



# WHY WAS VINYL CHLORIDE ON A TRAIN IN EAST PALESTINE, OHIO?

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MJPhD, LLC

*3 April 2025*



## WHAT I HOPE TO LEAVE YOU WITH

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- Inorganic chemistry created the chemical industry and remains important, but not particularly valued
- Scale remains the major source of competitive advantage in commodity chemicals
- Sustainability is multifaceted and complex with hidden interactions.

# EAST PALESTINE, OHIO

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## TRAIN DERAILMENT FACTS

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- Norfolk Southern Railway train 32N derailed in East Palestine, Ohio on February 3, 2023
- a faulty wheel bearing caused the derailment
- fire ignited during the derailment and grew to involve 35 railcars
- derailed equipment included 11 tank cars carrying hazardous materials
  - 3 hazardous materials tank cars sustained mechanical and released flammable or combustible materials
  - 5 vinyl chloride (VCM) tank cars were not mechanically breached during the derailment
- VCM cars were explosively breached to initiate a vent and burn
- news outlets described the cargo as toxic, flammable and carcinogenic
- it was widely mentioned the burning created toxic materials

*So why was VCM on the train?*

**Raymond, MN 30 March 2023**



**23 ethanol cars**

**BNSF Railway freight train L-TWI8801-291**

## TRAIN COMPARISON

- Vinyl chloride
  - flammable
  - toxic
  - carcinogenic
  - makes toxic materials when burned
    - HCl
    - CO<sub>2</sub>
    - trace other stuff
  - fully-synthetic, unnatural
  - coproducts during production
- Ethanol
  - flammable
  - toxic
  - carcinogenic
  - makes toxic materials when burned
    - CO<sub>2</sub>
    - trace other stuff
  - natural

## VIEWS ON VINYL



© Kevin Castle / Greenpeace

PVC is single most environmentally damaging type of plastic.

PVC is one of the most toxic substances saturating our planet and its inhabitants. PVC contaminates humans and the environment throughout its lifecycle: during its production, use, and disposal.

*Greenpeace*

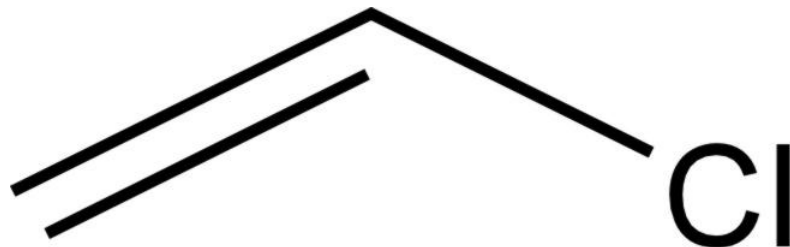
<https://www.greenpeace.org/usa/toxics/pvc-free/>

# CARCINOGENIC

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- carcinogens are substances that may increase your risk of cancer.
  - Cleveland Clinic
- a carcinogen is a substance, organism or agent capable of causing cancer.
  - National Human Genome Institute
- a substance, organism, or agent capable of causing cancer
  - International Agency for Research on Cancer
- substances, mixtures, or exposure circumstances that are known or reasonably anticipated to cause cancer in humans
  - National Toxicology Program (NTP)
- any substance that causes cancer.
  - National Cancer Institute



## Vinyl Chloride Monomer(VCM)

Olin produced ~5 billion pounds/year

World demand is 49 billion pounds

Growth averages 4-5%

Source: Chemical Week product focus

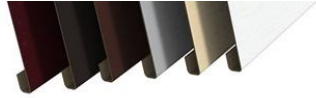
# USED TO MAKE POLYVINYL CHLORIDE (PVC)

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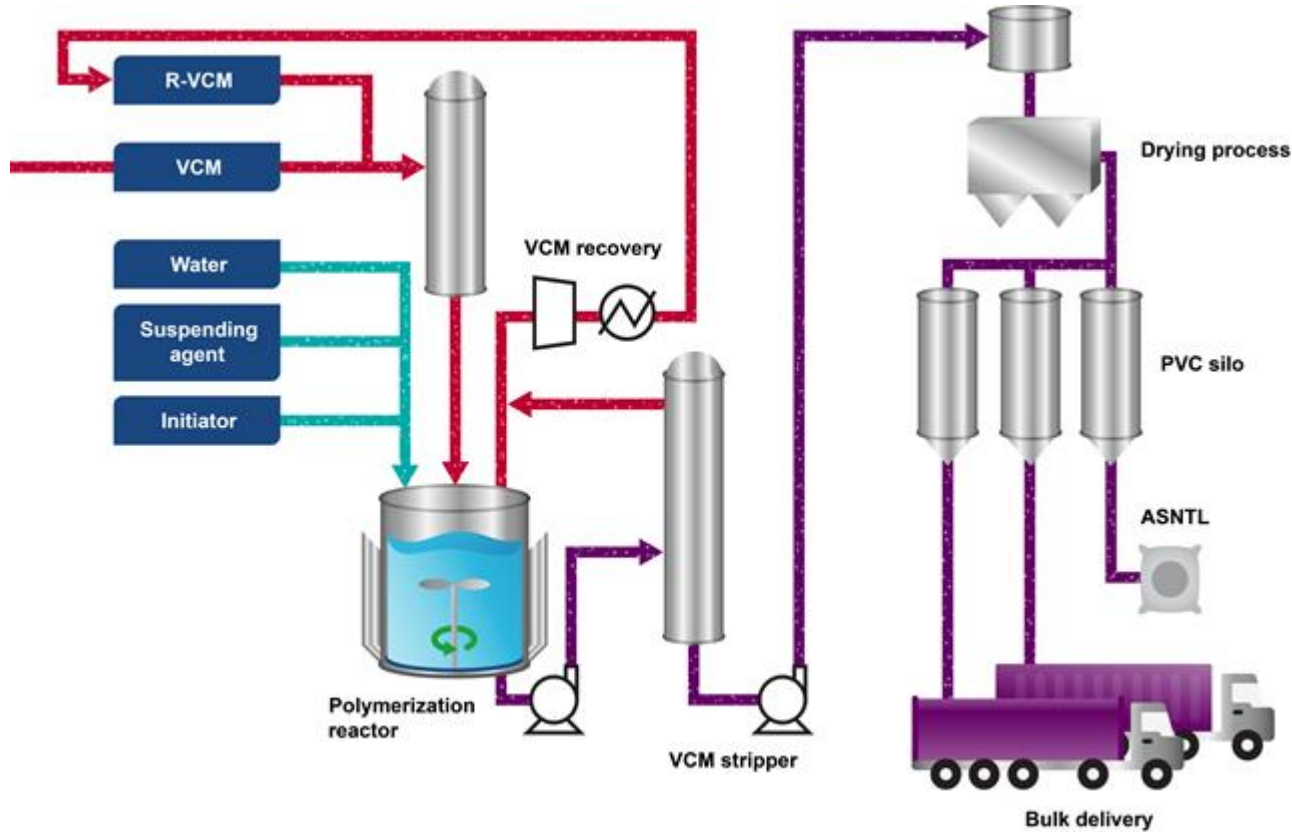
- third largest polymer (by weight)
- infrastructure polymer
  - piping
  - siding
  - flooring
- main medical polymer

Vinyl chloride was on the train to make polyvinyl chloride.

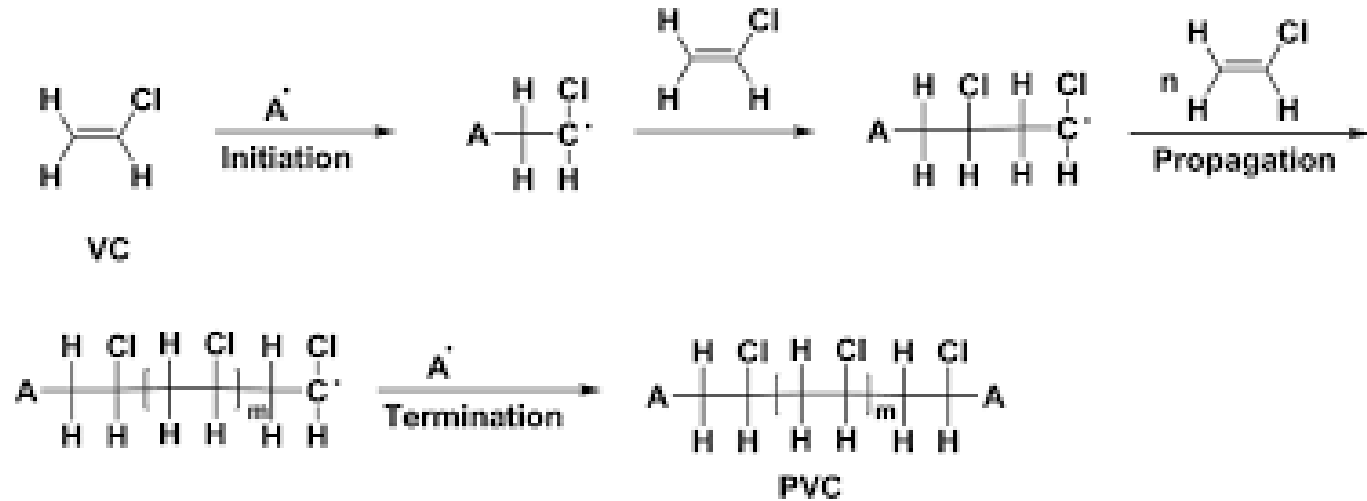


- really bad material properties
  - brittle
  - low melting point
  - poor solvent resistance
- saving graces
  - cheap
  - takes filler well
  - solvent weldable
  - great with plasticizers
  - naturally flame retardant

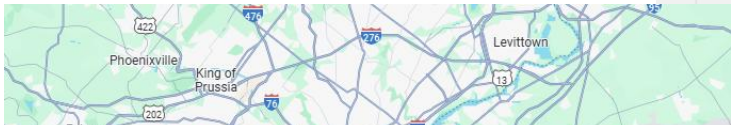
# PVC PRODUCTION: SUSPENSION POLYMERIZATION



# FREE RADICAL PROCESS



Going to Pedrickstown, NJ



## OxyVinyls Rail Route

from La Porte and Ingleside, TX  
to Pedricktown, NJ



Vinyl chloride was on the train to provide feedstock for a polymer production facility far away from a monomer production facility.



887,400 pounds of VCM loaded at the Oxy Vinyls VCM plant in LaPorte, Texas

# NOT THE FIRST TIME

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- November 30, 2012  
derailment on a moveable  
bridge in Paulsboro, New  
Jersey
- 3 VCM tank cars came to  
rest in Mantua Creek
- one was breached and  
released about 20,000  
gallons of vinyl chloride

# 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



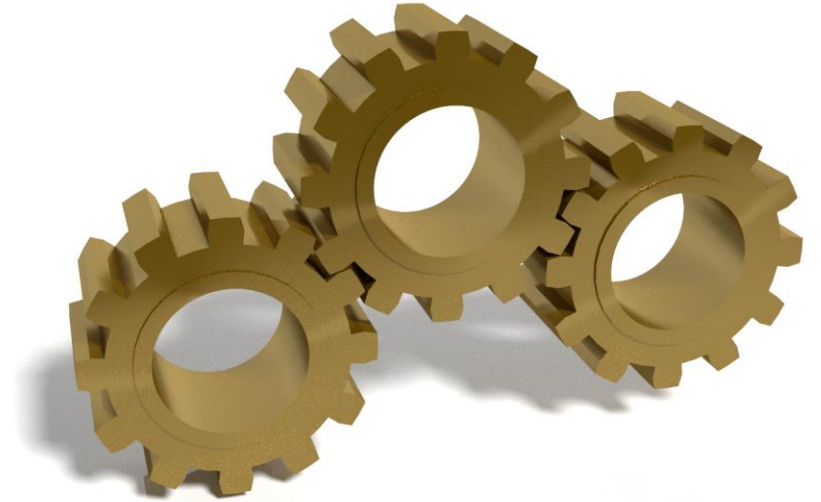
1925-present

petroleum  
NGL

# WHAT IS INTEGRATION?

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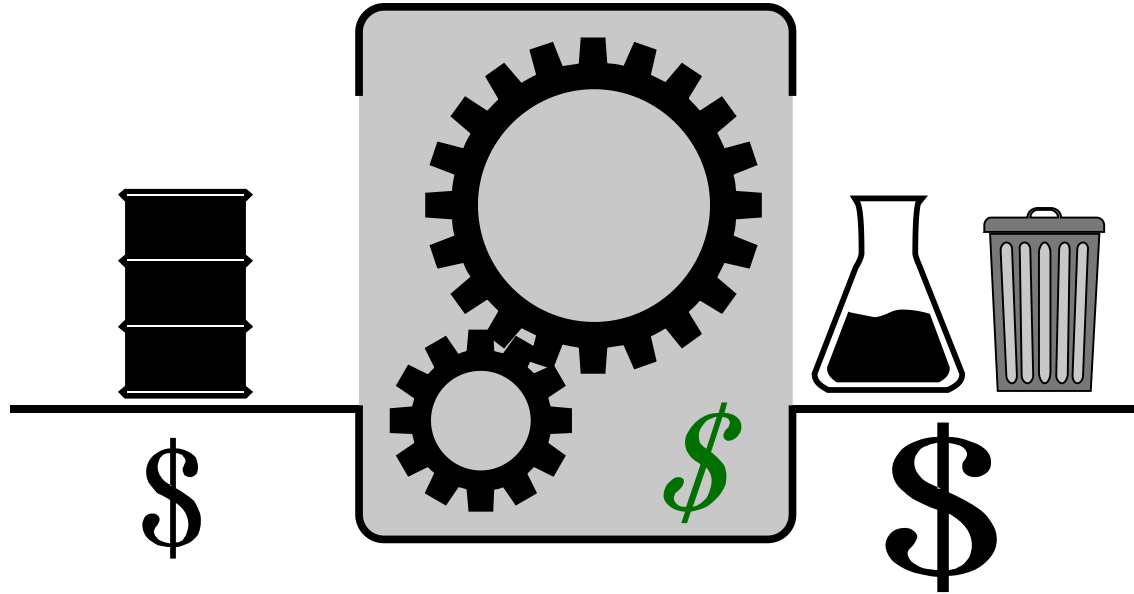




Linkage of mass and energy flows that create a significant advantage.

# SIMPLIFIED CHEMICAL INDUSTRY

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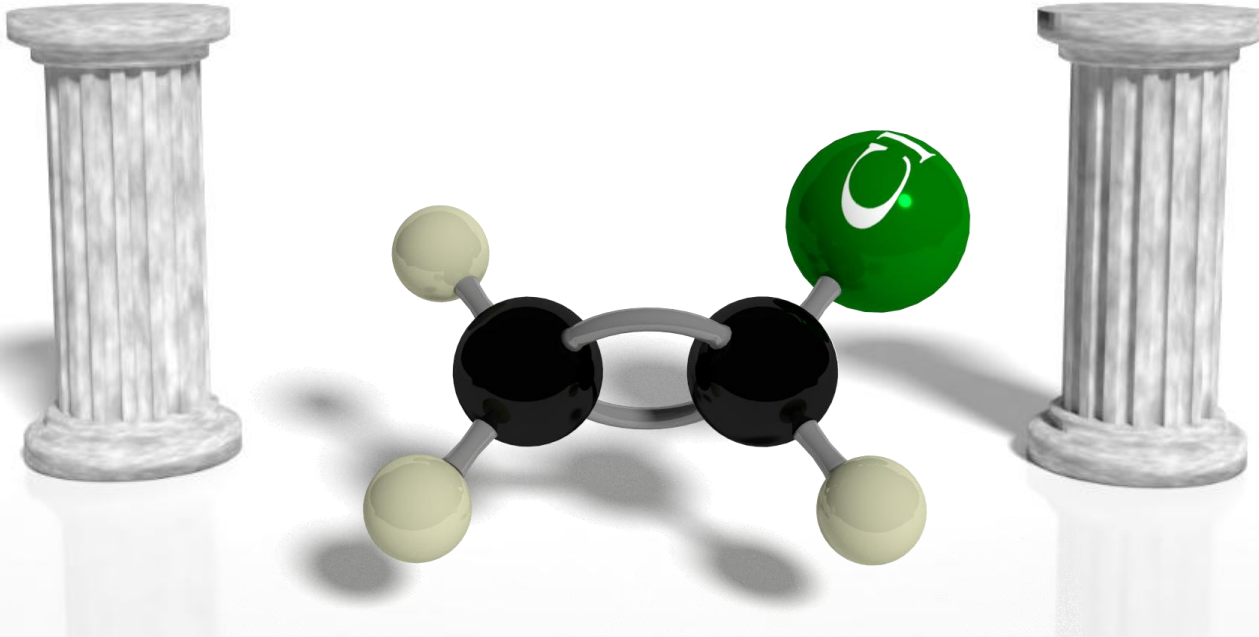


# FOUNDATIONAL PillARS OF THE MODERN CHEMICAL INDUSTRY

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## Electrochemical Chlor-Alkali

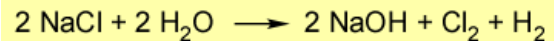
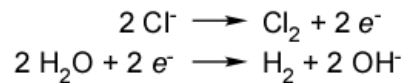
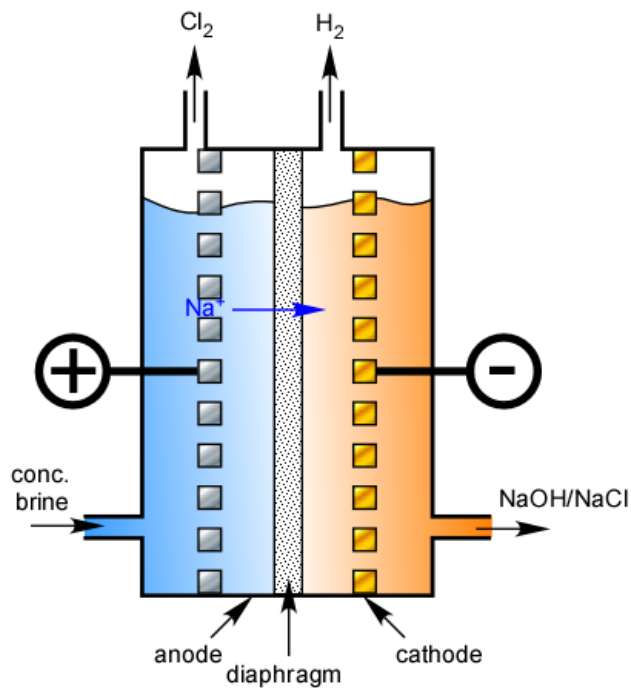
## Steam Cracking





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# CHLOR-ALKALI



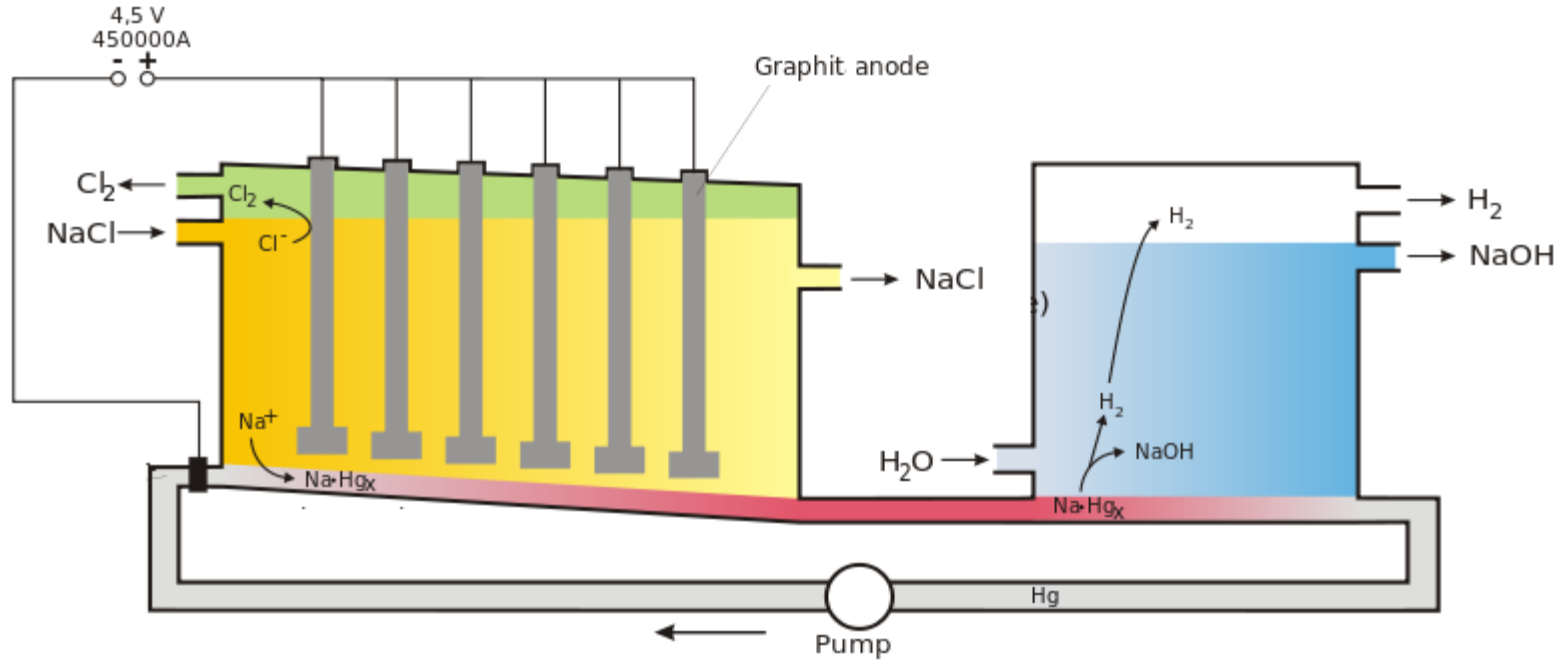
## BLEACH WAS THE PRODUCT

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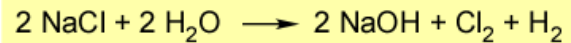
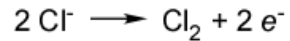
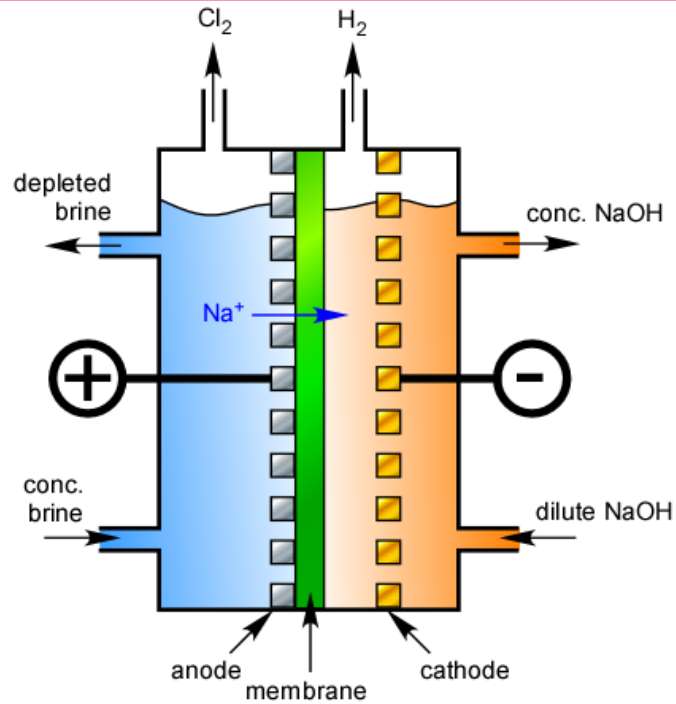


- The oxidizing power of chlorine was what was desired.
- *No net production of alkali*

# MERCURY CELLS



# MEMBRANE CELLS



## CO-PRODUCT PROCESSES

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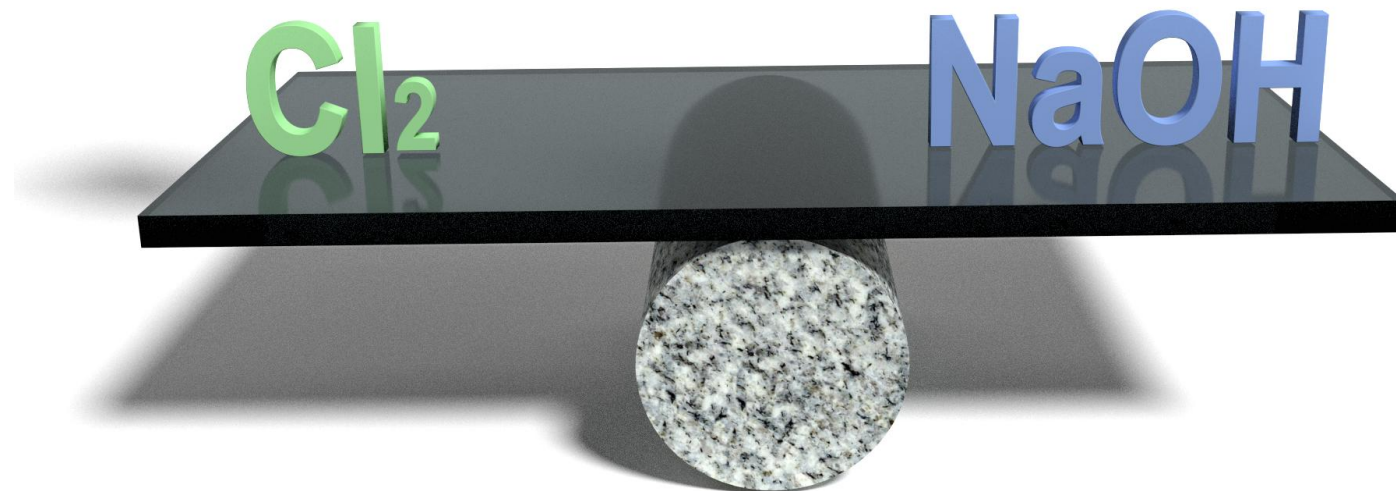


<https://www.youtube.com/watch?v=YYkj2yYaGtU>



## BALANCING THE ECU

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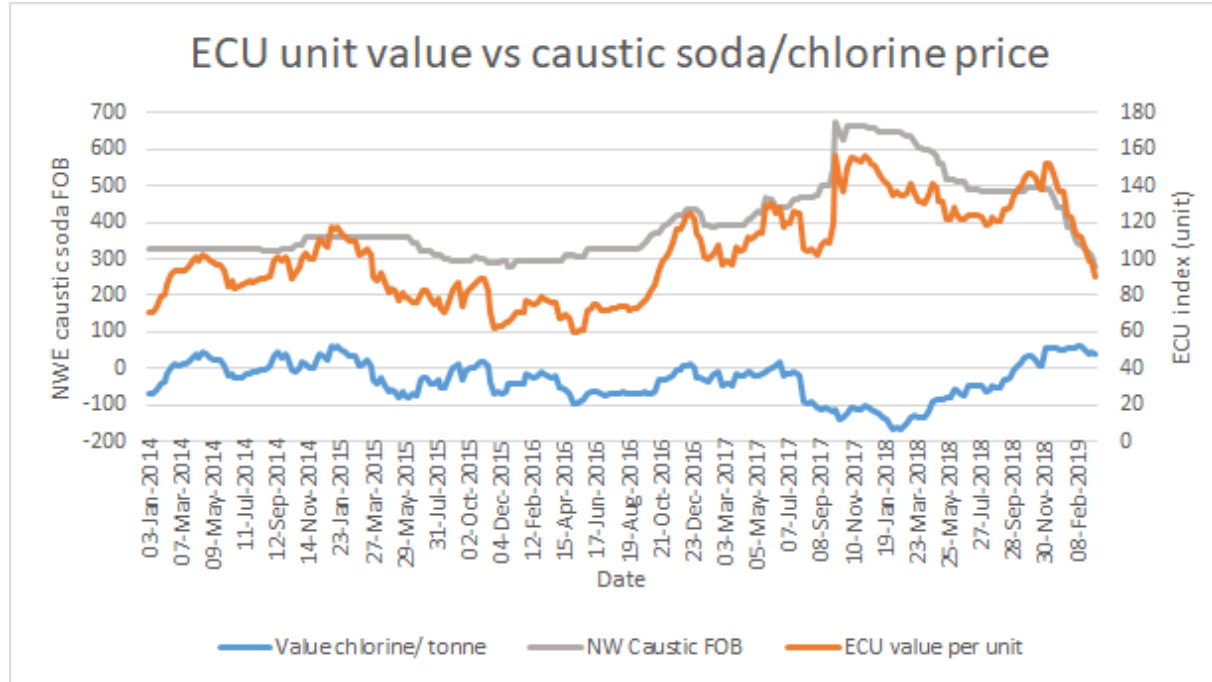
## Caustic Soda Chemistry and End Product Uses

## 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**.

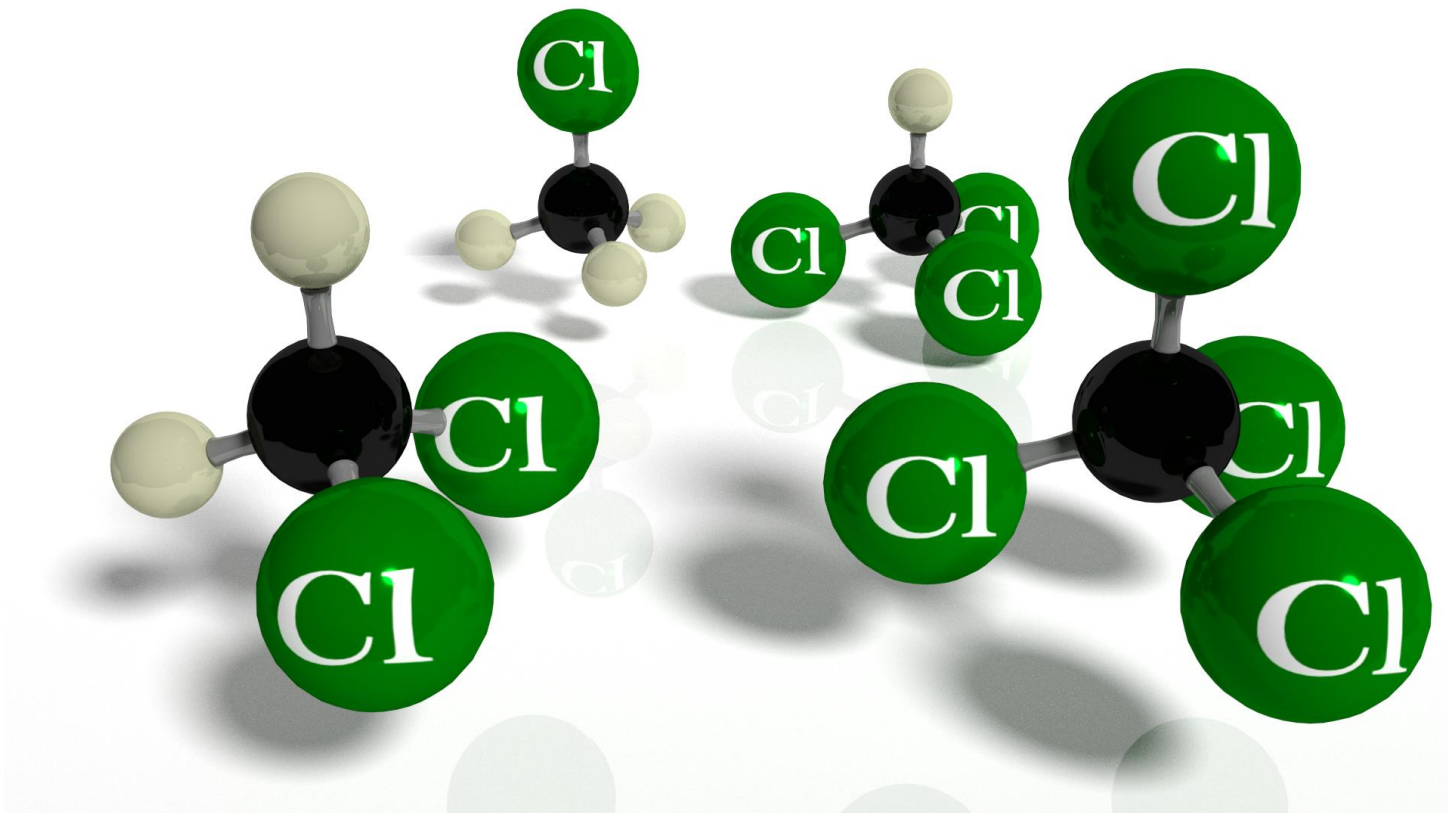
# ECU PRICING



[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

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# SUPER SOLVENTS

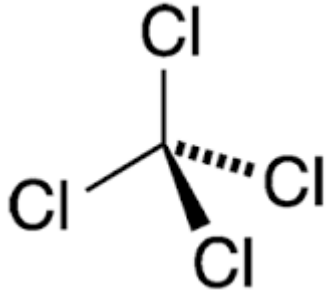
Ban

1970

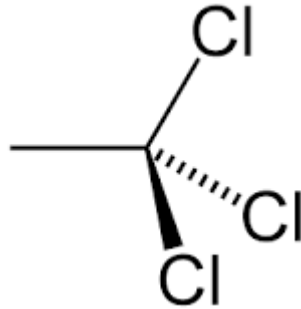
1996

2025

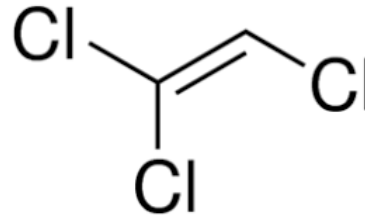
2025



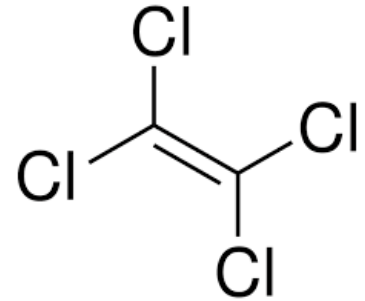
carbon tetrachloride  
carbon tet  
tet



1,1,1-trichloroethane  
1,1,1  
TCA

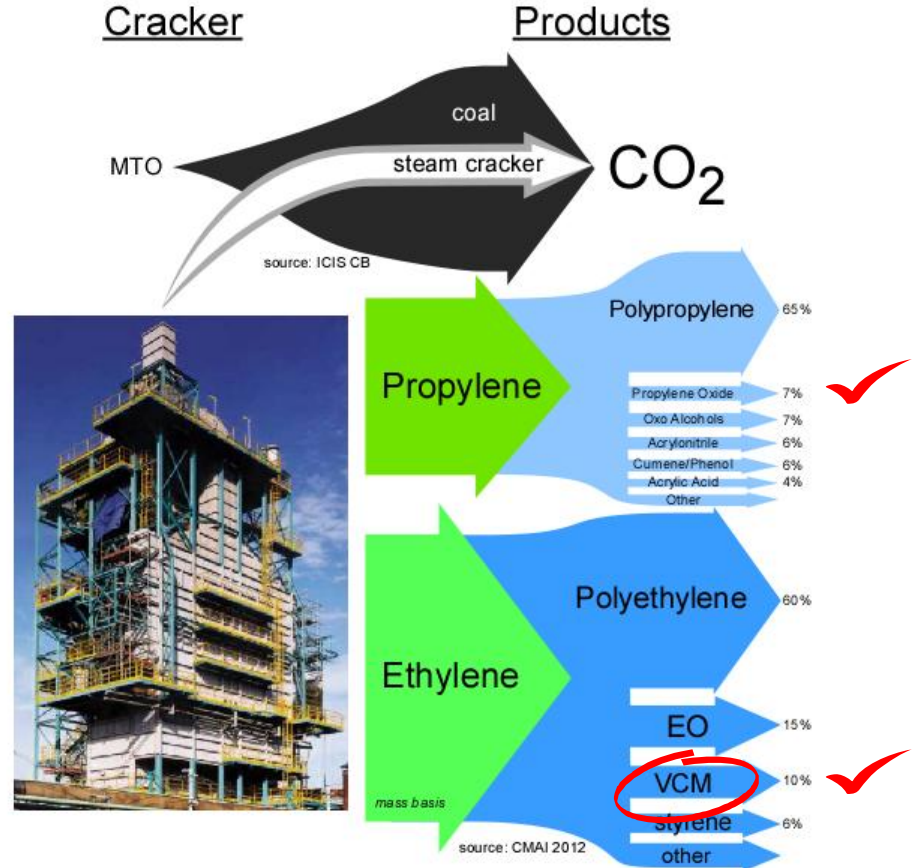
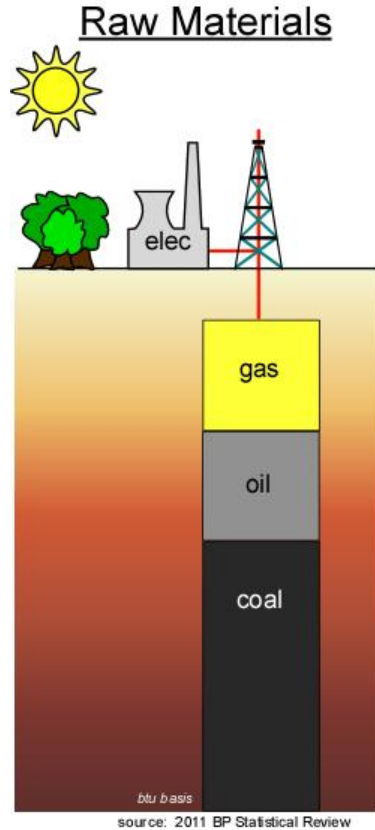


trichloroethylene  
tric  
TCE



tetrachloroethylene  
perchloroethylene  
perc  
PCE

# CHEMICAL INDUSTRY SNAPSHOT



# ROUGH INDUSTRY MASS BALANCE

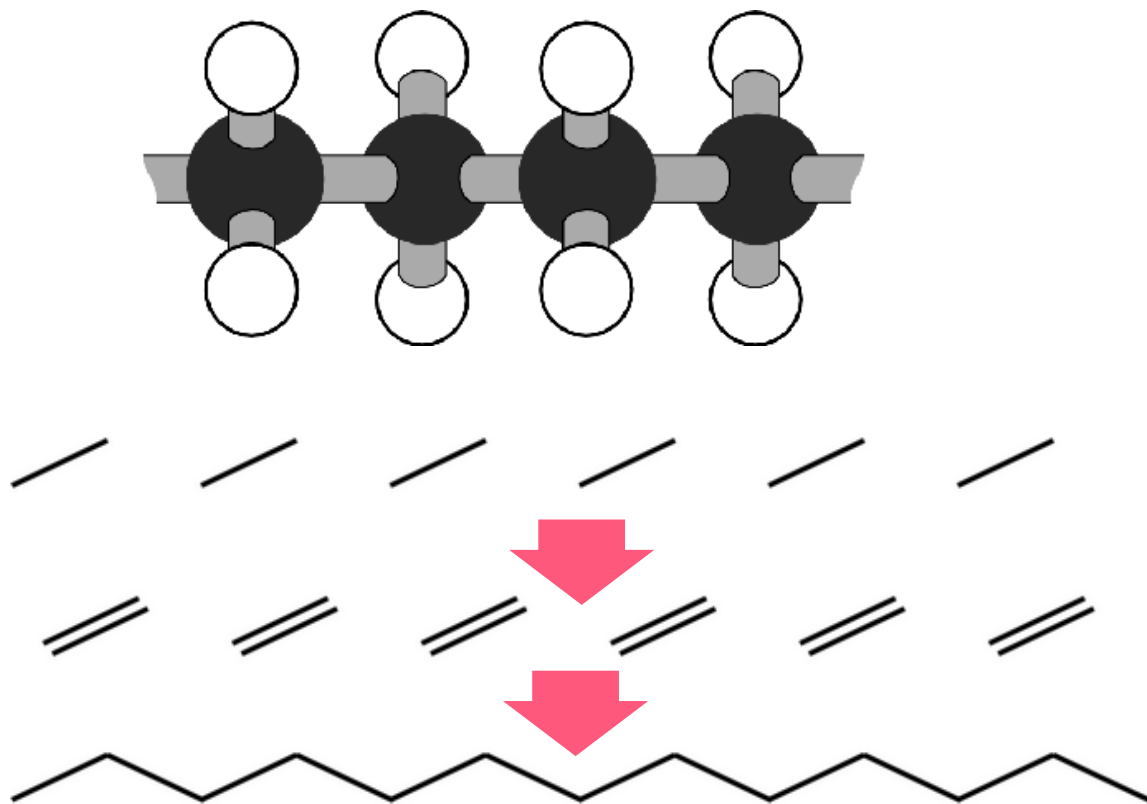
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# CHEMICAL TRANSFORMATION

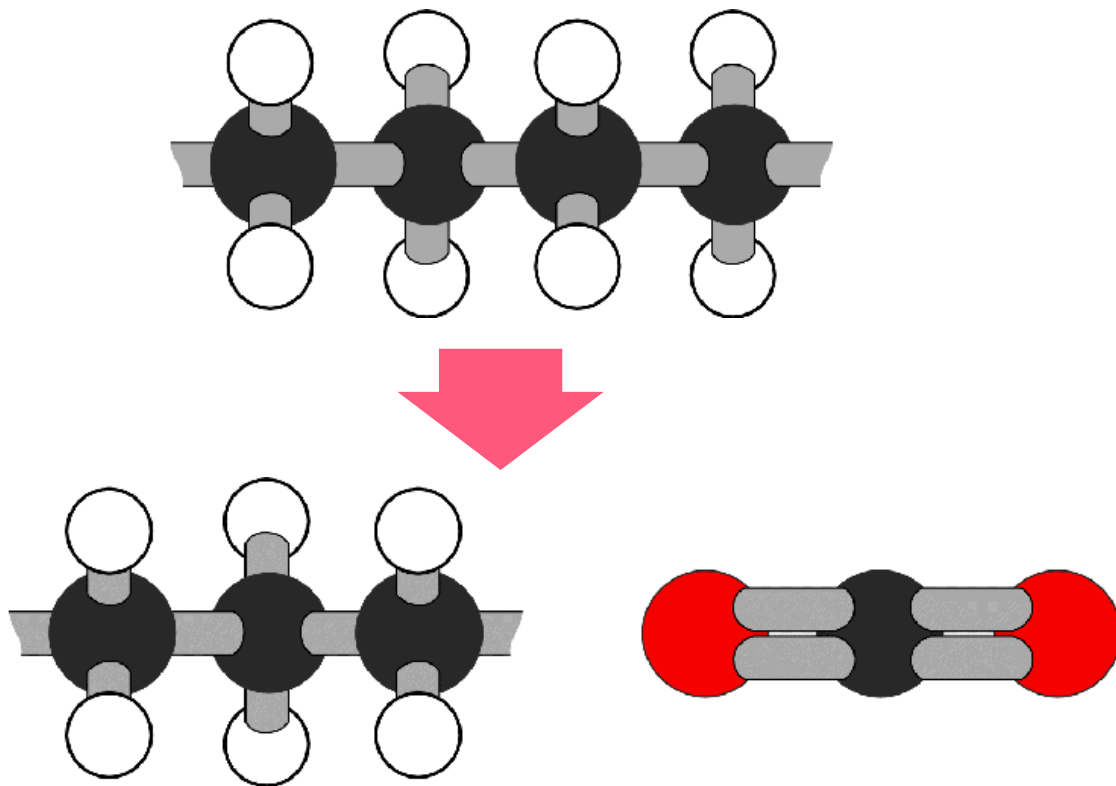
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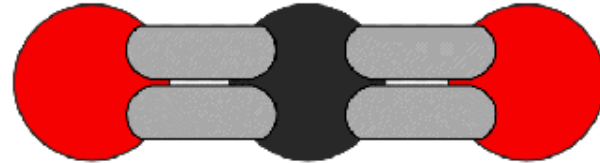
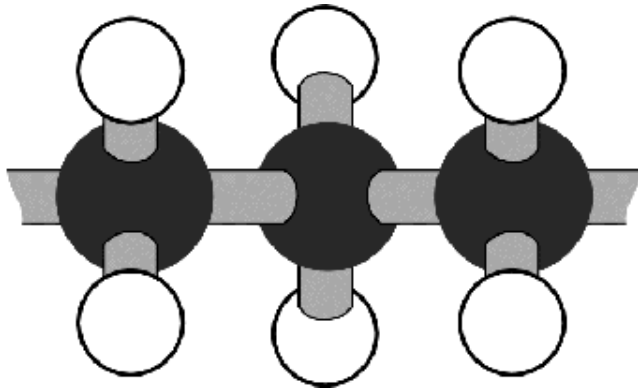
# ROUGH MASS BALANCE

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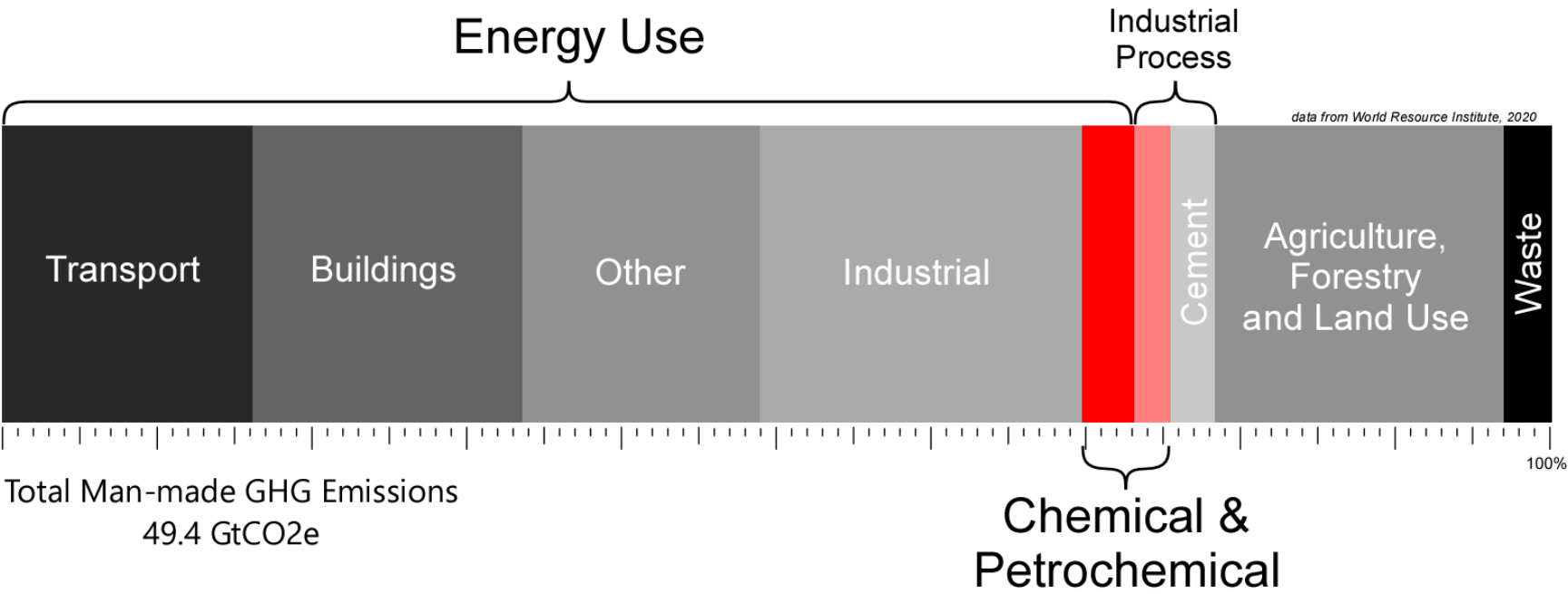


# IMPLICATIONS

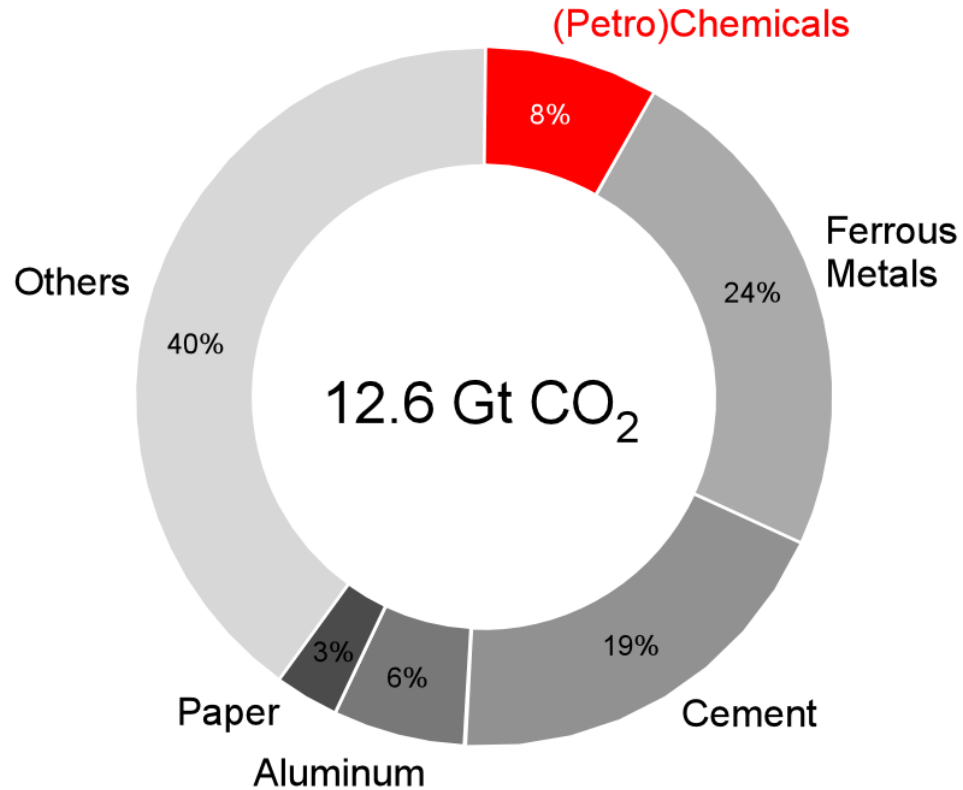
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# CARBON FOOTPRINT OF INDUSTRY

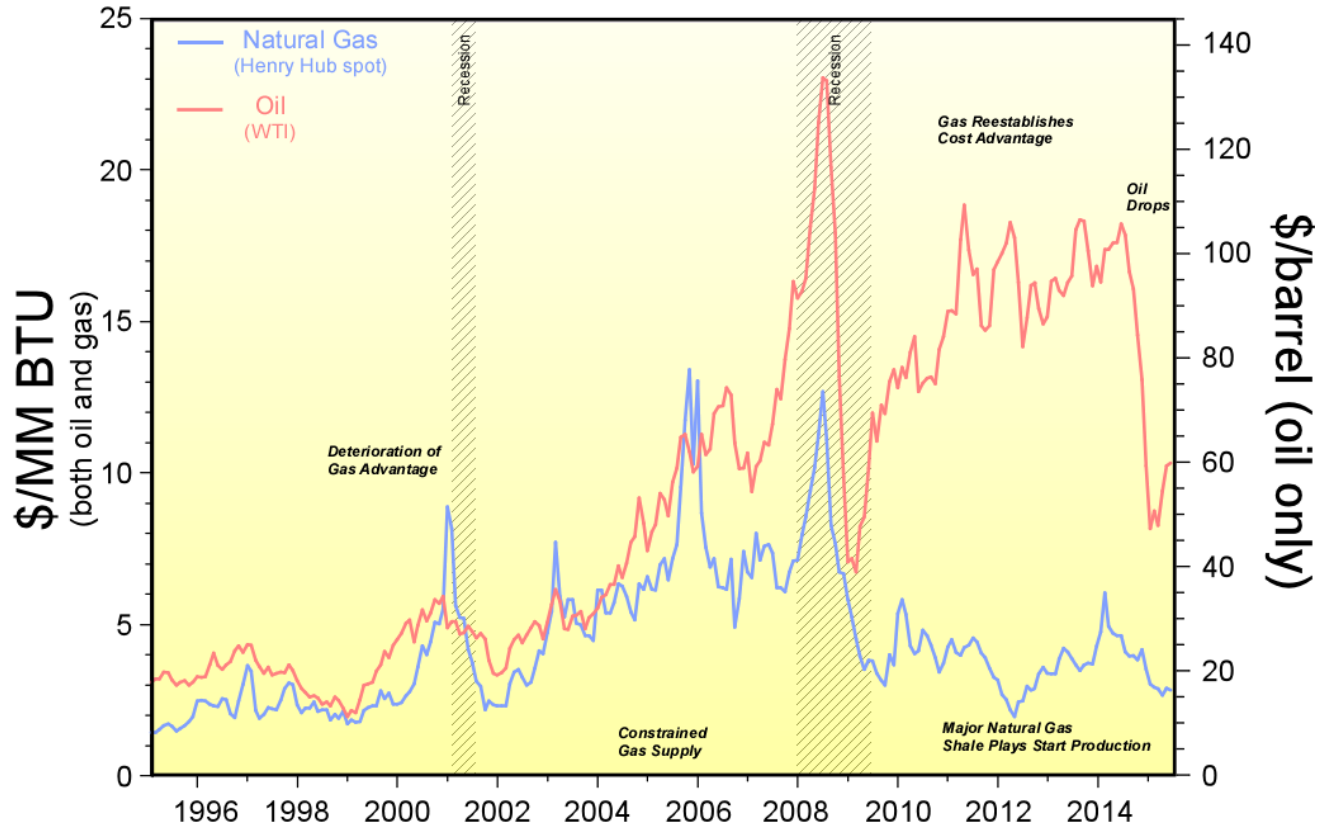


# GLOBAL CO<sub>2</sub> EMISSIONS FROM INDUSTRY

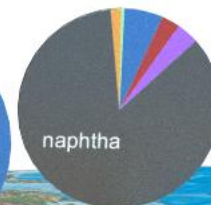
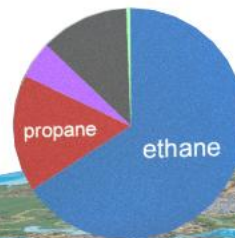
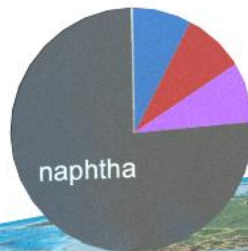
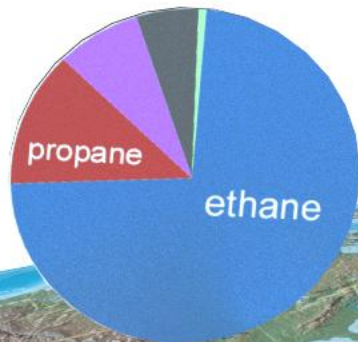


Martin Brudemuller, BASF at the World Economic Forum, 21 Jan 2020

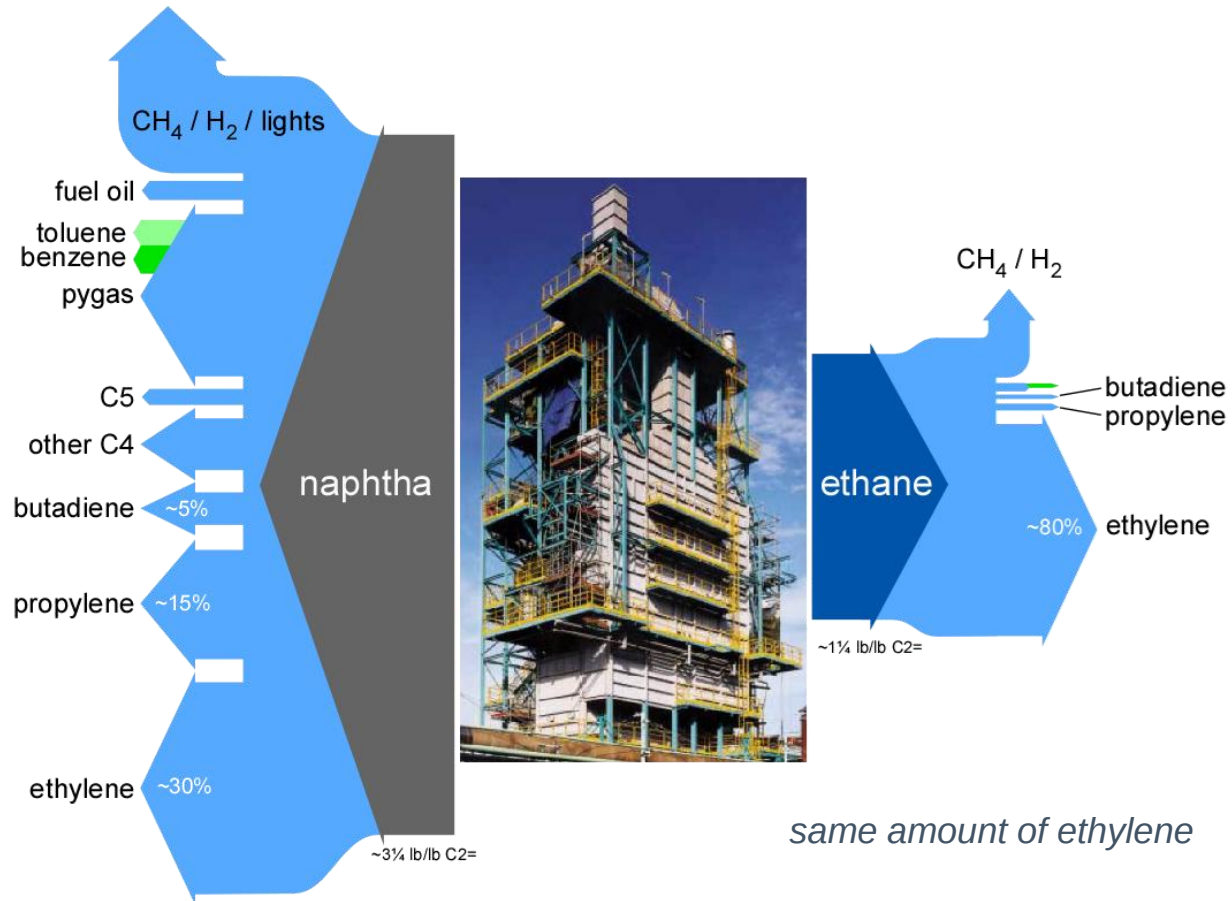
# RECENT INDUSTRY HISTORY



■ ethane ■ propane ■ butane ■ naphtha ■ MTO/CTO ■ other

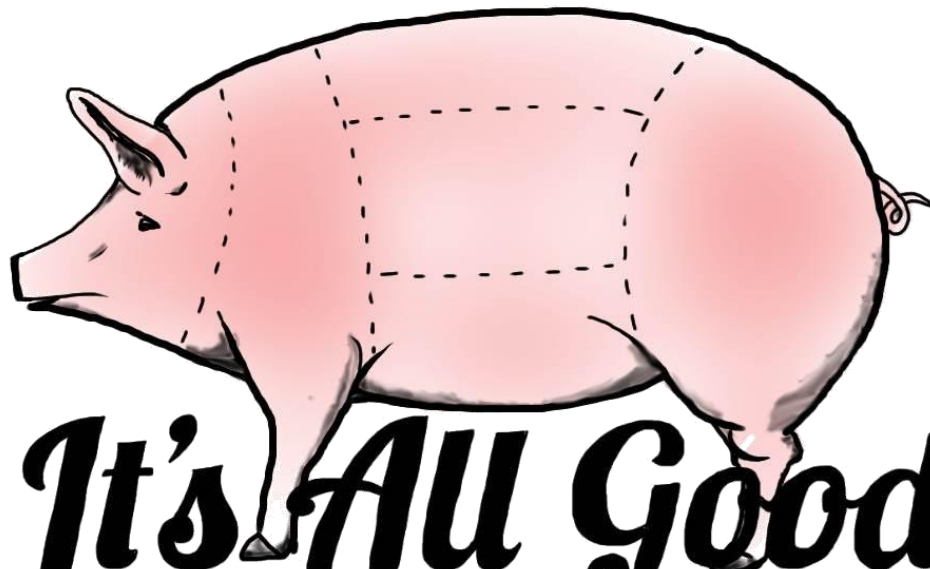


# CRACKING COMPARISON



## ALL REACTION PRODUCTS FIND USES

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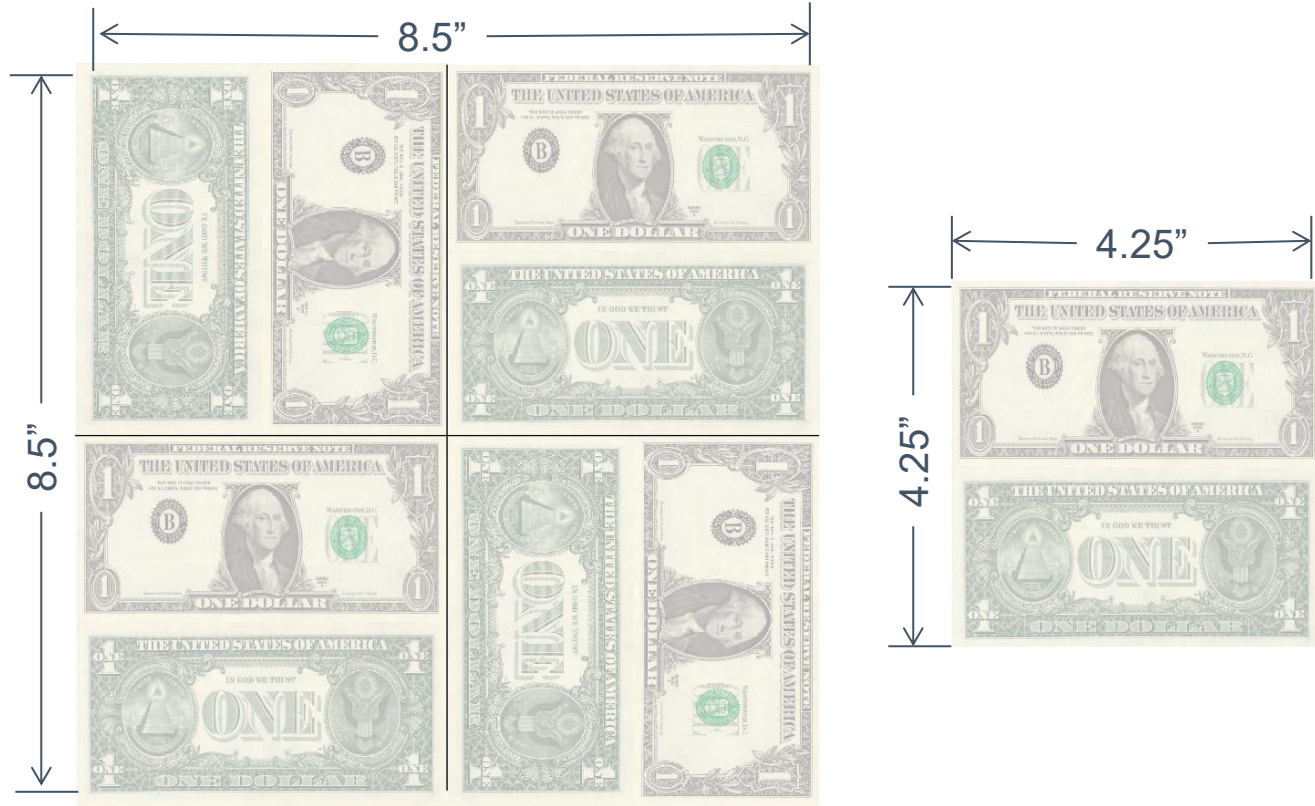
***It's All Good!***

# SCALE IS IMPORTANT

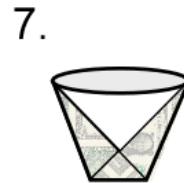
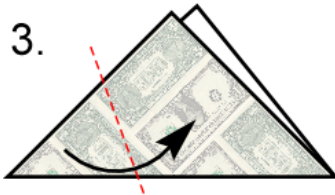
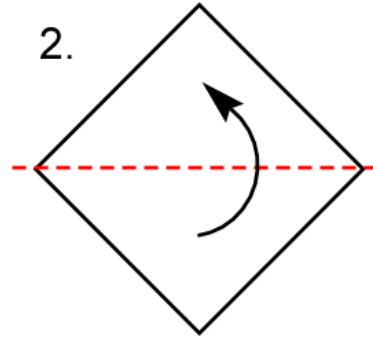
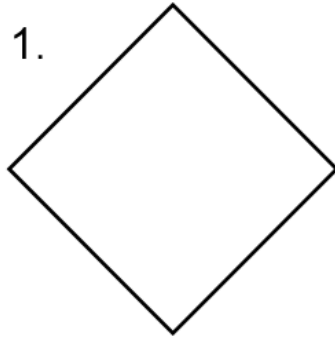
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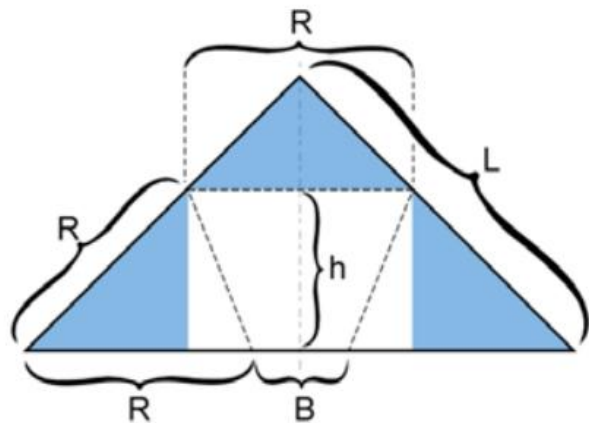
# ORIGAMI DEMO



## SCALE DEMO



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



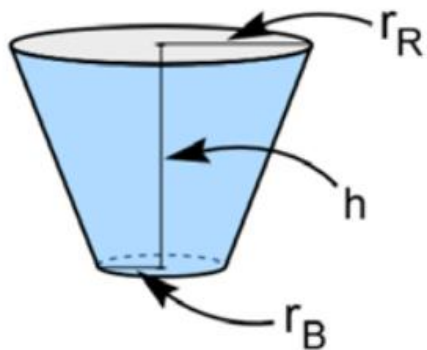
$$A = L^2$$

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

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

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

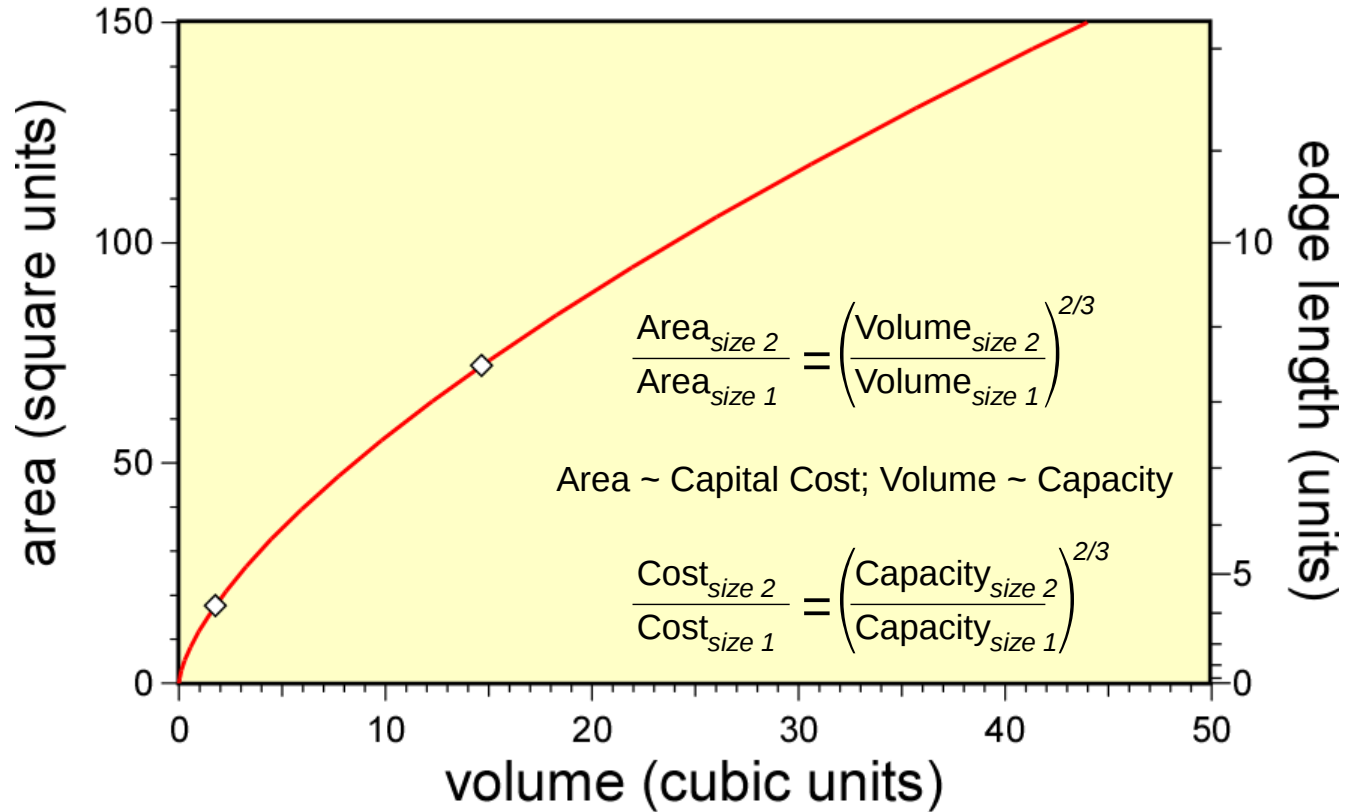
$$\frac{V_L}{V_{L/2}} = 8$$



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

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

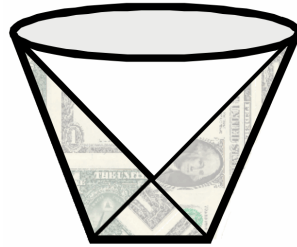
# POWER LAW



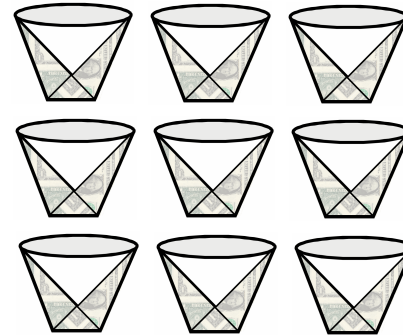
# IMPACT OF SCALE TO CONTAIN SAME VOLUME



>2X material  
~9X labor to construct



=



# SCALE ALWAYS WINS

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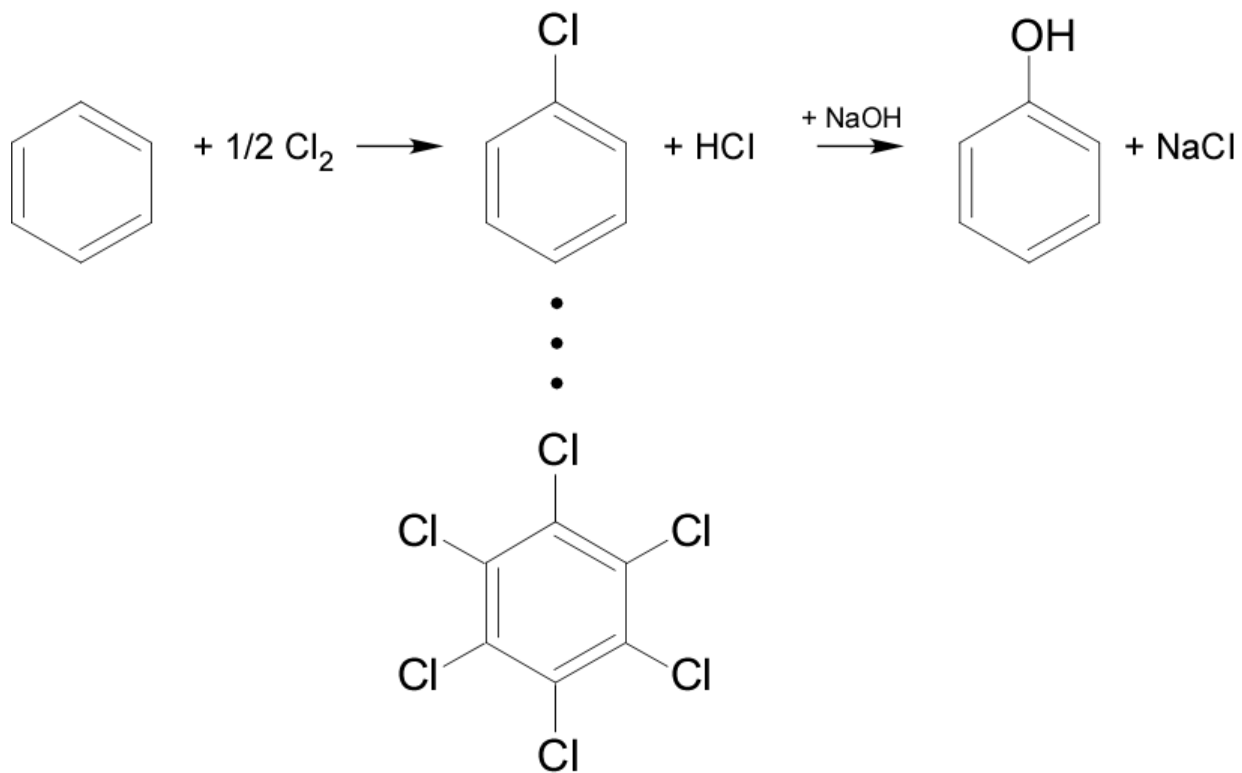


If you are moving mass around, scale reduces cost faster than experience.



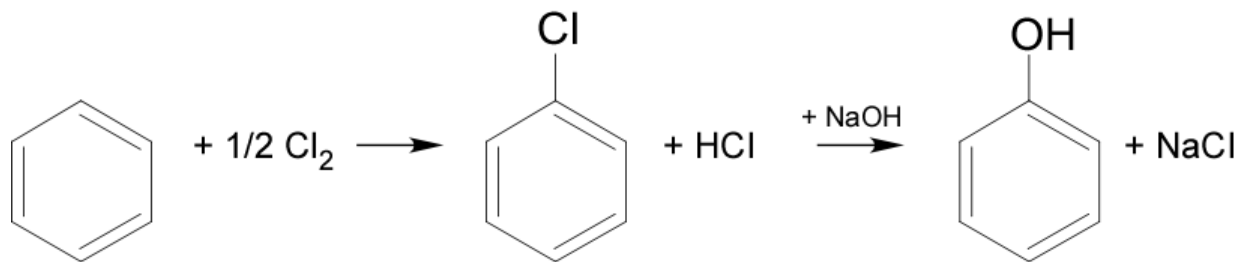
## CHLORINE AS AN OXIDANT

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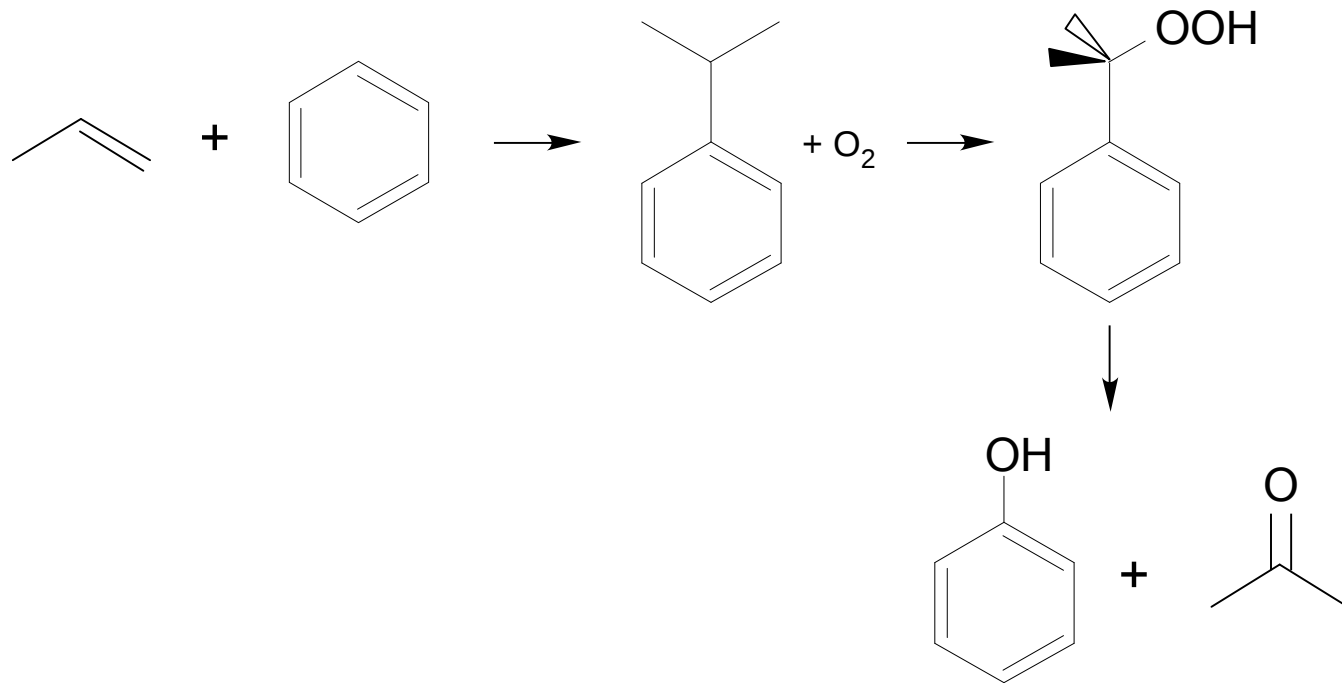
## CHLORINE AS AN OXIDANT

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# PHENOL TODAY

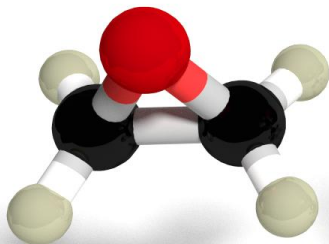
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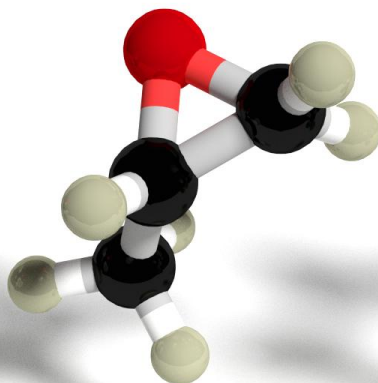
# EPOXIDES

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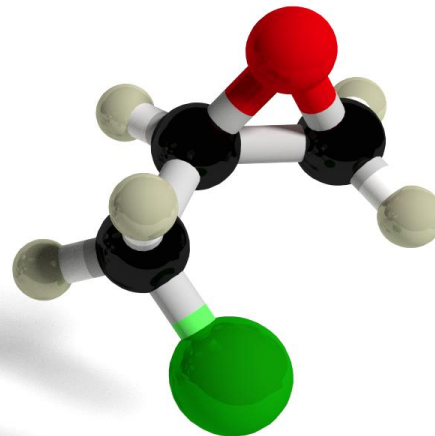
EO  
ethylene oxide



PO  
propylene oxide

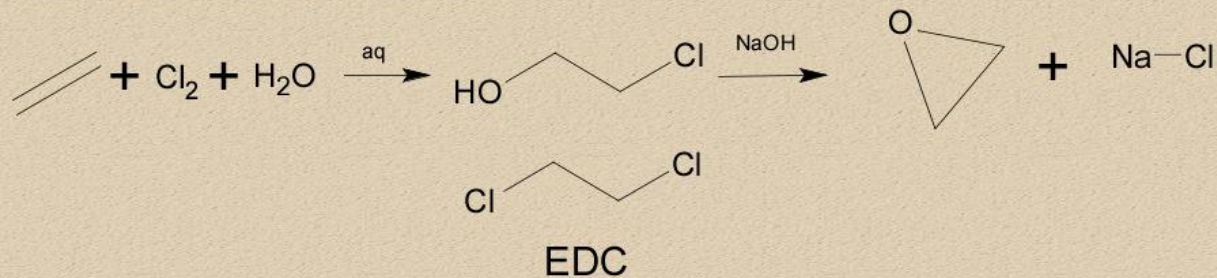


EPI  
epichlorohydrin



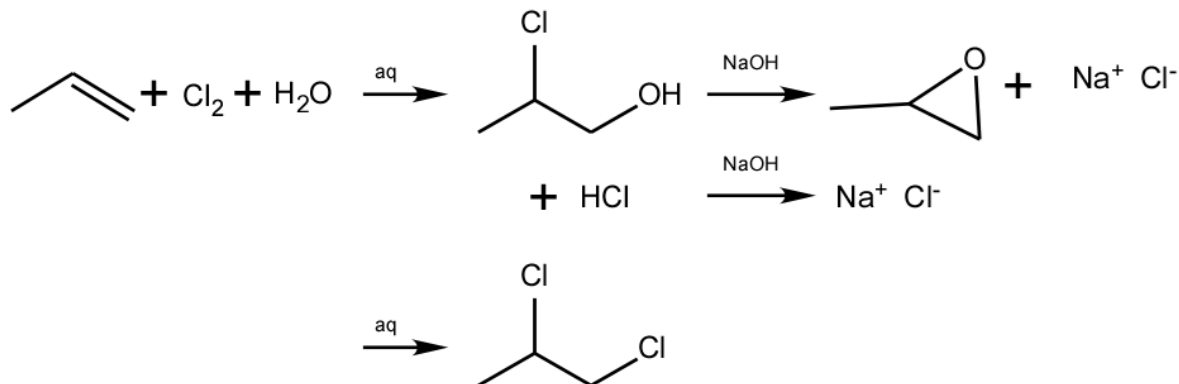
# CHLOROHYDRIN CHEMISTRY

## Chlorohydrin Ethylene Oxide



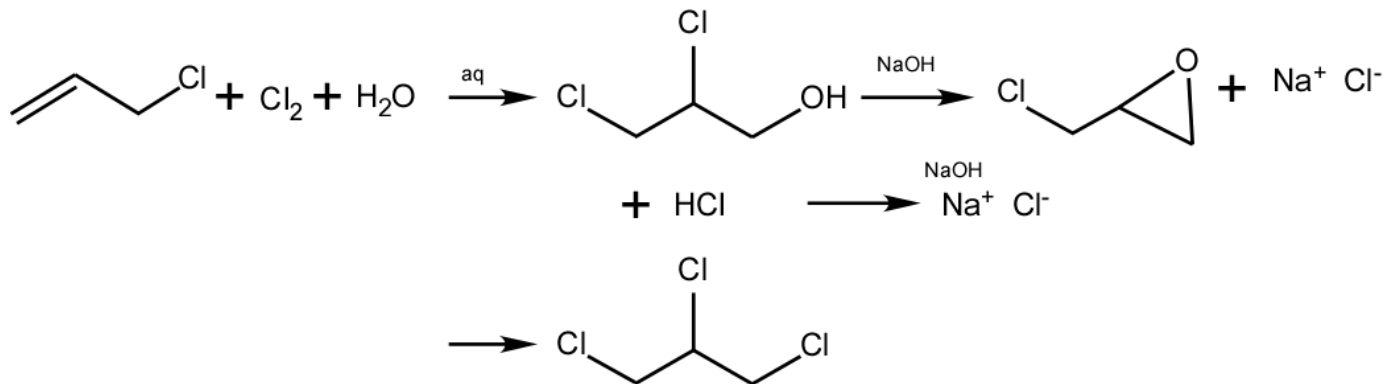
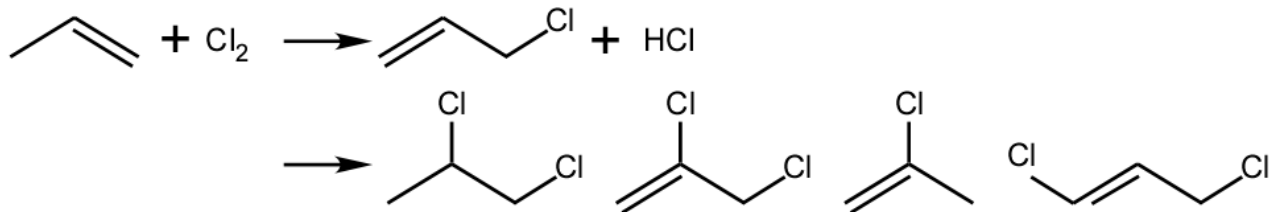
1915-1975

## Chlorohydrin Propylene Oxide

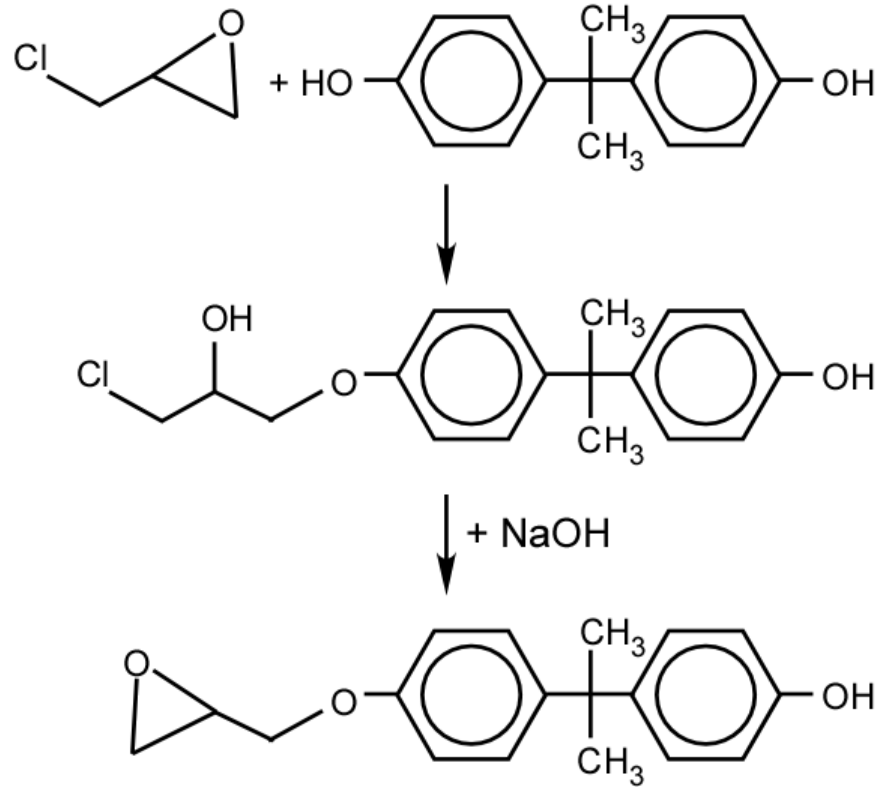


# MORE CHLOROHYDRIN CHEMISTRY

## Chlorohydrin Epichlorohydrin

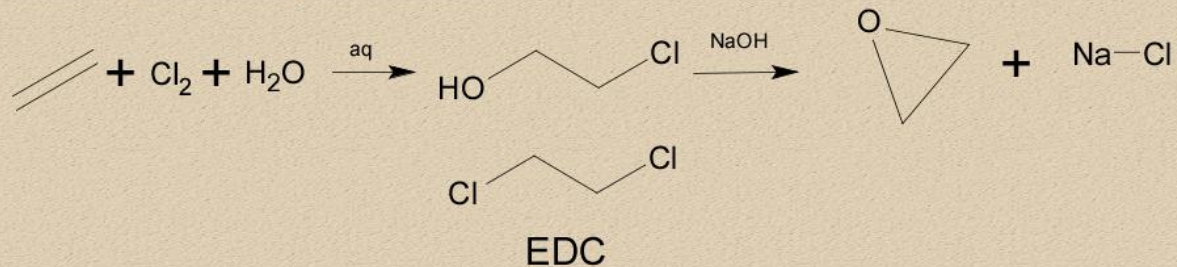


# EPOXY RESINS

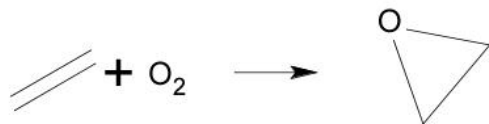


## DIRECT OXIDATION

### Chlorohydrin Ethylene Oxide

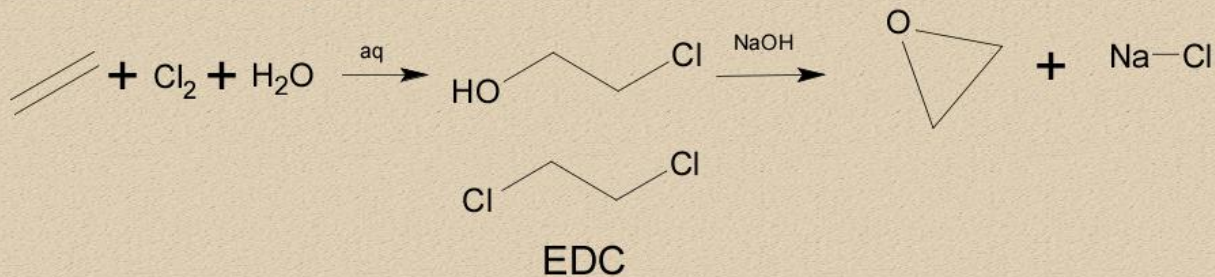


### Direct Oxidation Ethylene Oxide

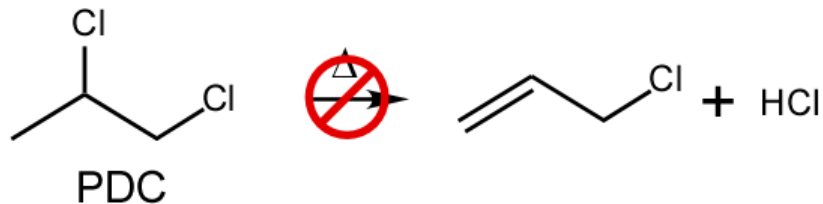
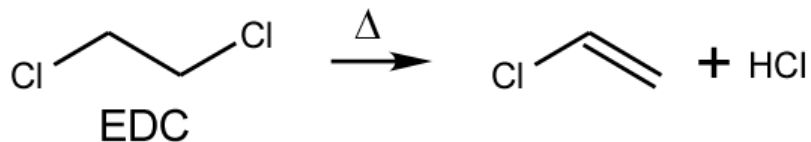


# CHLOROHYDRIN CHEMISTRY

## Chlorohydrin Ethylene Oxide

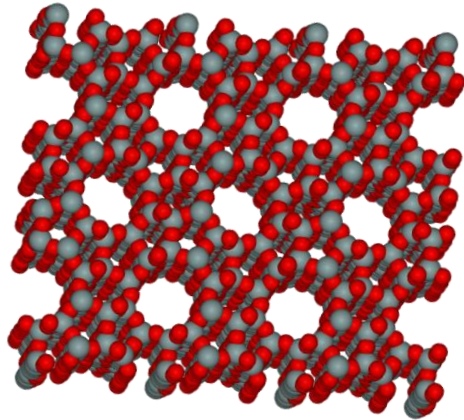
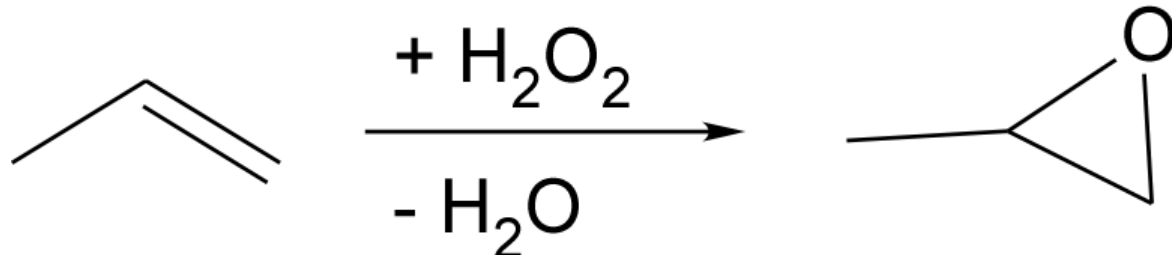


1915-1975



# HYDROPEROXIDATION

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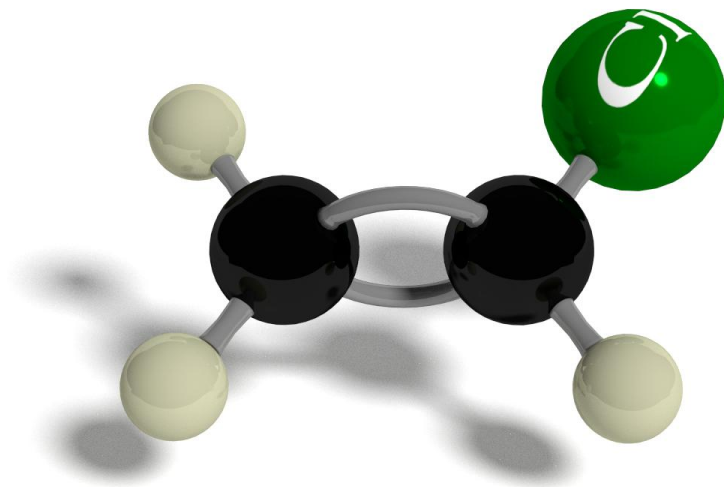
titanium silicate catalyst

0.5 nm pores

suitable for packed bed reactor

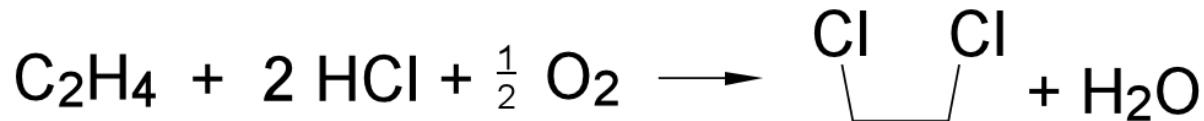
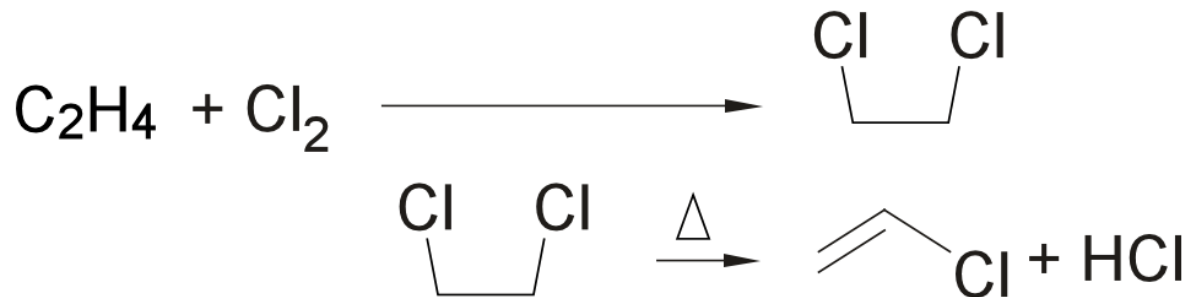
# VINYL CHLORIDE

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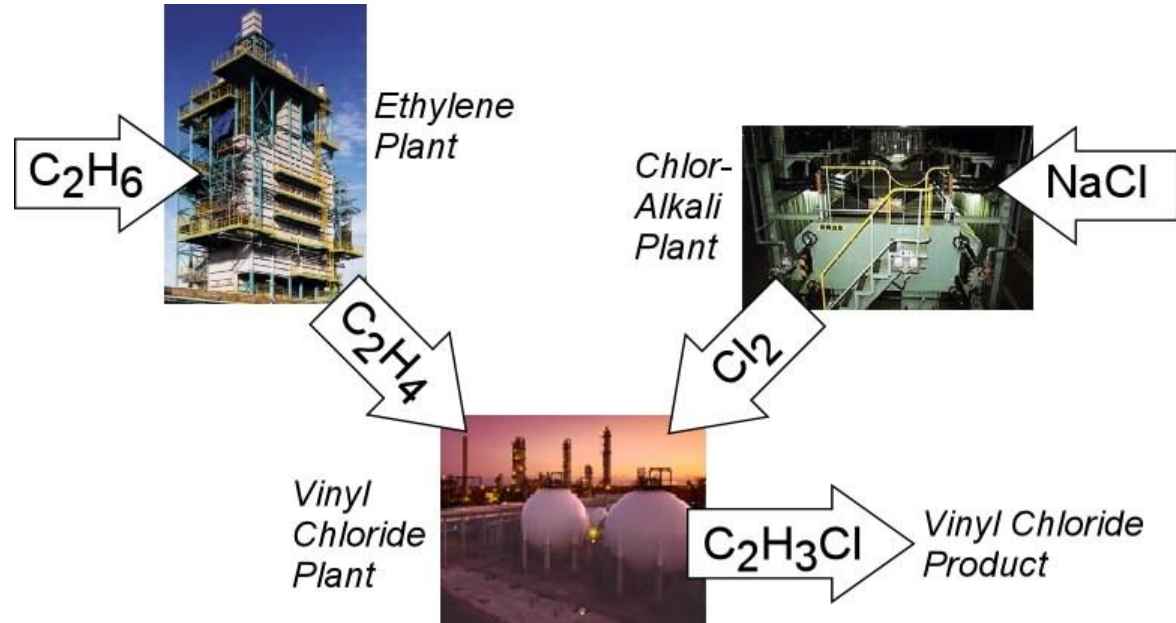


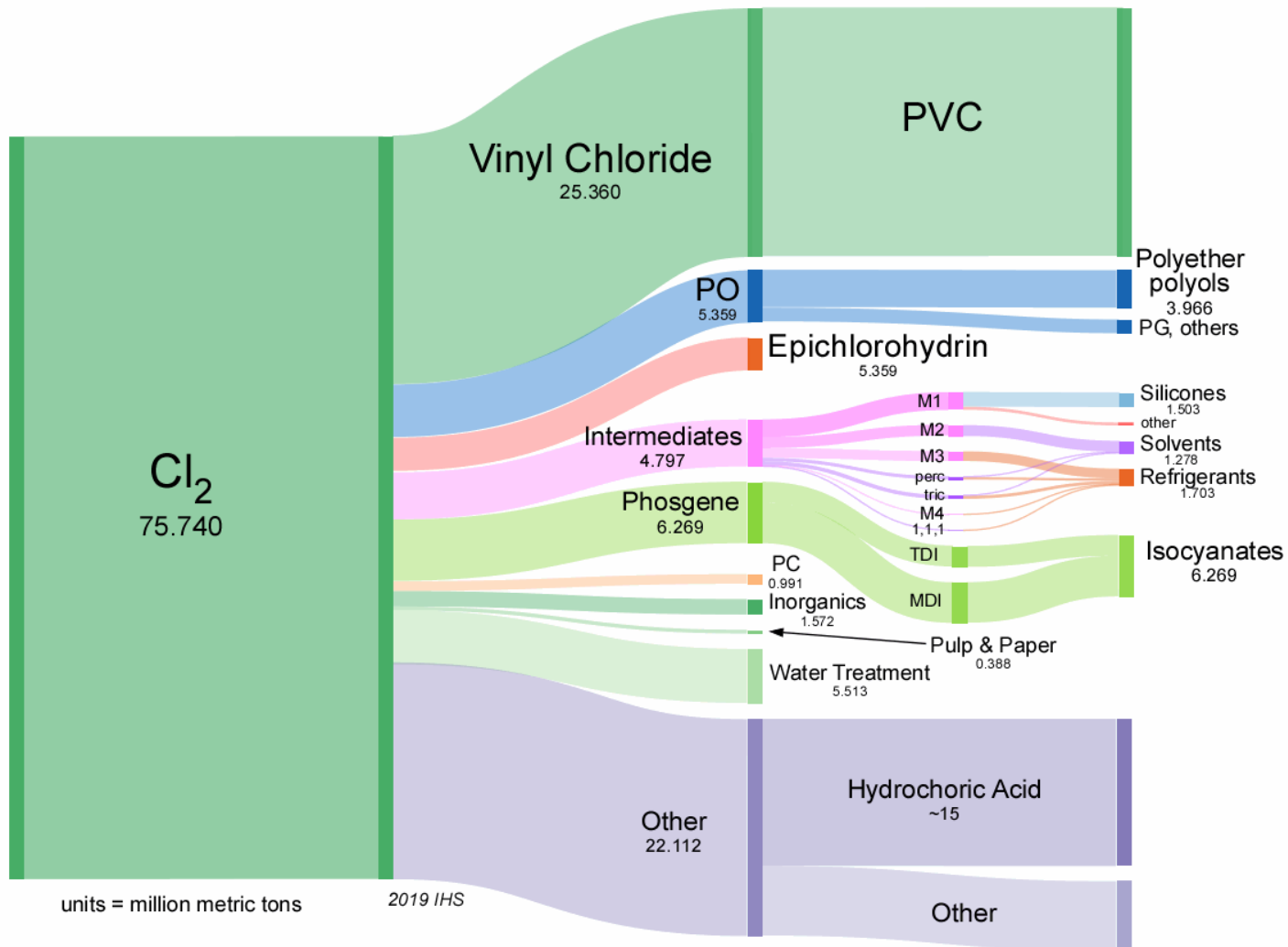
## CONVENTIONAL PRODUCTION

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# CONVENTIONAL VCM



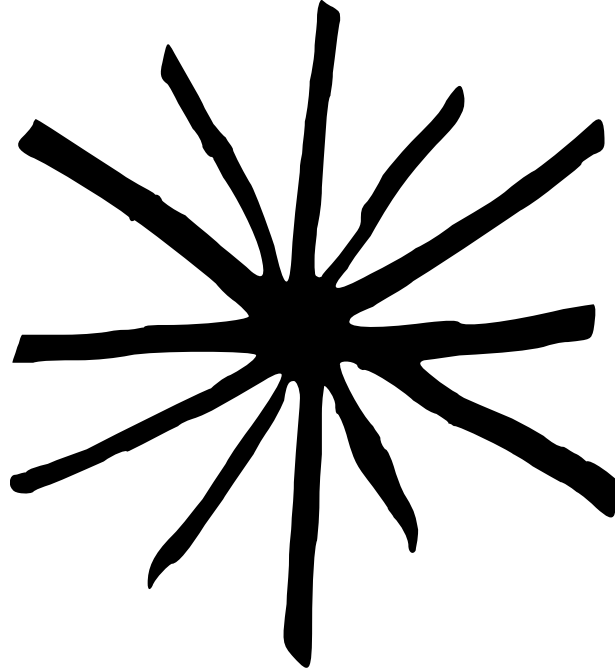


units = million metric tons

2019 IHS

# BREAKFAST OF CHAMPIONS

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



Vinyl chloride was on the train because PVC production is the sink for chlorine that allows production of caustic soda.



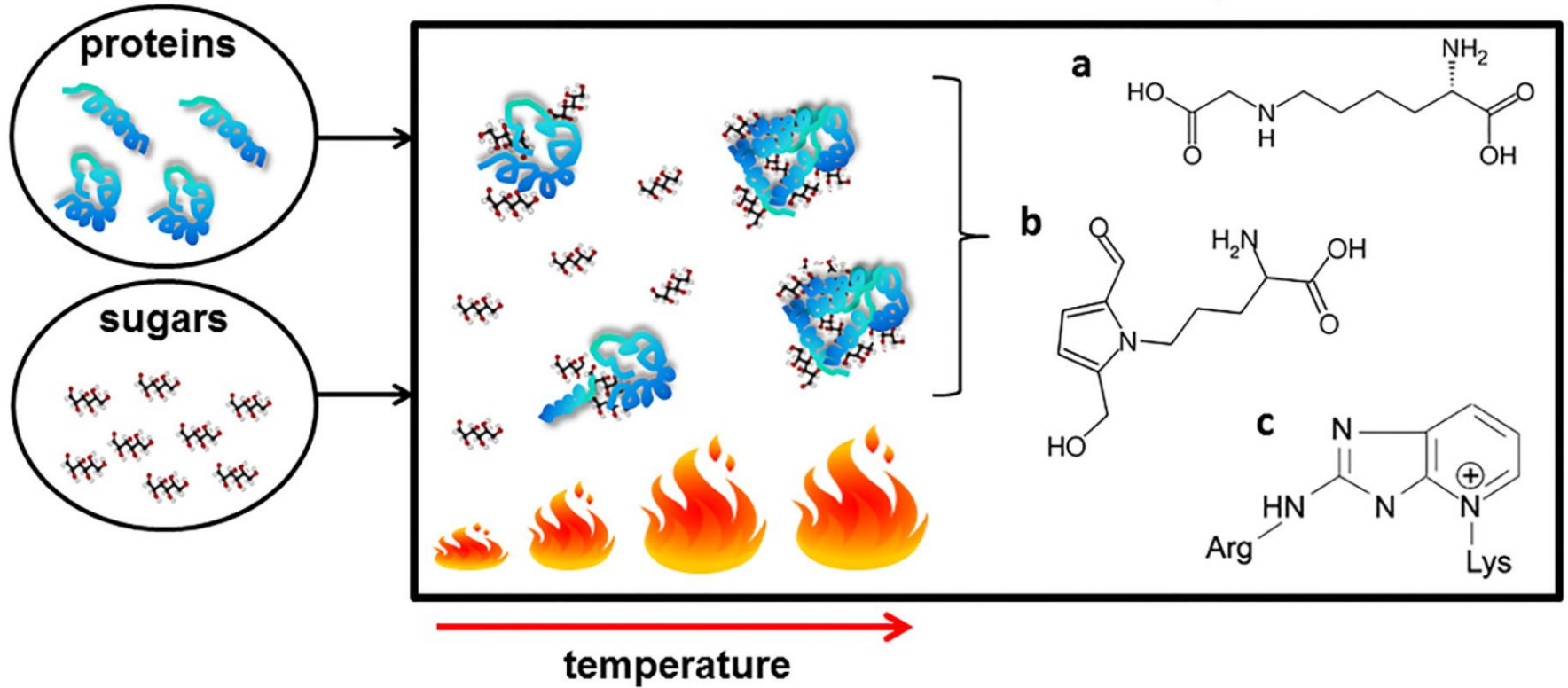
## CO-PRODUCT PROCESSES

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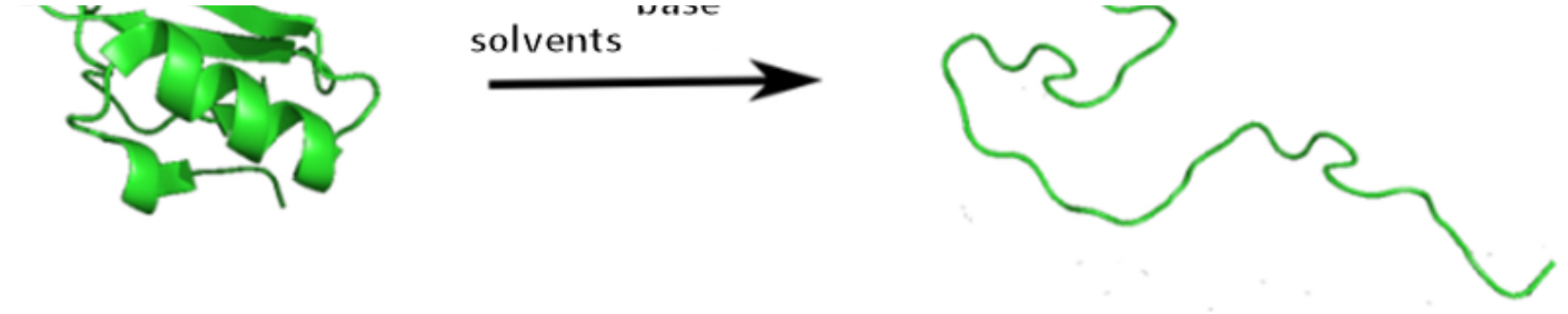


## Formation of Maillard reaction products



## Denaturing Proteins

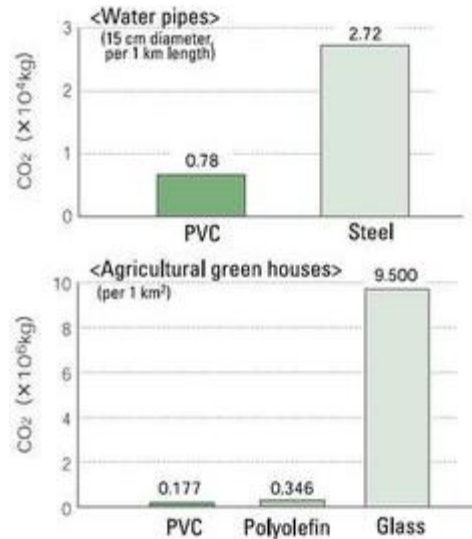
Vinyl chloride was on the train because of pretzels (and all the other uses of caustic necessary for modern life).



<https://montessorimuddle.org/2013/11/17/proteins-via-food-science/>

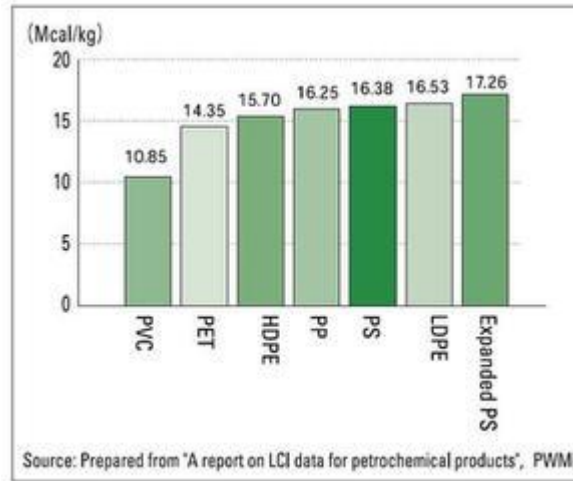
# VINYL SUSTAINABILITY

## Lower Carbon Footprint



Source: Prepared from the survey report by Chem Systems

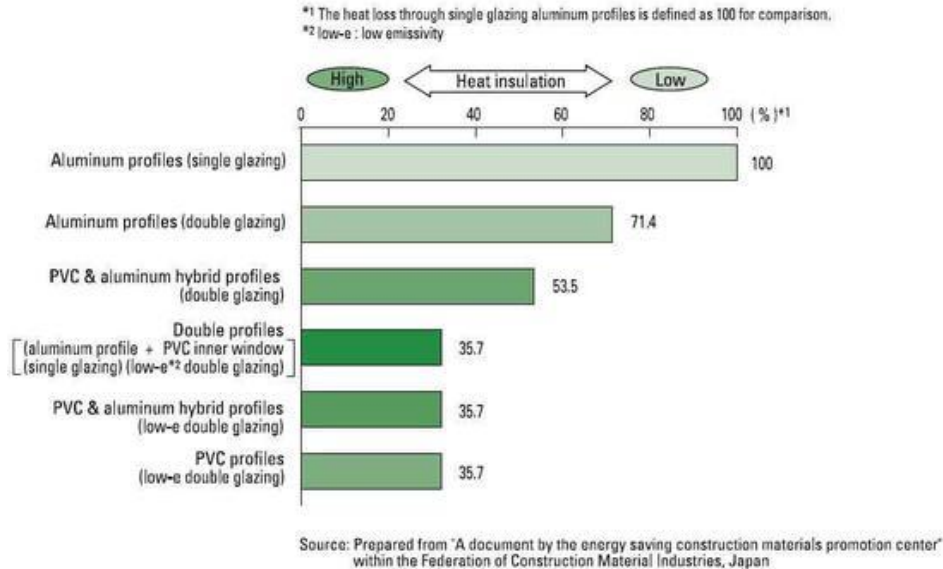
## Energy Efficient



Source: Prepared from "A report on LCI data for petrochemical products", PWMI

Atom efficient – most inputs end up in the product

## Energy Savings Over Lifetime



Long lifetimes during use in infrastructure.

## WHAT I HOPE I'VE LEFT YOU WITH

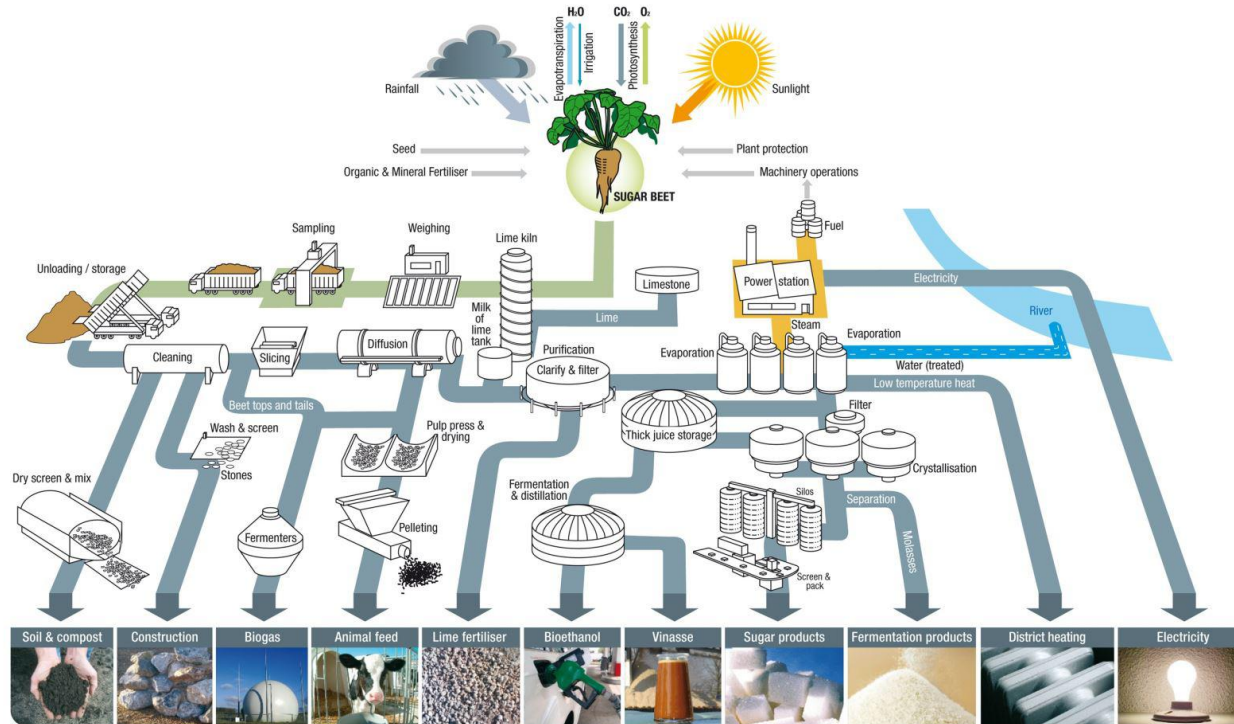
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- Inorganic chemistry created the chemical industry and remains important, but not particularly valued  
*vinyl and caustic are critical, just not particularly profitable*  
*chlorine has largely been replaced as an oxidant*
- Scale remains the major source of competitive advantage in commodity chemicals  
*for undifferentiated materials, production cost is king and scale lowers production cost*
- Sustainability is multifaceted and complex with hidden interactions.



**MJPhD**

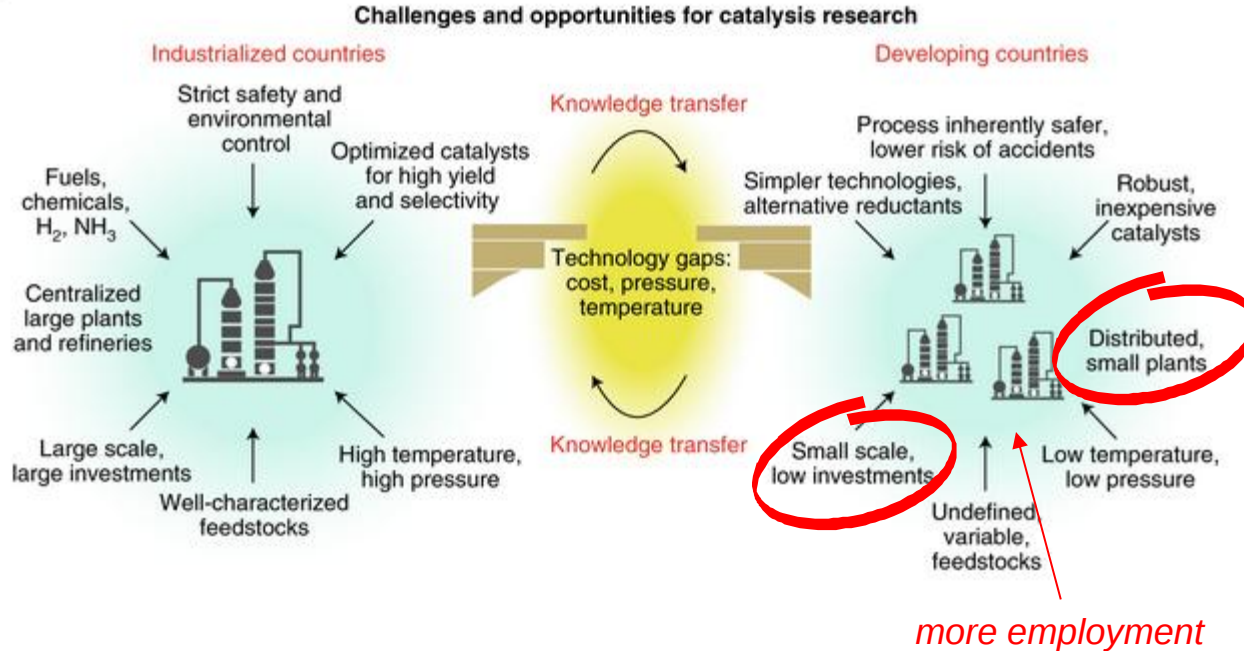
## FROM BEET FIELD TO SUGAR FACTORY



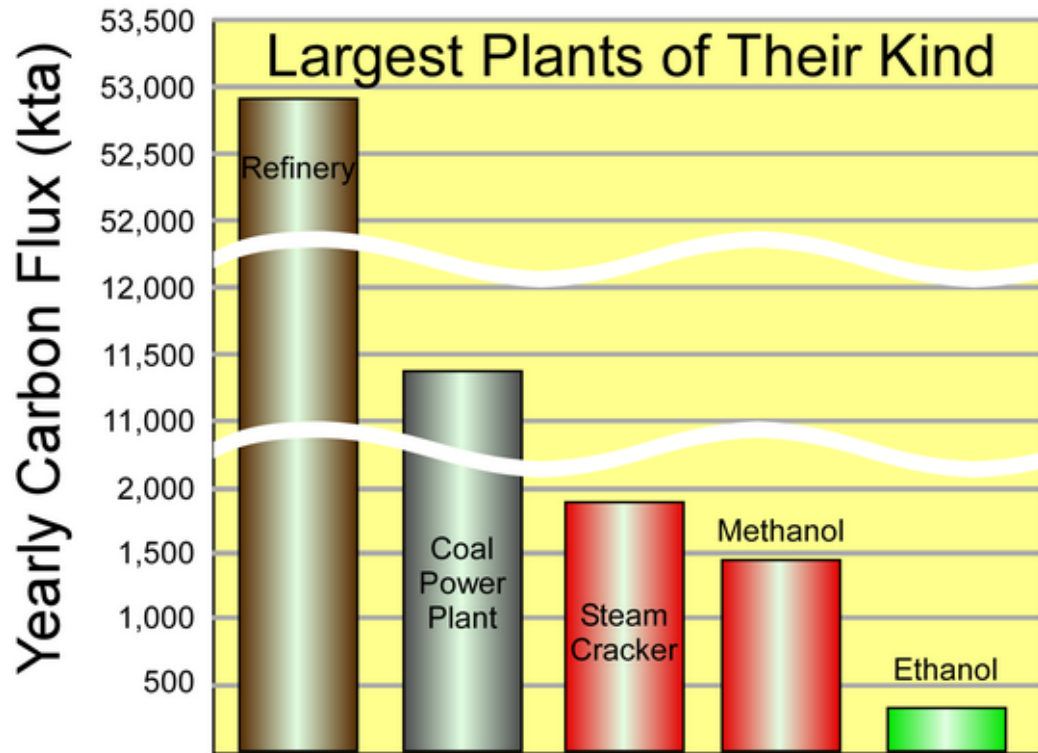
Source: CIBE and CEFS (after British Sugar)

[prokris.nl/production/](http://prokris.nl/production/)

# DISTRIBUTED MANUFACTURING



Resasco DE, Wang B, Sabatini D. Distributed processes for biomass conversion could aid UN Sustainable Development Goals. *Nature Catalysis*. 2018 Oct;1(10):731.



# AG VERSUS CHEMICAL COMPARISON

