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CHEMRAWN XVI CONFERENCE

Predicting Chemical Profitability in the Chemical Industry

New Breakthrough Chemical Manufacturing Technologies

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SRI Consulting

August 9, 2003

Introduction

Process
Economics
Program

- **PEP** program provides in-depth, independent technical and economic evaluations of both commercial and emerging technologies for the chemical and refining industries.
- Areas Covered:
  - Specialty Chemicals
  - Polymers
  - Refining Technologies
  - Life Sciences
  - Environmental Technologies
  - Information Technologies
  - Biotech

Introduction

Process
Economics
Program

- **A new approach to evaluating technology**
- Tools:
  - Process Simulation
  - Equipment Sizing
  - Investment Estimation
  - Reliable Operating Cost Forecasts

PEP Reviews Almost Every New Petrochemical Development Impacting the Industry

- PET
- Chemicals from Renewable Resources
- Global Petrochemical Outlook
- Sulfur Removal from Petroleum Fuels
- Advances in Oxidation Technology
- Chemicals for Electronic
- Yearbook 2002
- Chiral Intermediates
- Ethylene Plant Enhancement
- Single Site Catalyst
- Ocean Transportation
- Cogeneration
- Innovative Reactors
- Alpha Olefins
- Membranes
- Aliphatic Diisocyanates
- Super-Absorbant Polymers
- Biocatalysis
- Polypropylene SSC
- Enzymes
- Industrial Coatings
- Non-Metallocenes
- MeOH Chemicals
- Bio Separations
- Epoxy/Carbonates
- Propylene Industry Outlook
- Alkylation for Motor Fuels
- Octane Improvers
- Propane Based Acrylonitrile
- Refinery Residue Gasification
- Experience Curves
- Biodegradable Polymer Life Cycle Assessment
- Custom Chemical Manufacture
- Strategic Business Units for Nylon
- Polystyrene
- Polypropylene Update
- Natural Gas Liquids
- Acetic Acid
- Fuel Cells for Vehicles and Power
- Propylene Oxide
- DME
- Nano-composites
- Near Zero Sulfur Diesel
- Green Polyurethanes
- Acetal Resins
- Electronic Polymers
- Amino Acids
- Plasticizers
- Fluropolymers
- GTL

Recent Reviews

PEP Review Studies

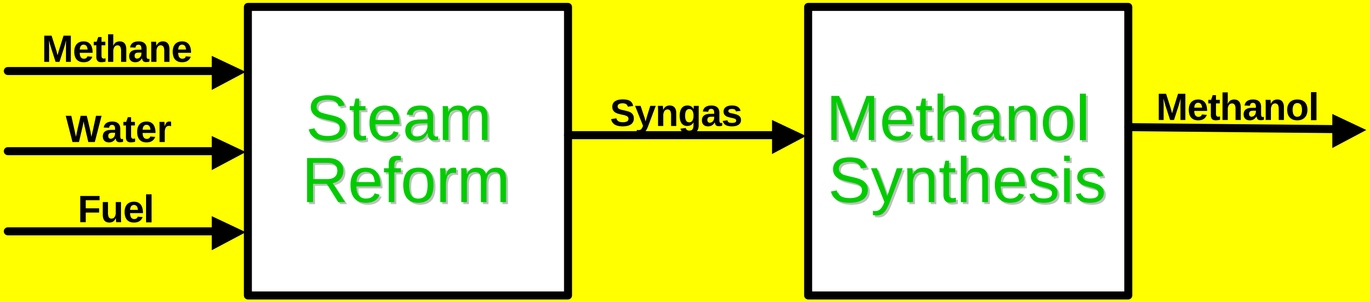
- Solid Acid Alkylation
- Caprolactam via Gas Phase Beckman Rearrangement
- Basell's Multizone Circulating Reactor
- ENI Slurry Technology
- Linear Alkylbenzene by Hetergeneous Catalysis
- Methyl Methacrylate
- Maleic anhydride from butane
- Hydroquinone
- Kryoto Update
- Experience Curve Effect on Plant Cost Estimation
- EU 2004 - new country profiles, effect on European chemical markets
- Refrigeration in process plants - CFCs are dead, and HCFCs and HFCs are under pressure
- Zero discharge wastewater strategies
- Online buying and selling of chemicals - a look at the economics
- Breakthrough Technologies
- Self assembling polymers
- Streamlined life cycle assessment of two competing products
- Ethylene vinyl alcohol copolymer
- Glucose
- The (air blown) Starchem Methanol Process
- Carbon Nanotubes for Hydrogen Storage
- Ethanol from Corn Stover
- Acrolein Production (Feed stock for 1,3 propanediol and methionine)
- Glycidyl methacrylate
- Bio computer chips
- Applications of Ionic Liquids
- Elf Atochem Direct route for Hydrogen Peroxide
- Philips Desorb
- Renewable fuel options for gasoline
- Canadian (Alberta) Tar Sands Upgrading
- Homogeneous Solution Polymerization of Fluoromonomers With Supercritical CO2
- Cellulose esters
- Peroxide route to Sulfuric acid
- Catalytic steam cracking for olefins production
- Cell culture processing developments
- Chemical Industry Market Concentration and Scale
- Slurry Phase DME Synthesis Technology.
- Lube Oil dewaxing
- Online, real time economic optimization
- Numerical Methods - overview
- Membrane Applications in natural gas processing
- Barge Mounted GTL Plants
- Membrane desulfurization of refined liquid fuels
- Micro chemical manufacturing
- Computation techniques for estimating physical properties
- Computational fluid dynamics applications in the chemical industry
- Hydotreating Lube Oils
- Methane Hydrate recovery
- Nutritional supplements
- Petroleum coke uses
- Syndiotactic PS & PP
- Valueing intellectual property

Potential "Breakthrough" Technologies Covered in 2003

- *Mega Reforming*
- *Olefin Manufacture via Steam Cracking*
- *Non-phosgene routes to polycarbonate*
- *Polystyrene developments*
- *Propylene Manufacture*
- *Integration in Petrochemical Complexes*

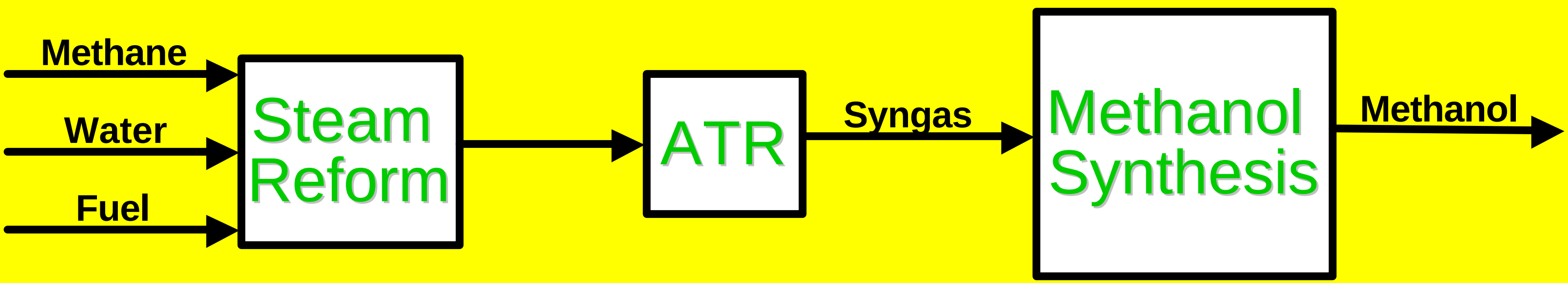
1. Mega Reforming

Conventional Technology



2,000 tons/day

New Technology



15,000 tons/day

1. Mega Reforming (continued)

Single-train capacity

2500 tons/day → 5000 tons/day → 15,000 tons/day

Many new projects

Middle East, Australia, Carribean

Many active developers

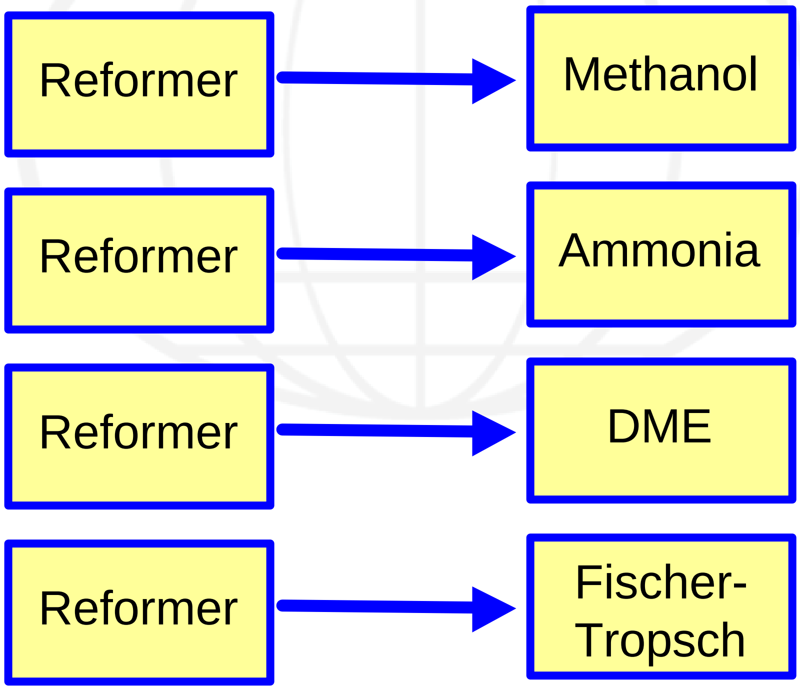
Lurgi, Eneos, Halder-Topsoe,, Shell, Mitsui,
Exxon, Methanex, JGC, many more

Many technical approaches

Compact reforming, Auto-thermal reforming, Combined two-stage reforming, Hot gas reforming, many more

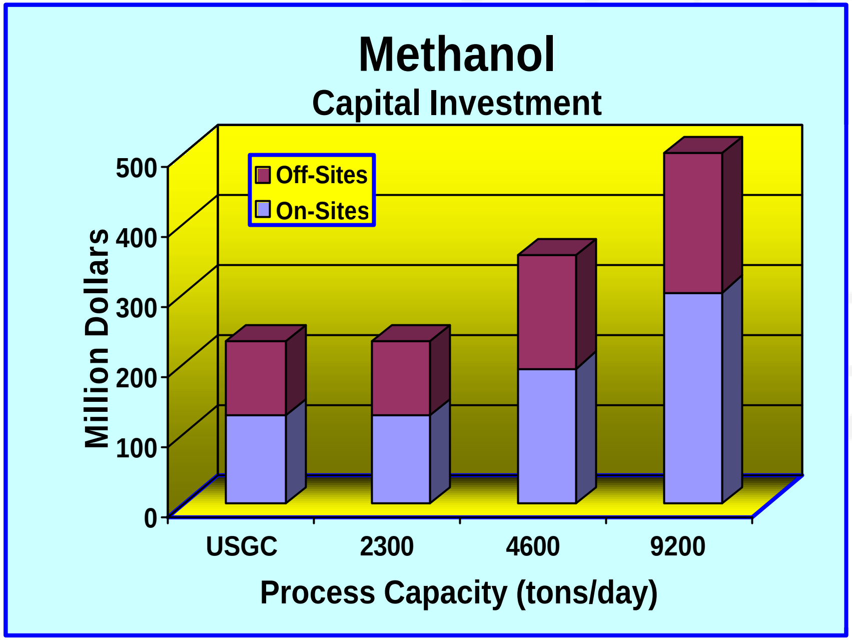
1. Mega Reforming (continued)

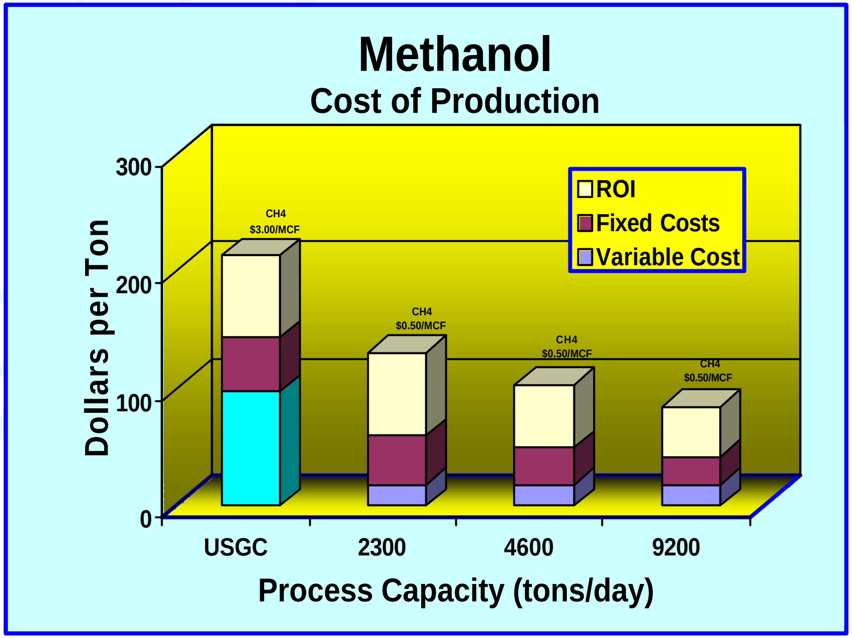
Methanol production costs as low as $50 - $80 per ton



1. Mega Reforming (continued)

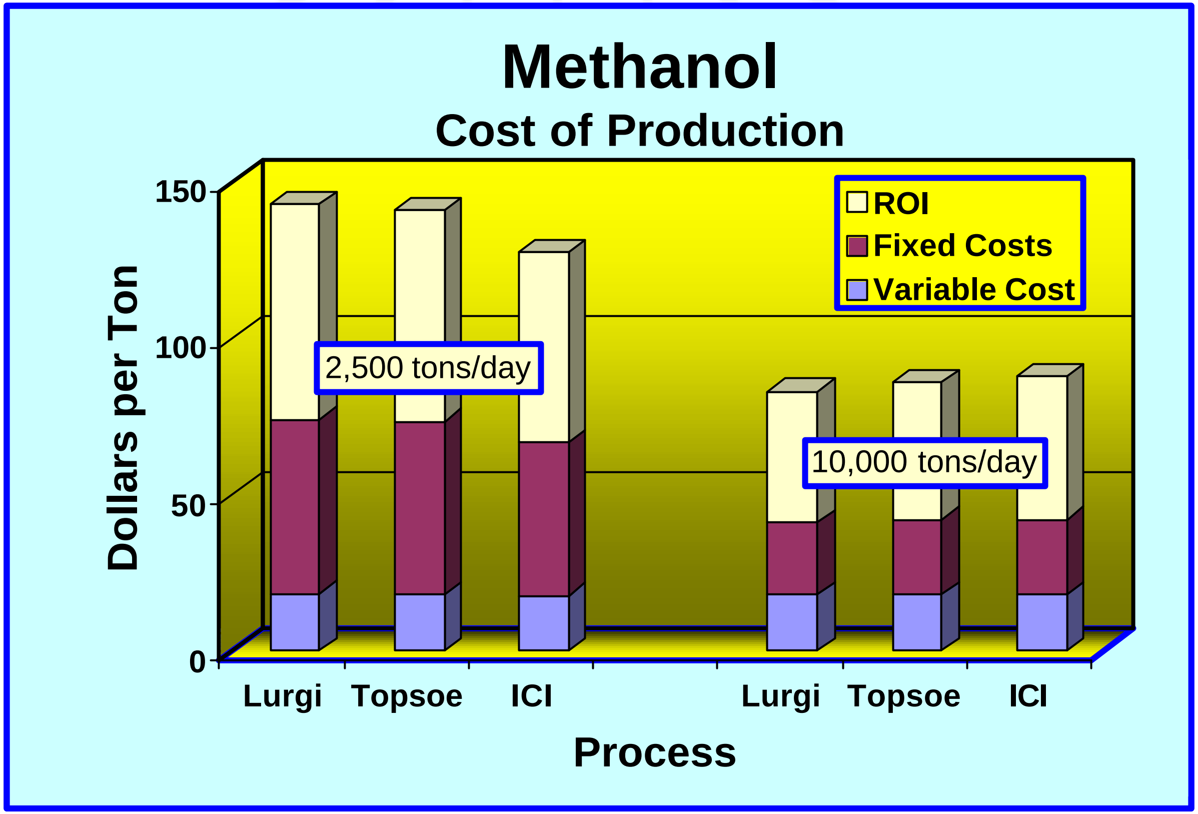
Impact of Capacity





1. Mega Reforming (continued)

Licensor Evaluation



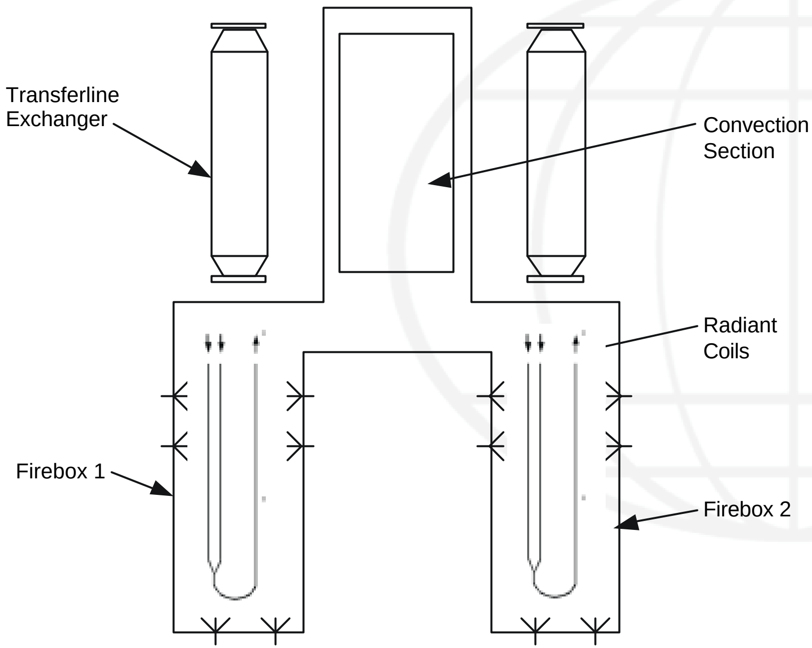
2. Steam Cracking

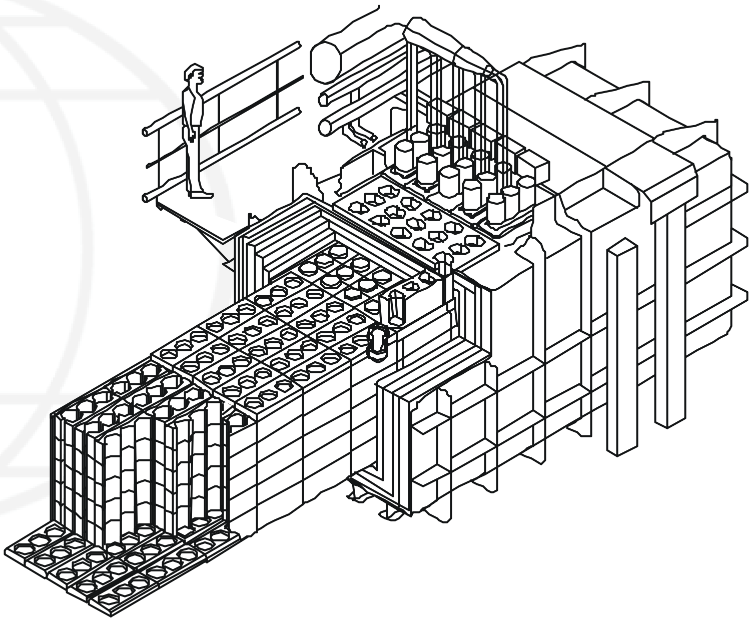
__Steam Cracking__

Ethane → Ethylene + Propylene + Others

- Very high temperatures
- Very short residence times

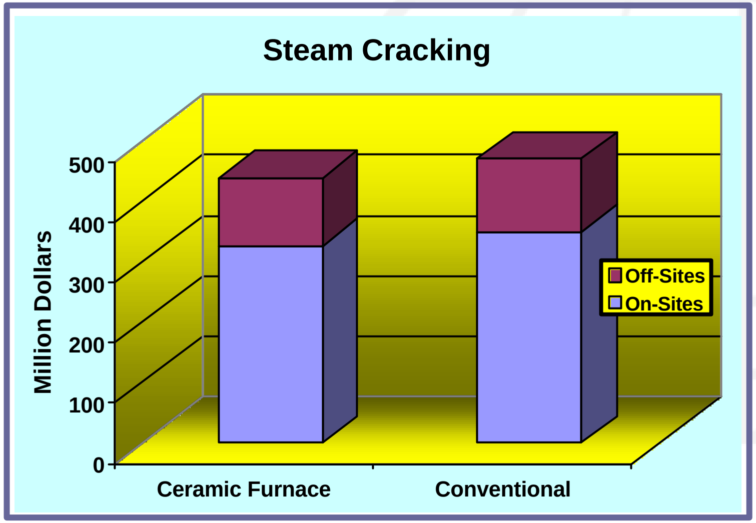
2. Steam Cracking(continued)

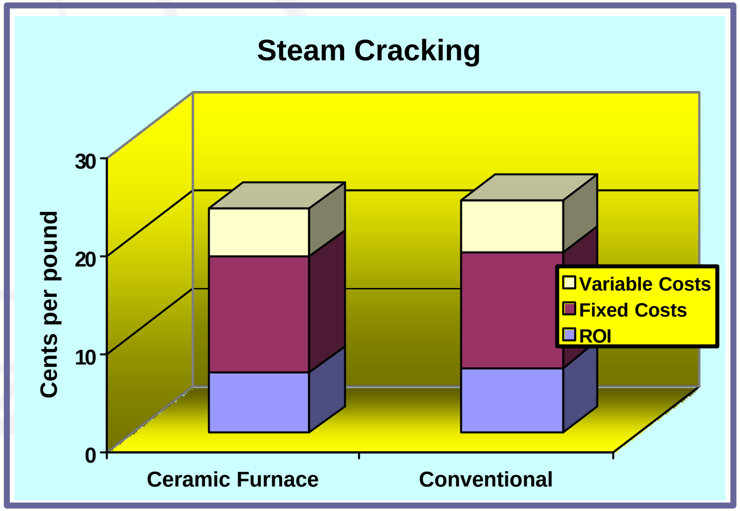




2. Steam Cracking(continued)

Economic comparison





- Largest volume petrochemical process

3. Non-phosgene routes to polycarbonate

$$2\ \mathrm{ROH} \quad + \quad \mathrm{Cl}\overset{\overset{\mathrm{O}}{\|}}{\mathrm{C}}\mathrm{Cl} \quad \rightarrow \quad \mathrm{ROCOR} \quad + \quad 2\ \mathrm{HCl}$$

phenol	phosgene	DPC	waste HCl

$$2\ \mathrm{ROH} \quad + \quad \mathrm{CO_2} \quad \rightarrow \quad \mathrm{ROCOR} \quad + \quad \mathrm{H_20}$$

phenol	carbon dioxide	DPC	water

3. Non-phosgene routes to polycarbonate (continued)

Phosgene

Security and safety concerns

Considered possible WMD

Environmental concerns

Disposal of waste HCl

Corrosion concerns

Aqueous HCl in process

CO and CO_2 alternatives available

3. Non-phosgene routes to polycarbonate (continued)

Process Options

Fixed Bed Carbonylation

Fluid Bed Carbonylation

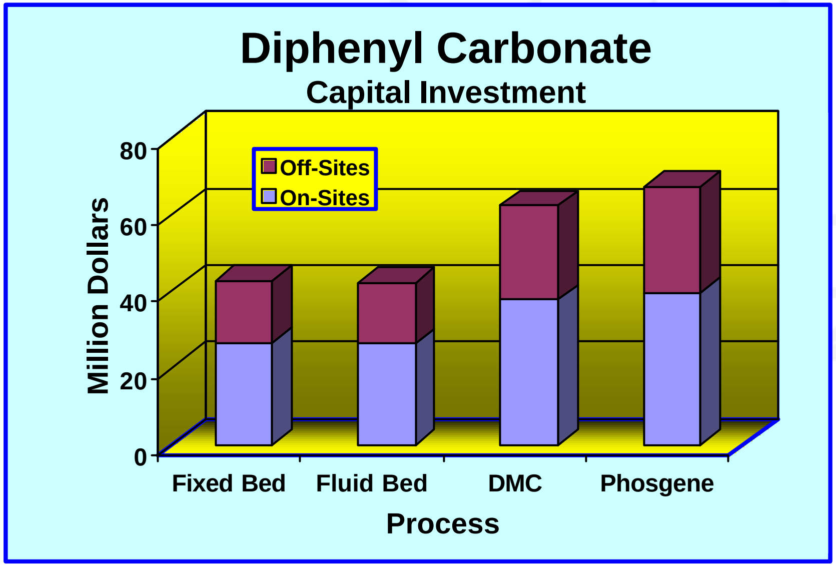
From DMC

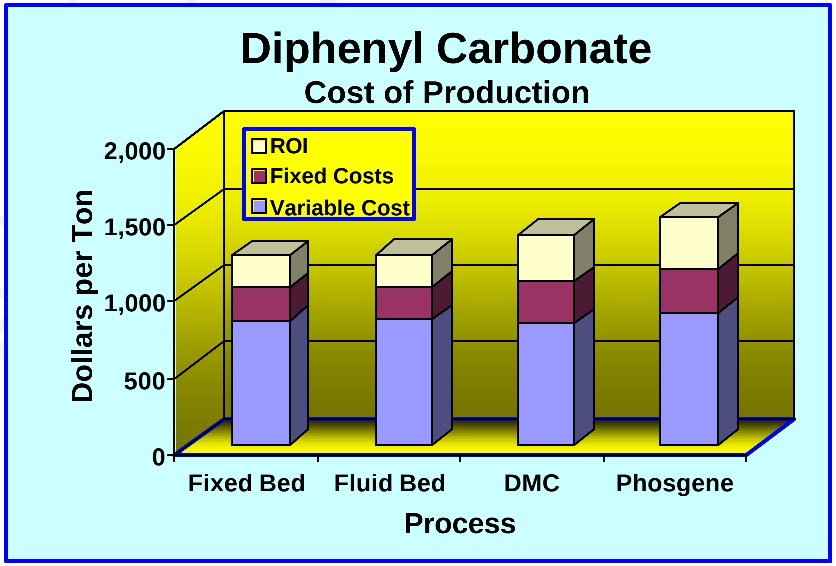
Companies active in catalyst R&D

Bayer, Dow, GE, Idemitsu, Mitsubishi, MGC, Teijin, Ube, Asahi, Daicel

3. Non-phosgene routes to polycarbonate (continued)

Economically competitive processes





4. Propylene

Steam Cracking

Naphtha → Ethylene + Propylene

2 : 1

MTP/MTO

Methanol → Ethylene + Propylene

1 : 2

Metathesis

Butene + Ethylene → 2 Propylene

4. Propylene (continued)

Tight propylene market in Asia

Increasing ethane based ethylene from Middle East

Strong demand for polypropylene

Potential Options

Methanol to Propylene

$$3\ CH_3OH \rightarrow CH_3CH{=}CH_2\ +\ 3\ H_20$$

Metathesis

$$CH_3CH{=}CHCH_3 + CH_2{=}CH_2 \rightarrow 2\ CH_3CH{=}CH_2$$

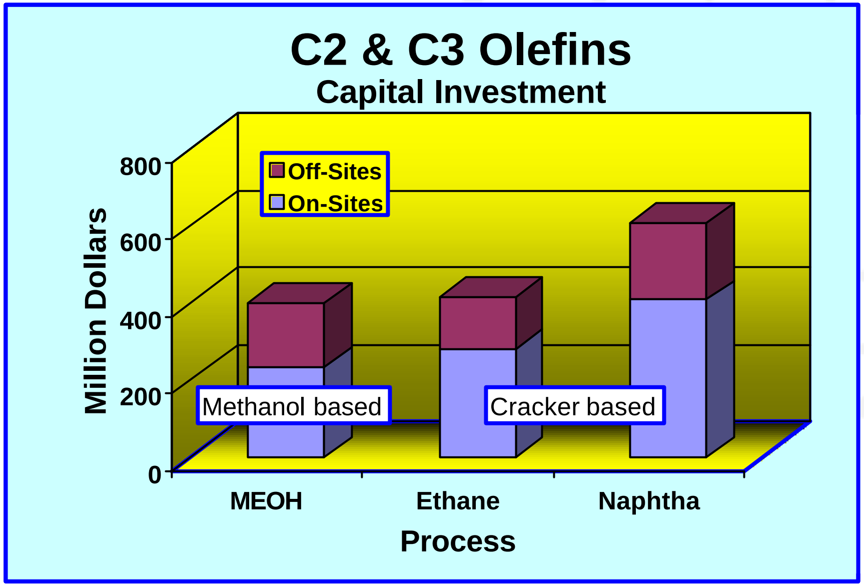
DCC from refineries

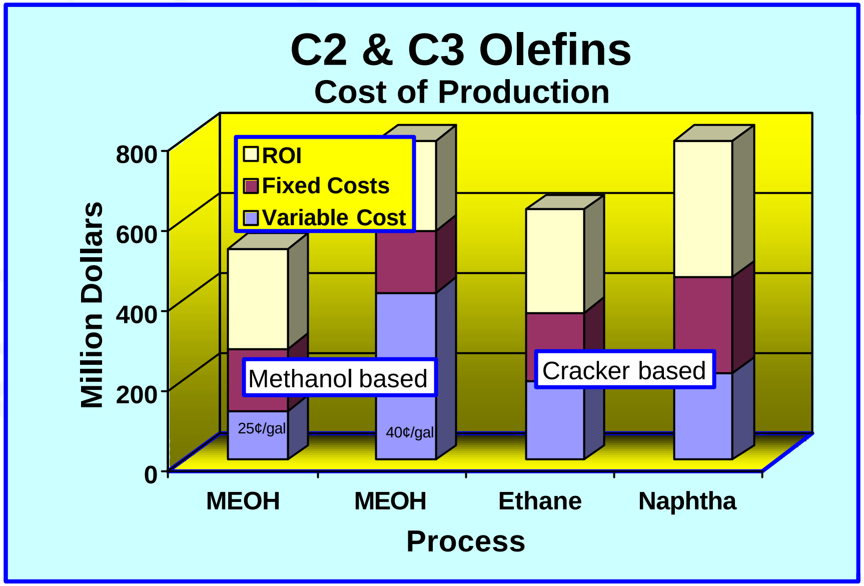
Active companies

Lummus, Lurgi, UOP, Synopec, Stone & Webster, others

4. Propylene (continued)

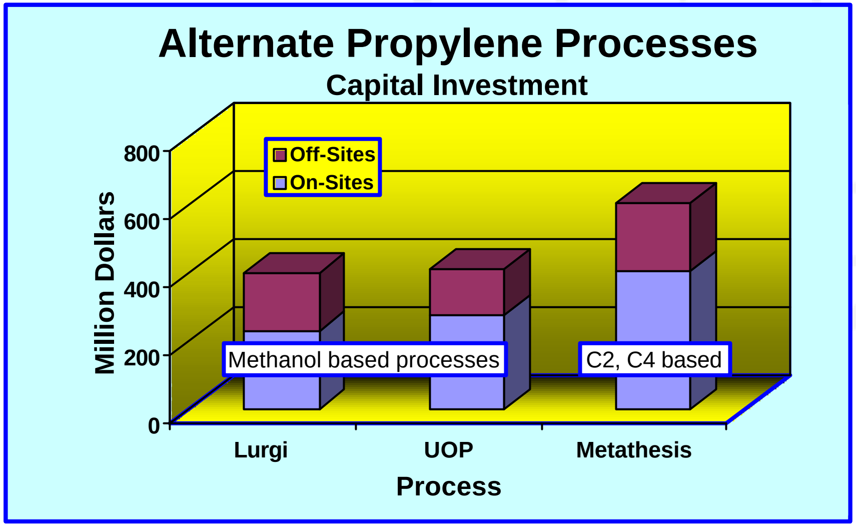
Alternative to Cracking

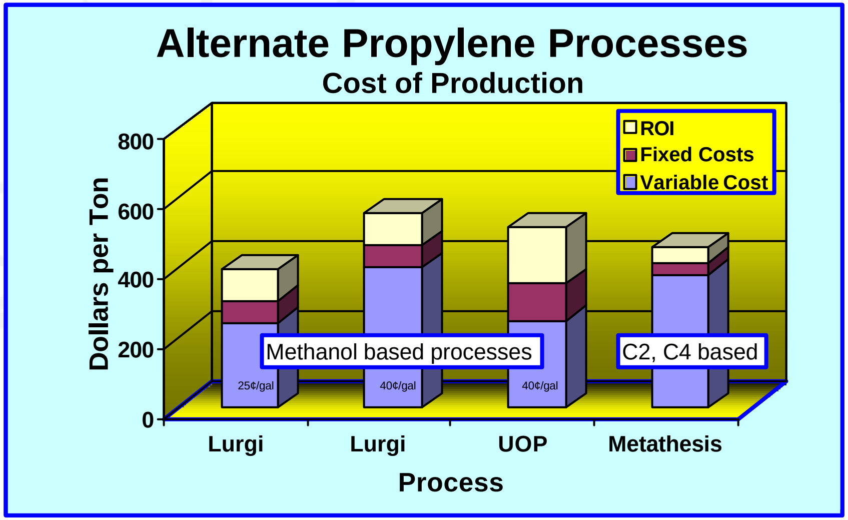




4. Propylene (continued)

Methanol vs Metathesis





- Logistical differences can drive the selection

4. Propylene (continued)

Integrated Metathesis

Products	Naphtha Cracker	Naphtha Cracker plus Methathesis
Ethylene (kmta)	1,000	850
Propylene (kmta)	500	920
Butylene (kmta)	300	-
Olefin Value* ($MM/yr)	855	885
Investment ($MM)	1,000	1080

Ethylene = $500/ton, Propylene = $500/ton, Butylene = $350/ton

5. Polystyrene developments

PS markets depend on properties and cost

Packaging (residual monomer)

Automotive (heat resistance)

Structural (strength)

No change in Ziegler-Natta process since 1970s

Free radical catalyzed polymerization

Anionic processes - explosively uncontrolable

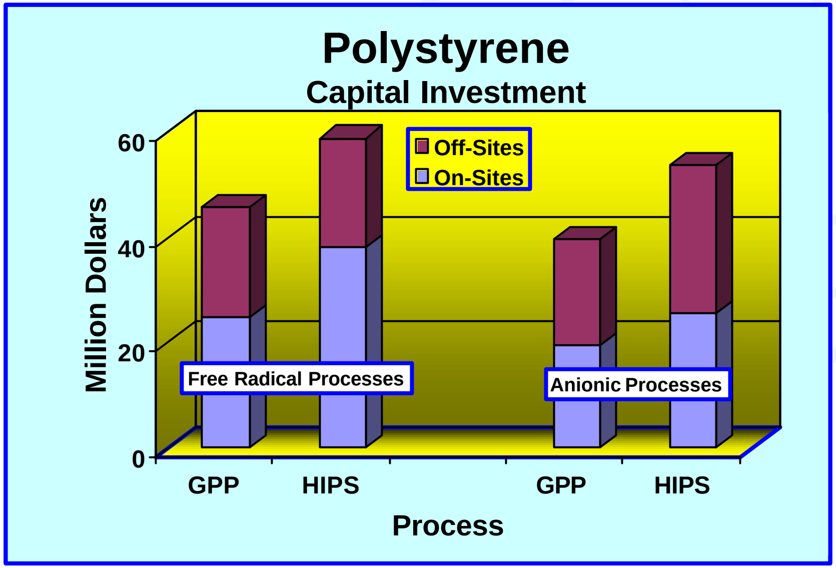
Rapid rate – highly exothermic

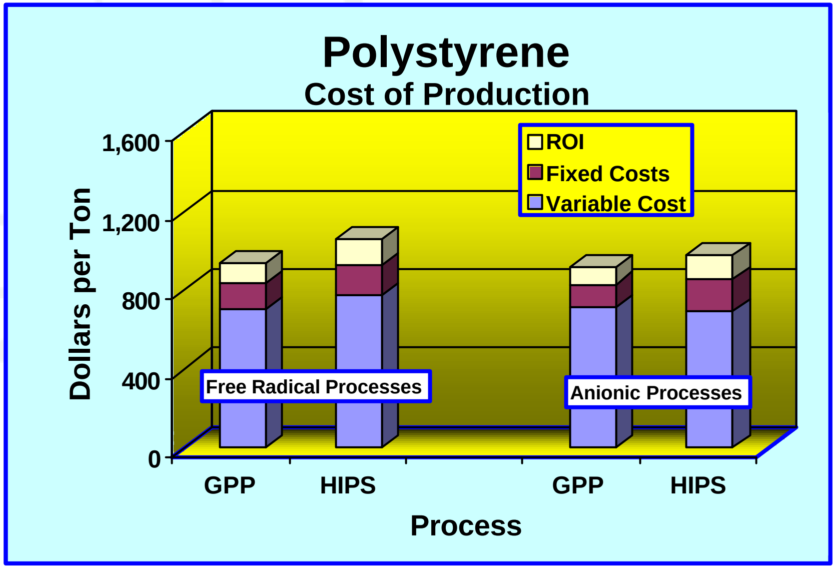
Active developers

Dow, Mitsubishi

5. Polystyrene developments (continued)

Competitive investment and operating costs





5. Polystyrene developments (continued)

Lower cost

Lower residual monomer

Higher strength

Trait	Conventional Free Radical	New Anionic
Capacity	68,000 tons/yr	Same
Capital investment cost	$30 million	$28 million
Production cost	$992/ton	$860/ton
Residual monomer	200 ppm	10 ppm

6. Integration in petrochemical complexes

Integrated olefin manufacturing sites

3+ Million tons per year

Extremely complex multi-product production

$10+ Billion dollar investments

Numerical methods – Simpler & Faster

e.g. Refinery LPs are commonly run once per shift or more

Many active developers

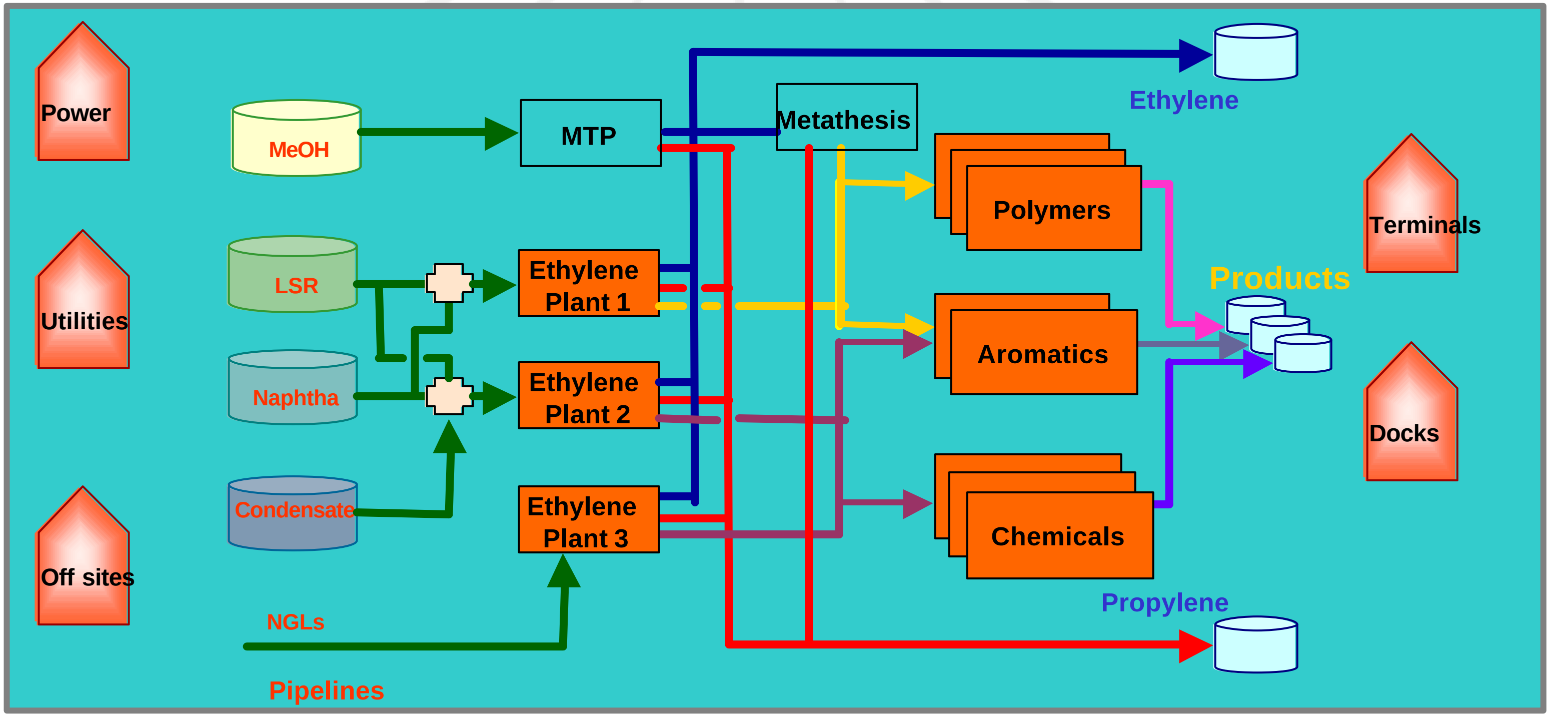
Aspen, SymSy, Honeywell, Invensys, SRIC, many more

Many opportunities for optimization

Savings can exceed 5% of total revenue

6. Integration in major petrochemical complexes (continued)

Integrated multi-product sites – even more so



6. Integration in major petrochemical complexes (continued)

Traits common to refineries and petrochemical complexes

Trait	PC Complex	Refinery
Multiple feeds	Yes	Yes
Multiple products	Yes	Yes
Multiple unit operations	Yes	Yes
Multiple intermediate streams	Yes	Yes
Complex storage and shipping	Yes	Yes
Online integrated optimization	No	Often
Daily optimization	Rarely	Always
Potential benefit of optimization	5-10%	5-10%

Evaluation of commercial potential is potent research stimulus

Process Economics Program