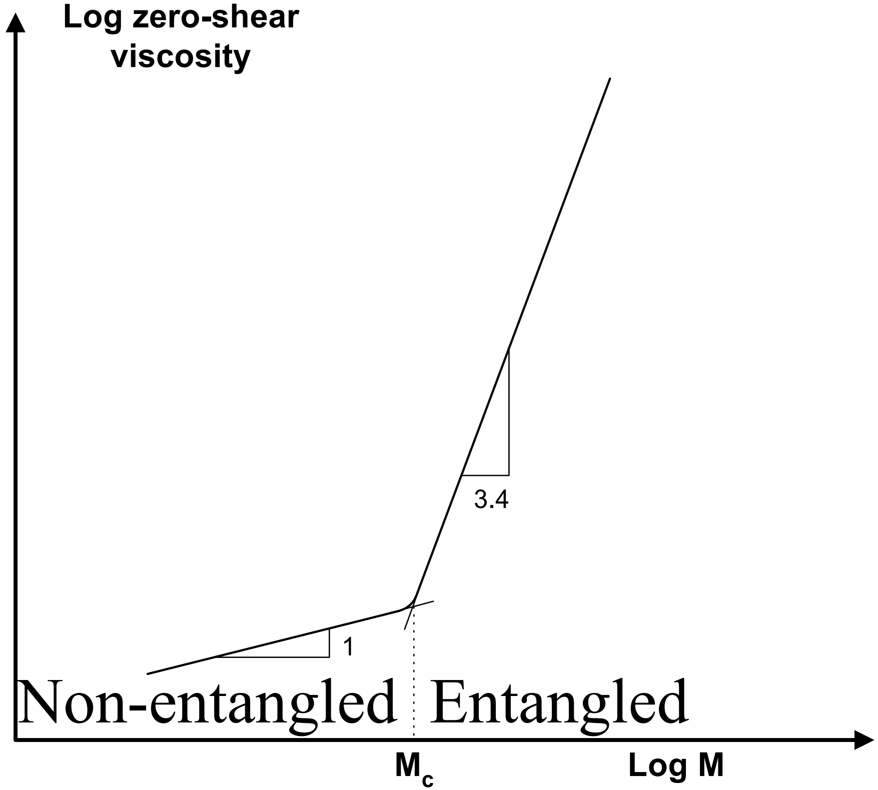
ecular structure & Rheology

- ritical
nglement
ecular weight
- amatic rheology
ange
- e to chain
tanglement

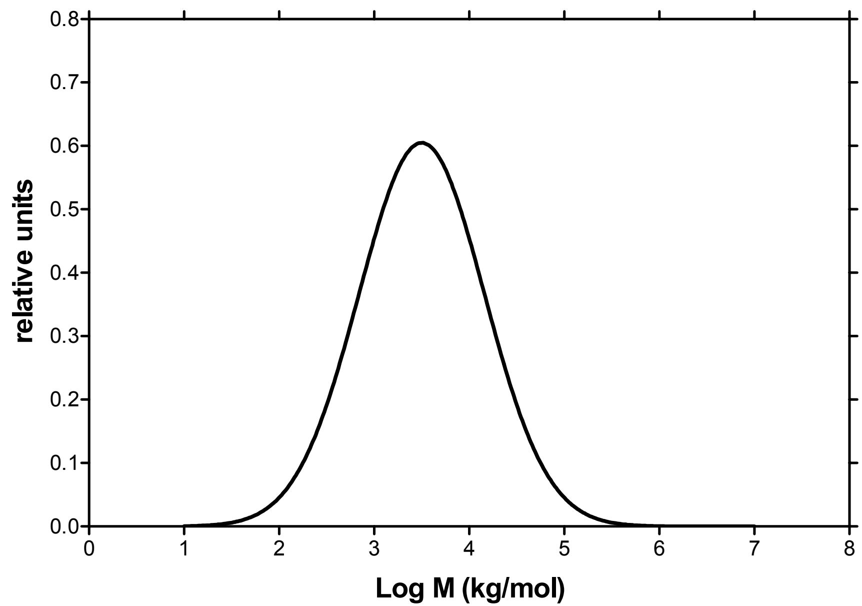


Polymer Architecture

ular Mass Distribution

)

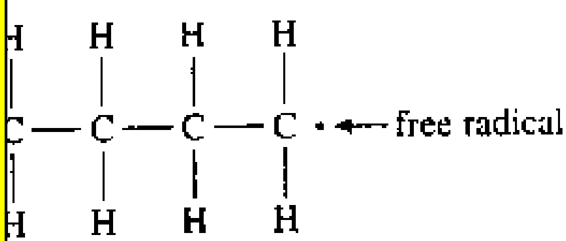
- ree of Polymerisation
  - Number of monomers in a polymer
- odisperse MMD
  - Polymers have same molecular mass
- disperse MMD
  - Polymers have different molecular mass
- nogenous MMD
  - Same polymer architecture independent of molecular mass
- erogenous MMD
  - Mixture of different polymer architectures



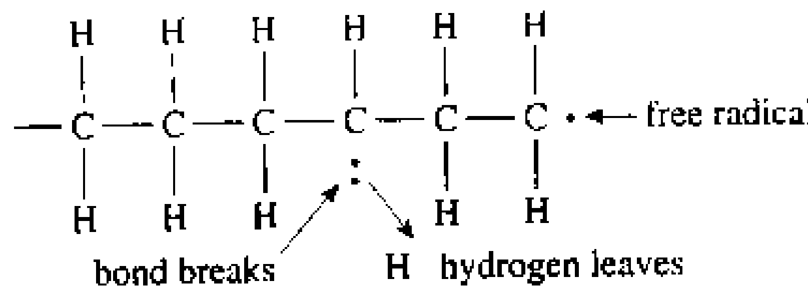
Polyethylene

sis:

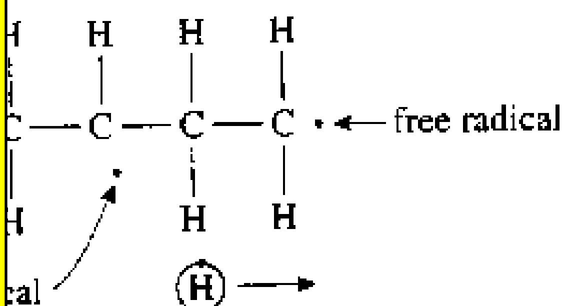
growth - free radical polymerisation

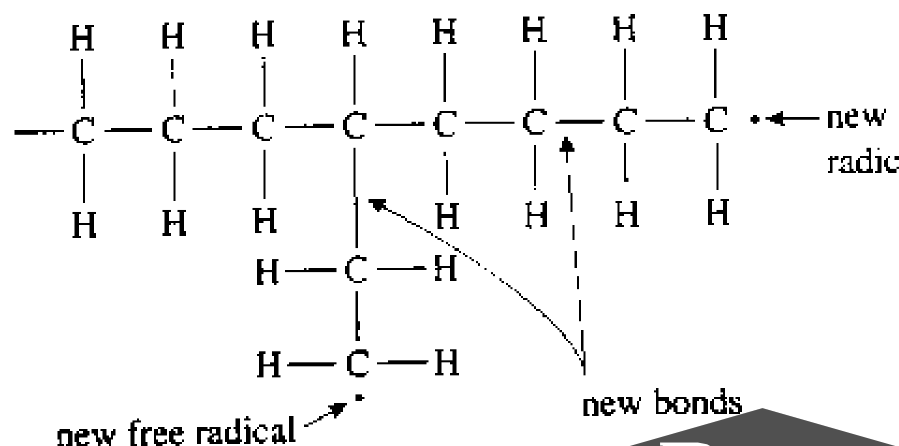


Growing polymer chain

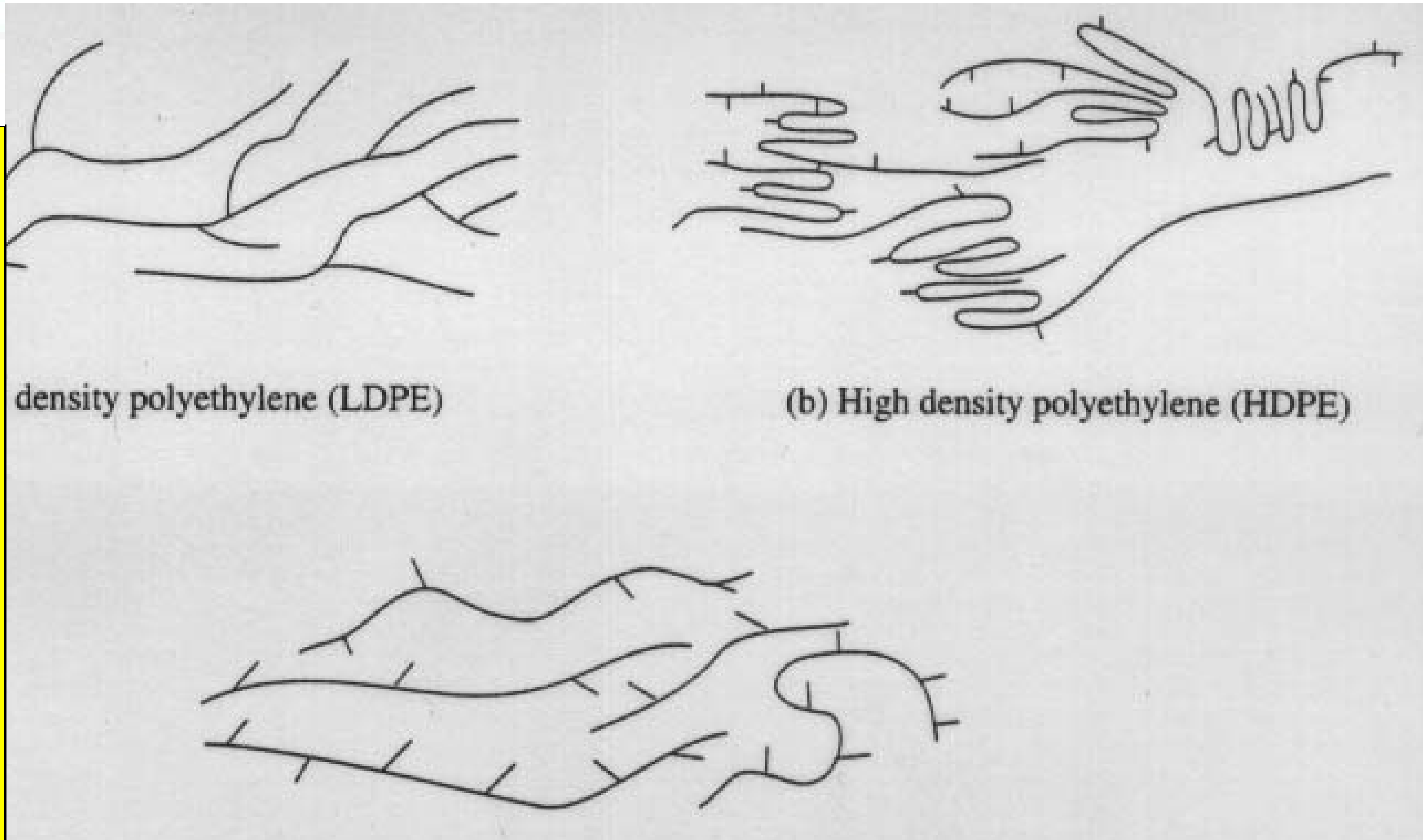


(b) Rupture of carbon-hydrogen bond





Polyethylene



density polyethylene (LDPE)

(b) High density polyethylene (HDPE)

(c) Linear low density polyethylene (LLDPE)

ymer Architectures

Polyethylene

High-Pressure		Low-Pressure		
toclave	Tubular	Solution	Gas phase	Slurry
00 - 3000	1000 - 3000	20 - 100	20 - 100	1 - 20
200	>200	100 -200	50-100	50-100
oxides	air peroxides	Ziegler-Natta metallocene	Ziegler-Natta metallocene	Ziegler-Natta metallocene
ical	radical	coordination	coordination	coordination
dom tree B+LCB	random tree SCB + LCB	linear, comb homopolymer copolymers SCB + LCB	linear, comb homopolymer copolymers SCB + LCB	linear,comb homopolymer copolymers SCB + LCB
-30	10-30	2-10	2-10	5 - 30
5 - 935	915 - 935	865 - 965	890 - 965	935 - 965
PE	LDPE	ULDPE VLDPE LLDPE HDPE	VLDPE LLDPE HDPE	MDPE HDPE UHMPE

Manufacturing Technologies

Polyethylene

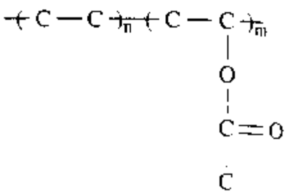
nity & Short Chain Branching effects on Properties

	How Increased Branching Affects the property
crystallinity	Decreases
point	Decreases
sistance	Decreases
trength	Decreases
	Decreases
s	Decreases
oughness	Increases
ency	Increases
e resistance	Decreases
ility	Decreases
resistance	Decreases
ility	Increases
e	Decreases

'olyethylene Co-polymers

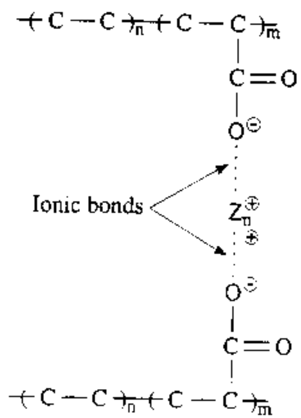
ene Vinyl Acetate (EVA)

- gh pressure process
- 50% wt VA
- gh Clarity film
- t melts

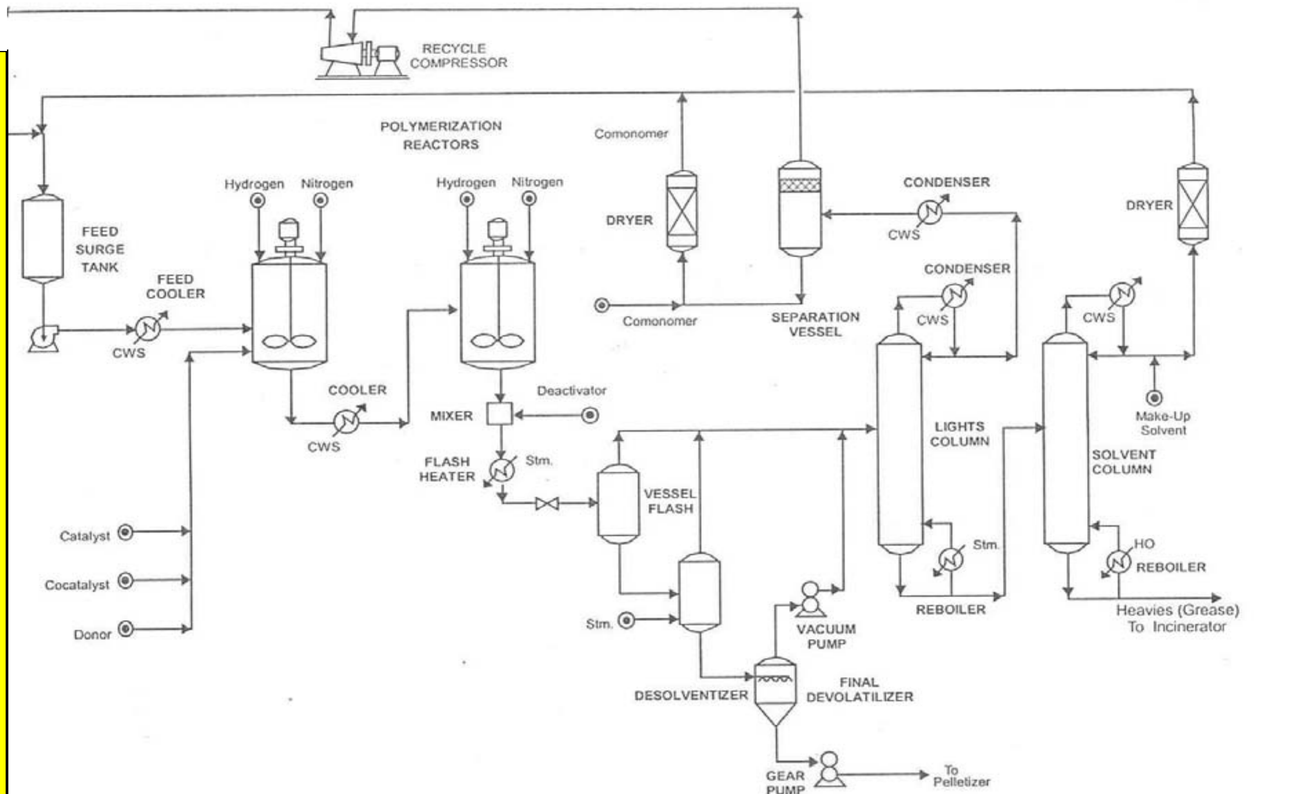


ene Acrylic Acid (EAA)

- gh pressure process
- 20% AA
- omers

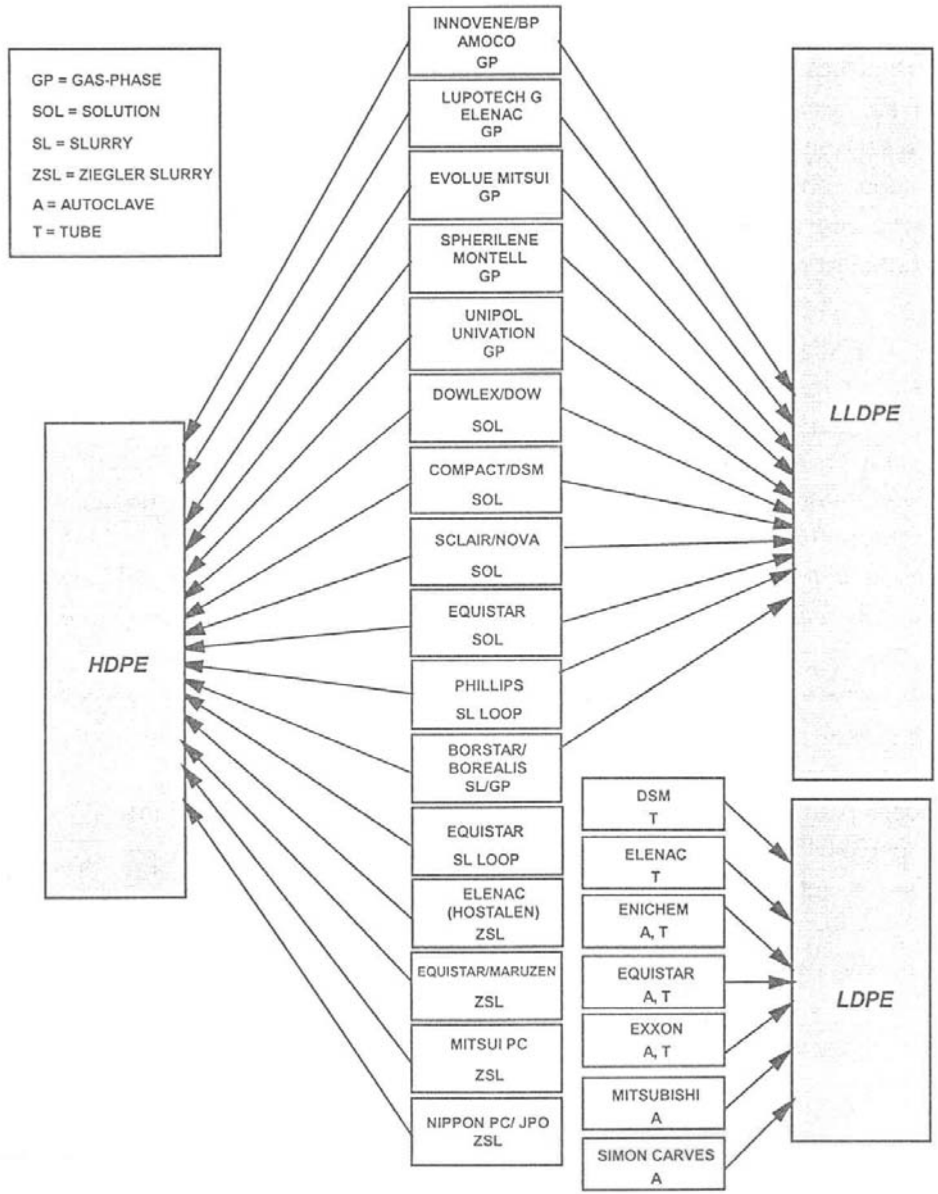


olyethylene Manufacturing



DOWLEX SOLUTION LLDPE
PROCESS REACTION AND
SOLVENT RECOVERY

LICENSING TECHNOLOGY COMPETITION



Polyethylene

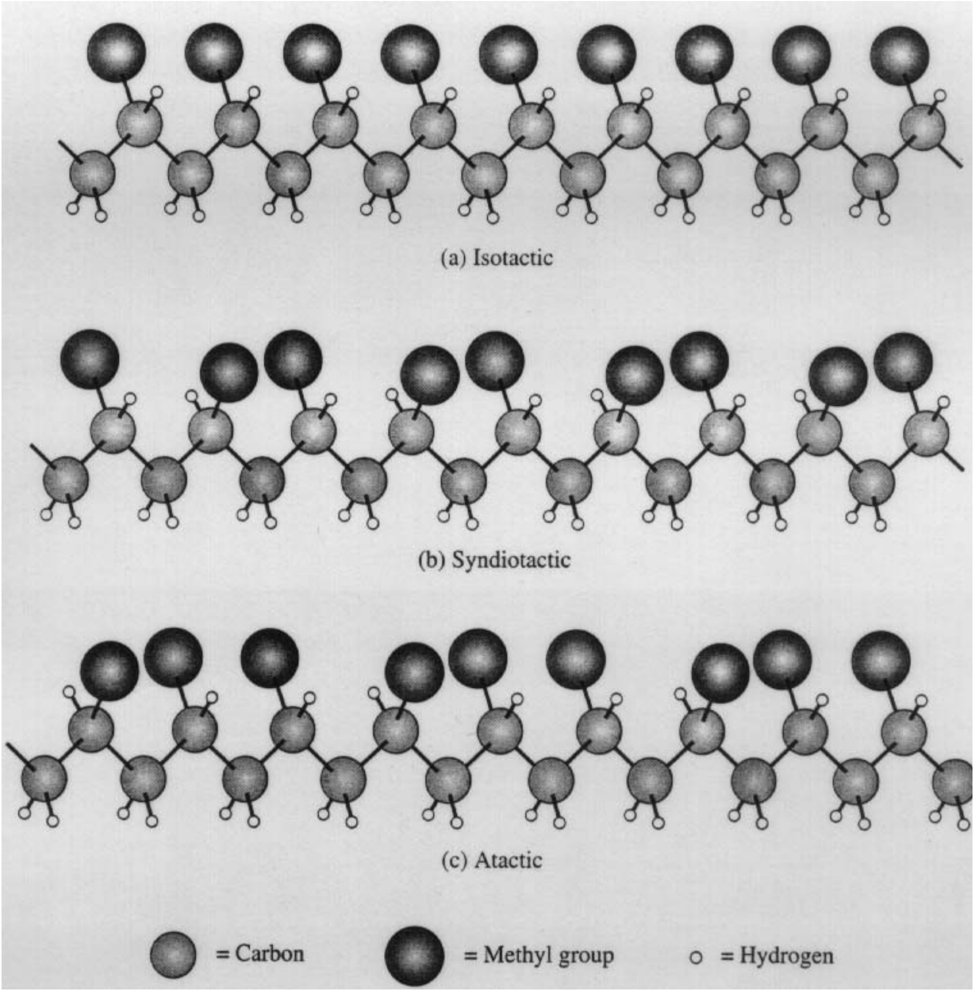
ethylene was produced more or less by chance in March 1933 under ***very high*** 00 bar) in an experimental plant run by the British company ***ICI***. It took a ears before the developers succeeded in polymerising ethylene in a controlled modified apparatus. Polyethylene melts at 115°C to 120°C and has a relatively ***PE-LD***) of 0.918. Even in 1939 a plant with an annual output of several was insufficient to meet the rapidly rising demand. In 1953 ***Karl Ziegler*** ew production method by which polyethylene could be polymerised at ***pressure*** using suitable catalysts in a suspension. This not only eliminated the blems associated with extremely high pressures, it also produced material of higher density (***PE-HD***) with a more crystalline structure and a higher melting ery much stronger material. Polyethylene is an excellent ***electrical insulator***. It or a multitude of different purposes ranging from ***household appliances***, d ***industrial equipment*** to ***toys***.

Polypropylene

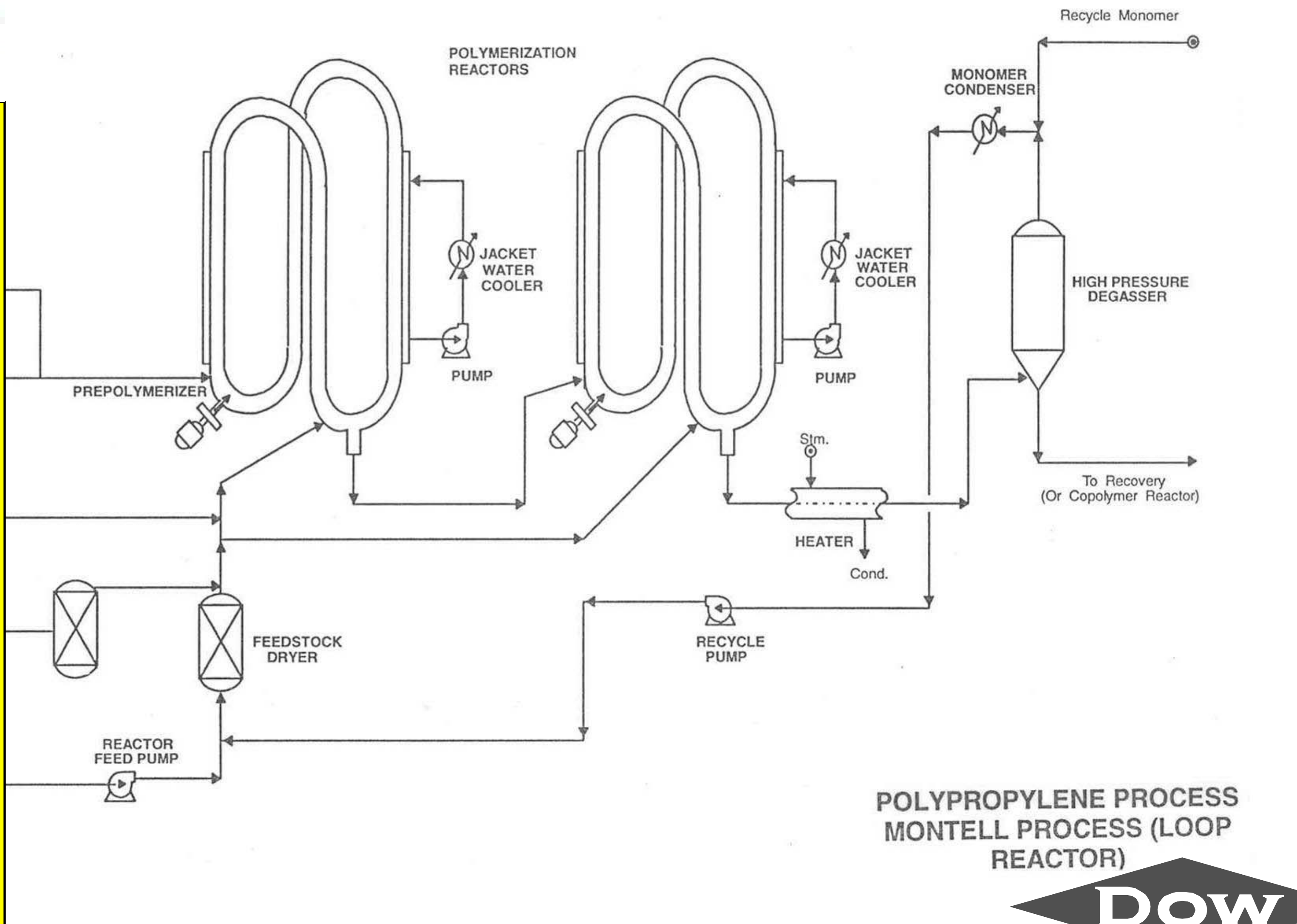
e is the youngest of the bulk plastics. It has evolved at breathtaking speed and
elf in a very wide range of fields. This plastic was developed in 1954 by
in cooperation with researchers at the firm of ***Montecatini***, where the material
produced on an industrial scale. Polypropylene is very similar to high-density
but has a ***lower density*** and is more ***rigid and harder***. It is the hardest of all
lymers and retains this quality even at temperatures ***above 100°C***. It is
resistant to friction, and its heat resistance is outstanding. It possesses
ectrical properties, is a ***good insulator*** and has especially ***high long-term***
ngth (10 million bending stress reversals). There are many different types of
e on the market. They can be used in a wide variety of applications, including
liances and ***household goods***, ***toys***, ***automotive components*** and ***sports***
ood packaging, ***agricultural equipment***, ***signs***, ***furniture***, and components
cals industry.

Polypropylene

)-Isomers

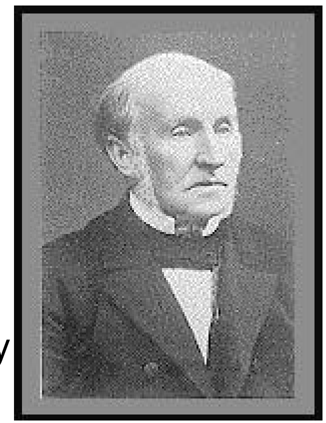


lypropylene Manufacturing

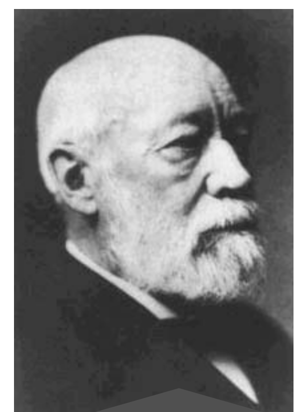


History of Plastics

- urally occurring substances (Rubber, Cellulose)
- 17-18th Century
  - Hevea (Ecuador) - Gutta-Percha (Indonesia/Malaya) Rubber
- 1823: C. Macintosh (Mackintosh)
  - Waterproof sheet of layers of fabric and rubber



- 1838: C. Goodyear
  - Sulfur vulcanization of rubber
- 1862: A. Parkes
  - “Parkesine” - nitrated cellulose for replacing Ivory
- 1869: J.W. Hyatt
  - Celluloid



History of Plastics

noplastics

909: H. Stobbe & G. Posnyak
- Polystyrene
- Commercial development in 1925 by IG Farben and commercialised in US by The Dow Chemical Company in 1938

913: F. Klatte
- Polyvinylchloride - revisited in 1927

927 - 1938: O. Röhm
- Plexiglass - Polymethylmetacrylate

934: E. Fawcett & R. Gibson
- High pressure research gave Polyethylene
- Commercial in 1939 as cable insulation material

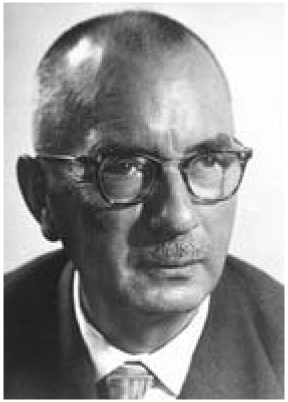
937: W. Carothers
- Step-growth polymerisation
- Polyamide - Nylon

941: J. Whinfield & J. Dickson
- Polyethylene Terephtalate - Terylene fibres

History of Plastics

1940's: K. Ziegler

- Coordination chemistry - Zr, Ti + alkyl-Al
- Low pressure Polyethylene



1954: G. Natta

- Polypropylene

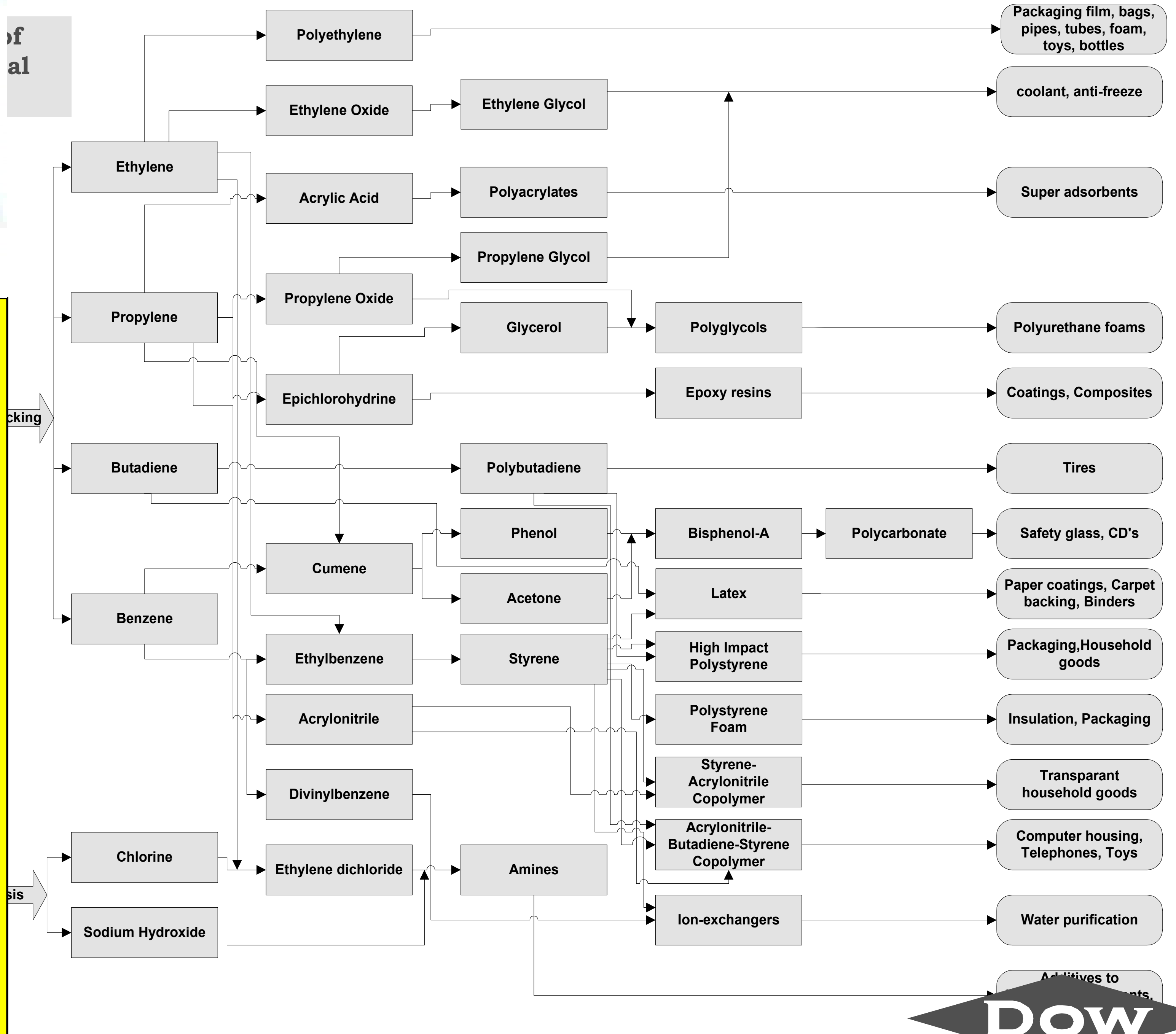
1956: H. Schnell - D. Fox

- Polycarbonate
- General Electric Co. - commercial in 1959 - Lexan

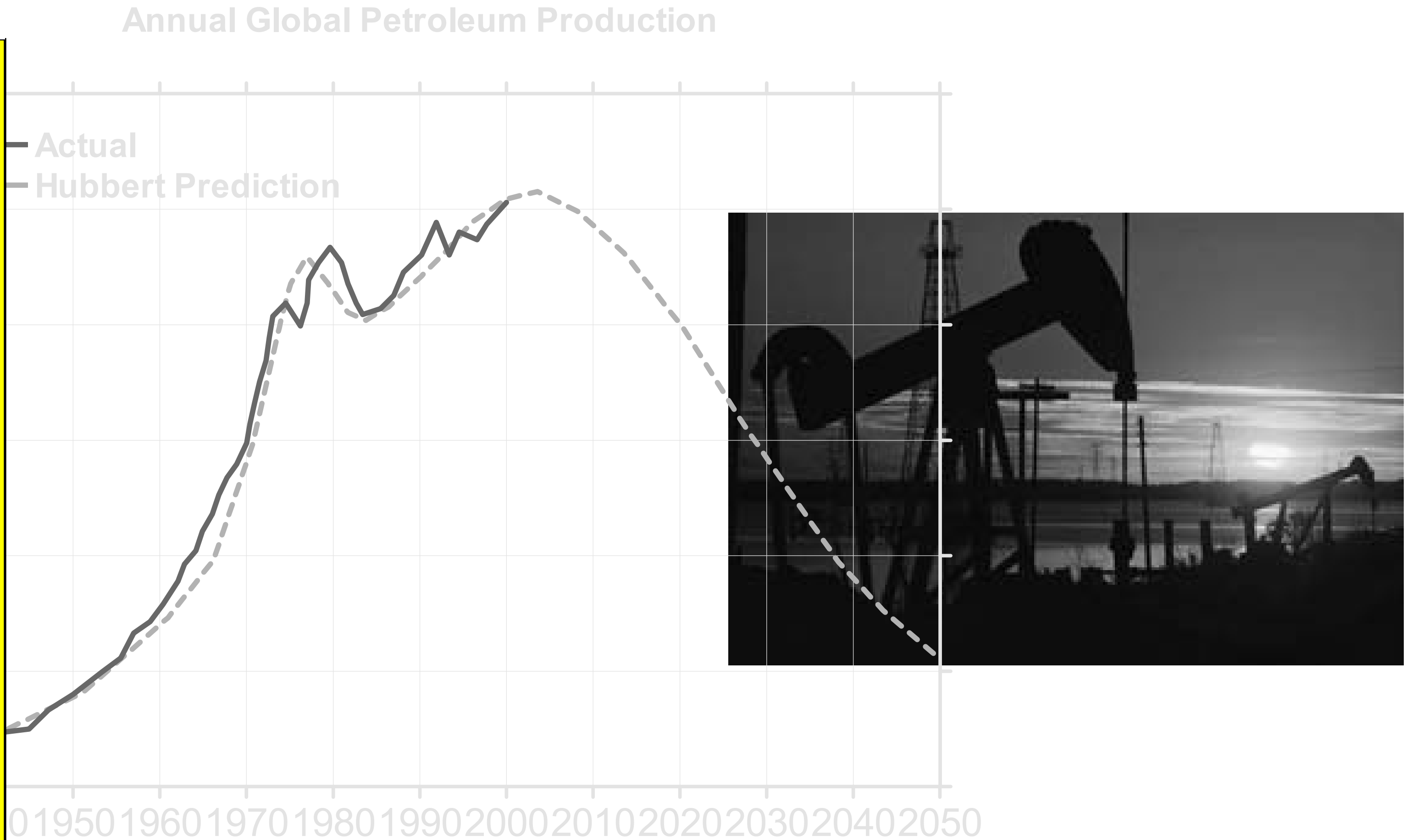
1955-1970: Composite materials

1960-1980: Manufacturing technology

1980-2000: Specialty plastics & new catalysts


of
al
cking
sis
Ethylene
Propylene
Butadiene
Benzene
Chlorine
Sodium Hydroxide
Polyethylene
Ethylene Oxide
Acrylic Acid
Propylene Oxide
Epichlorohydrine
Cumene
Ethylbenzene
Acrylonitrile
Divinylbenzene
Ethylene dichloride
Ethylene Glycol
Polyacrylates
Propylene Glycol
Glycerol
Polybutadiene
Phenol
Acetone
Styrene
Amines
Polyglycols
Epoxy resins
Bisphenol-A
Latex
High Impact Polystyrene
Polystyrene Foam
Styrene-Acrylonitrile Copolymer
Acrylonitrile-Butadiene-Styrene Copolymer
Ion-exchangers
Polycarbonate
Packaging film, bags, pipes, tubes, foam, toys, bottles
coolant, anti-freeze
Super adsorbents
Polyurethane foams
Coatings, Composites
Tires
Safety glass, CD's
Paper coatings, Carpet backing, Binders
Packaging,Household goods
Insulation, Packaging
Transparant household goods
Computer housing, Telephones, Toys
Water purification

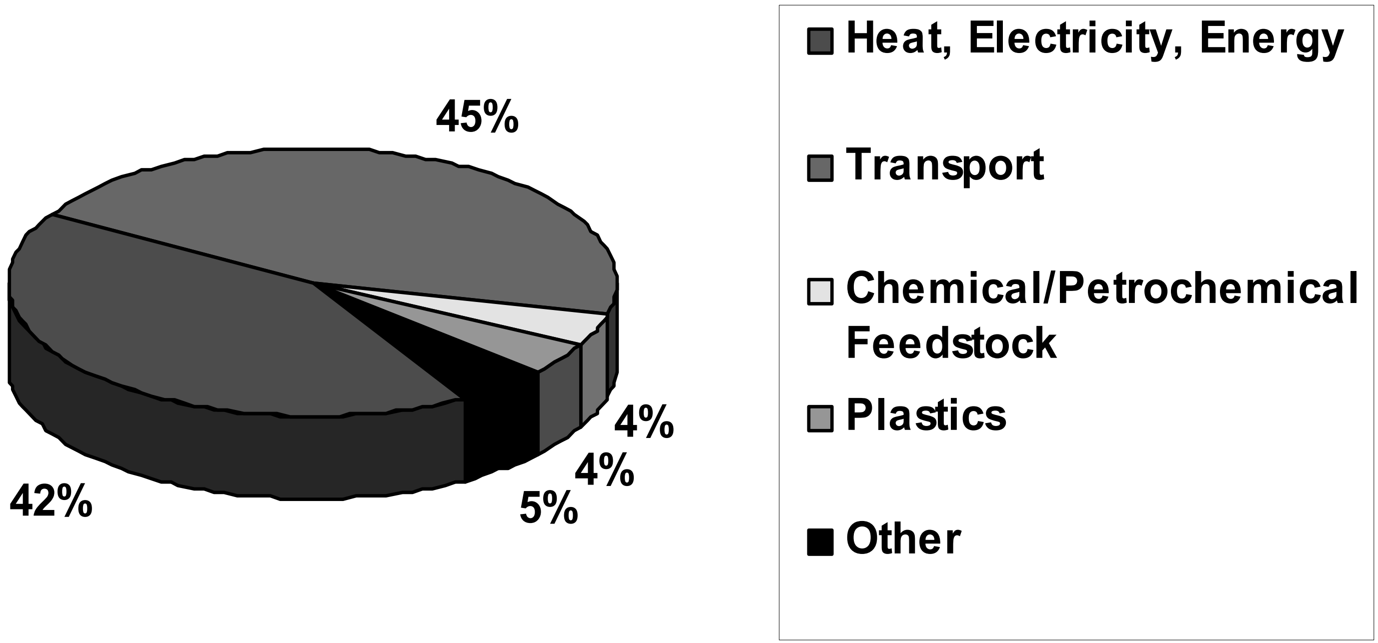
Challenges of Today



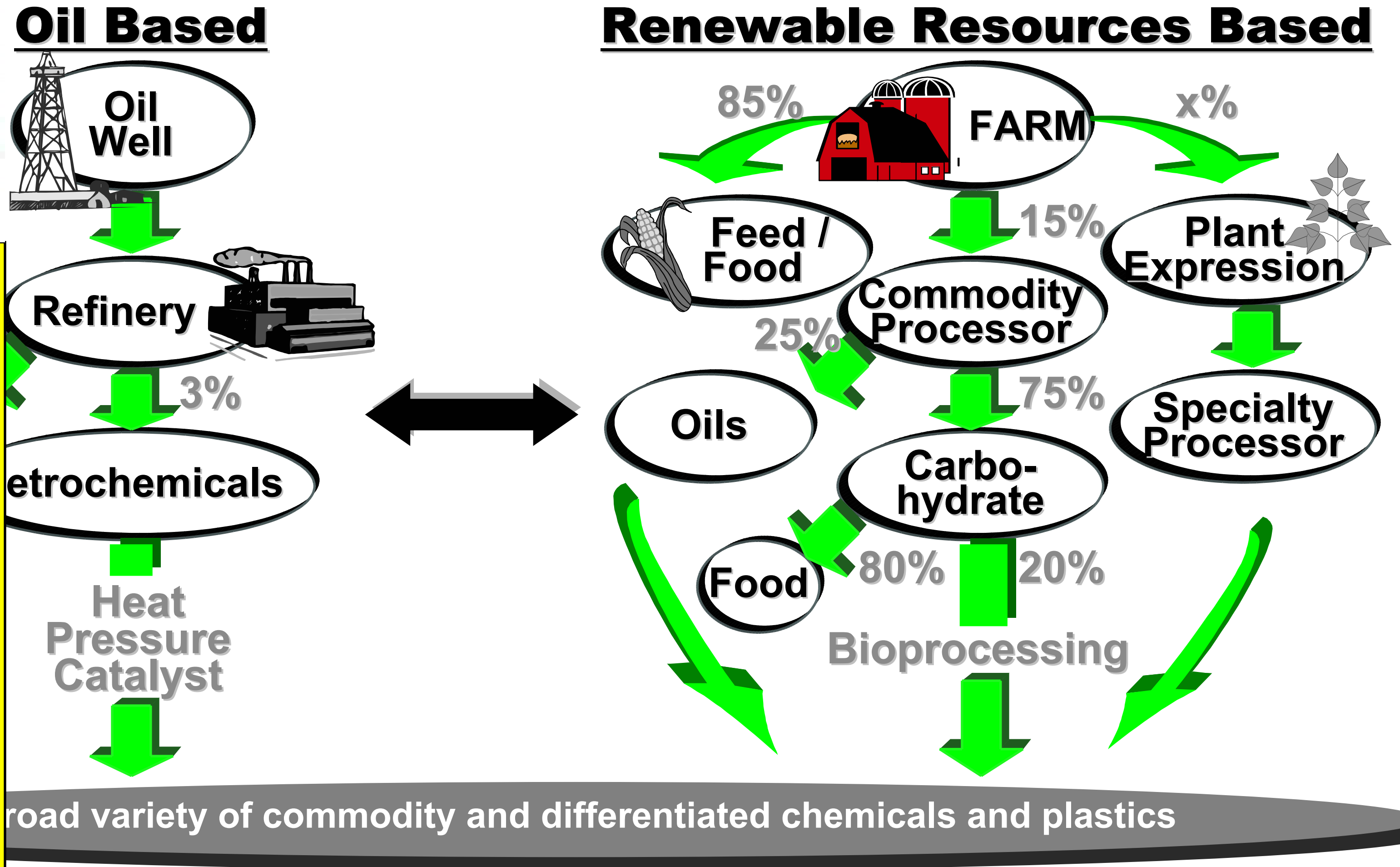
C.Campbell, J. Laherere, Sci. Amer

Challenges of Today

ive use of Petroleum



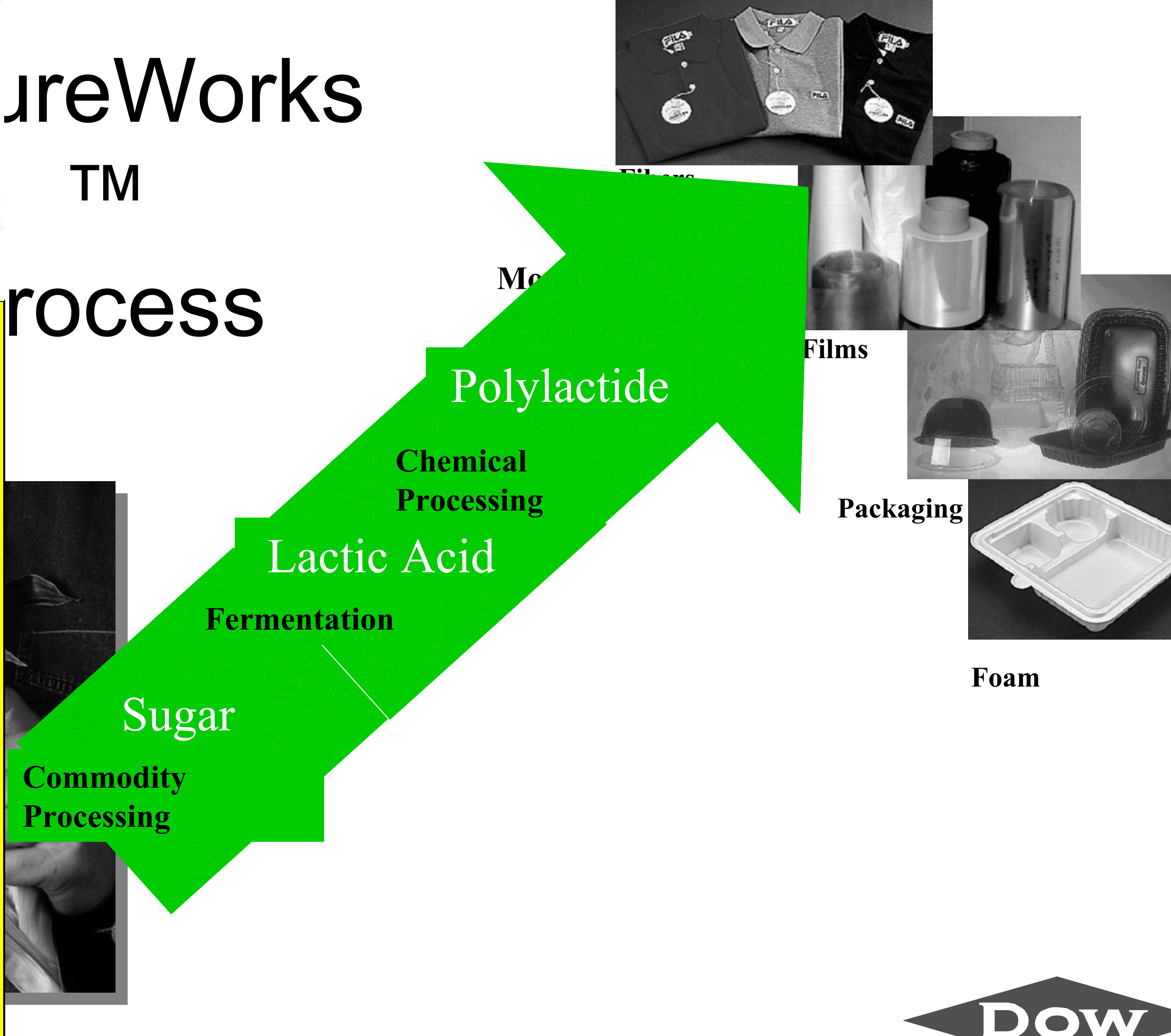
:merging Future: Duality in Feedstocks and Processes



EY COMPETENCIES
s ngineering Science

KEY COMPETENCIES
• Biotech Basics • Bioprocessing • Chem Engineering • Material Science

…ureWorks TM …rocess

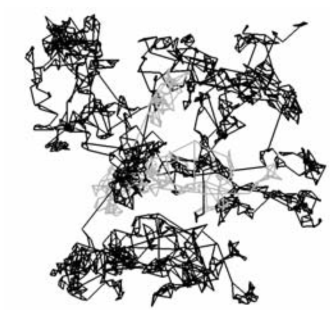


Future Challenges

odeling

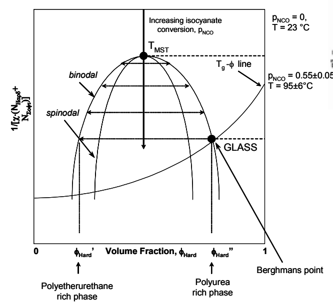
lergoing
ardener

Molecular Dynamics
Monte Carlo



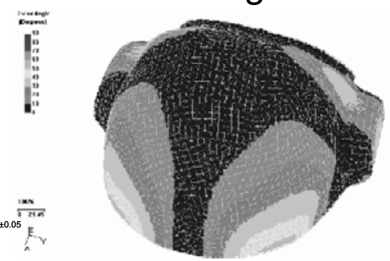
Cluster linkage in poly(urethane-urea) networks

Continuum Models



Microstructural phase transition in flexible polyurethane foam formation

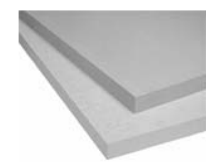
Finite Element Modeling
Design



Helicopter pilot helmet - predicted shear angles for carbon/epoxy prepreg

Processing
End-User Application

Wind Mill Blades, PCB Laminates, Refrigerator Insulation, Industrial Building Using Steel-Faced Sandwich Panels



time

Stake holder Value

The
usiness
Goal ?

Stake Holder Value Creation

Conclusions

- om product push to product pull
  - Sustainability
  - Stakeholder value creation
- &D is essential to growth
  - Controlled performance
  - Integration – Multi-disciplinary
- obal reach & local integration
- eople