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Offentligt

DTU

# Plastics or Polymers
# – After all What's the difference?

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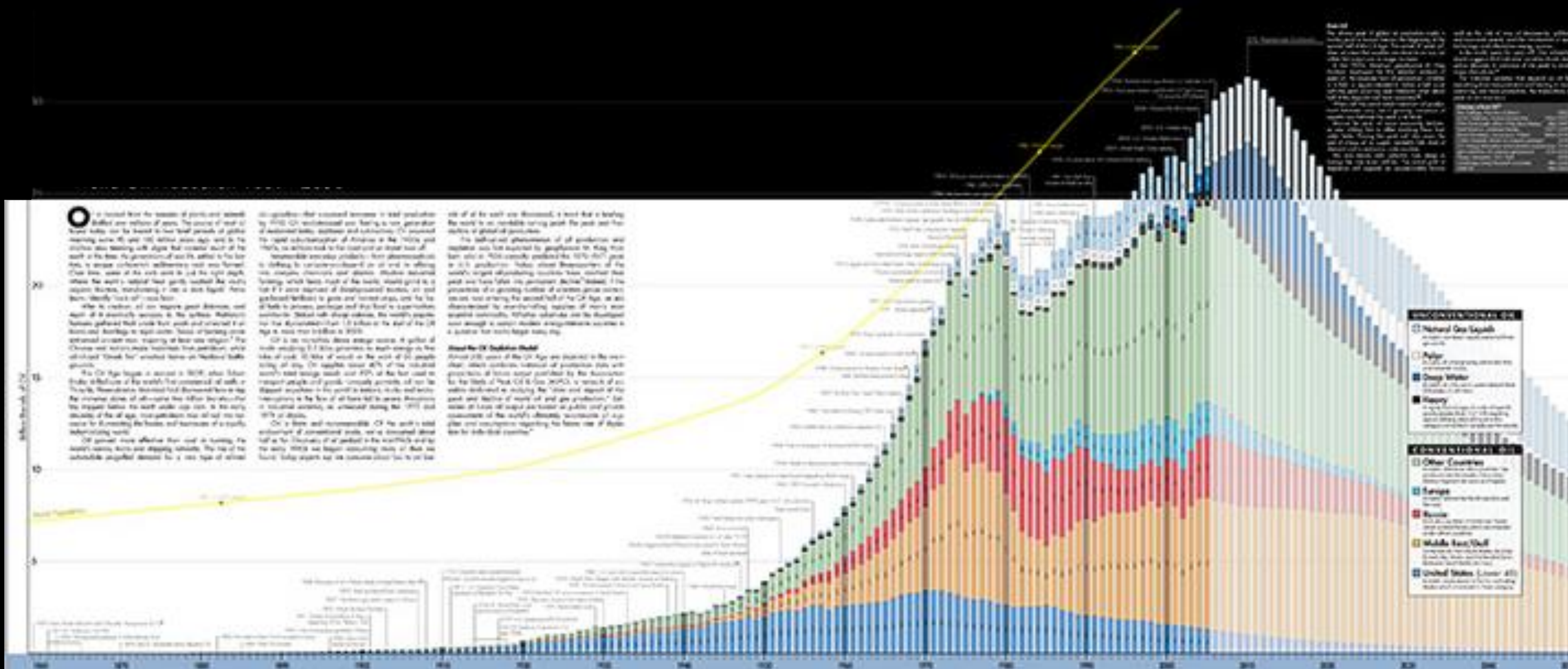
# Plastics – Imagine life without!

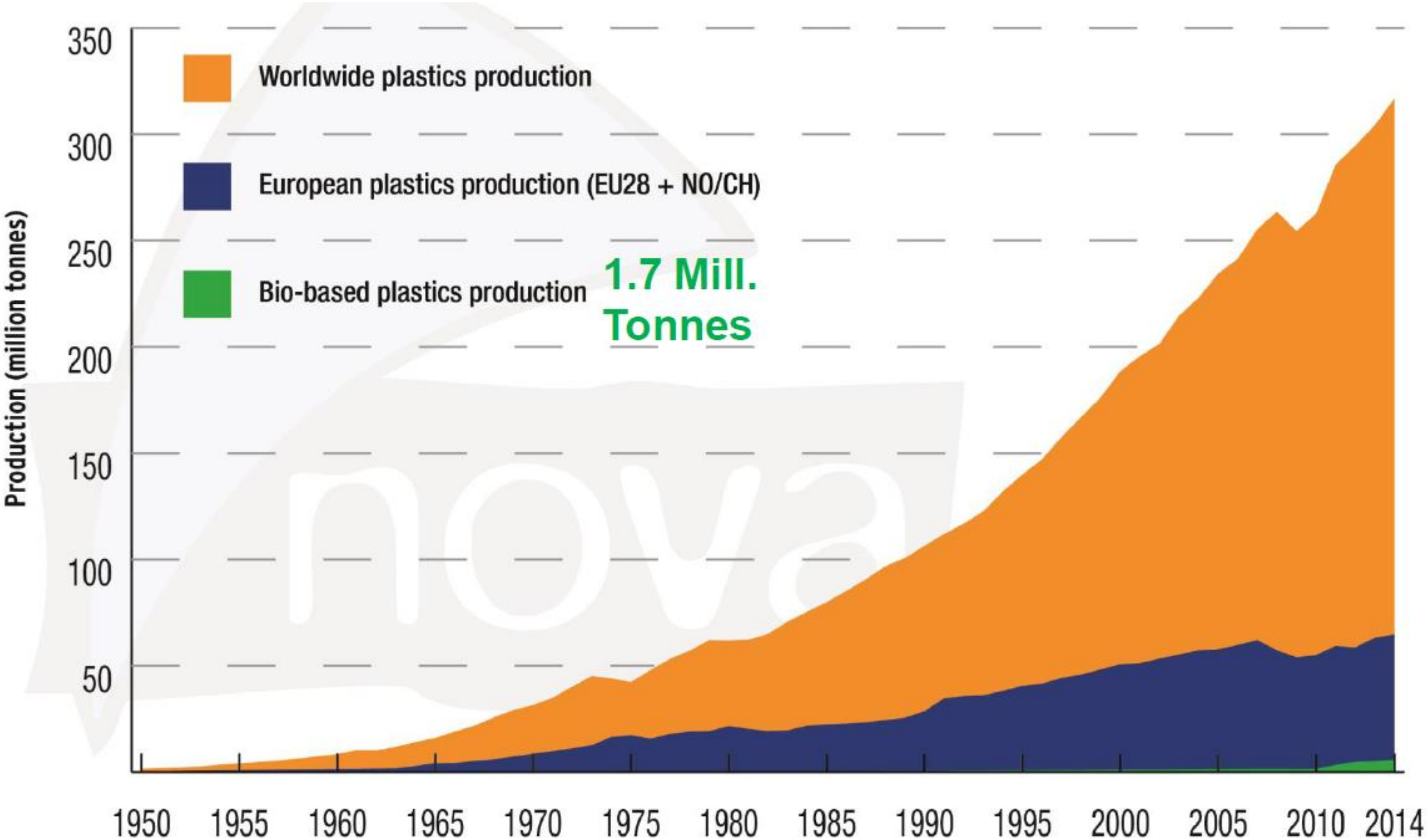
Source: Sandra Krautwaschl, Plastik Freie Zone

# The oil age world production 1859-2050



Source: http://scimaps.org/mapdetail/the_oil_age_world_oi_73

# Current production of plastics




Source:Plastics Europe and Nova-Institute

# Challenges for the future of plastics

- Feedstock for polymers (chemistry, bioprocesses)
  - Biomass
  - Oil/coal

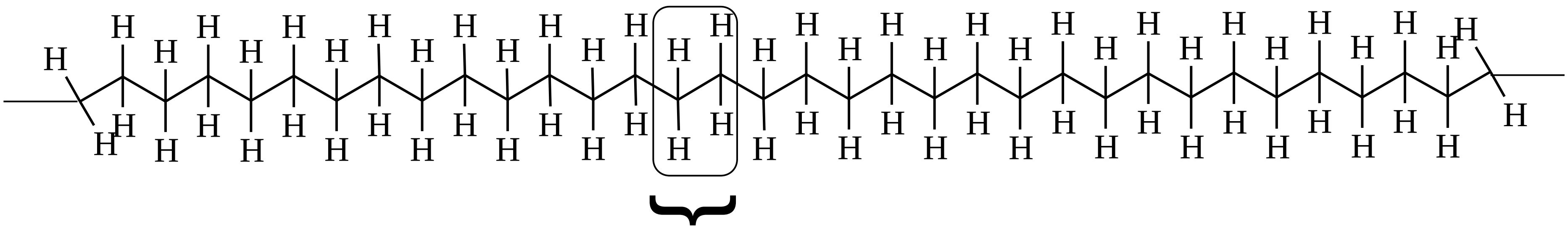
- Monomers & new polymers (chemistry and polymer chemistry)
  - Traditional processes
  - New methods – Enzymatic polymerization? Bacterial synthesis?

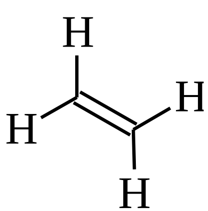
- Plastics/Materials (materials science)
  - Plastics as we know them
  - Tomorrows materials – superior properties

- End-of-life? (environmental engineering)
  - How do we dispose and reuse the polymers we have used?
  - Design parameters?

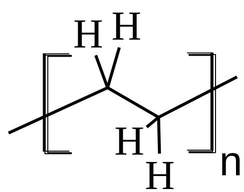
# What is a Polymer?

## Poly (many) mer (repeat unit)



Monomer




Polymer

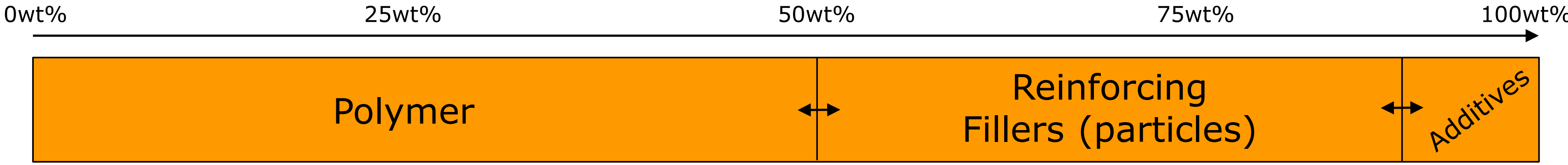
Polymonomer => Polyethylene

# Industrial use of polymers

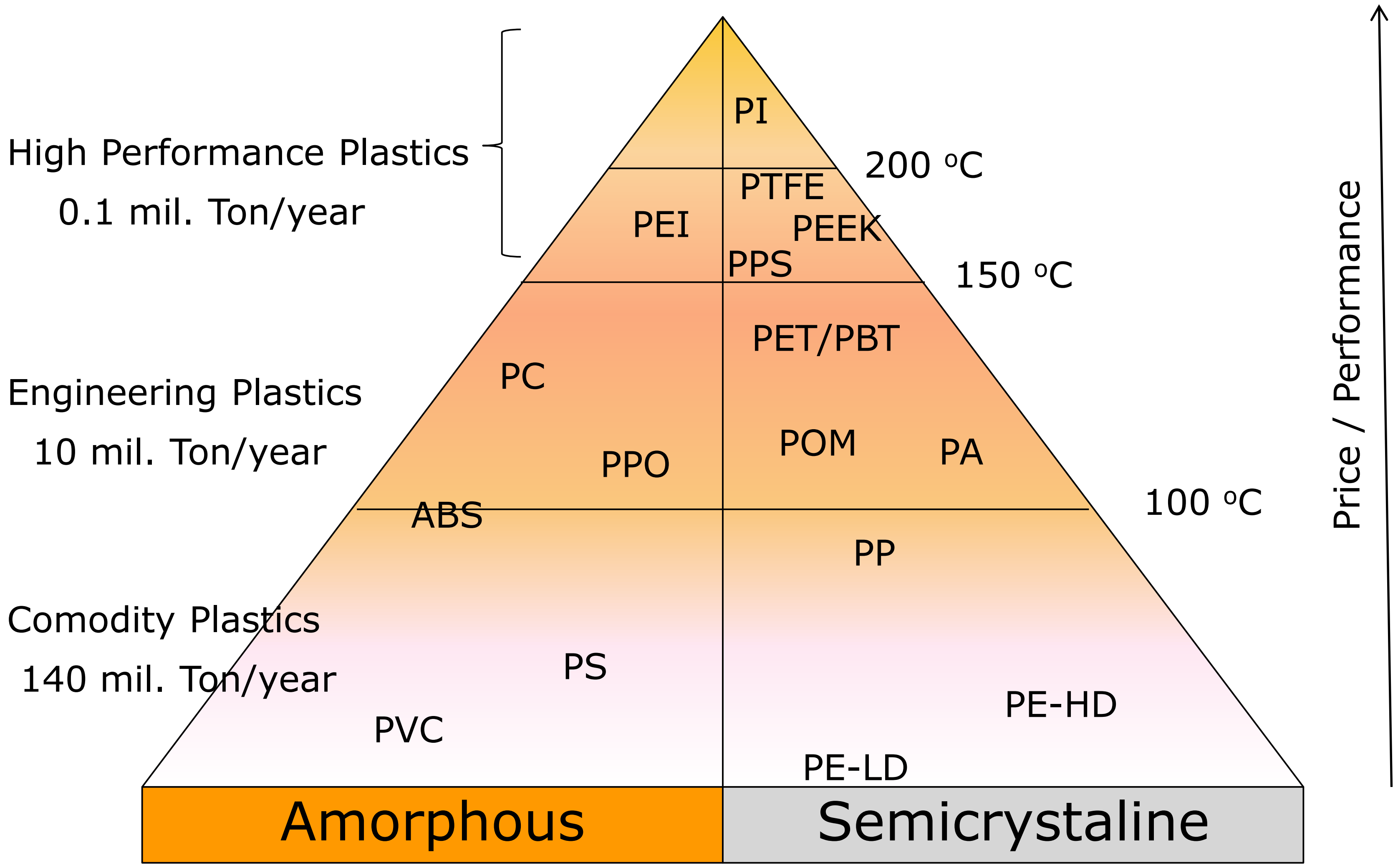
- Plastics
- Fibers
- Rubbers (elastomers)
- Coatings & Adhesives
- Composites

- Polymers used in industrial applications:
  - Formulation
  - Fillers, additives, stabilizers, blockers, flame retardants, …

## Composition of a plastic



# Plastic Pyramid

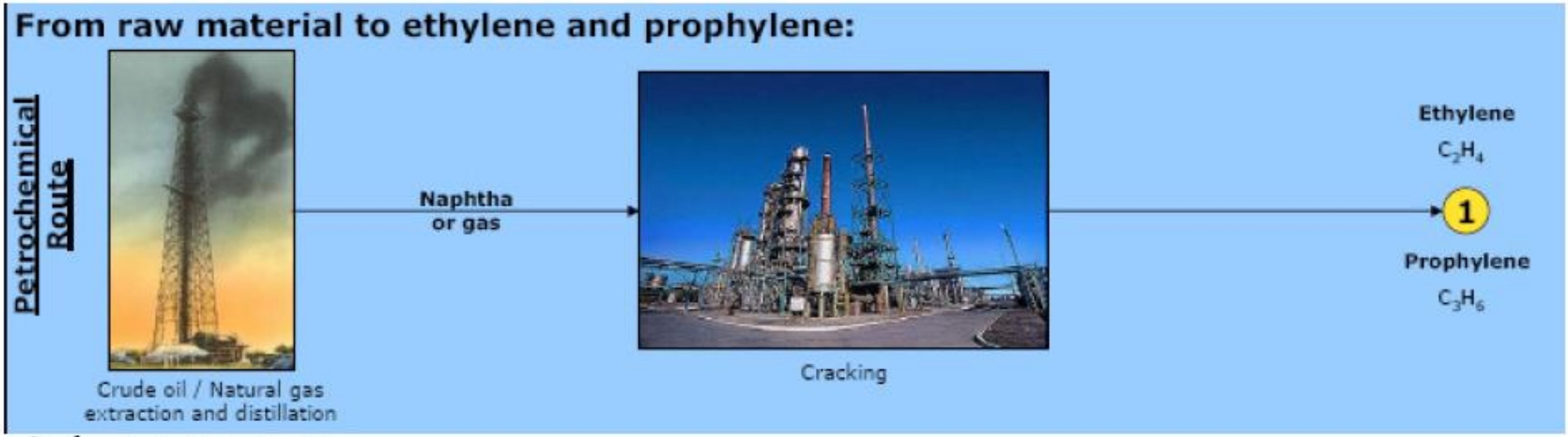


# Polymers world-wide – percentage in market

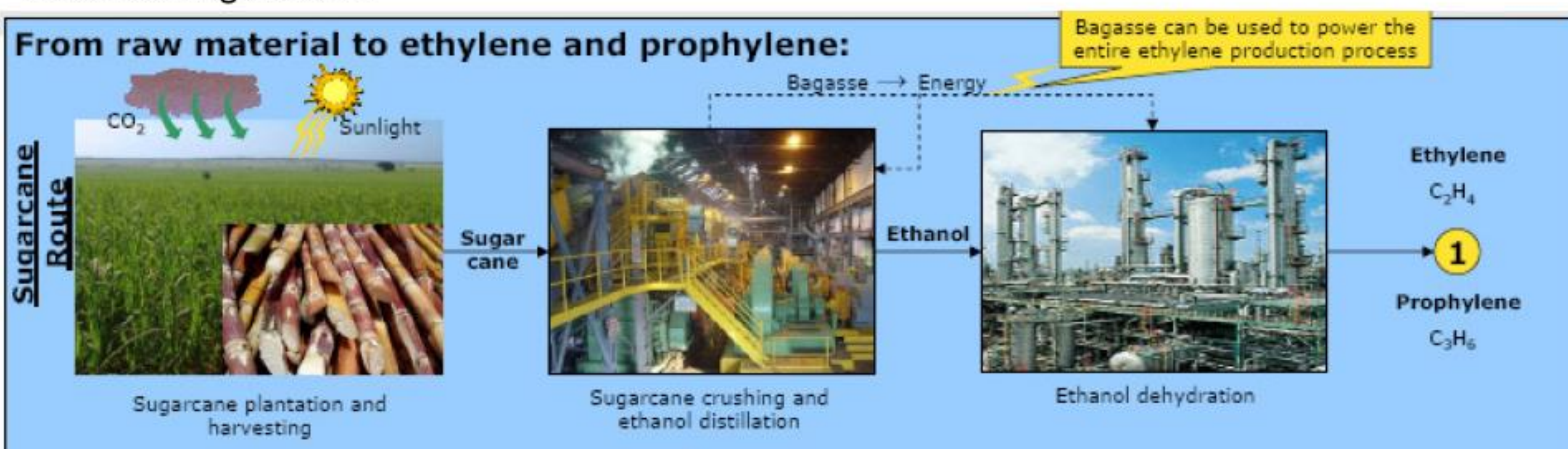
- HDPE : 13%, LDPE : 19 %,  PP : 11 %
- PS : 9 %, PVC : 15 %
- ABS : 3 %
- Phenolics, polyesters: 11 %
- Urea-melamine: 4 %
- Urethanes: 4 %

# Biobased polymers

1. from mineral oil:




2. from sugarcane:



# What are „Biobased & Biodegradable Plastics“?

PlasticsEurope

- The term „Biobased & Biodegradable Plastics“ is ambivalent and calls for a differentation, in respect of raw materials and functionality:
  - **Biobased plastics** are manufactured from renewable raw materials
  - **Biodegradable plastics** (degradable; biodegradable; compostable) are manufactured from renewable or fossil raw materials, or they are blends (mixtures)
- A biobased plastic material (from renewable resources) is not necessarily biodegradable, whereas a biodegradable plastic material can be made from mineral oil

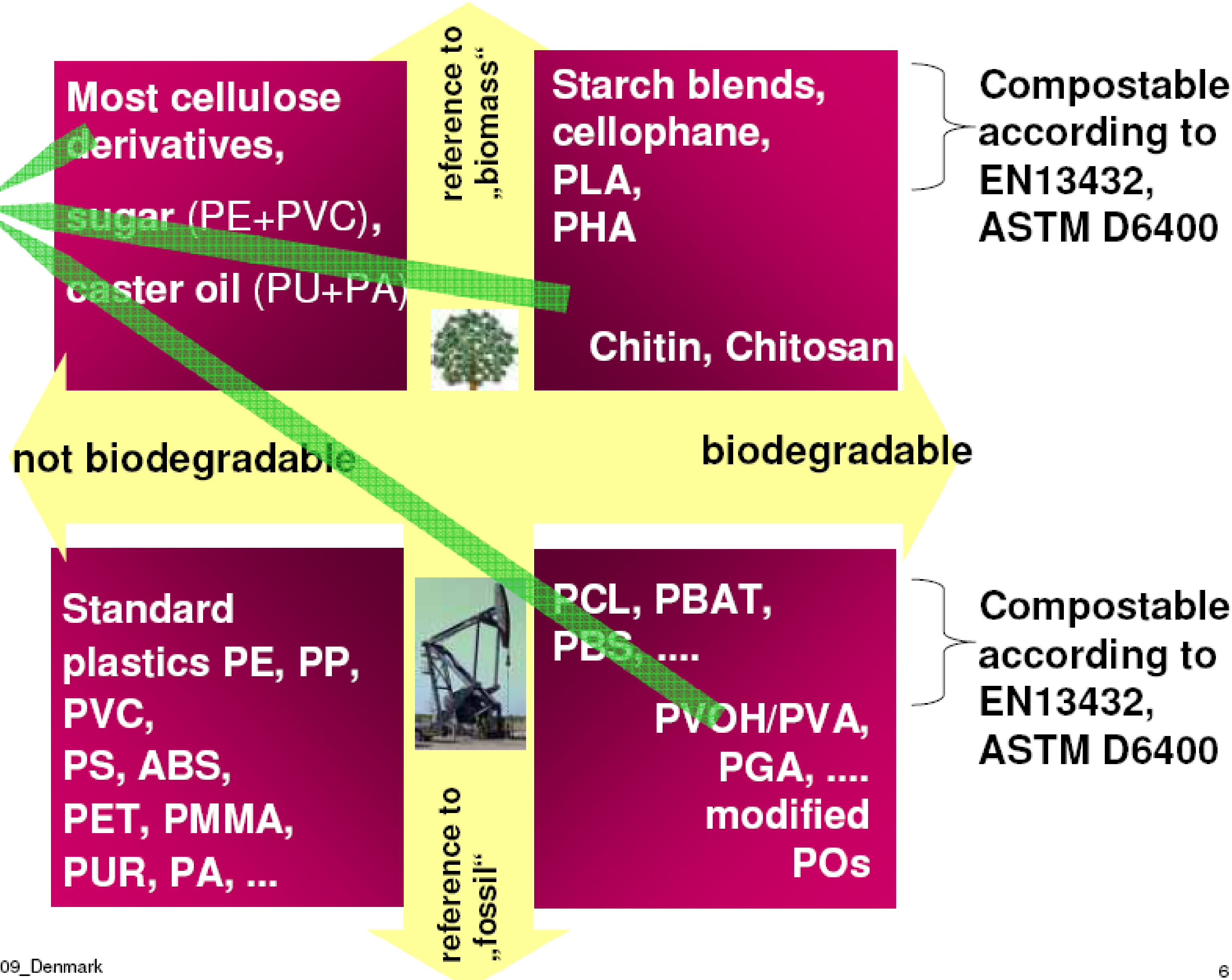
# Biodegradable versus biobased plastics

PlasticsEurope

„Bio- plastics“

- This term is easy to use in marketing

- but difficult in practical realization



# Biodegradable plastics

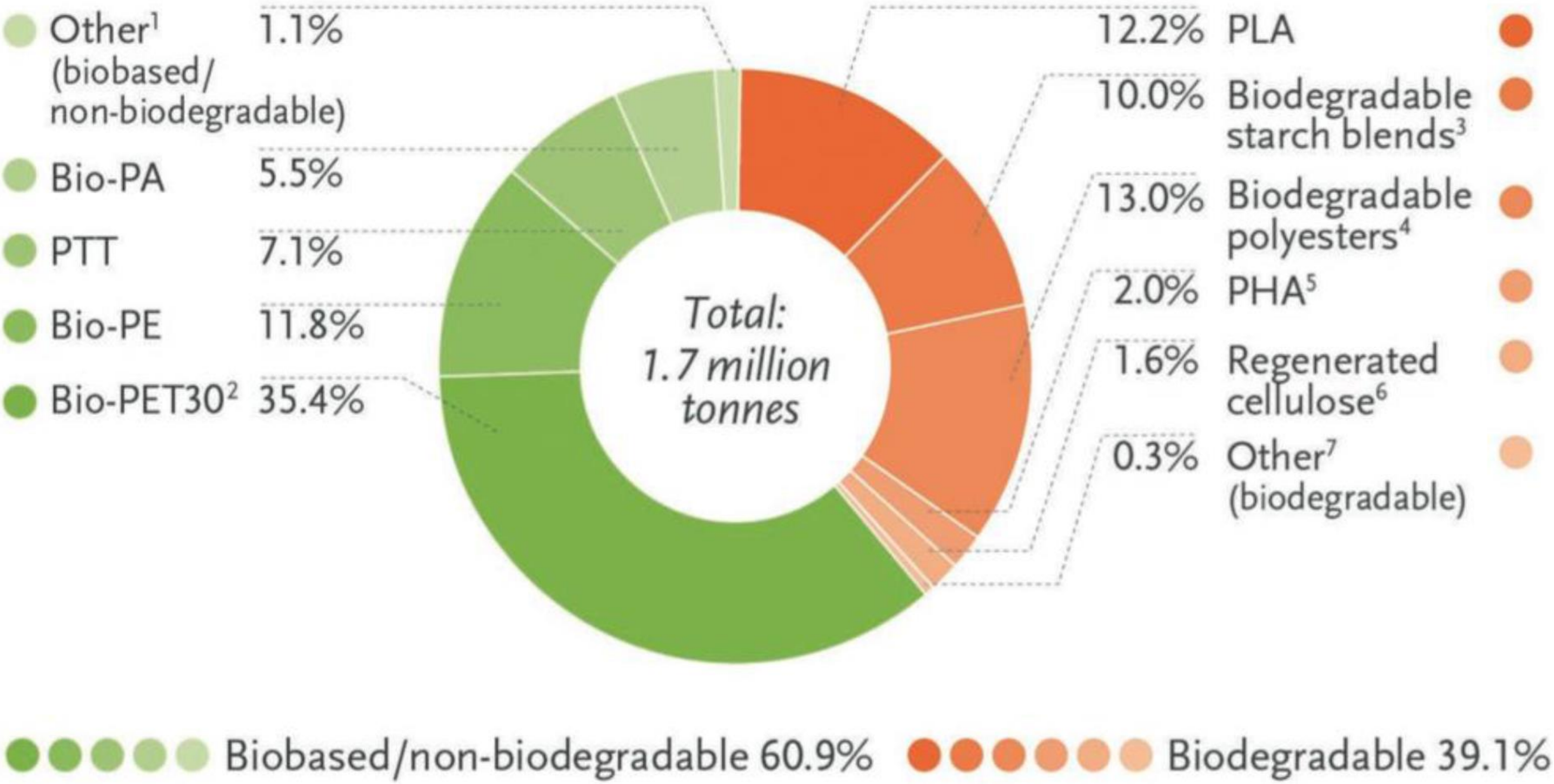
PlasticsEurope
Association of Plastics Manufacturers

Golf tees for leisure time

Mulch films for agriculture

Carrier bag for fruit, suitable for biowaste

# Bioplastics produced




*[1]Contains durable starch blends, Bio-PC, Bio-TPE, Bio-PUR (except thermosets); [2]Biobased content amounts to 30 %; [3]Blend components incl. in main materials; [4]Contains fossil-based PBAT, PBS, PCL; [5]Incl. Newlight Technologies ($CO_2$-based); [6]Compostable hydrated cellulose foils [7]Biodegradable cellulose ester*

Source: Institute for Bioplastics and Biocomposites, Nova-institute (2015)

# Processing of Plastics – Main Classes

- Thermoplastic (termoplast)
  - can be reversibly cooled & reheated, i.e. recycled
  - heat until soft, shape as desired, then cool
  - ex: polyethylene, polypropylene, polystyrene.

- Thermoset (hærdeplast)
  - when heated forms a molecular network (chemical reaction)
  - degrades (doesn't melt) when heated
  - a prepolymer molded into desired shape, then chemical reaction occurs
  - ex: paints, unsaturated Polyesters, epoxies, formaldehyde resins (Phenol/FA; Urea/FA; Melamine/FA), vulcanized rubber, elastomers (e.g. PDMS)

# Composites – Polymers with fillers

- Combination of fillers
  - – Glass fiber / Carbon fiber
  - - Chalk, others
- Matrix
  - – Typically thermosets
  - – Epoxy
  - – Unsaturated polyesters

- Nanocomposites
  - – Similar, but with other amounts of fillers
  - – Carbon Nanotubes
  - – Nanoclays

# Outlook

- Monomers
  - Many new and existing monomers can now be produced from biobased raw materials.
  - Which ones will be the most usefull ones?

- Materials
  - The increasing amount of new monomers will lead to development of a range of new polymeric materials
  - Properties based on chemistry

- End-of-life challenges
  - Recycling
  - Bio-degradable materials?
  - Intelligent design

- Overall we are looking at a new age of polymer development that could become as central to the future use of plastics as the 1930-1950ies.

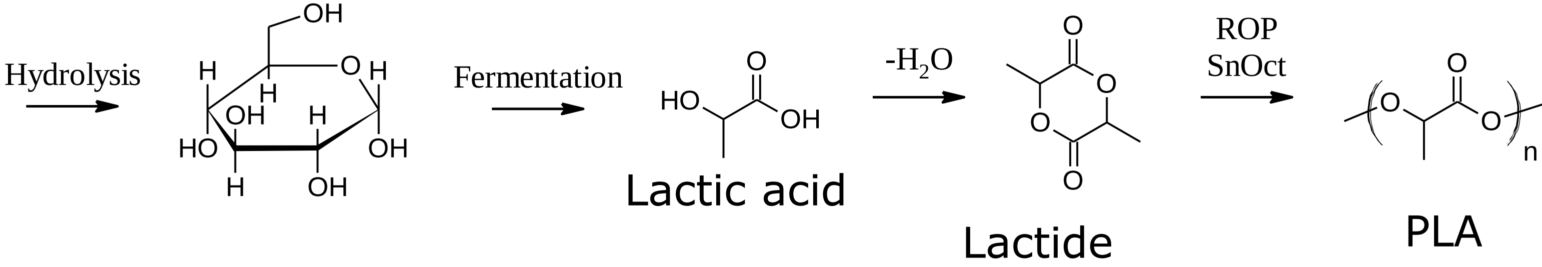
# End-of-Life challenges on the way to a sustainable solution

- Polymers in general (Biobased polymers/petrochemical based polymers)
  - Recycling
  - Stabilizers, additives
  - Non-intended additives
  - Industrial waste
  - Complex combinations of polymers

- Biodegradable polymers
  - Composting(e.g. PLA) is it compatible?
  - Recycling – PLA processing is difficult, reuse even more so
  - Do we even want most polymer materials to degrade?

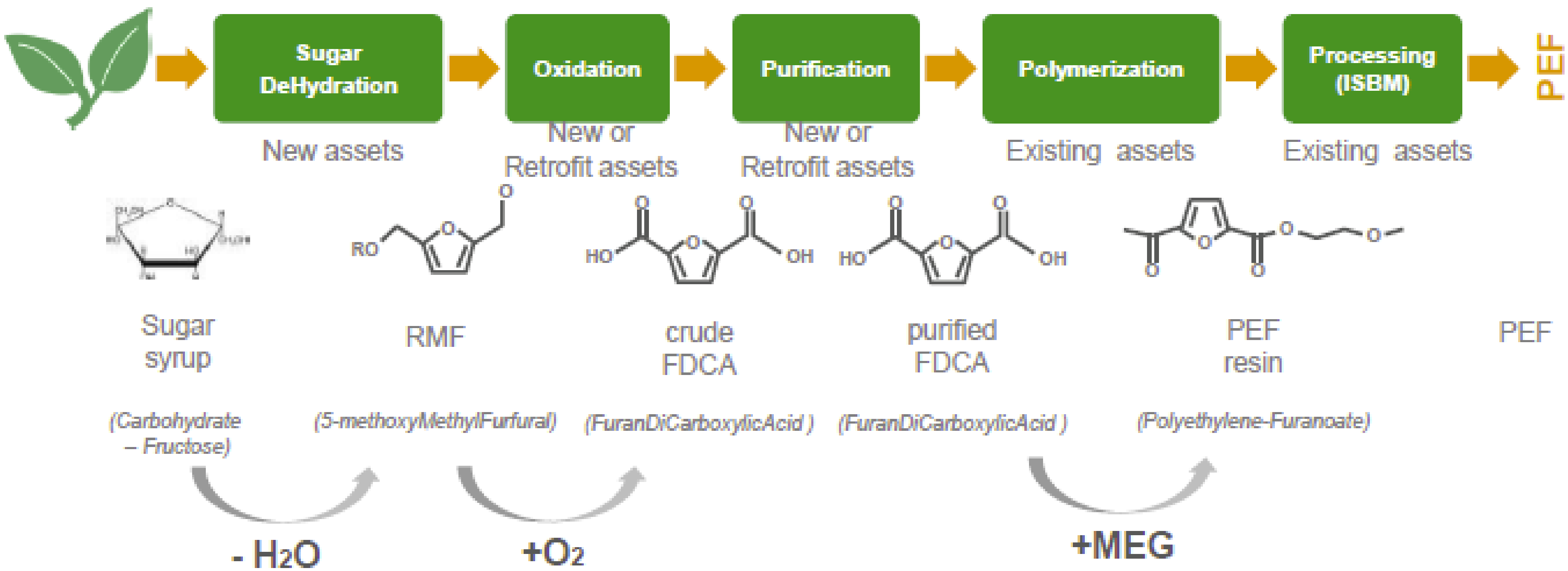
# Poly(lactide) or poly(lactic acid) (PLA)

Sources of starch




- PLA properties
  - Production > 100.000 tonnes/year.
  - Comopostible app. 100% in 45 days
  - $T_g$ of 60°C, $T_m$ 160°C
  - Properties compare to PS

# New polymer system for replacement of PET: PEF developed by Avantium




- PEF oxygen barrier is 10 times better than PET
- PEF carbon dioxide barrier is 4 times better than PET
- PEF water barrier is 2 times better than PET

- The $T_g$ of PEF is 86° C compared to the $T_g$ of PET of 74°C
- The $T_m$ of PEF is 235°C compared to the $T_m$ of PET of 265°C

Avantium.com

# Polymer Additives

- Most well known is propably plasticizers

- Why use additives?

- How much?

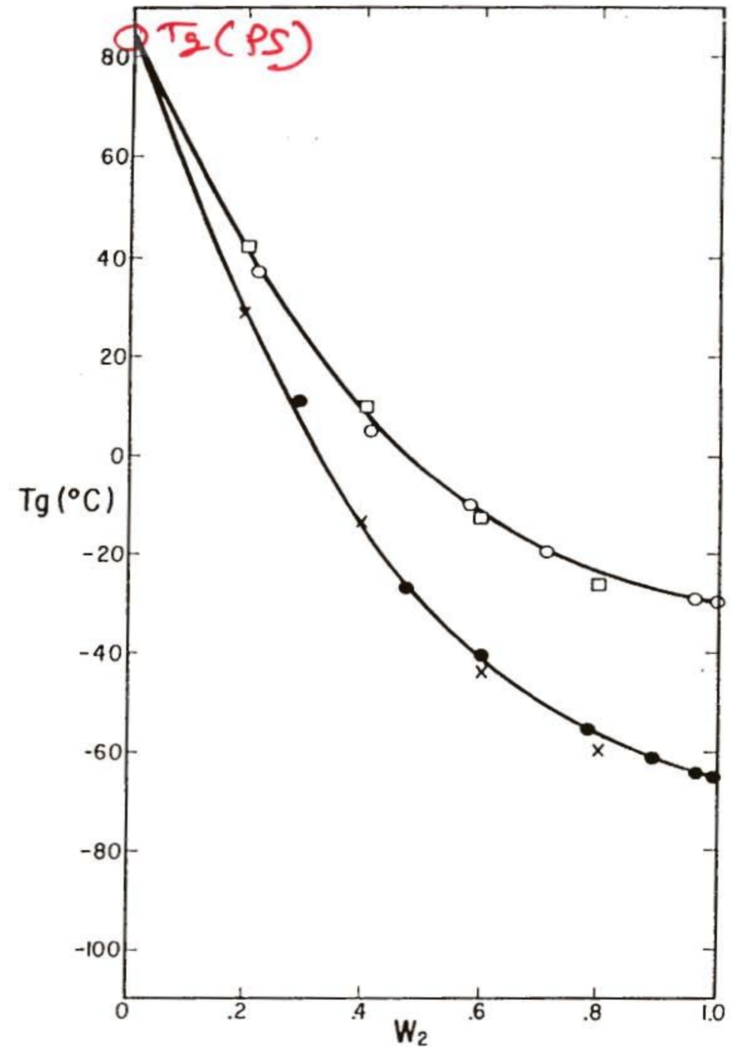



Figure 14. Glass transition temperature of plasticized polystyrene. Tricresyl phosphate in polystyrene: ● Experimental, X Equation 1. Naphthyl salicylate in polystyrene: O Experimental, □ Equation 1. $W_2$ = weight fraction of plasticizer.

PS/salicylate $T_g = 85.5w_1 - 29.5w_2 - 124\, w_1 w_2$

PS/phosphate $T_g = 85.5w_1 - 64.5w_2 - 164\, w_1 w_2$

# Polymer Additives

- Improve mechanical properties, processability, durability, etc.

- Fillers
  - Added to improve tensile strength & abrasion resistance, toughness & decrease cost
  - E.g: Carbon black, silica gel, wood flour, glass, limestone, talc, etc.

- Plasticizers
  - Added to reduce the glass transition temperature Tg below room temperature
  - Presence of plasticizer transforms brittle polymer to a ductile one
  - Commonly added to PVC - otherwise it is brittle

# Polymer Additives (cont.)

- Stabilizers
  - Antioxidants
  - UV protectants

- Lubricants
  - Added to allow easier processing
  - polymer “slides” through dies easier
  - ex: sodium stearate

- Colorants
  - Dyes and pigments

- Flame Retardants
  - Substances containing chlorine, fluorine, and boron

# Protection agains UV light

- Blockers
  - Carbon black
  - Titanium dioxide

- Stabilizers
  - Hindered amines
  - Stabilize radicals inside the polymer
  - Cd, Zn, Pb – stabilize HCl from PVC

- Absorbers
  - Benzophenones/benzotriazoles
  - Absorb and reemit at less harmfull wavelenghts