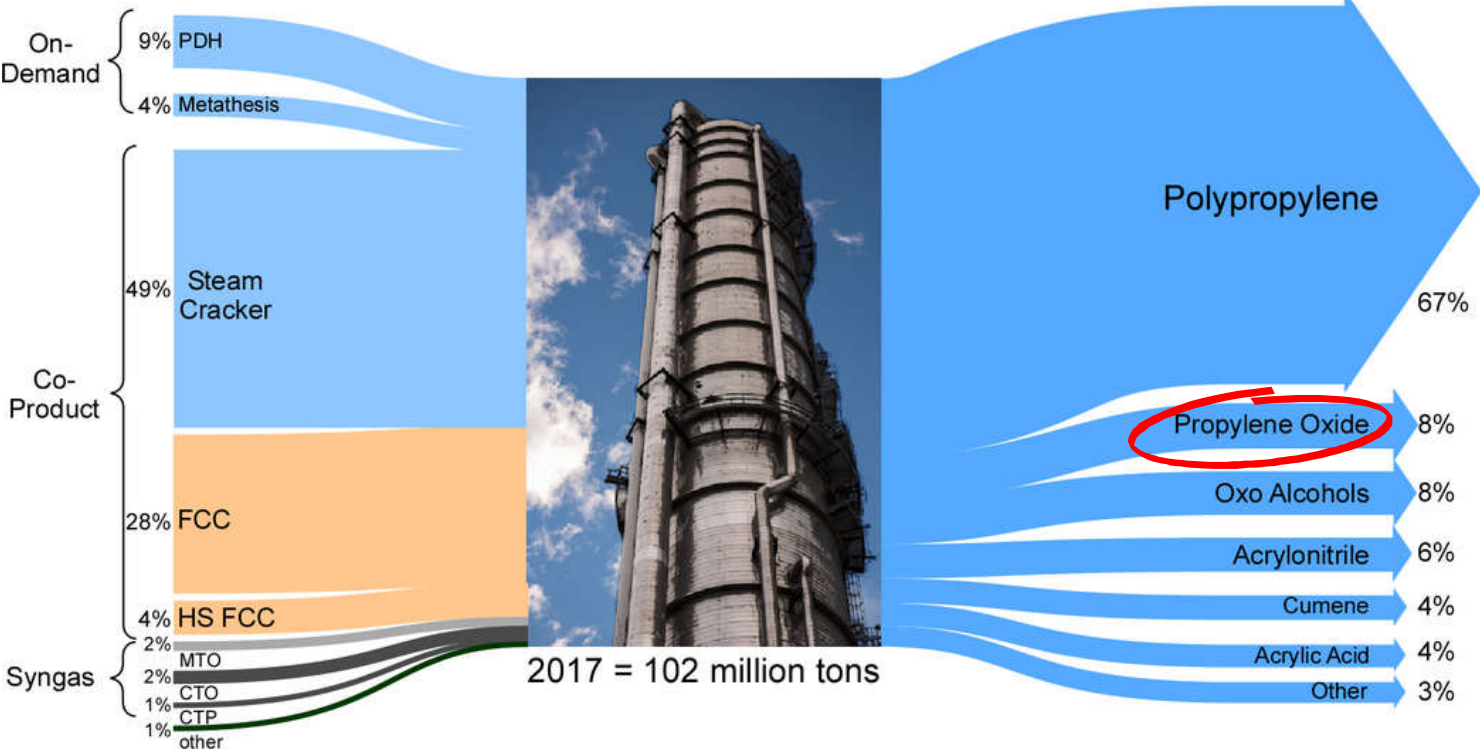
CRACKING COMPARISON



PRODUCTION OF C3/C4 DROPPED



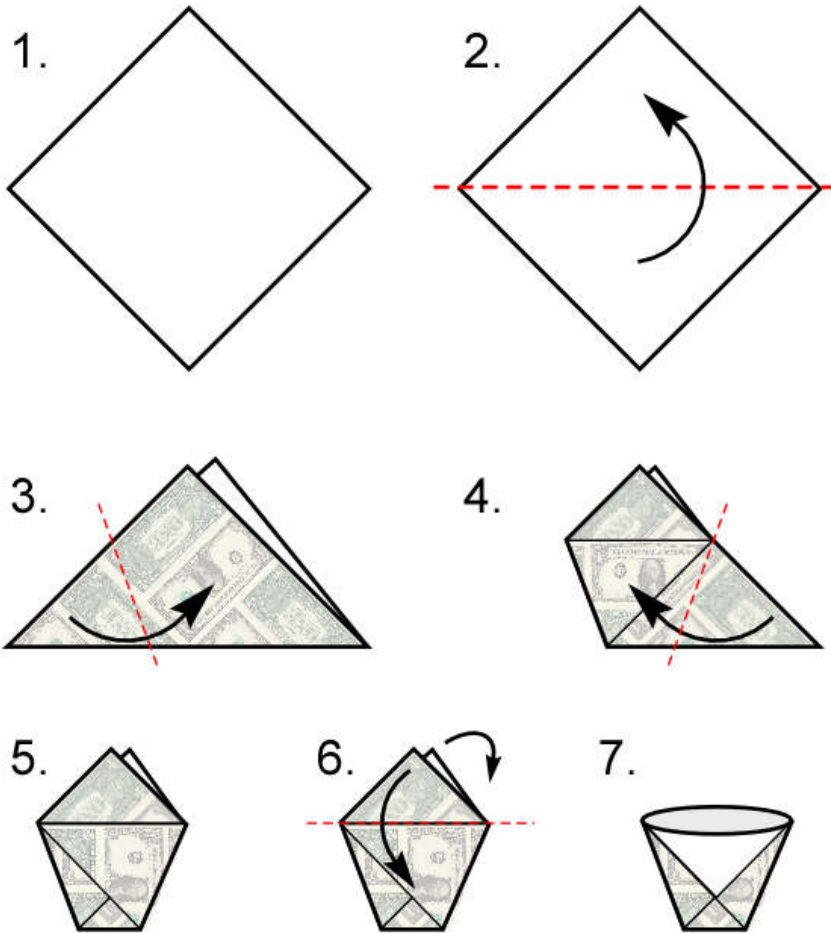
WORLD PROPYLENE



SCALE IS IMPORTANT



SCALE DEMO



Make a cup
with an $8\frac{1}{2}$ "
square and
another with a
 $4\frac{1}{4}$ " square

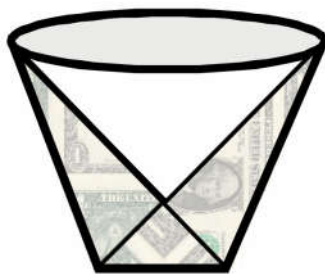
Origami Demo of Scale



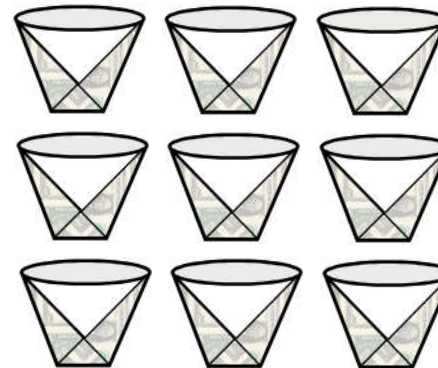
IMPACT OF SCALE TO CONTAIN SAME VOLUME



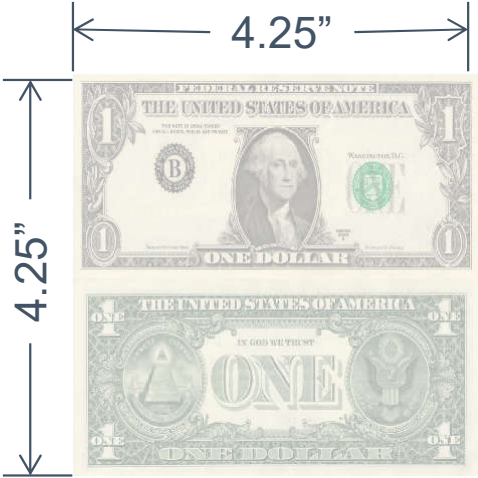
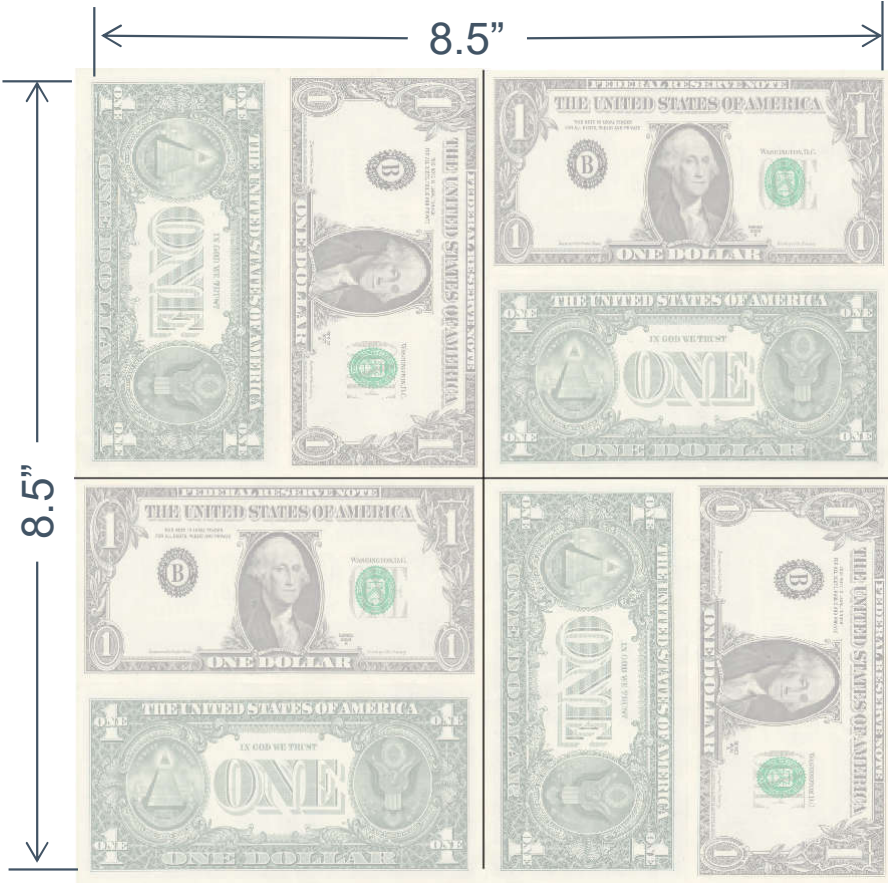
>2X material
~9X labor to construct



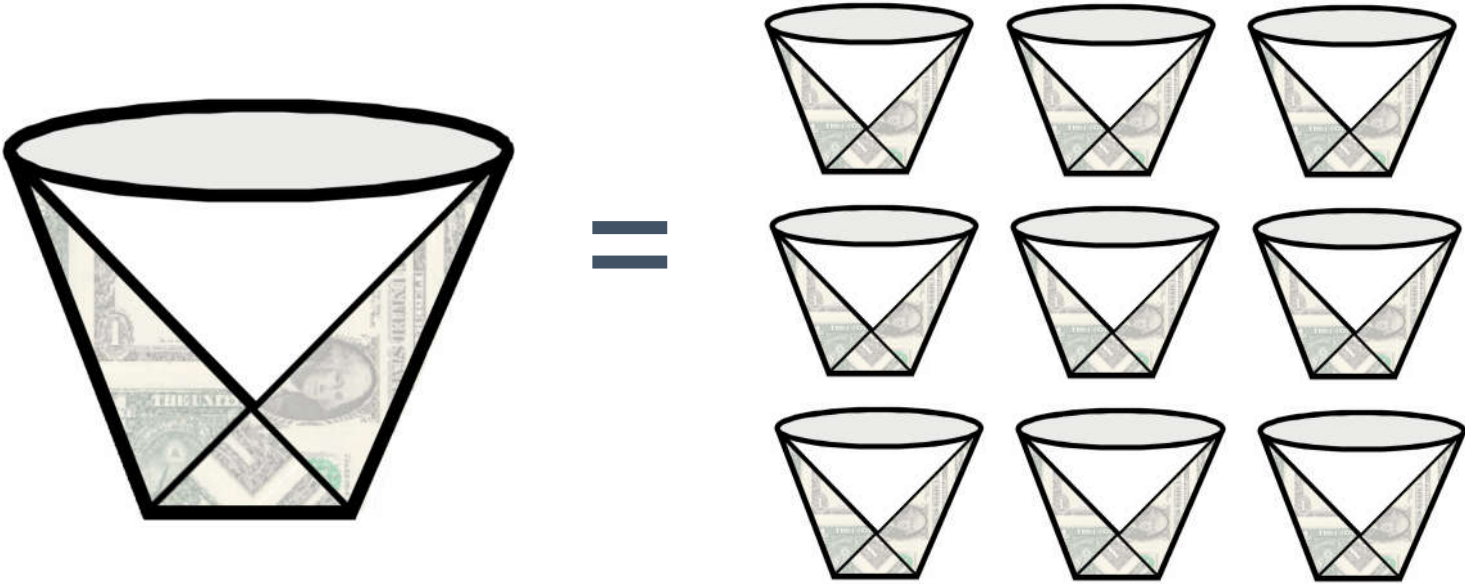
=



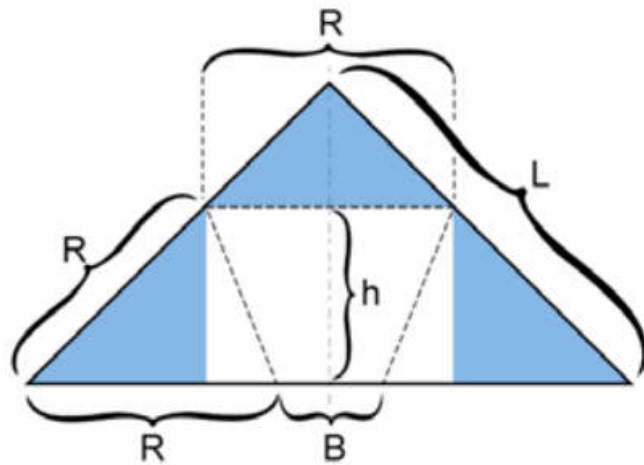
VIDEO DEMO



SCALE WINS



DEMO MATH



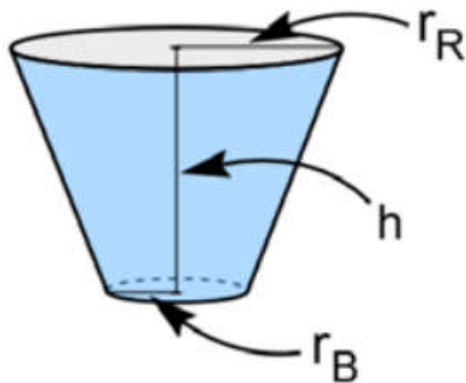
$$A = L^2$$

$$h = \frac{L}{1 + \sqrt{2}}$$

$$R = \frac{\sqrt{2} L}{1 + \sqrt{2}}$$

$$B = \frac{L(2 - \sqrt{2})}{1 + \sqrt{2}}$$

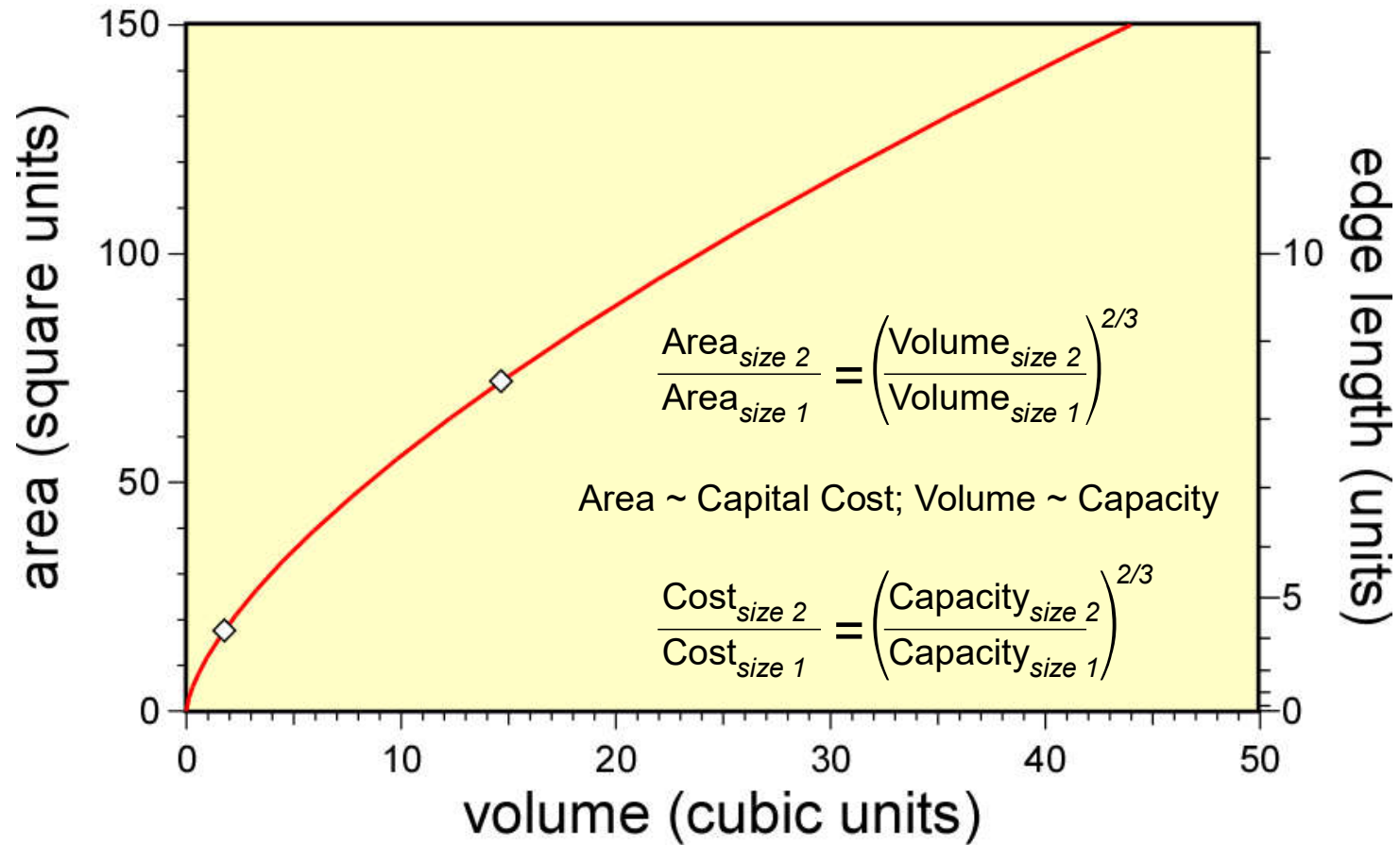
$$\frac{V_L}{V_{L/2}} = 8$$



$$r_B = \frac{B}{\pi} = \frac{L(2 - \sqrt{2})}{\pi(1 + \sqrt{2})}$$

$$r_R = \frac{R}{\pi} = \frac{\sqrt{2} L}{\pi(1 + \sqrt{2})}$$

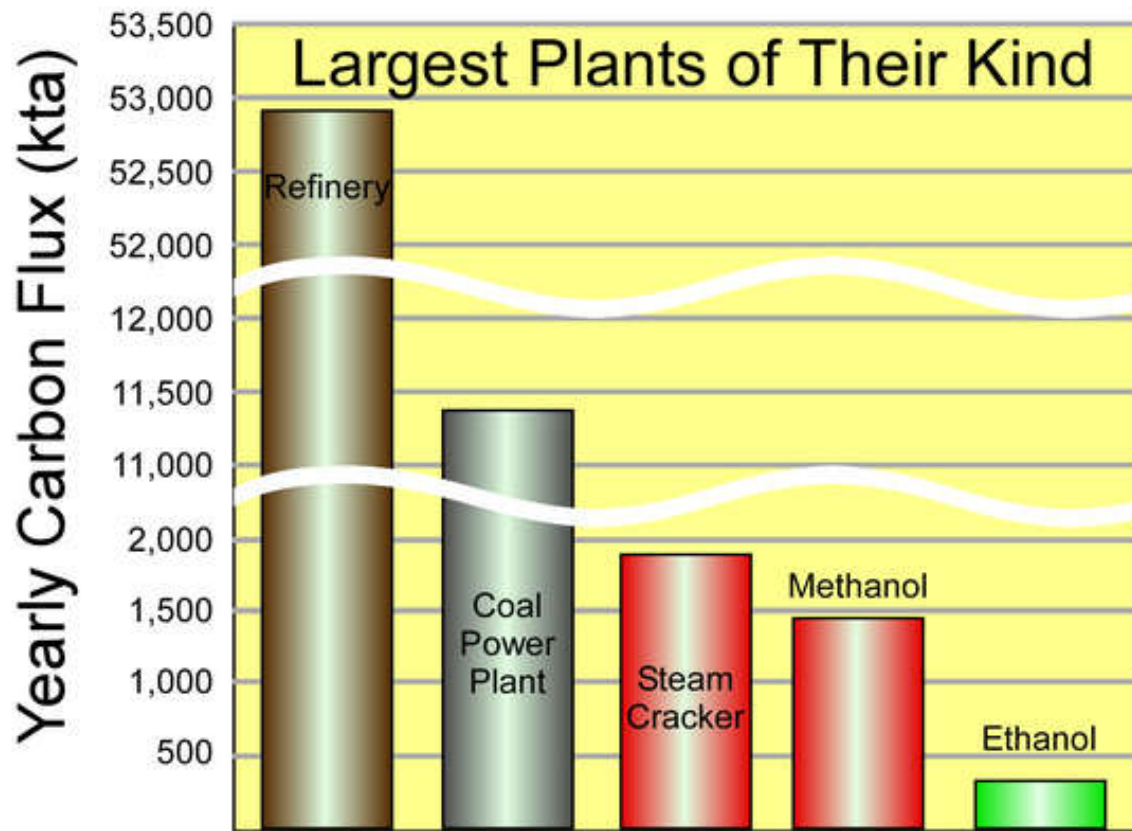
POWER LAW



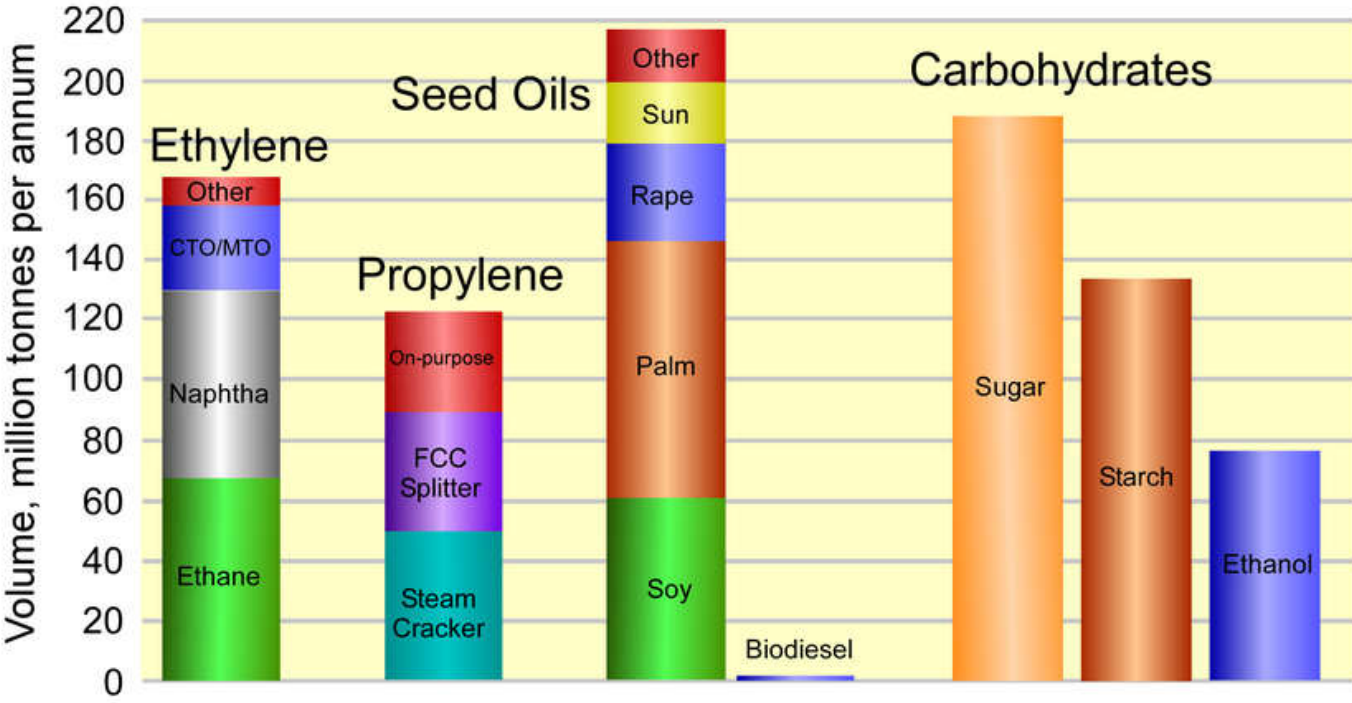
SCALE ALWAYS WINS



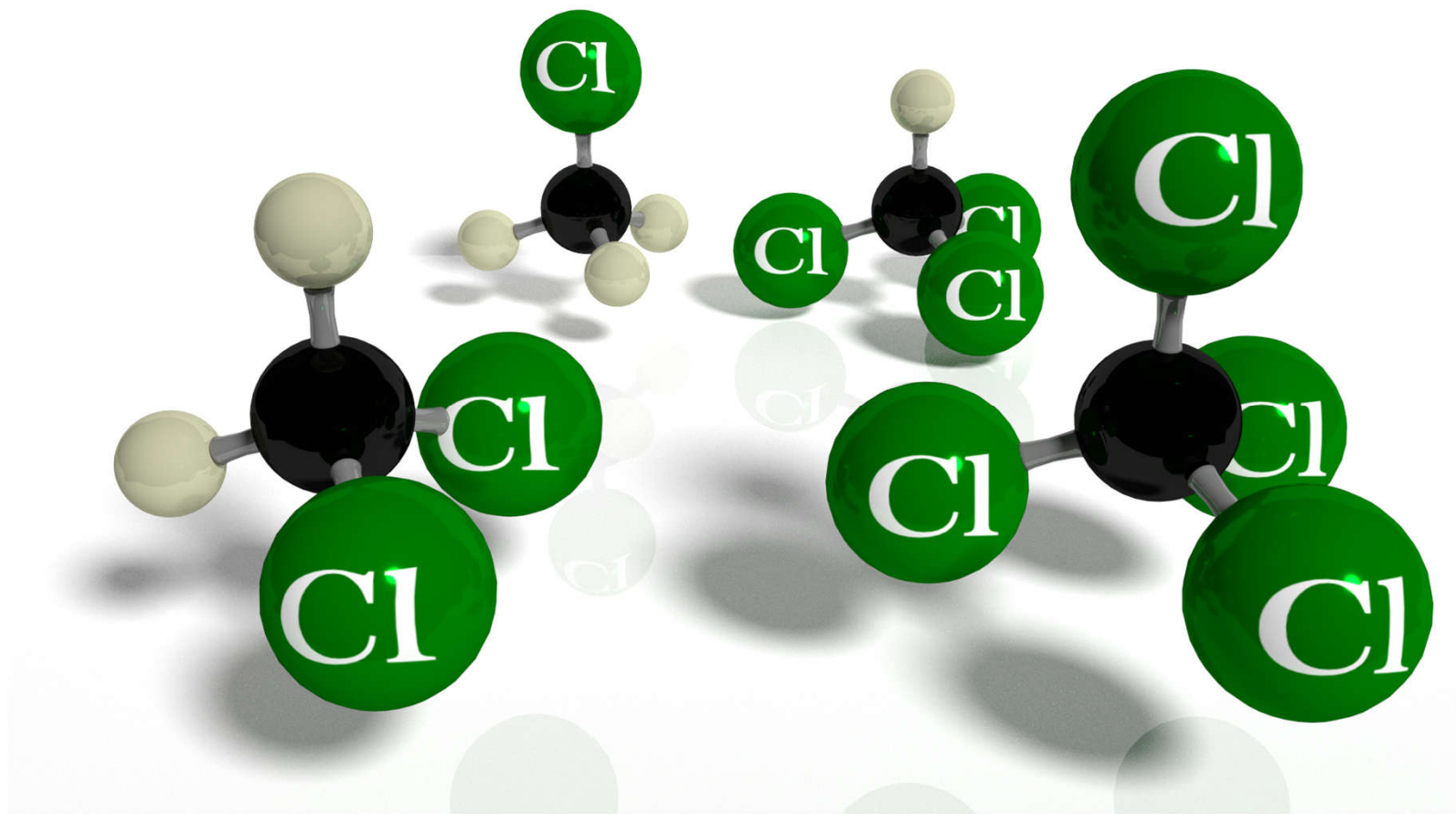
If you are moving mass around, scale reduces cost faster than experience.



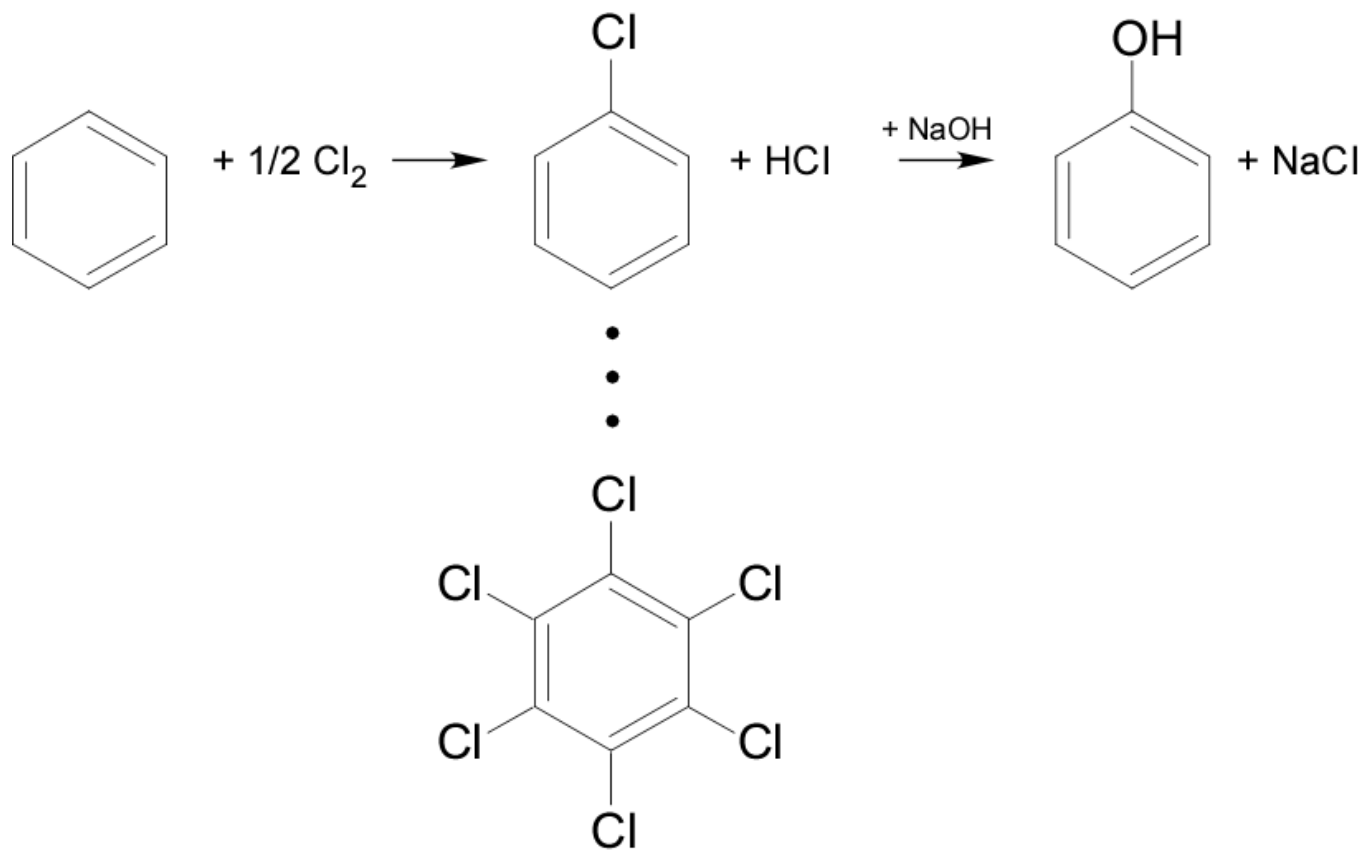
AG VERSUS CHEMICAL COMPARISON



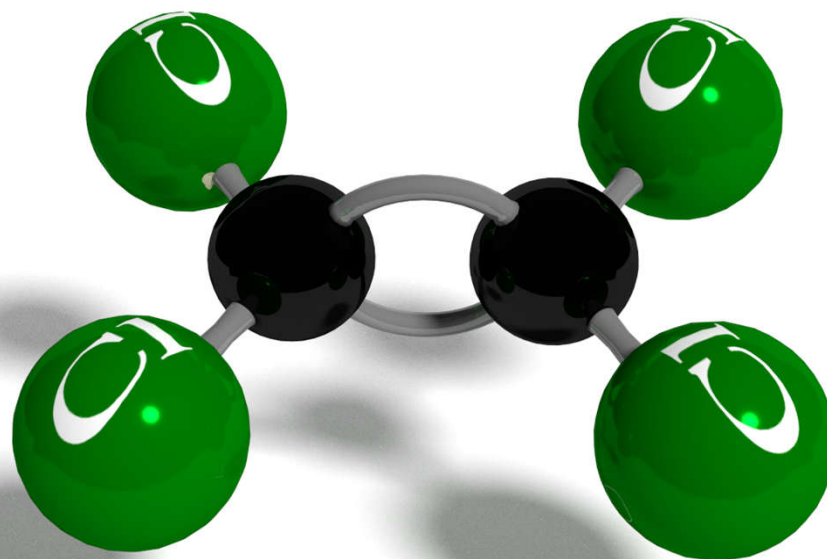
ORGANOCHLORIDES



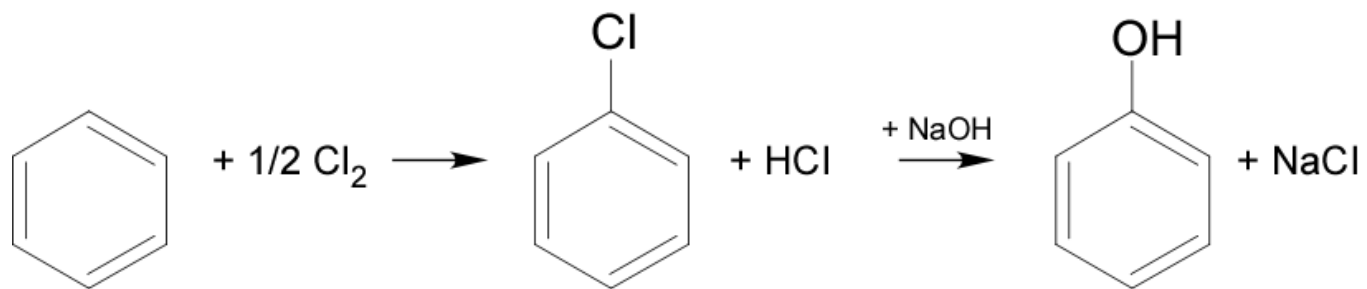
CHLORINE AS AN OXIDANT



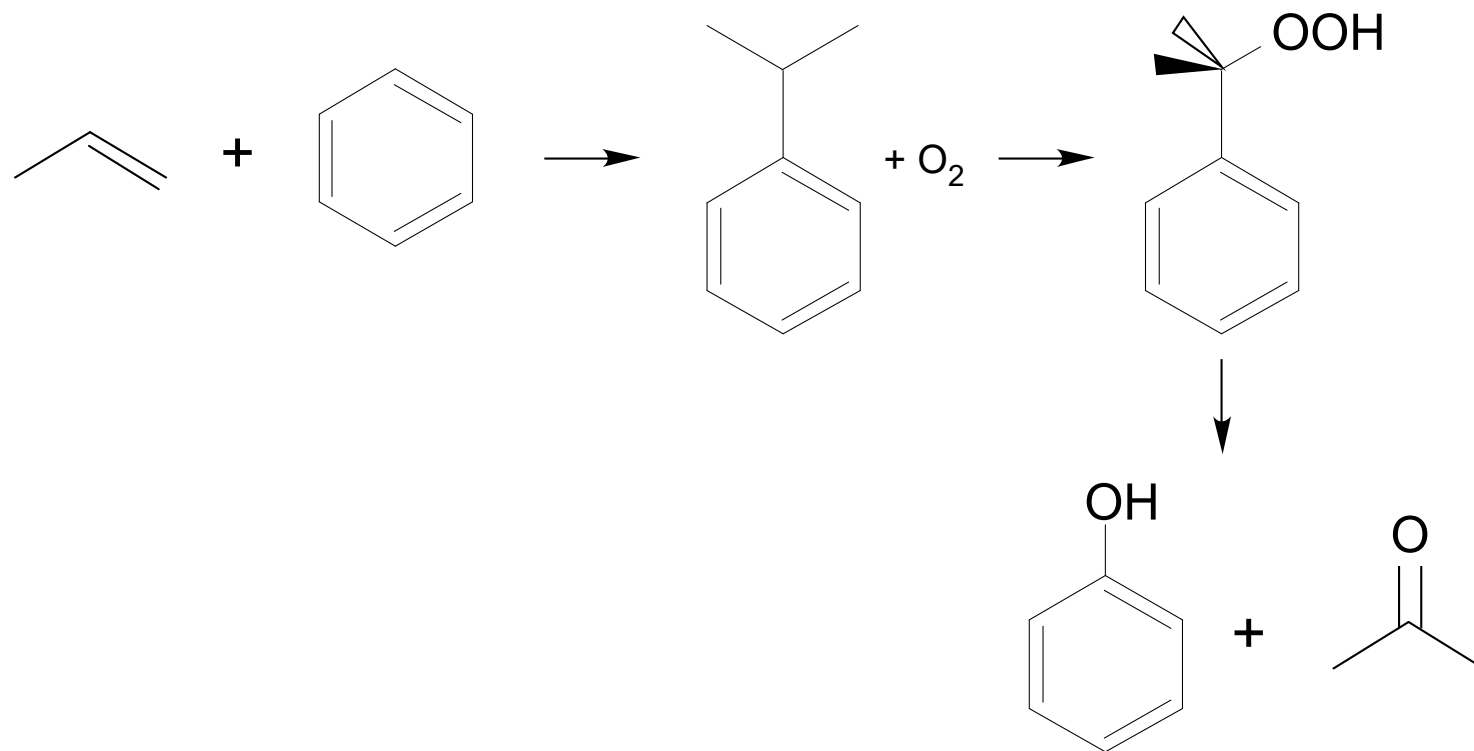
PERCHLOROETHYLENE



CHLORINE AS AN OXIDANT

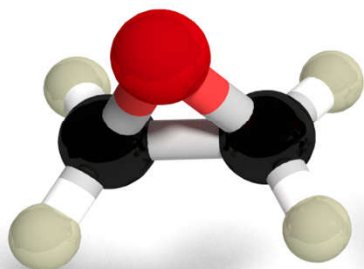


PHENOL TODAY

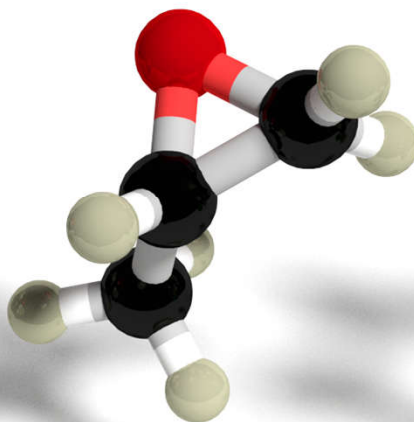


EPOXIDES

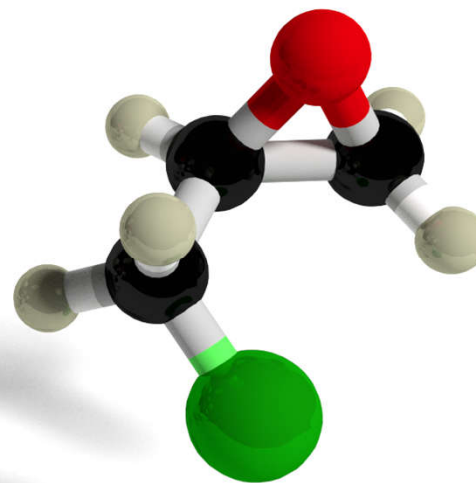
EO
ethylene oxide



PO
propylene oxide

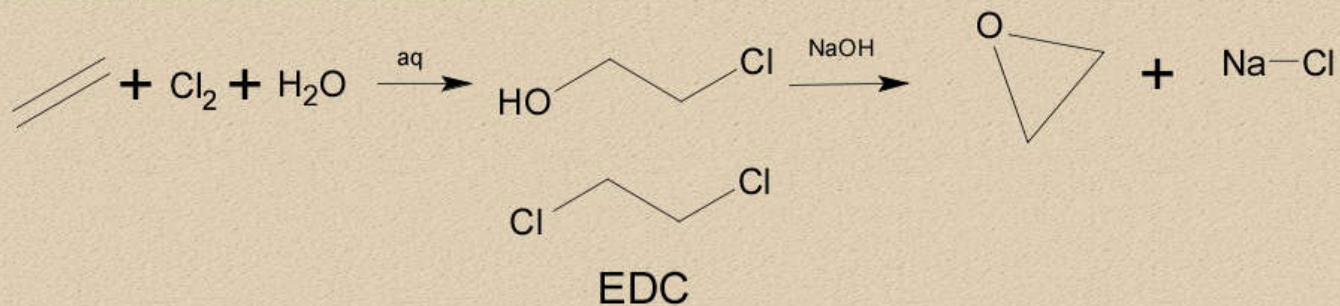


EPI
epichlorohydrin



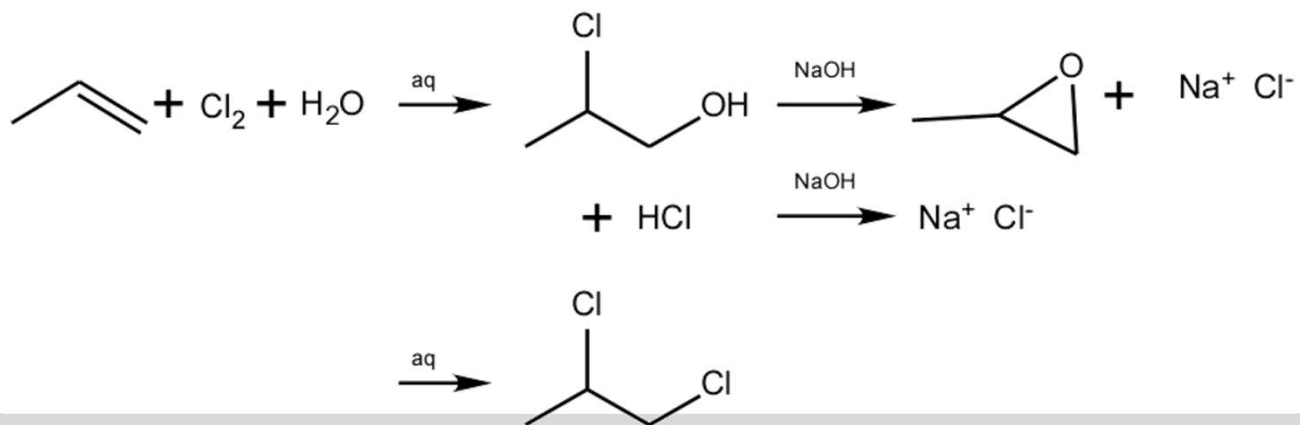
CHLOROHYDRIN CHEMISTRY

Chlorohydrin Ethylene Oxide



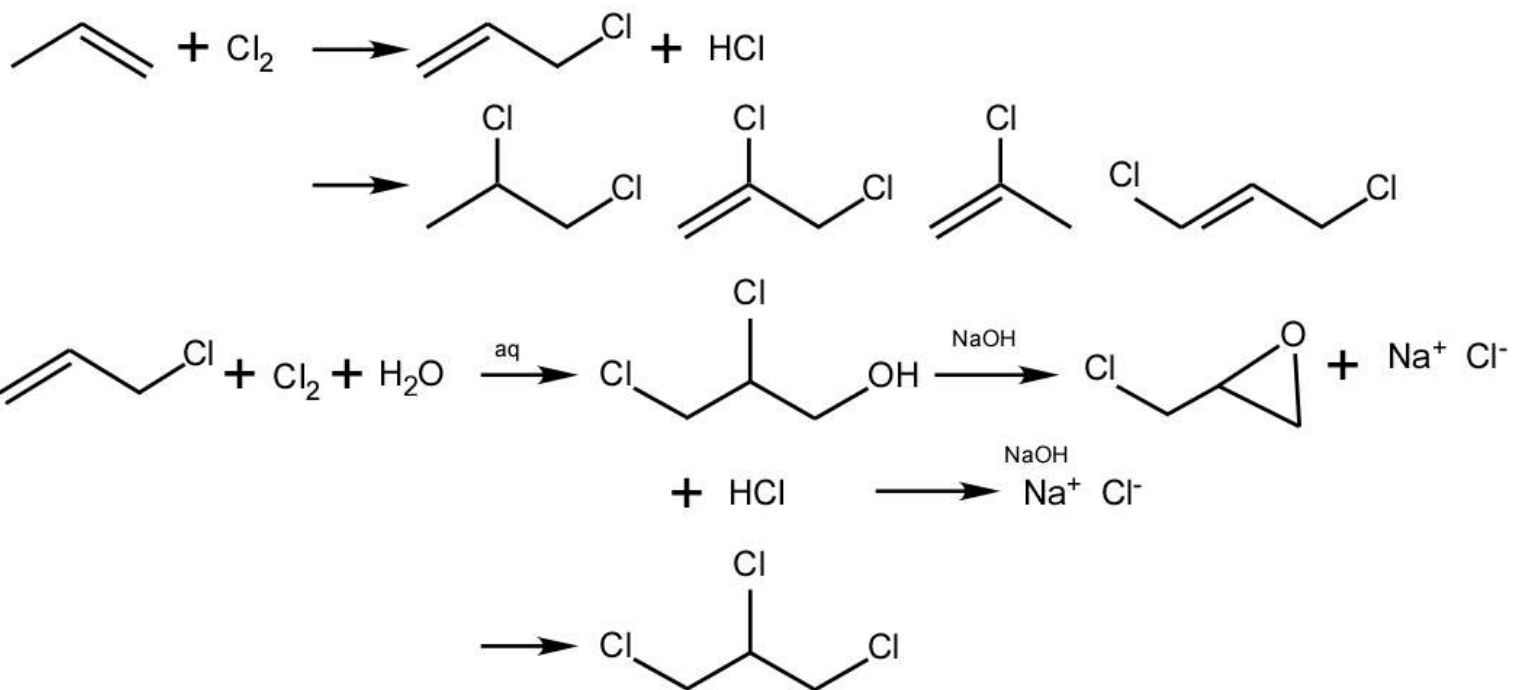
1915-1975

Chlorohydrin Propylene Oxide

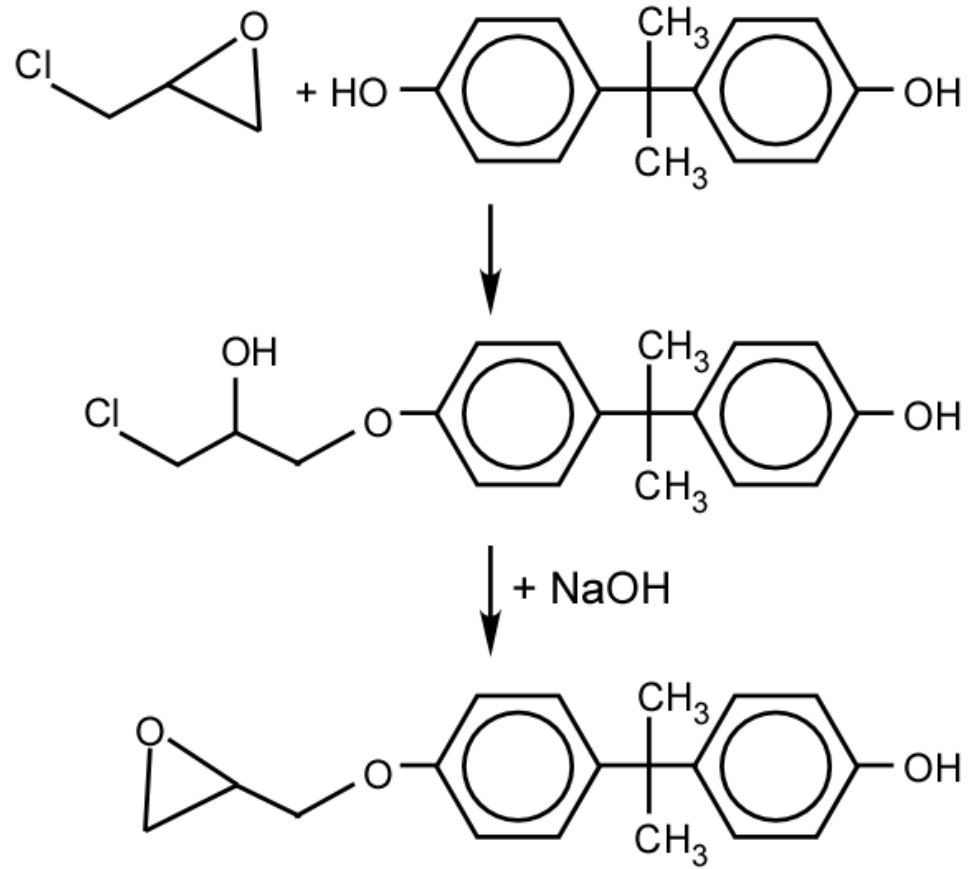


MORE CHLOROHYDRIN CHEMISTRY

Chlorohydrin Epichlorohydrin

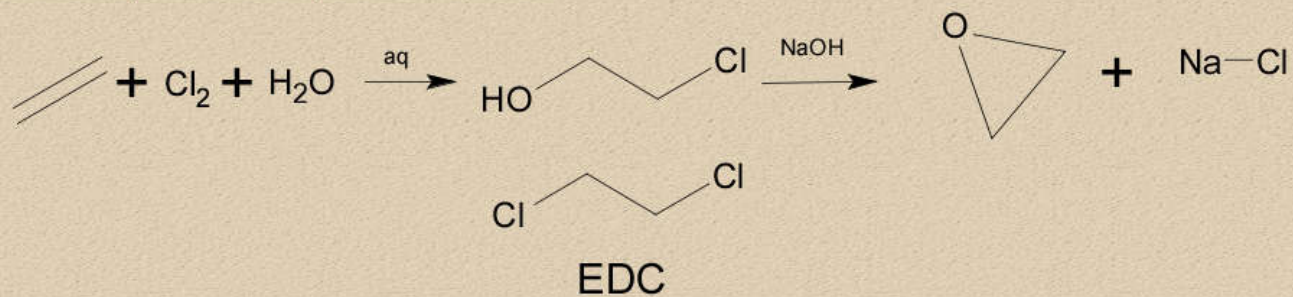


EPOXY RESINS



DIRECT OXIDATION

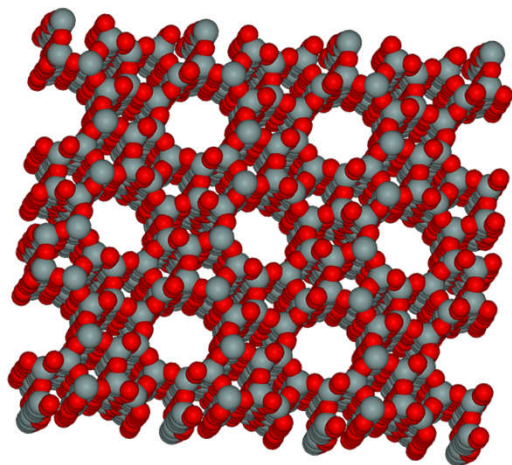
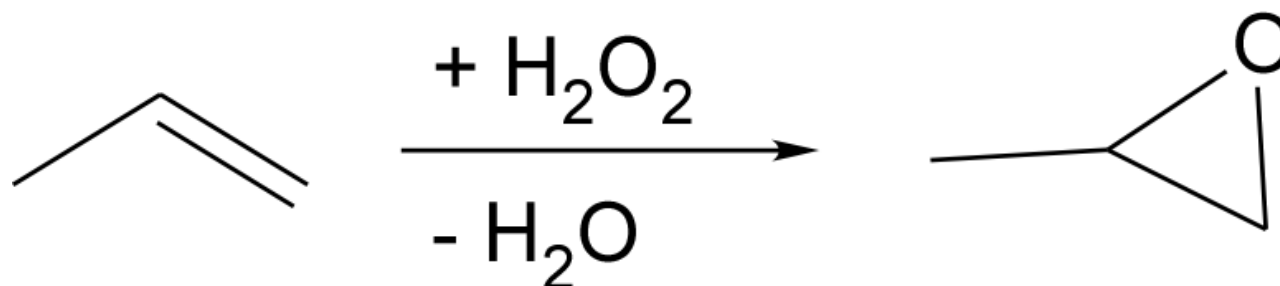
Chlorohydrin Ethylene Oxide



Direct Oxidation Ethylene Oxide



HYDROPEROXIDATION



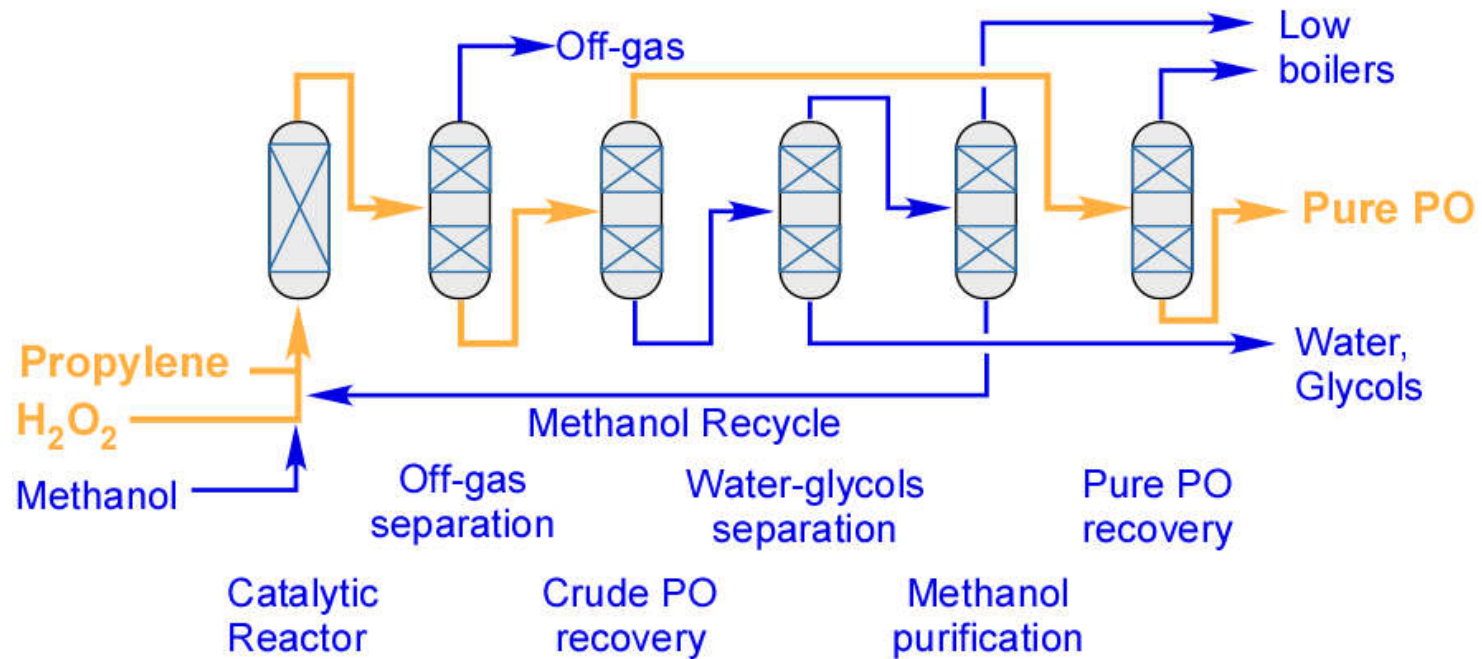
titanium silicate catalyst

0.5 nm pores

suitable for packed bed reactor

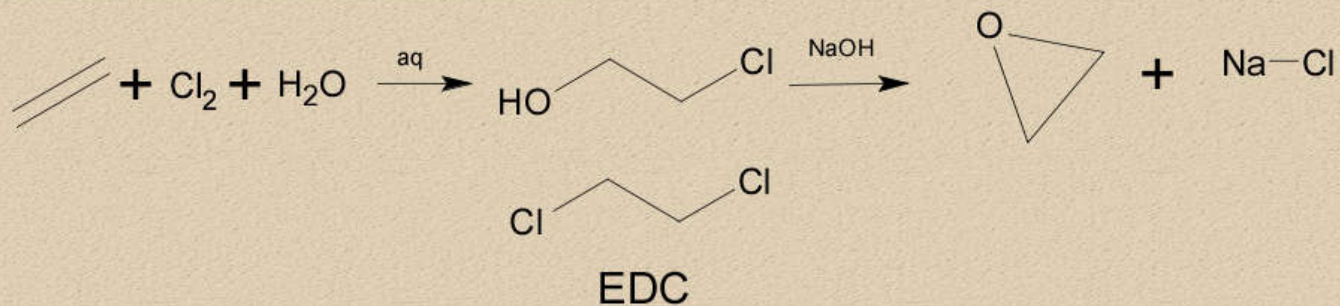
HOPO

Simplified Process Flowsheet

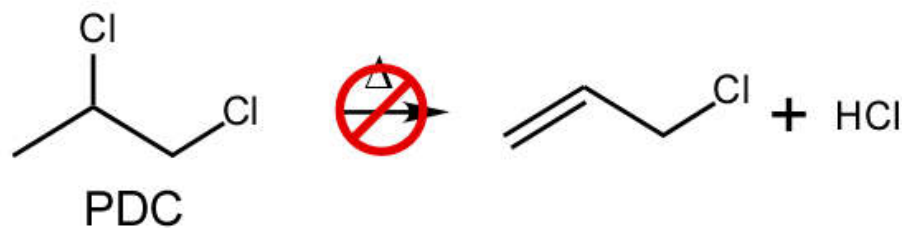
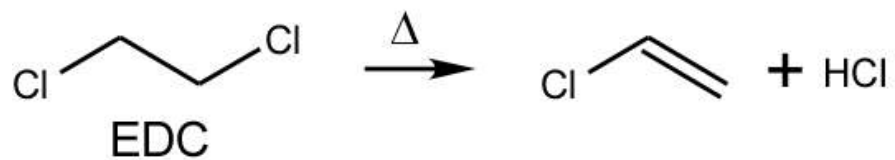


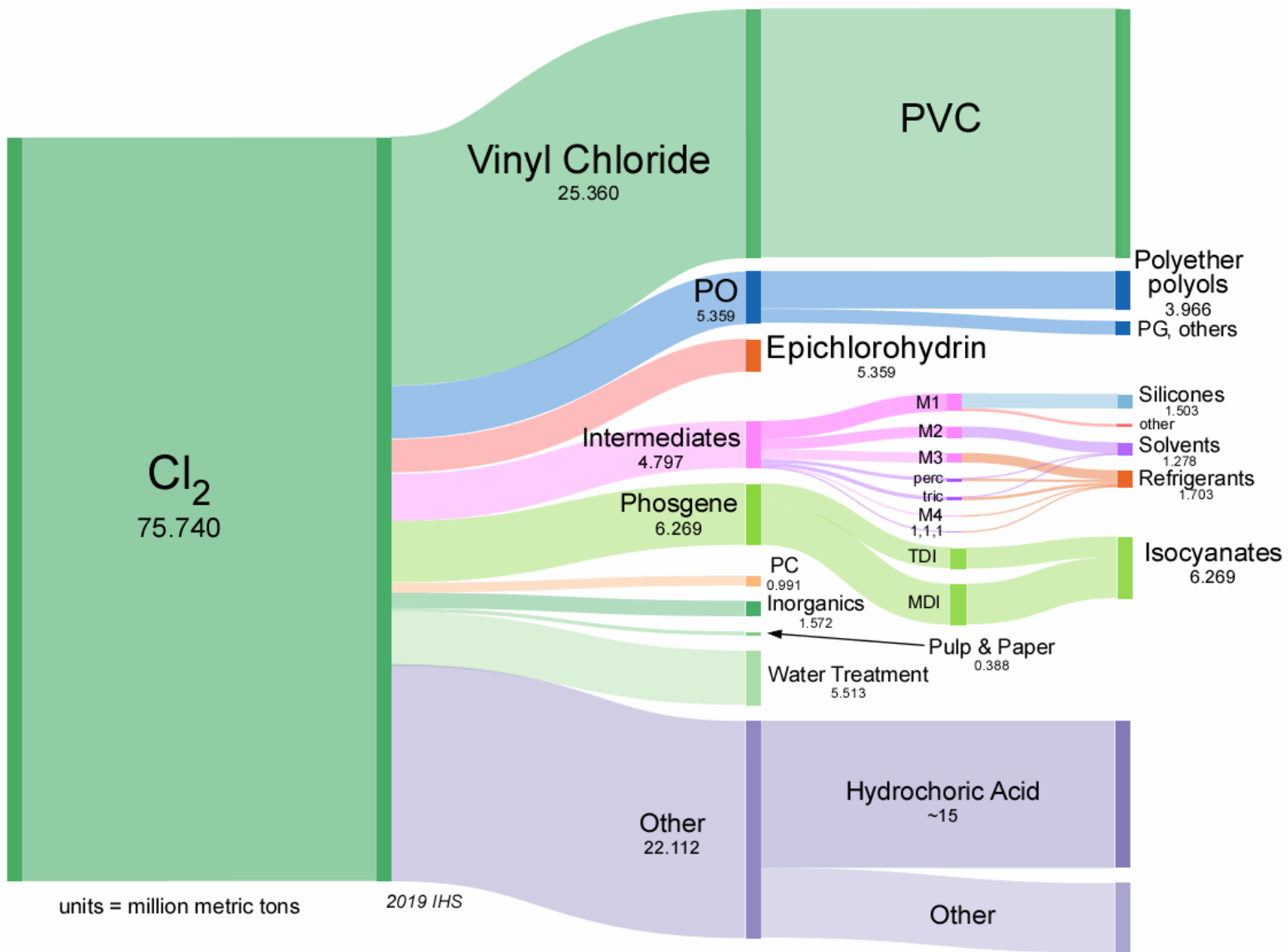
CHLOROHYDRIN CHEMISTRY

Chlorohydrin Ethylene Oxide

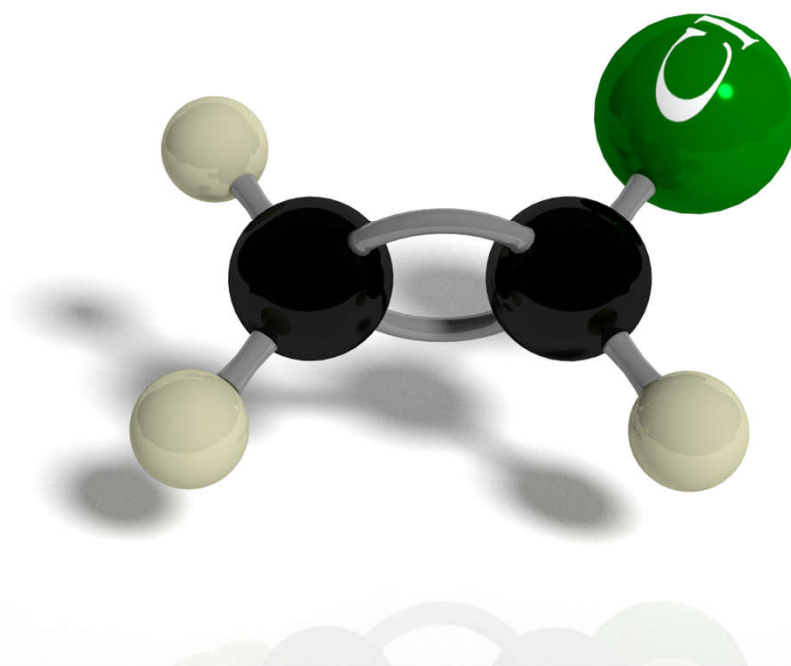


1915-1975

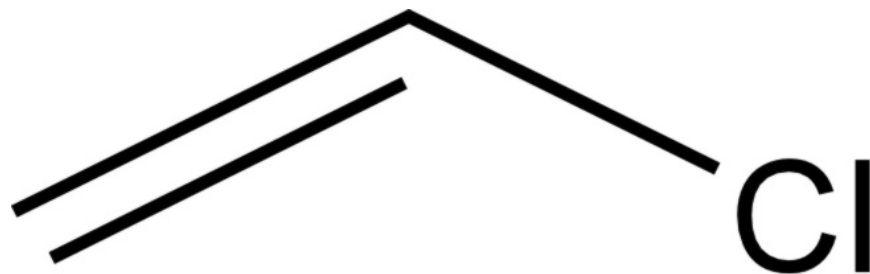




VINYL CHLORIDE



VINYL CHLORIDE – LARGEST CHLOROCARBON PRODUCT



Vinyl Chloride Monomer(VCM)

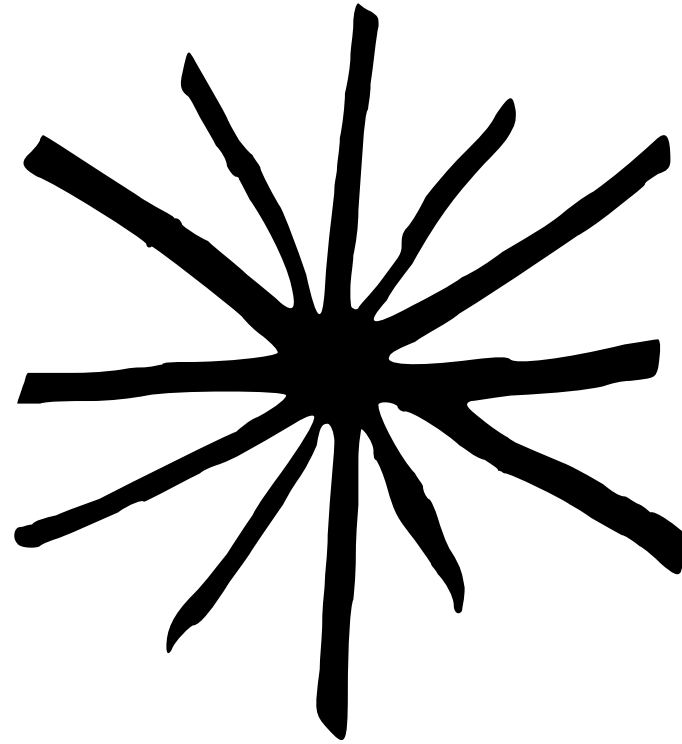
Dow produced ~5 billion pounds/year

World demand is 49 billion pounds

Growth averages 4-5%

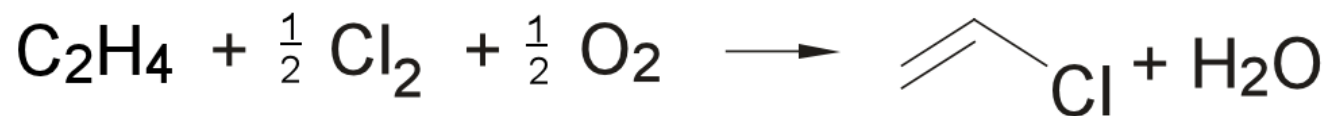
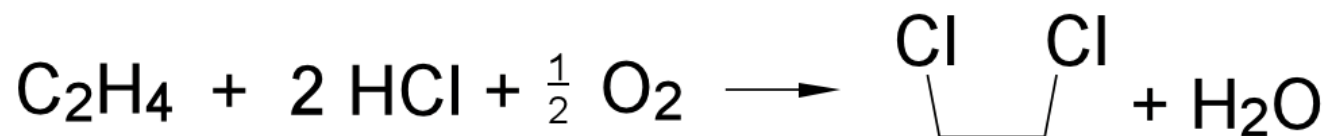
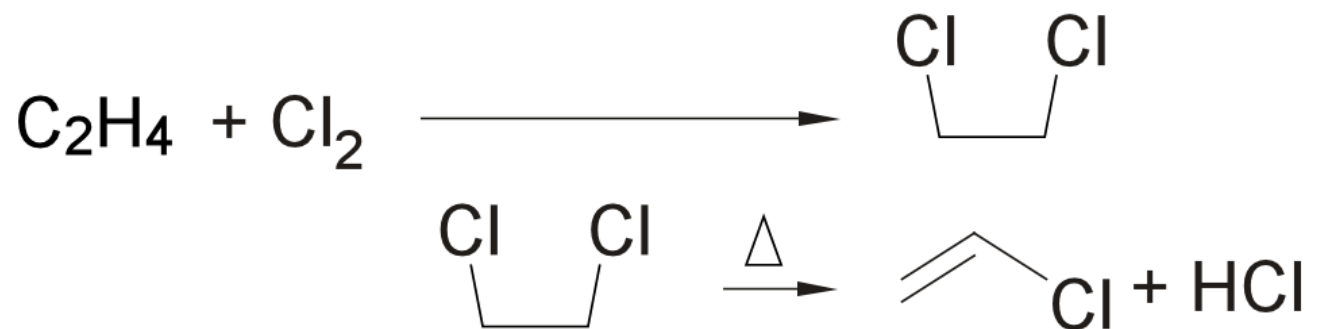
Source: Chemical Week product focus

BREAKFAST OF CHAMPIONS

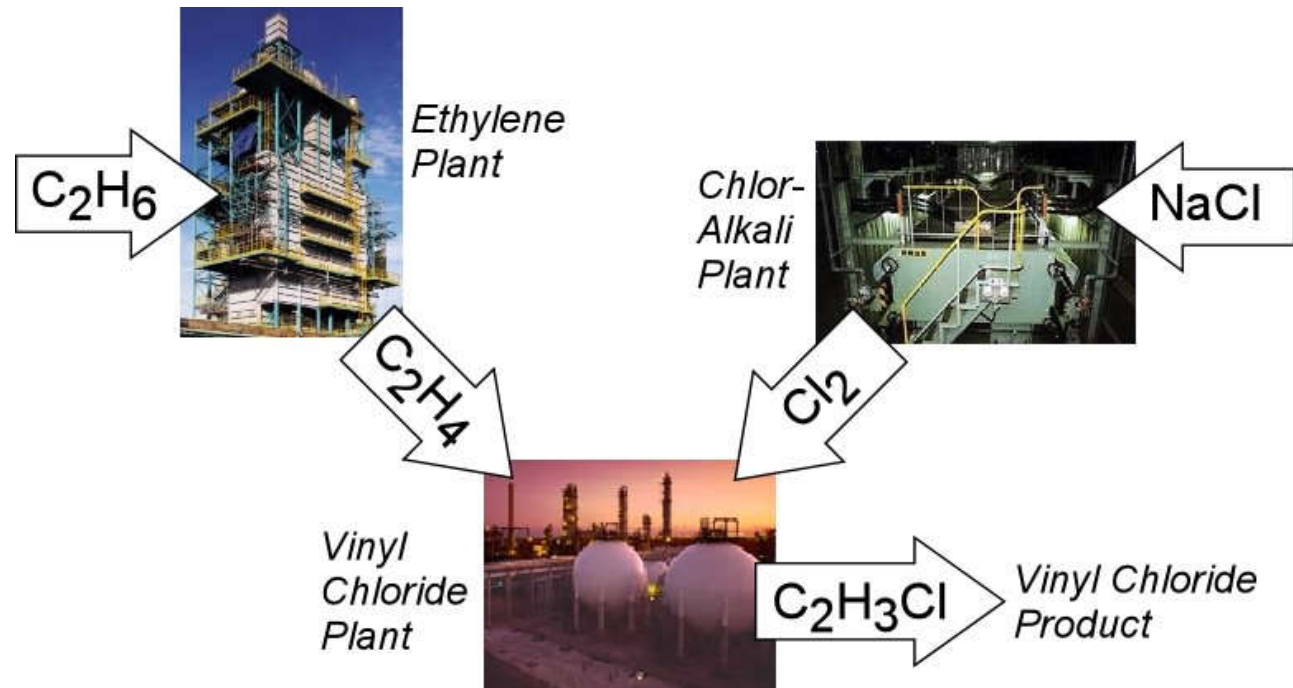


see Vonnegut's *Breakfast of Champions*
or
Pete Davidson's *The King of Staten Island*

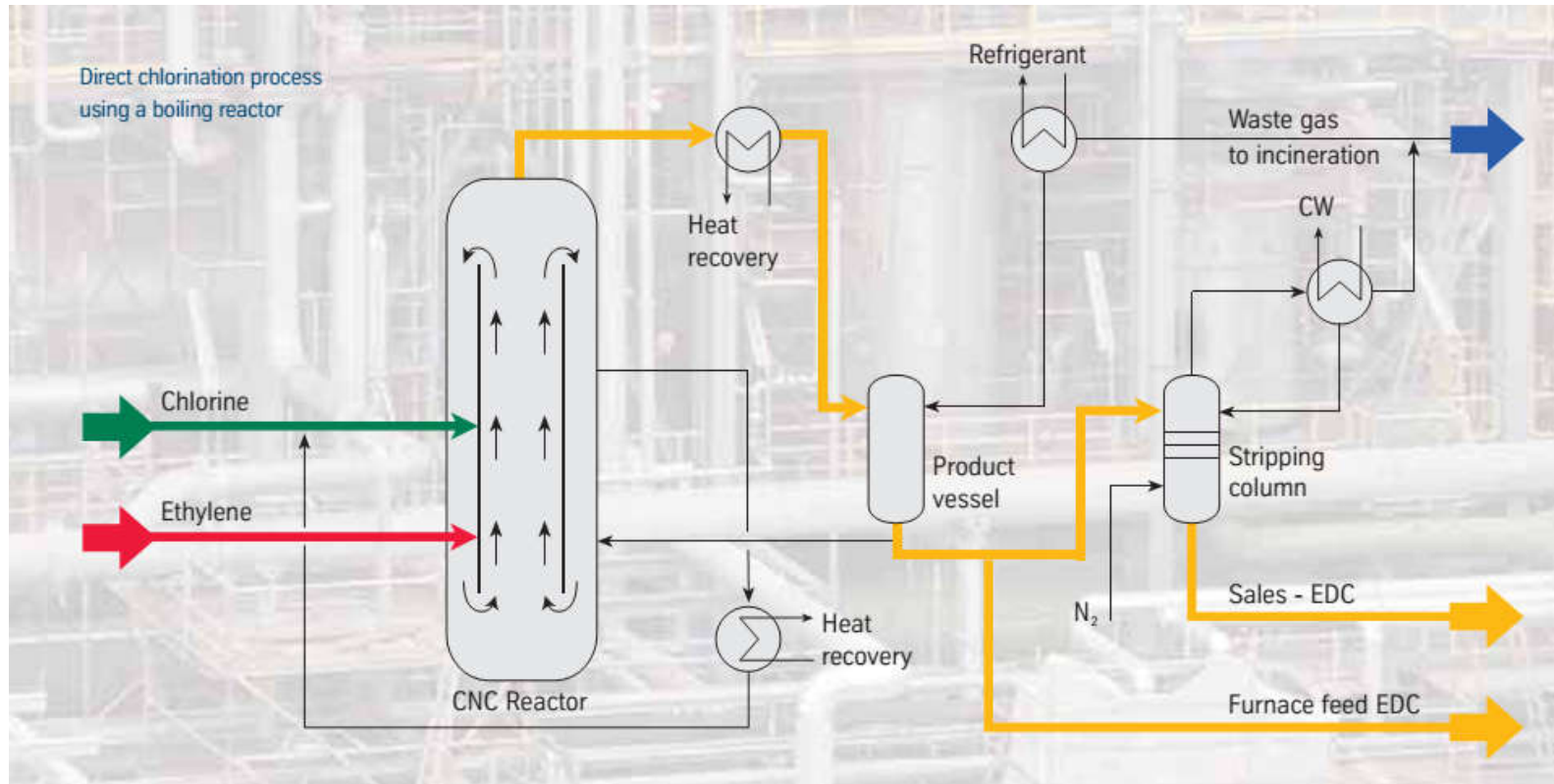
CONVENTIONAL PRODUCTION



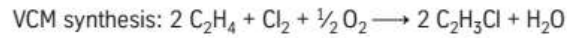
CONVENTIONAL VCM



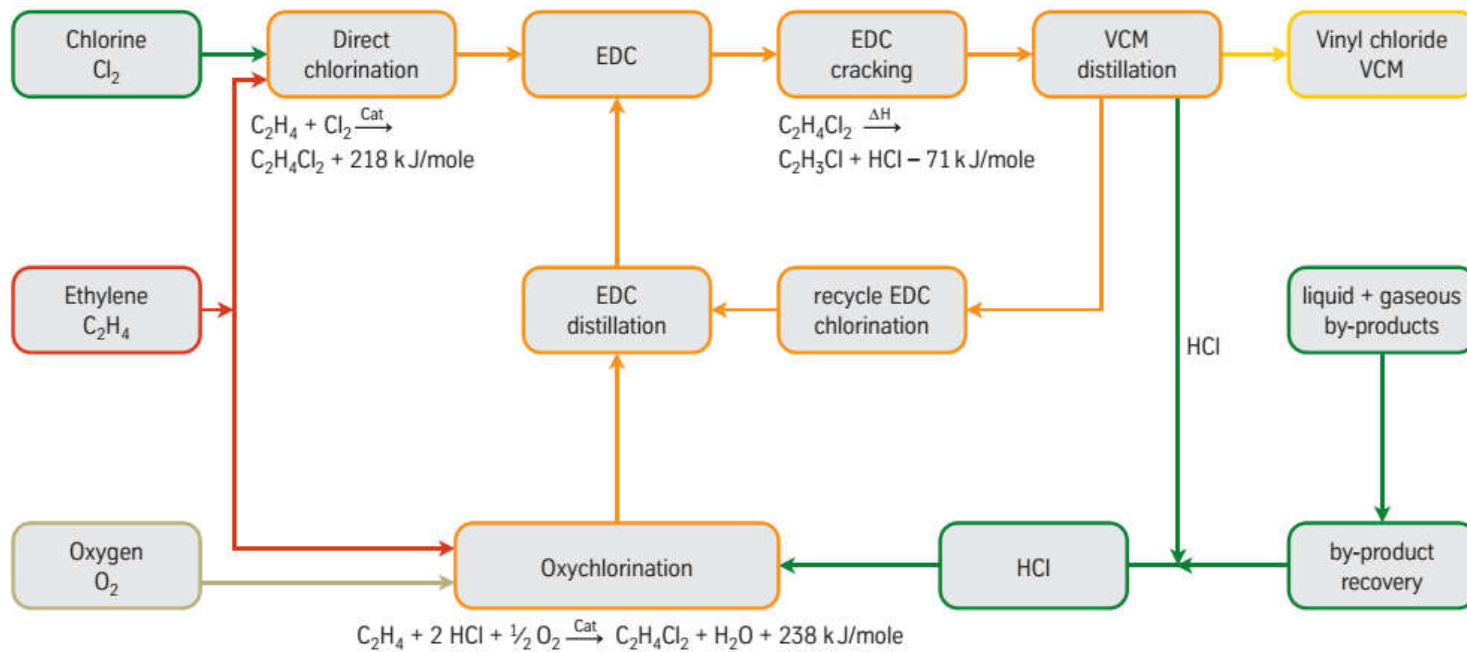
DIRECT CHLORINATION



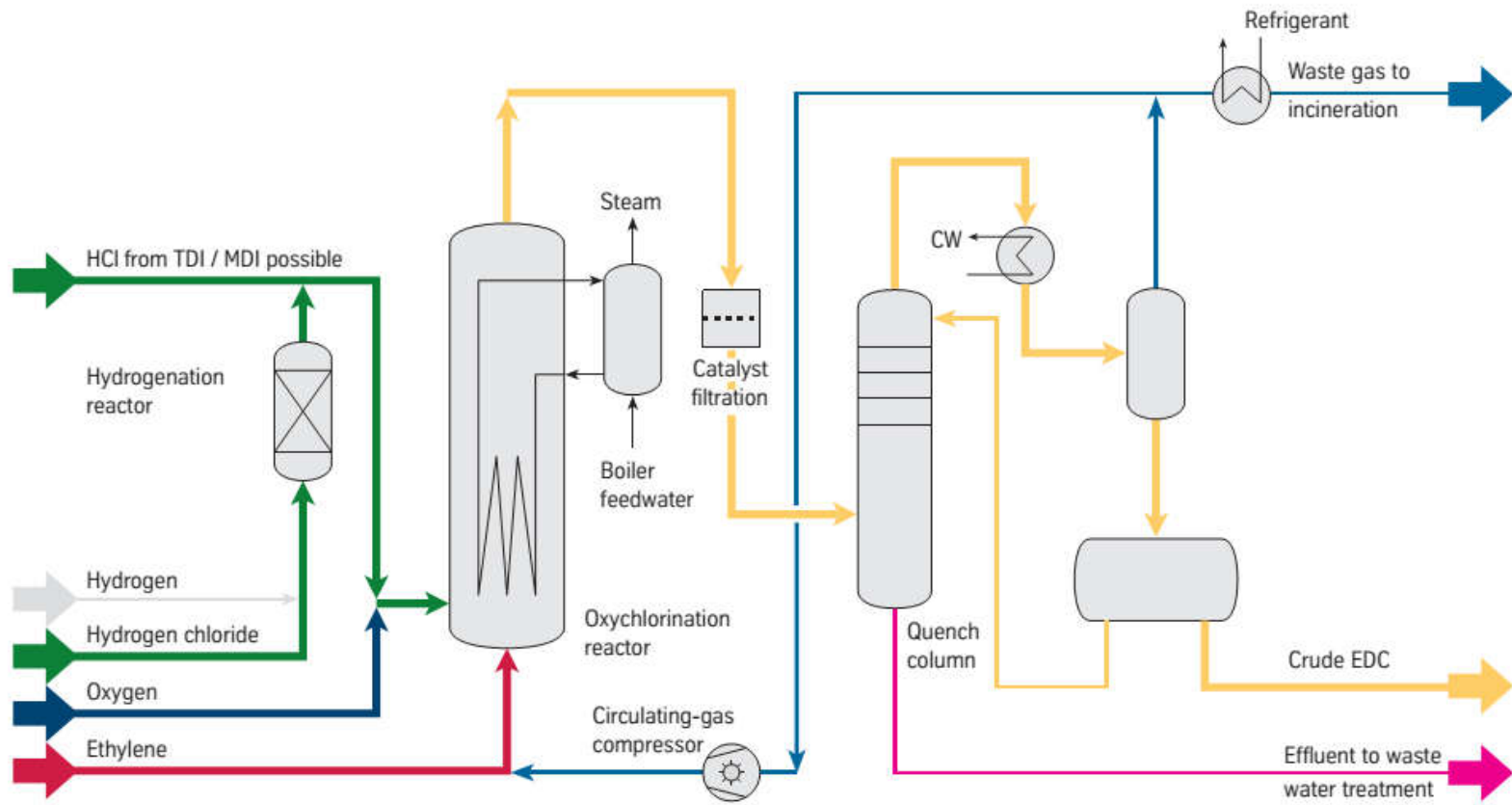
MORE DETAIL



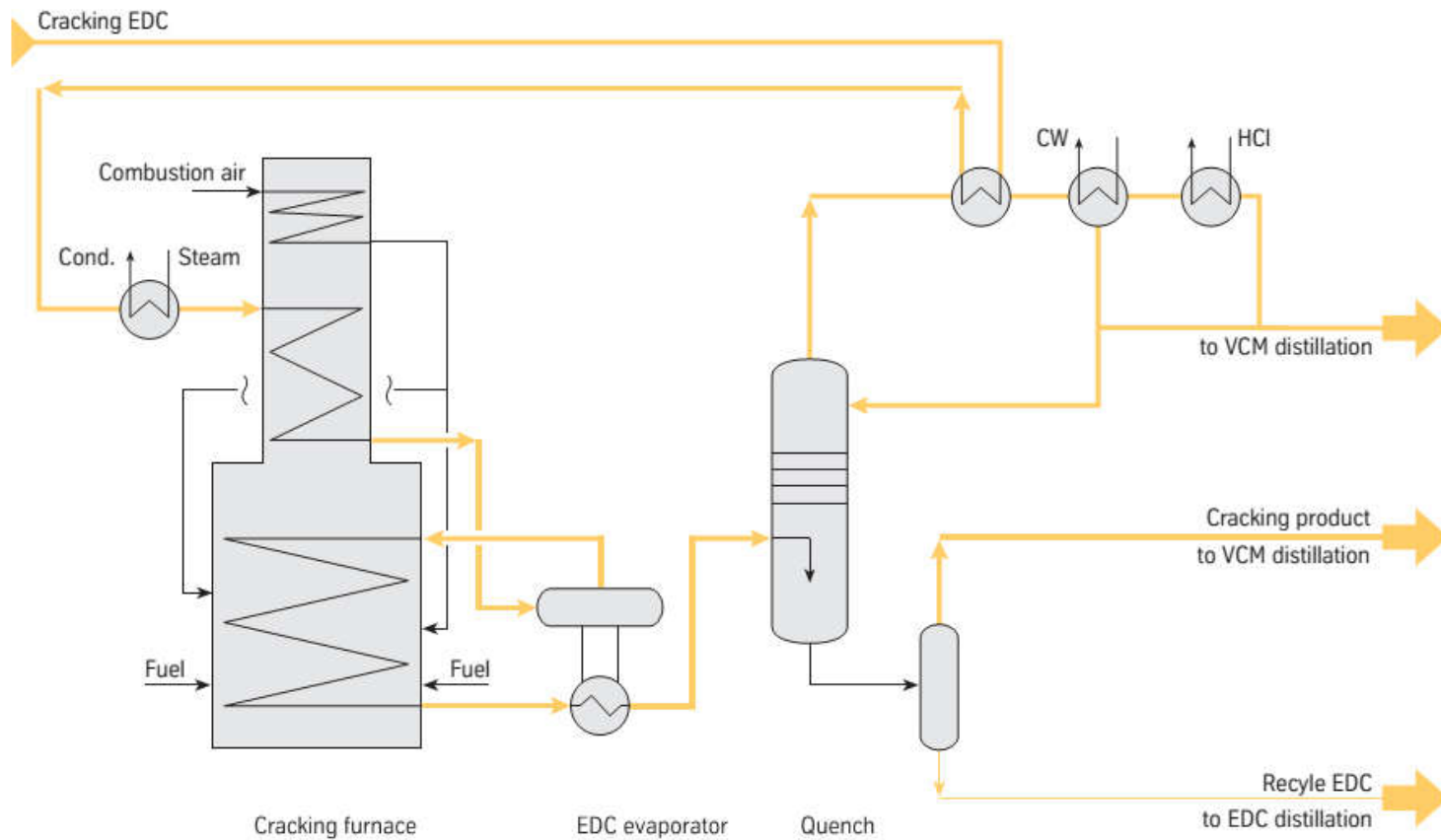
Schematic diagram of a VCM plant



OXYCHLORINATION



CRACKING



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Vinnolit

Uhde
ThyssenKrupp

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WHAT I HOPE I'VE LEFT YOU WITH

- Integration was crucial in the development of the chemical industry but has decreased in importance
chlorine has largely been replaced as an oxidant
- Inorganic chemistry created the chemical industry and remains important, but not particularly valued
vinyl and caustic are critical, just not particularly profitable
- Scale remains the major source of competitive advantage in commodity chemicals
for undifferentiated materials, production cost is king and scale lowers production cost

EAST PALESTINE, OHIO



CO-PRODUCT PROCESSES





MJPhD