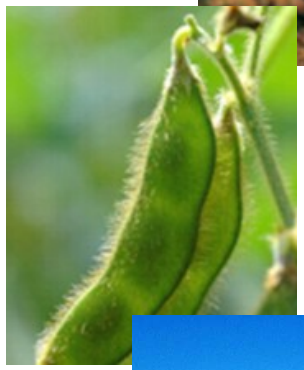

Compounding PVC with renewable materials

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Why formulate with renewable materials?

- Petroleum has increased significantly its price - renewable materials are more cost competitive
  - "The stone age didn't end because of lack of stones"
- Reduction of green house gases
- Technology is improving substantially
  - Agriculture
  - Industrial processes
  - Alternative sources
- It's an excellent opportunity to further improve the image of PVC
- This paper covers only resin and plasticizers. Other additives could be the object of a later study

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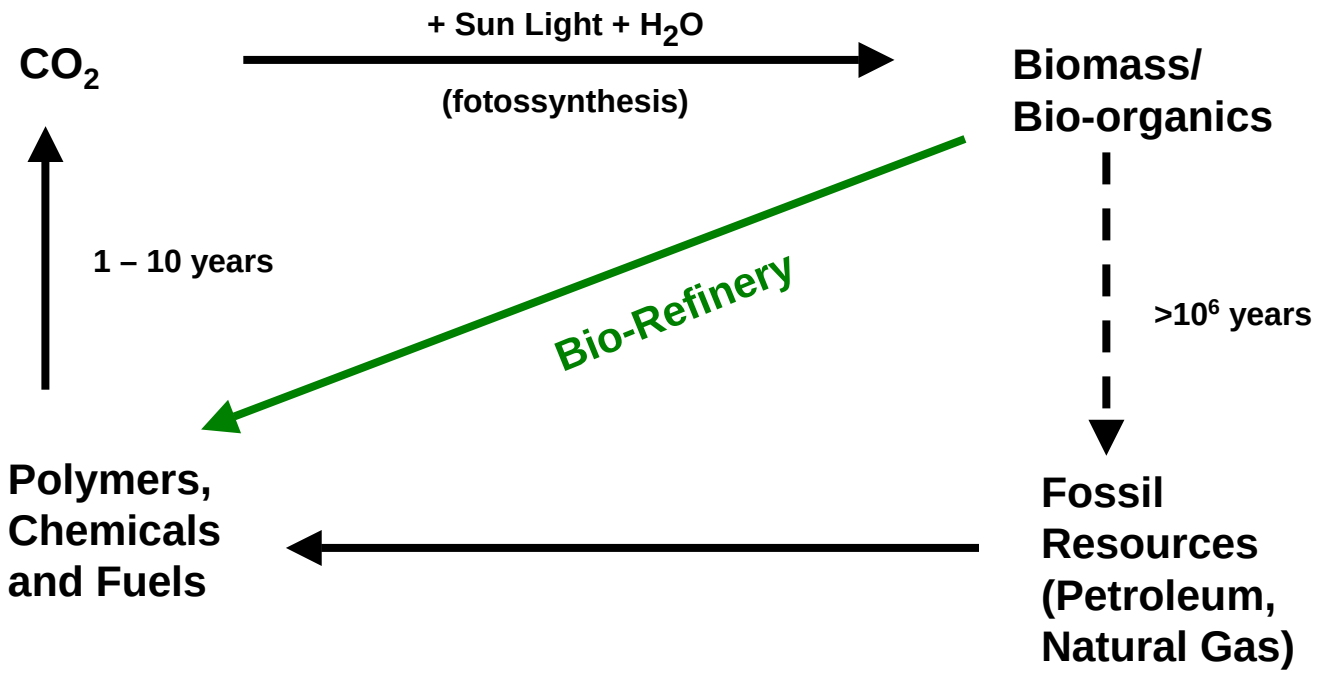
Defining Renewable – the Carbon Cycle



R. Narayan, Michigan State University (2005)

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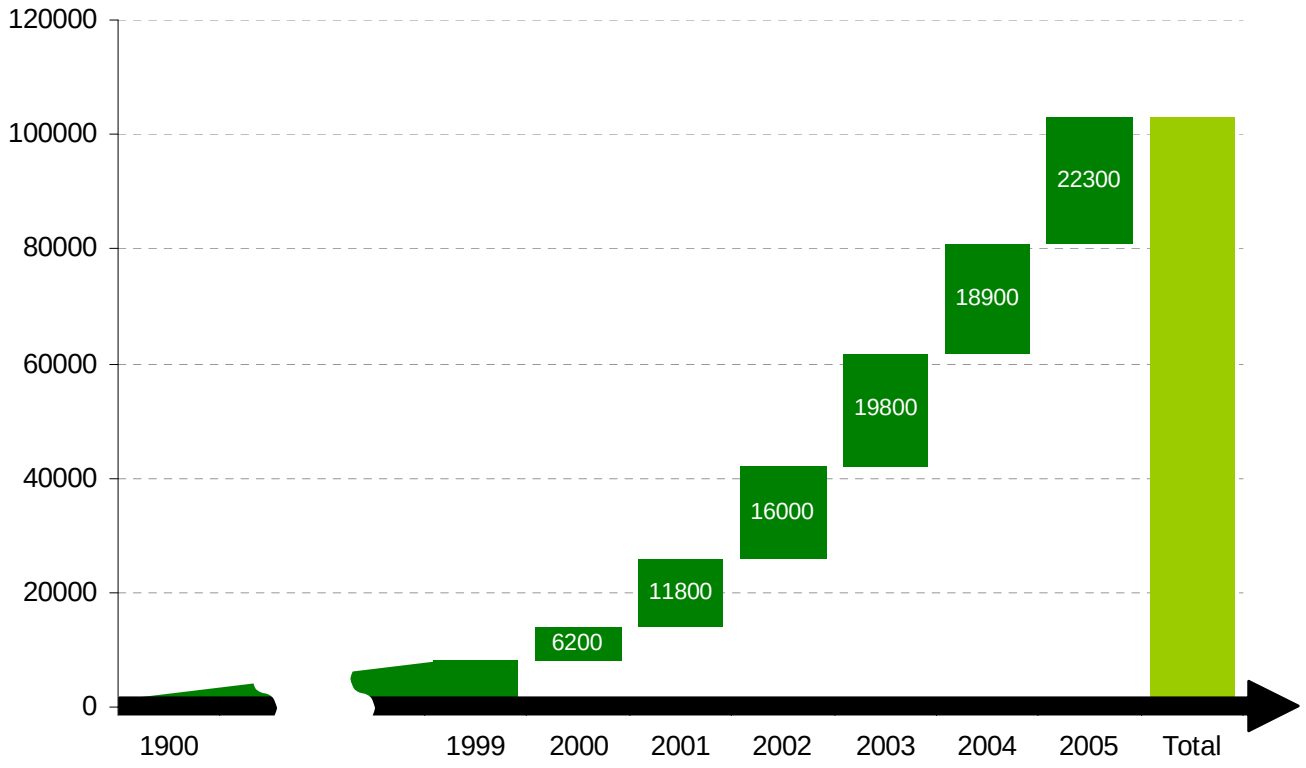
The innovation...

Number of Industrial Biotech Patents Issued

Selected Industrial Bio-Products/Processes



McKinsey Data

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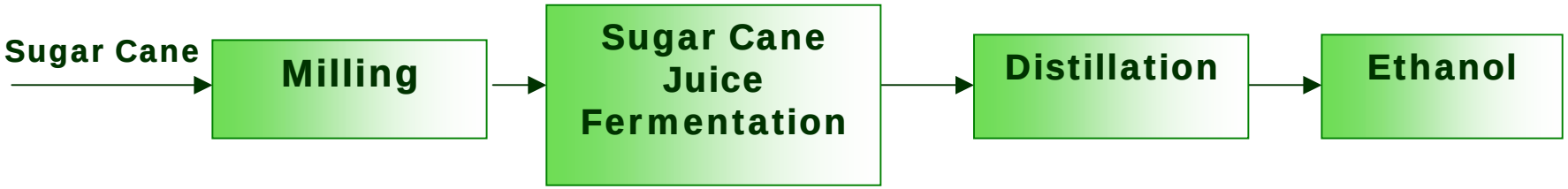
Ethanol Production From Sugar Cane

- Brazilian Ethanol:
  - Brazil has a total arable surface of approximately 360 million hectares (42% of its territory), 5.0 million of them intended for sugar cane crops;
  - Arable surface means all the land that has the appropriate soil and climate conditions for agriculture. It excludes urban areas, preservation areas and natural forests.
  - 7500 L of Ethanol are produced in one hectare of land;
  - 800 Kg of Ethanol (1000 L) would require 12 ton of sugar cane;
  - Ethanol plants use sugar cane leaves and bagasse to produce electricity enough for its own needs and sells the excess to the Brazilian grid;



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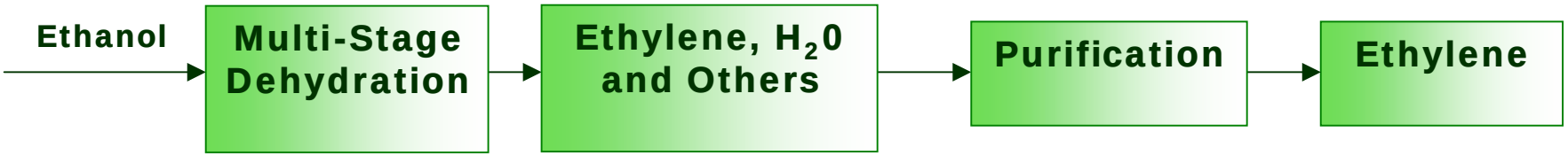
Bio-Ethylene Production – From Ethanol to Ethylene

- Process- Generals



– Overall Reaction:

$$C_2H_5OH \xrightarrow{\text{heat}} C_2H_4 + H_2O$$

– Yield: 1.9 ton of Ethanol provides 1 ton of Bio-Ethylene;

– Bio-Ethylene specifications are exactly the same as for naphtha/natural gas ethylene;

- Besides being renewable, ethanol is known to remove and fix carbon dioxide from the atmosphere.

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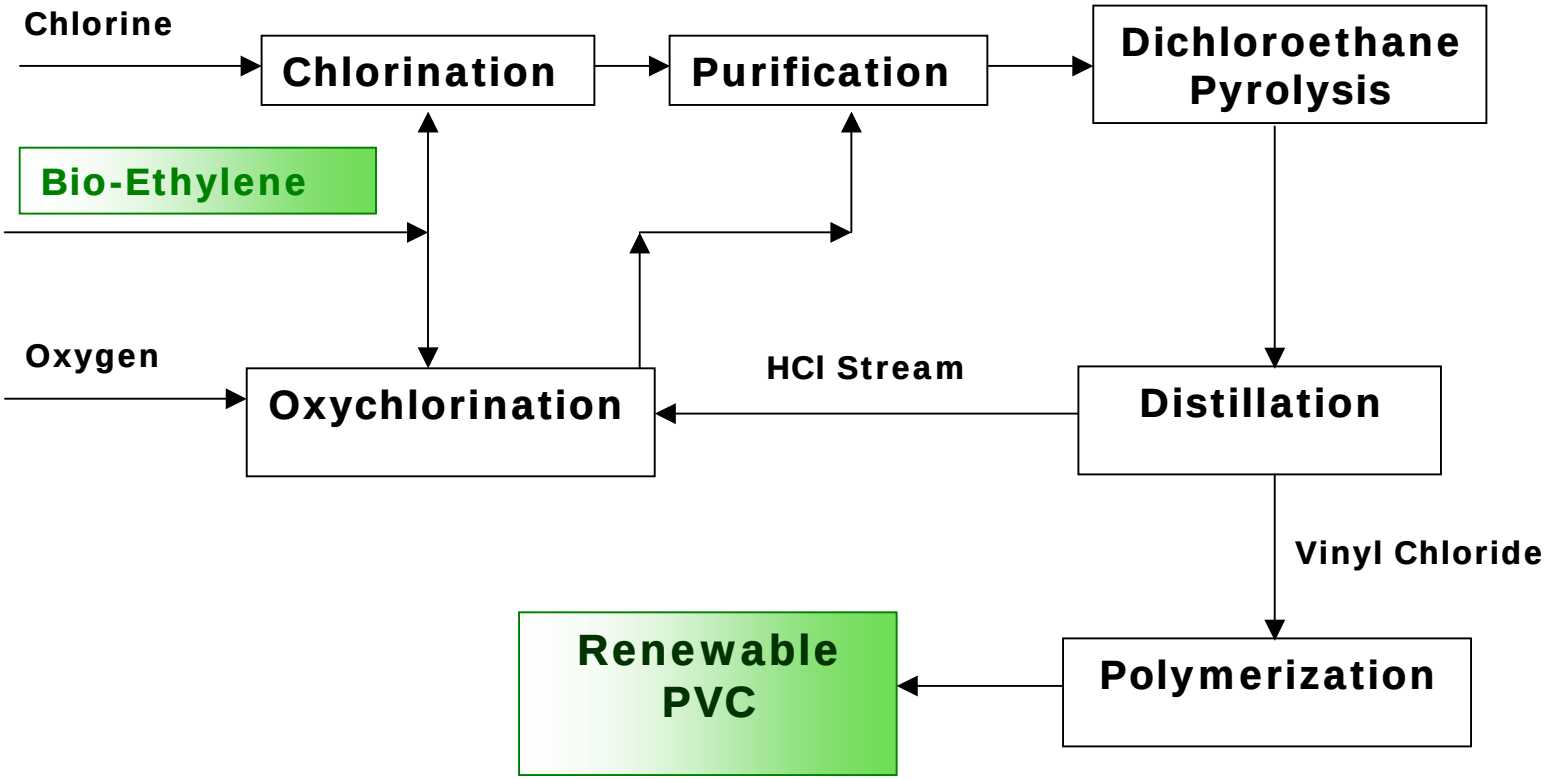
Renewable PVC production – From Sugar and Salt to make plastic



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Renewable PVC production – From Sugar and Salt to make plastic

Solvay Indupa's Brazilian new plant (start in 2010)

60 Kton / year of Bio-Ethylene and 125 Kton / year of Renewable PVC

Reduction of 300 Kton / year of CO_2 emissions

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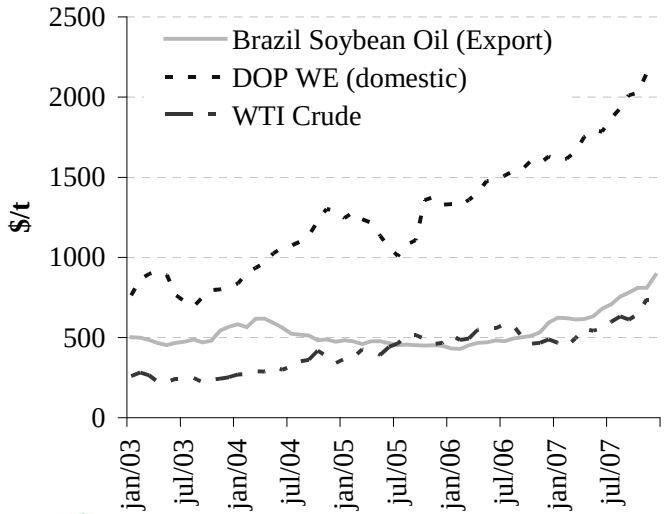
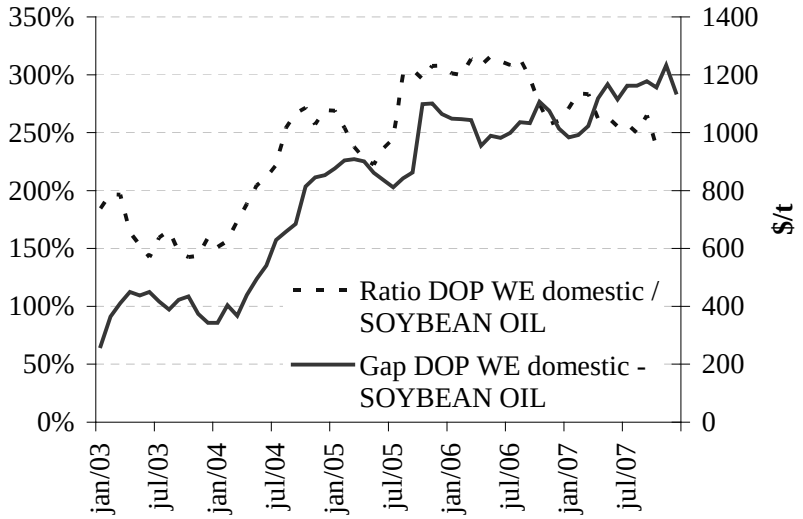
Plasticizers

- Renewable plasticizers have become cost competitive in the last years
- Different grades deriving from soybean, linseed and castor oil provide flexibility of compound properties for the formulator: ESO (Epoxidized Soybean Oil), ELO (Epoxidized Linseed Oil), MES (Methyl Epoxy Soyate), ACO (Acetylated Castor Oil)
- Application tests have shown encouraging prospects
- The source is mostly based on oilseed grains, but recent technical evolution demonstrates possibilities with algae and ethanol production derivatives, as well as palm and babaçu alcohols

Pricing Evolution



DOP and Soybean Oil Price Evolution



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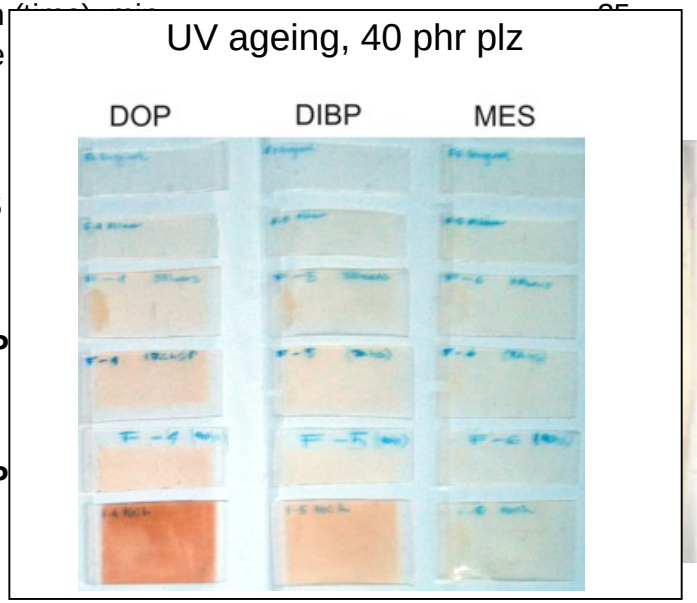
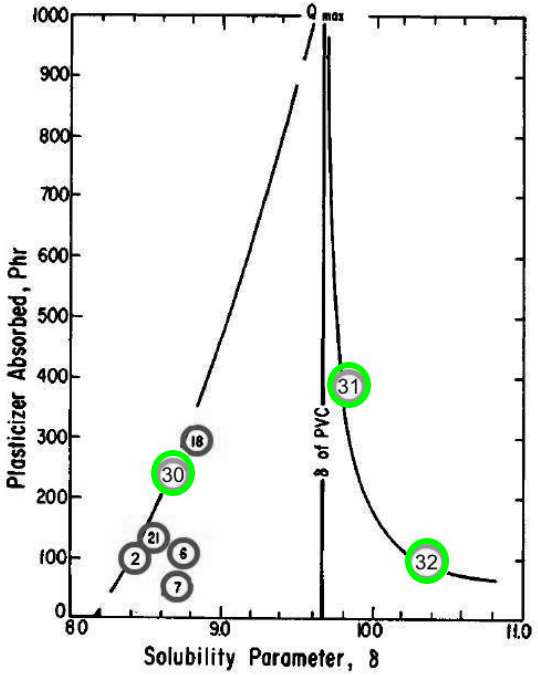
Plasticizers – Performance comparison

Compound properties, adjusted to same hardness	DOP	MES
Elongation (%)	264	357
Tensile Strength (MPa)	14.8	16.2
Weight Loss, %, (144 hrs, 40°C)	0.16	0.51
Weight Loss, %, (72 hrs, 70°C)	1.16	3.67
Viscosity of Plastisol, 0h, low shear	3.1	3.5
Viscosity of Plastisol, 48h, low shear	4.8	5.7
Water extraction, 75 C, 1% soapy water, 48h	0.13	1.82
Solvent extraction, Isoparaffin, w%, 48h	14.4	3.36
Butane extraction, w%, 48 h	18.5	9.7
Fish Eyes (count)	29	21
Débullage (volume of foam), ml	53	65
Resin Absorption		8
Low Temperature		-23

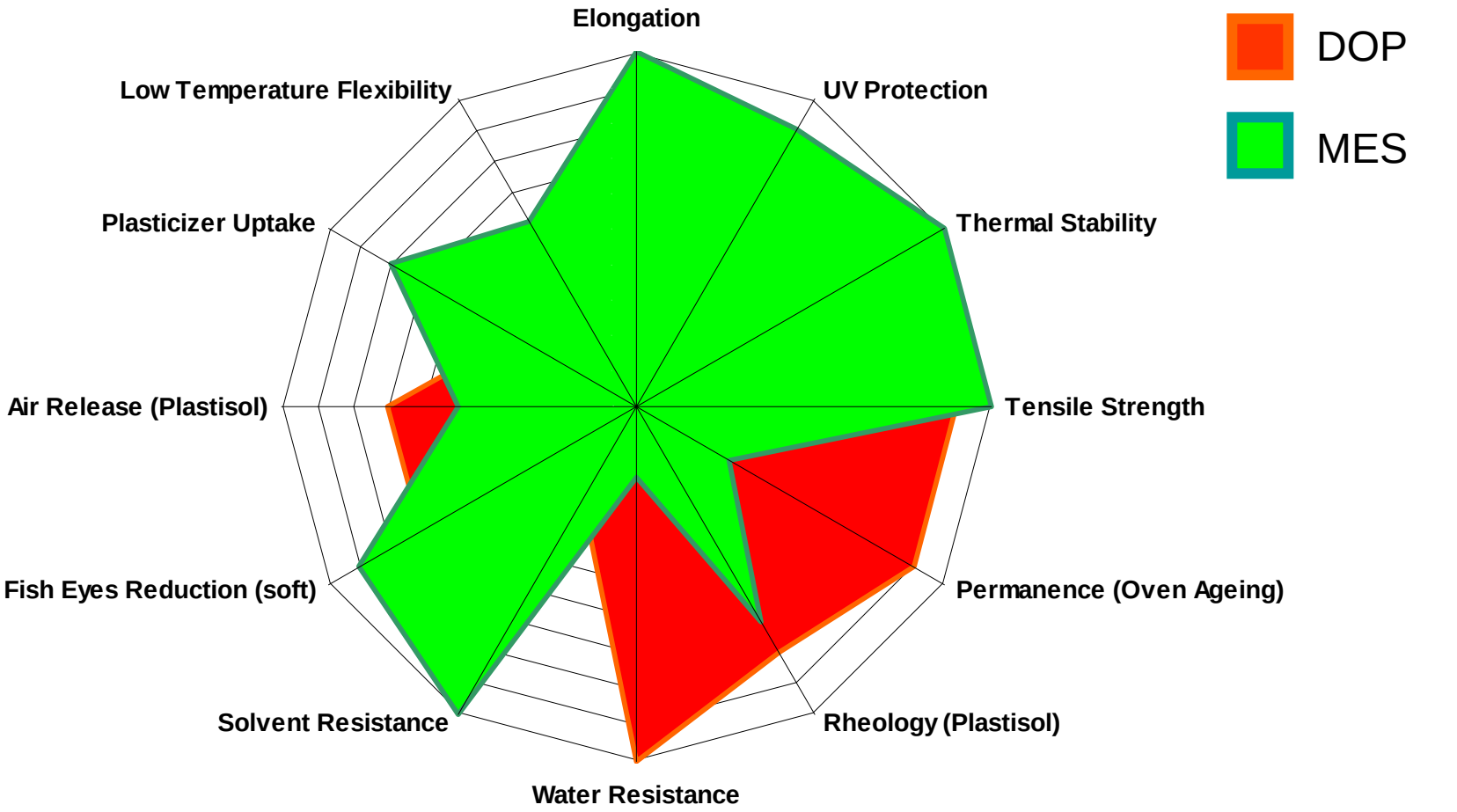




Key:
2: DOA (Dioctyl Adipate)
6: BES (Butyl Epoxy Stearate)
7: OES (Octyl Epoxy Stearate)
18: DOP (Dioctyl Phthalate)
21: DIDP (Diisodecyl Phthalate)
30: ESO* (Epoxidized Soybean Oil)
31: MES* (Methyl Epoxy Soyate)
32: ACO* (Acetylated Castor Oil)

* theoretical only
Source: Sears & Darby

Plasticizers – Performance comparison



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Sustainability

- Sustainable = looking at the whole cycle of use of a product, including emissions, human toxicology, ecotoxicology, preservation of species, economy, society
- The technology improvement, the available land, the possibilities of harvesting the sea, indicates that renewable materials are still in the beginning of the development cycle
- Renewable solutions are key for long term sustainability

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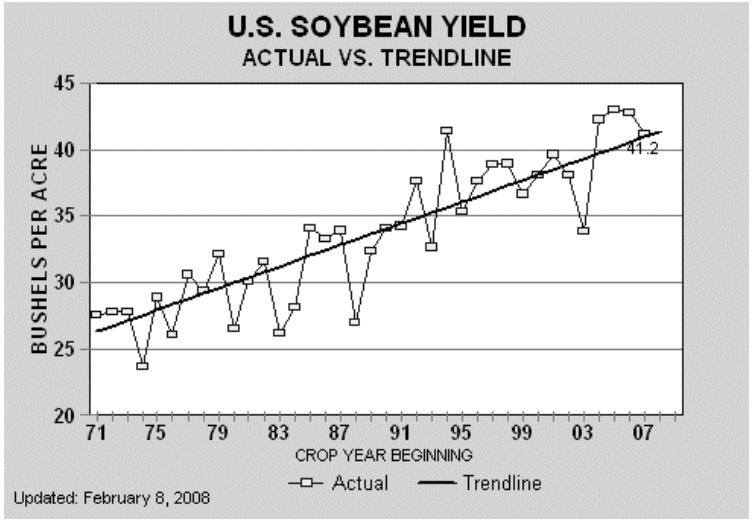
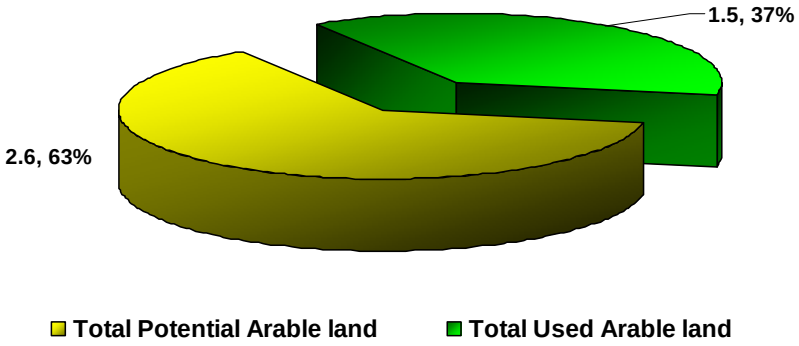
Sustainability

- Yields are improving significantly
- Other technologies arising: algae, cellulosic, etc
- Higher biodegradability
- No negative toxicology results
- Greenhouse gases reduction
- Cost effective
- Potential for expansion of current sources



Arable Land, Billion Ha (FAO)



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Conclusion

- Renewable PVC compound
  - Commercially competitive
  - Can be formulated for almost all applications
  - Technically suited
  - Already available, various grades
  - Sustainable
  - Appears as a natural evolution in the direction of a more sustainable PVC supply chain

Example: 71 Shore A Crystal-Clear Vinyl Renewable Compound

100kg Renewable PVC+ 60 kg MES+4 kg ESO+1 kg Ca/Zn Stabilizer = 165 kg compound

240 kg CO_2[1] 141 kg CO_2[2] + 0 + 0 = 381 kg CO_2

2.3 ton CO_2 / ton compound

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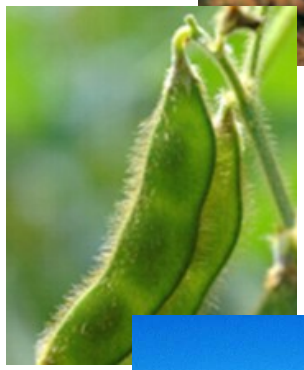
Brighton,
April 23rd 2008

Thank you for your attention!



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