"Genomics: - A Cellulosic Route to Biofuels"

Earl R. Beaver

Sustainable Engineering Forum

November 21, 2006

Impacts

- Societal Concerns
- Biosourcing
- Information Technology
  - Service Component
  - Sustainable Decision-making

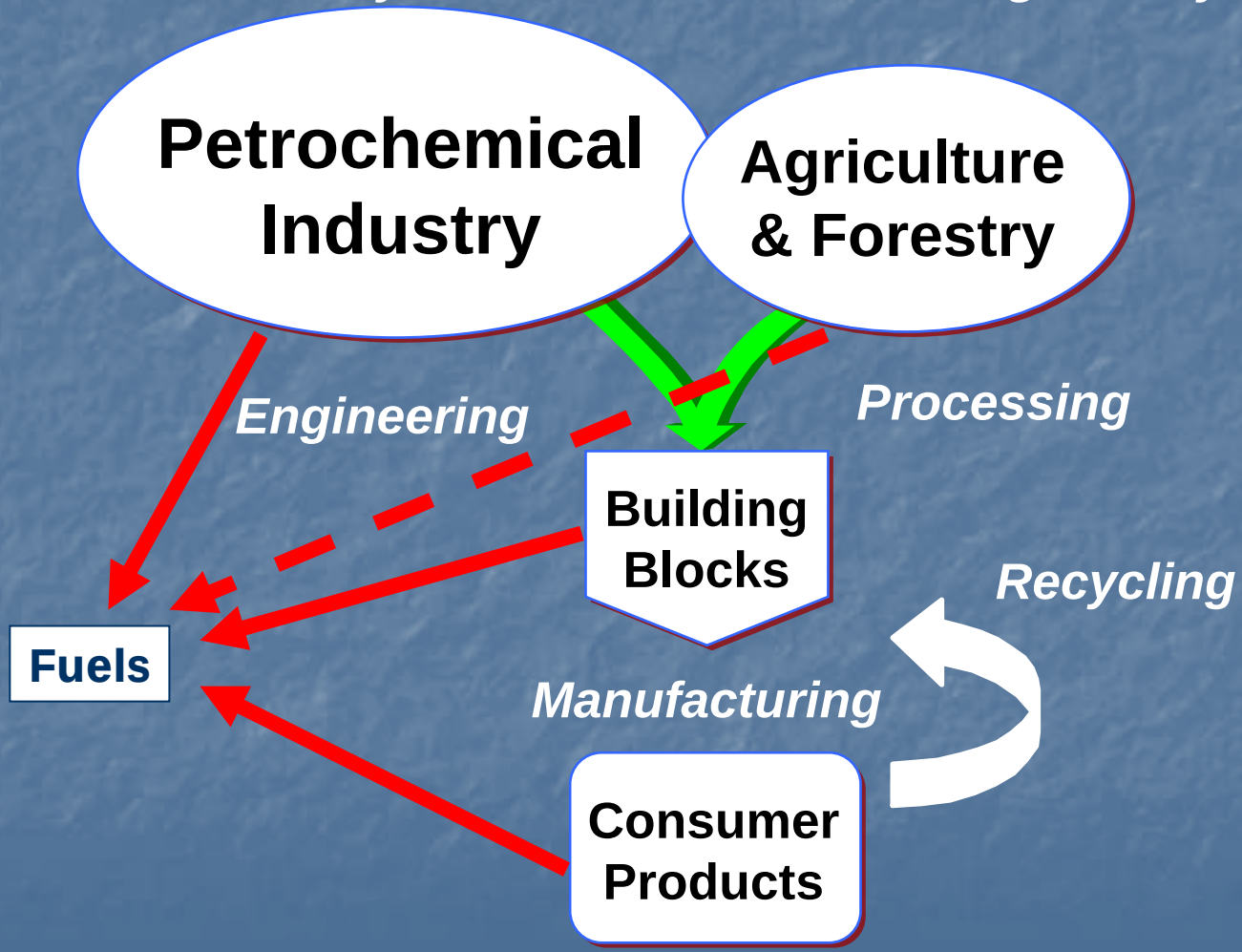
Essential Issues in Product & Service Innovation

- Forecast, understand & shape opportunities in the front end of innovation
- System to develop breakthrough innovations in light of raw material supply
- Create high performance strategic alliances
- Techniques for building a patent estate
- Recognize & capture opportunities from outside
- Transfer innovation to customers via methods for user innovation
- Risk-adjusted valuation for early-stage of projects
- Online idea management within the company
- Generate & evaluate ideas under time pressure
- Deal with societal priorities influencing product innovation now and in the future

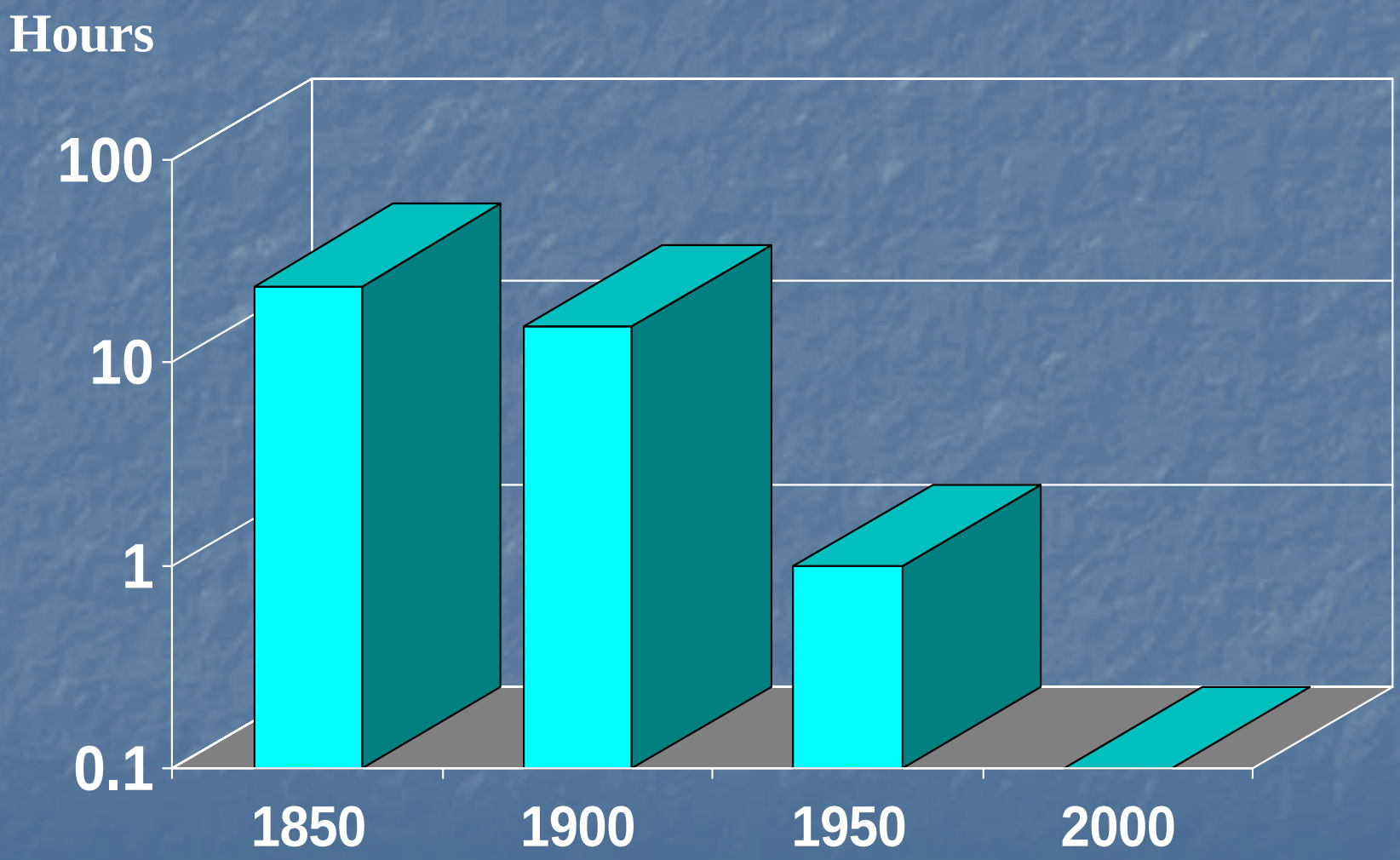
Adapted from The Fuzzy Front End

Two Routes to Products

Chemistry ⟷ Biotech ⟷ Agronomy



Agricultural Advance:
Person-hours to harvest 1 acre wheat...



Source: Mindshift, P. Pritchett.

Agriculture and More

Feedstocks → **Conversion Processes** →

Trees
Grasses
Agricultural Crops
Agricultural Residues
Animal Wastes
Municipal Solid Waste

- Acid/enzymatic hydrolysis
- Fermentation
- Bioconversion
- Chemical Conversion
- Gasification or Pyrolysis
- co-firing

USES

Fuels:
- **Ethanol**
- **Renewable Diesel**

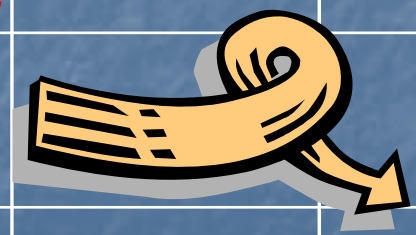
Power
- **Electricity**
- **Heat**

Products
- **Plastics, resins, foams**
- **Phenolic resins**
- **Solvents, cleaning fluids**
- **Chemical Intermediates**
- **Adhesives**
- **Fatty acids**
- **Carbon black**
- **Paints, coatings**
- **Dyes, Pigments, and Ink**
- **Detergents**
- **Hydraulic& lubricating fluids**

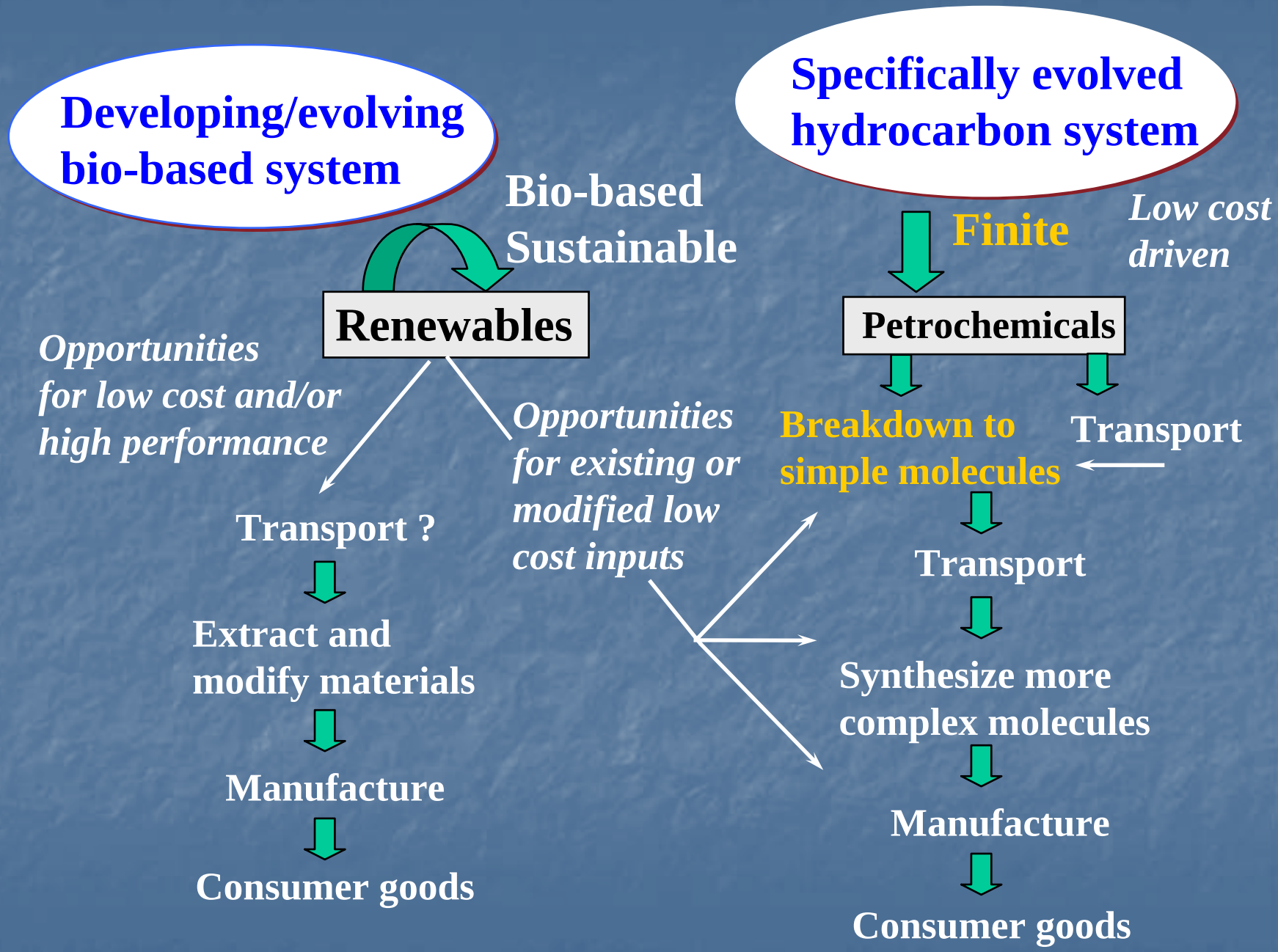
Technology "front" includes chemistry and biotechnology...

Demand for Consumables

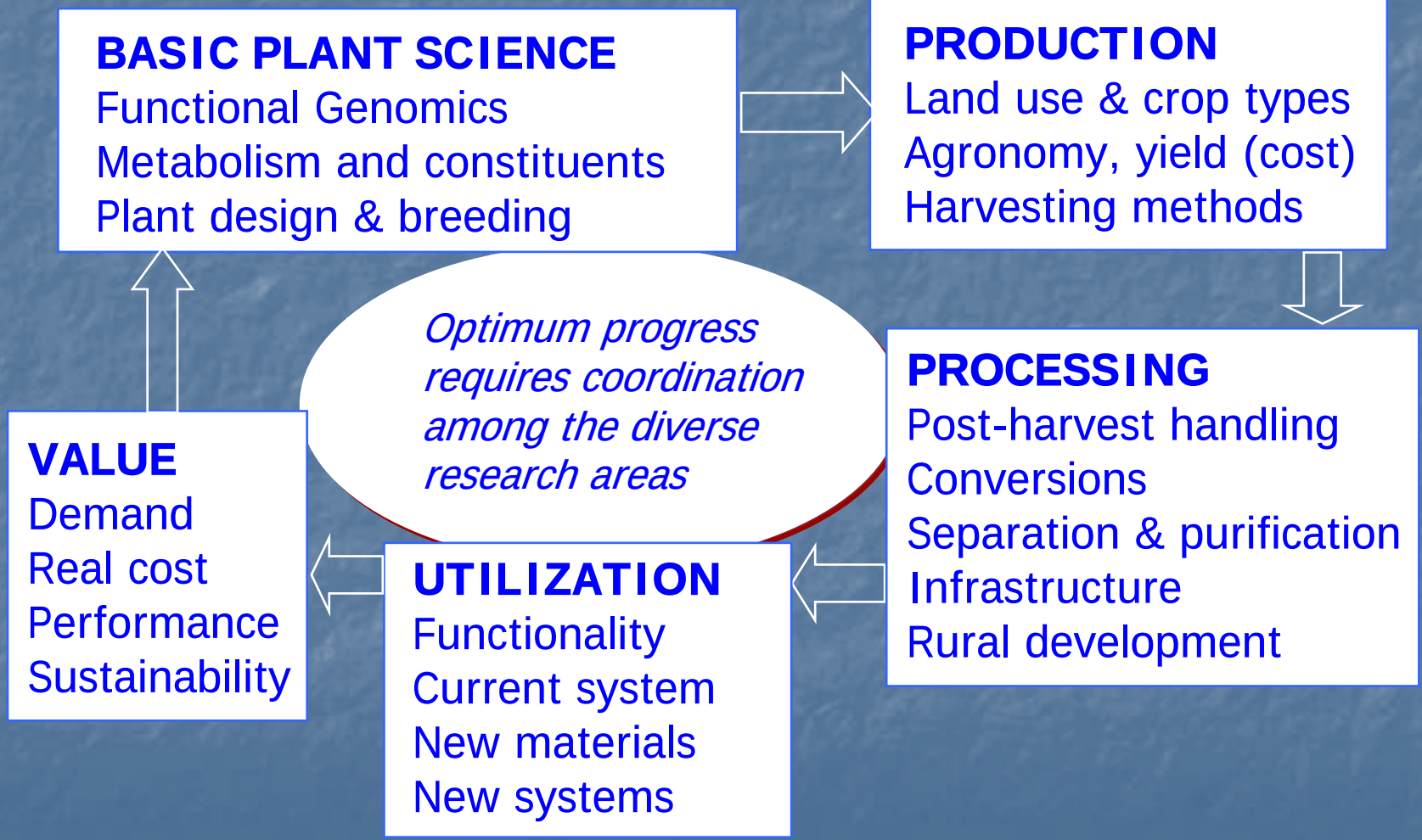
		CURRENT PRODUCTS			NEW PRODUCTS
		Processing systems			
		Traditional Technology	Modified Technology	Bio-processes	Novel Molecules
PLANT INPUT	Waste & By-products				
	Existing Crop Parts		*Technology front today*		
	Dedicated Crops				
	Modified Genetics				*Year 2020*



Adapted from: J. MacLaren, Inverizon, USDOE

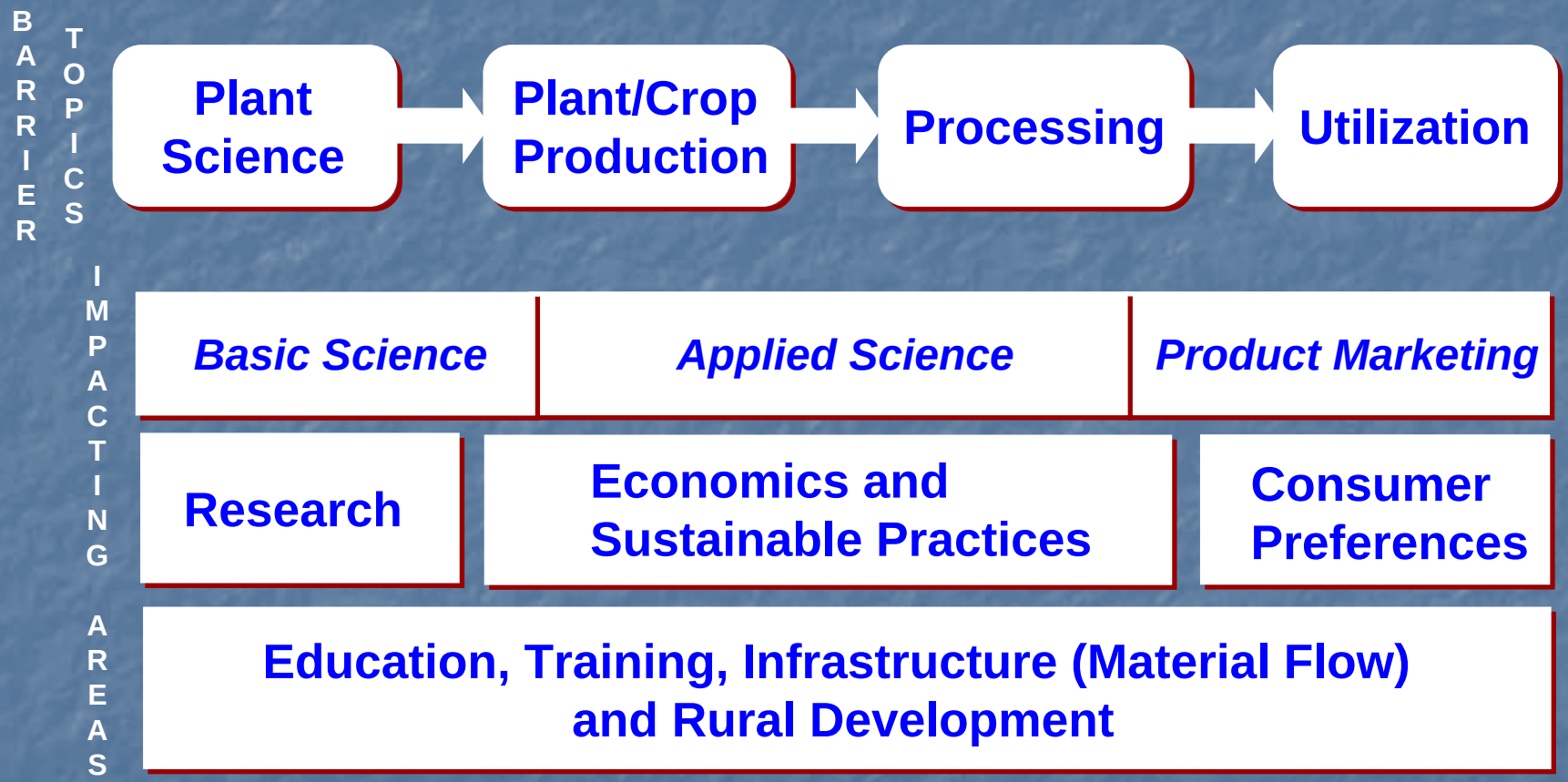

Developing/evolving bio-based system
Bio-based
Sustainable
Renewables
Opportunities for low cost and/or high performance
Opportunities for existing or modified low cost inputs
Transport ?
Extract and modify materials
Manufacture
Consumer goods
Specifically evolved hydrocarbon system
Finite
Low cost driven
Petrochemicals
Breakdown to simple molecules
Transport
Transport
Synthesize more complex molecules
Manufacture
Consumer goods

Product/Process Cycle



Adapted from: J. MacLaren, Inverizon, USDOE

Dual Perspective



North American Corn Utilization

Seed
2%

76%

Feed

3%

3%

15%

7%

Food Use

Dry Mill

Wet Milling

1%

Direct Consumption (sweet corn, etc)

Germ removed

Ground

Acid steep then ground and separated. Germ removed

Oil

Flours
Grits
Bran

Alkaline cooked

Tortillas, chips

Ethyl Alcohol

Fuel

Starch

fermented

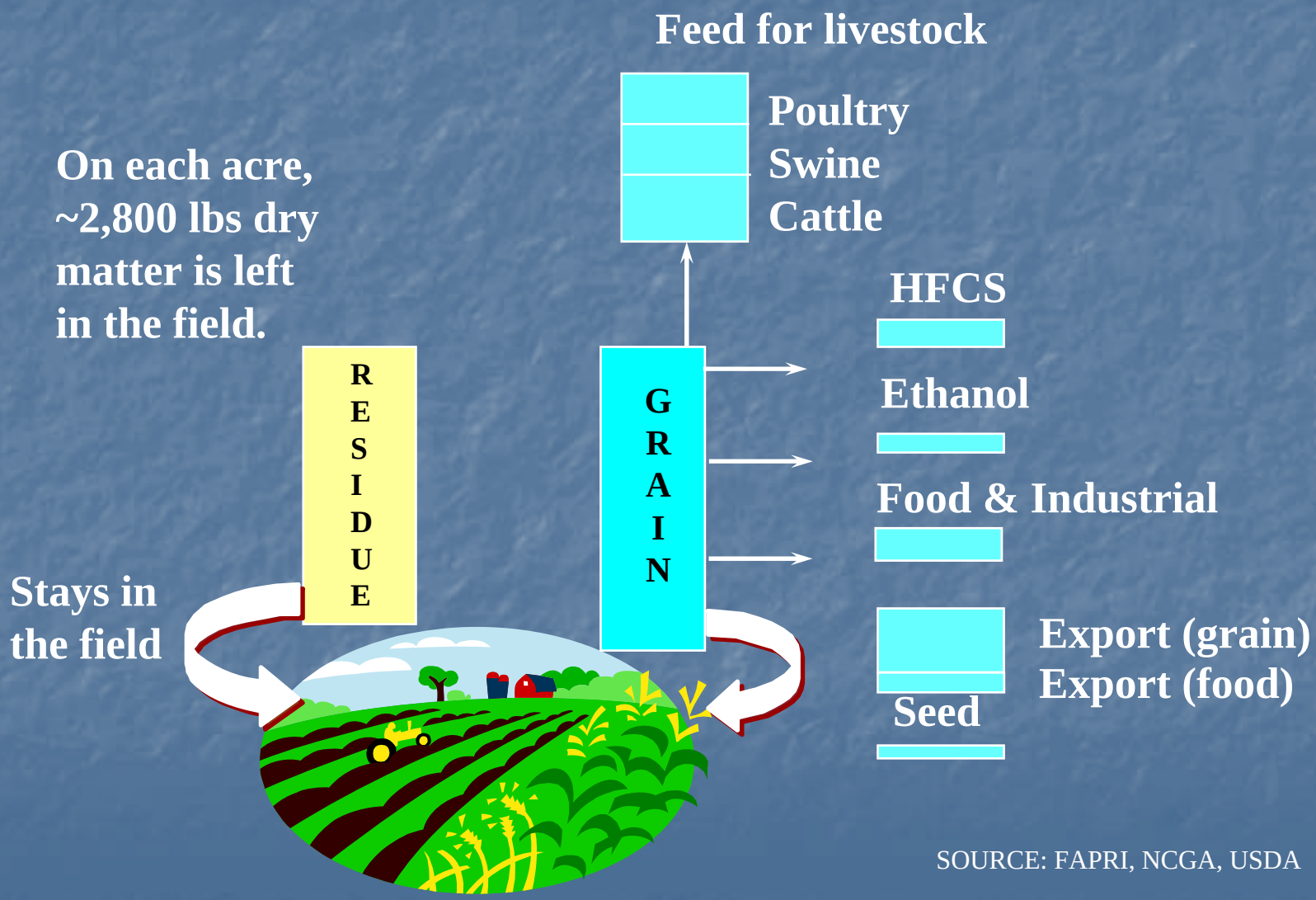
Gluten

Syrups

Foods & Industrial uses

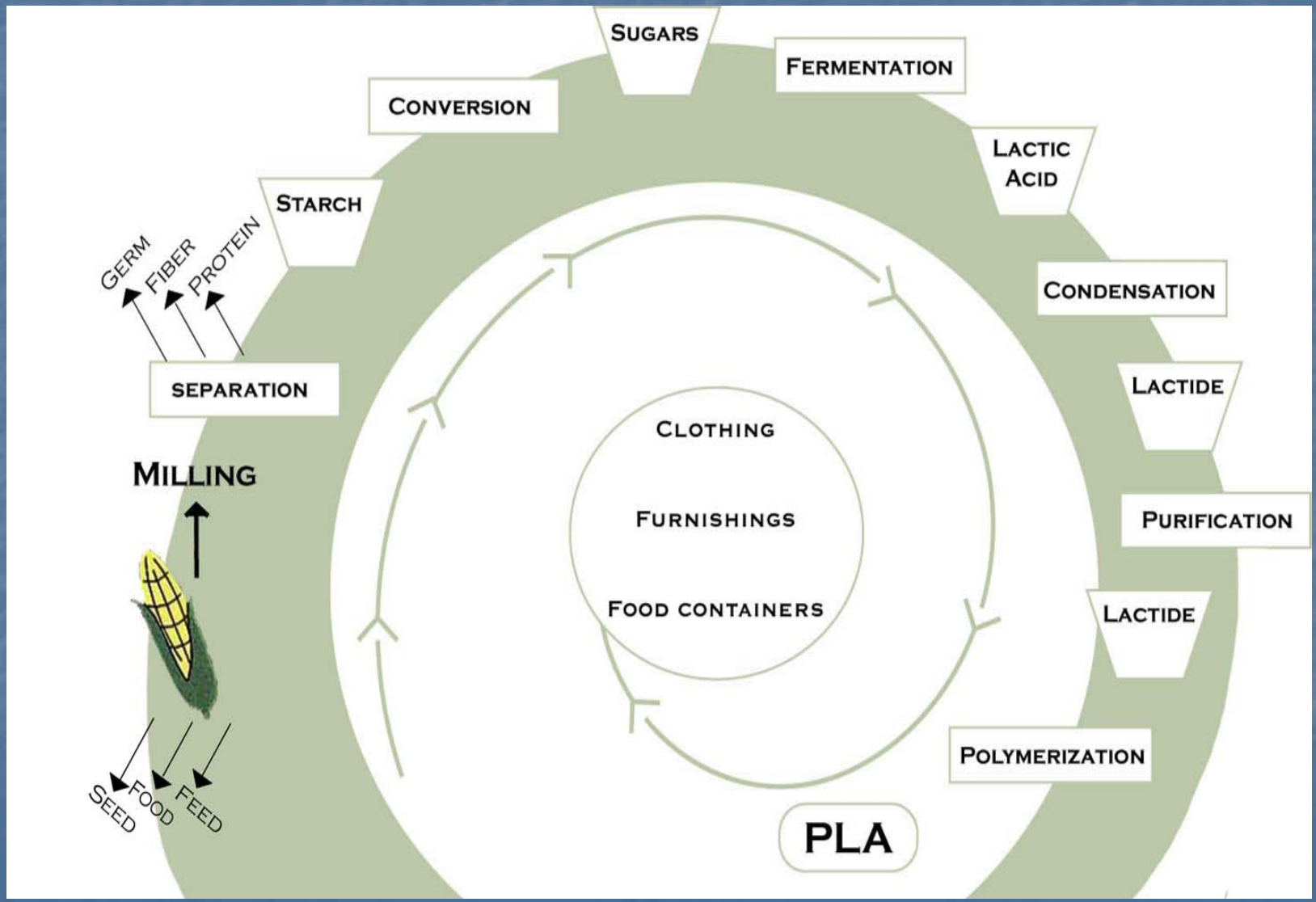
SOURCE: USDA, Corn Refiners Association, NCGA

Where does a field of corn go..



SOURCE: FAPRI, NCGA, USDA

Poly-Lactic Acid



What's in a field of soybeans…

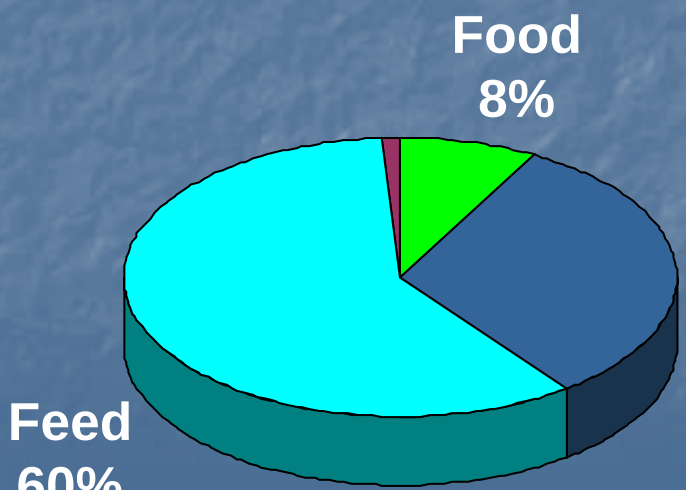
RESIDUE

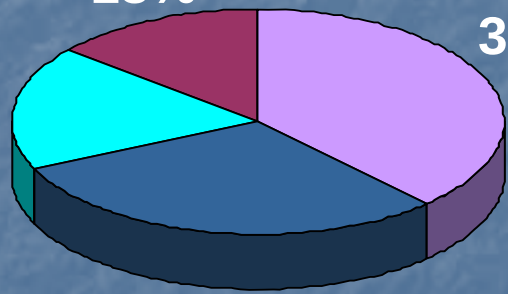
Stays in the field

SOYBEANS

Export accounts for around 35% production

Typical Domestic Use





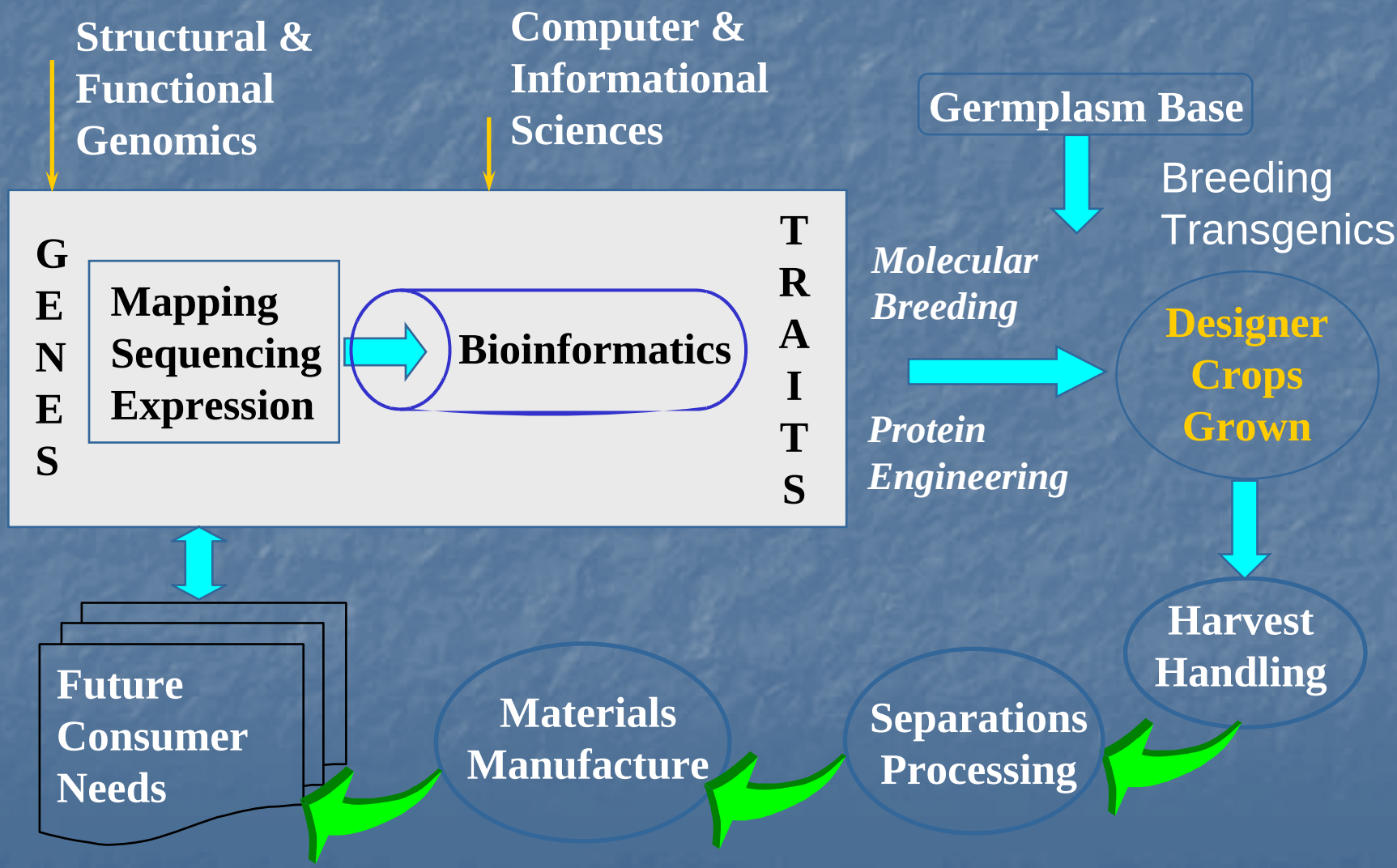
Typical composition

Technology & Commercial Needs

Plant Science	Production	Processing	Function Development	Utilization
				
Genomics Enzymes Metabolism Composition	Unit costs Yield Consistency Infrastructure Designer plants	Economics Separations Conversion Bio-catalysts Infrastructure	Economics Functionality Performance Novel uses	Price/value Performance Perception

Adapted from: J. MacLaren, Inverizon, USDOE

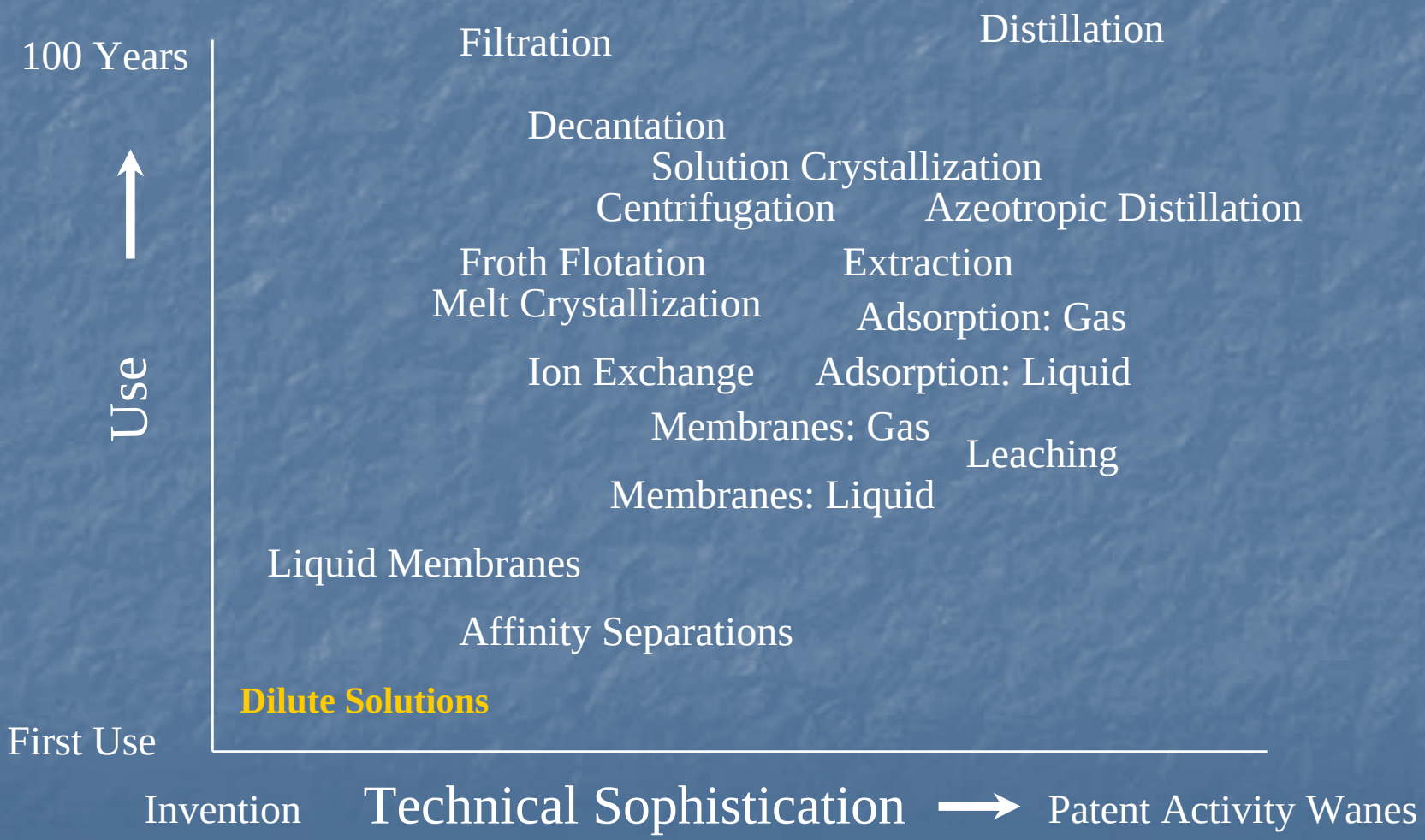
Adapt Supply to Need



Crosscutting Issues

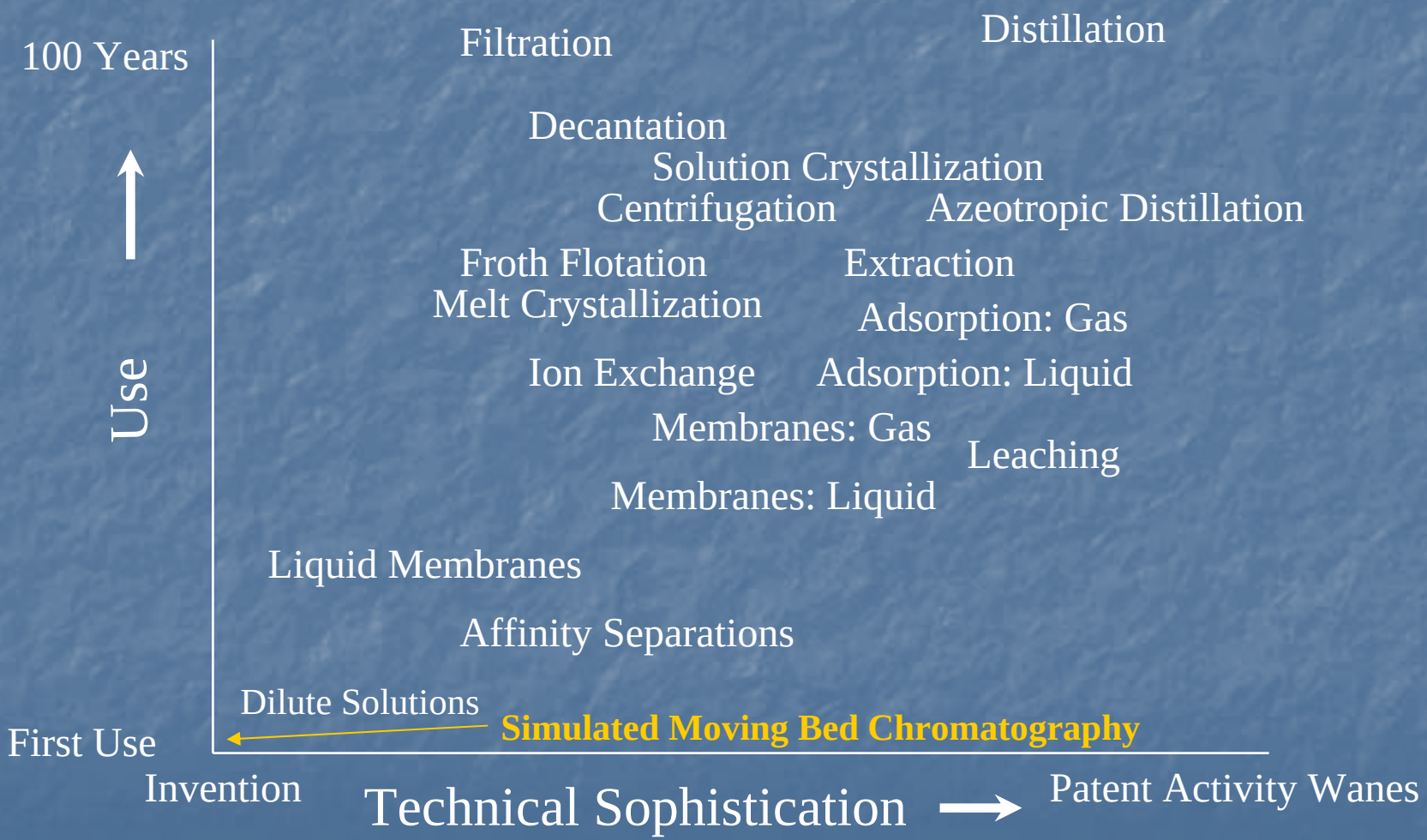
- Separations
- Chemical Synthesis
- Fresh water - use, reuse and release
- Energy consumption
- Resource consumption
- Modeling of processes - design & operation
- Sustainable Development

Maturity of Separations Processes



Adapted from George Keller, 1987

Maturity of Separations Processes



Adapted from George Keller, 1987

Research Areas for Extraction

- Physical properties: emulsion, Marangoni & coalescence
- Equilibrium models: electrodynamic, diluent & quantum mechanical effects
- Improve science of “rag layers”
- Predict effects of surfactants and contaminants
- Develop large-scale homogeneous extraction models
- Develop selective solvents

Water Separations

- Water separations are everywhere
- Water separations are likely to be more prevalent in industry the future
- Need methods to make rapid and accurate flow-sheet predictions
- Need to make non-distillation separations as predictable as distillation

Source: David Short - DuPont

Dilute Solutions Research Needs

- New separations materials
  - Immobilization of separations agents
  - Synthesis of highly selective agents
  - Robust catalysts
  - Switchable ligands
- Hybrid systems
  - Complexation filtration
  - Magnetic filtration
  - Field-induced filtration
  - Reactive extraction & reactive membranes

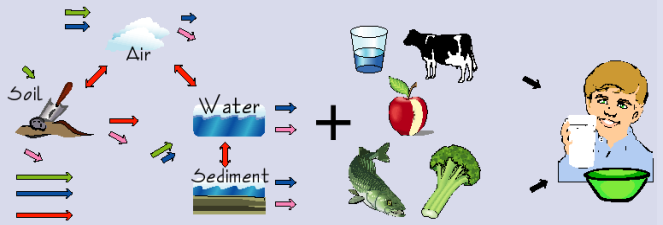
Synthesis Needs

- New synthetic techniques
- New catalysts & reaction systems
- Stereospecificity - Chirality
- Alternative raw materials
- Synthesis tools for molecular control
- Molecular architectures in alternative reaction media

Inventory of Stressors
Land Use
Chemical Emissions
Water Use
Fossil Fuel Use

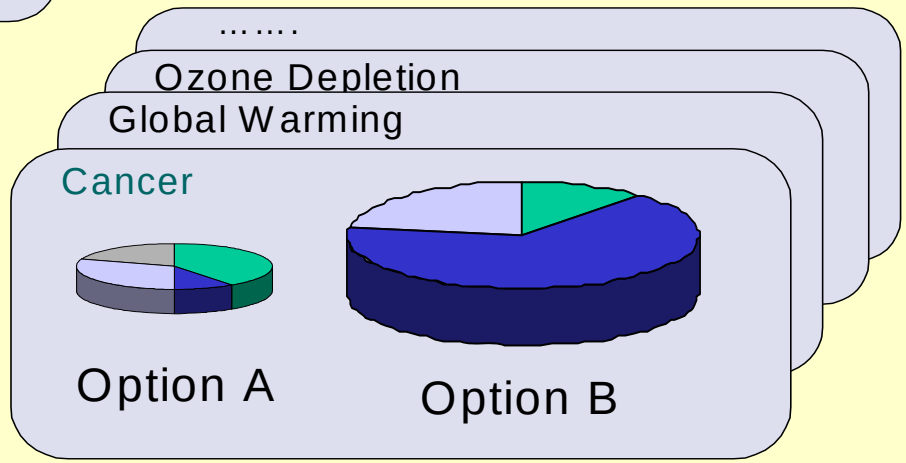
Impact Categories
Ozone Depletion
Global Warming
Acidification
Cancer
Noncancer
Criteria
Eutrophication
Smog Formation
Ecotoxicity
Fossil Fuel Use
Land Use
Water Use

Characterization (e.g., Cancer)



TRACI

Tool for the Reduction and Assessment Of Chemical and Other Environmental Impacts



Original Source: Jane Bare - EPA

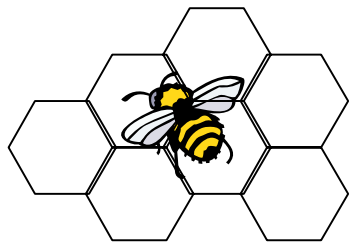
Indicators in BEES 3.0

Indicators currently calculated in BEES 3.0

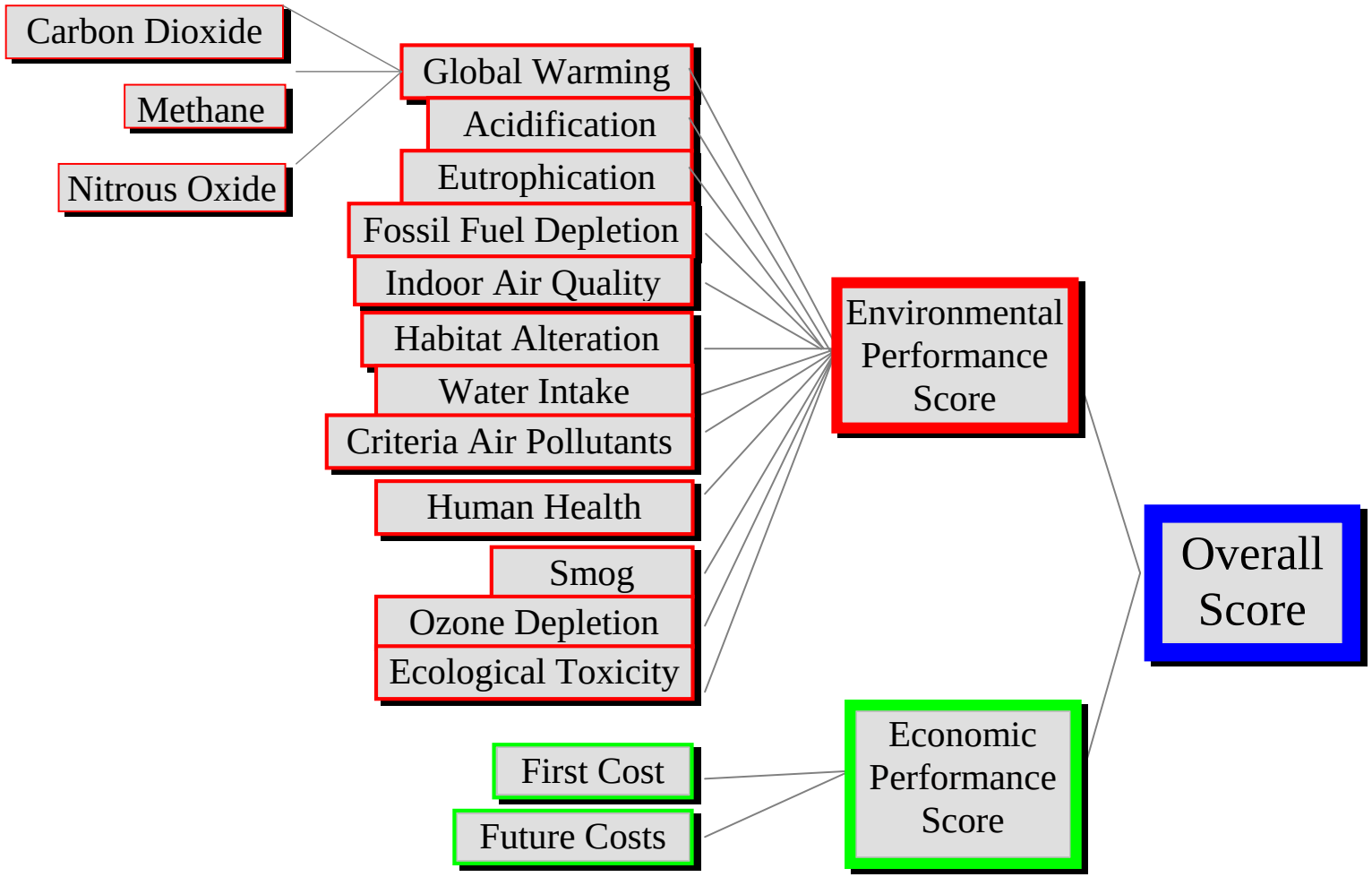
- Habitat Alteration / Land Use (landfills only)
- Fossil Fuel Depletion, Total Primary Energy
- Water Intake
- Global Warming
- Ozone Depletion
- Smog formation
- Air Acidification
- Criteria Air Pollutants / Particulates
- Indoor Air Quality
- Eutrophication
- Ecotoxicity
- Human toxicity (cancer, non-cancer)

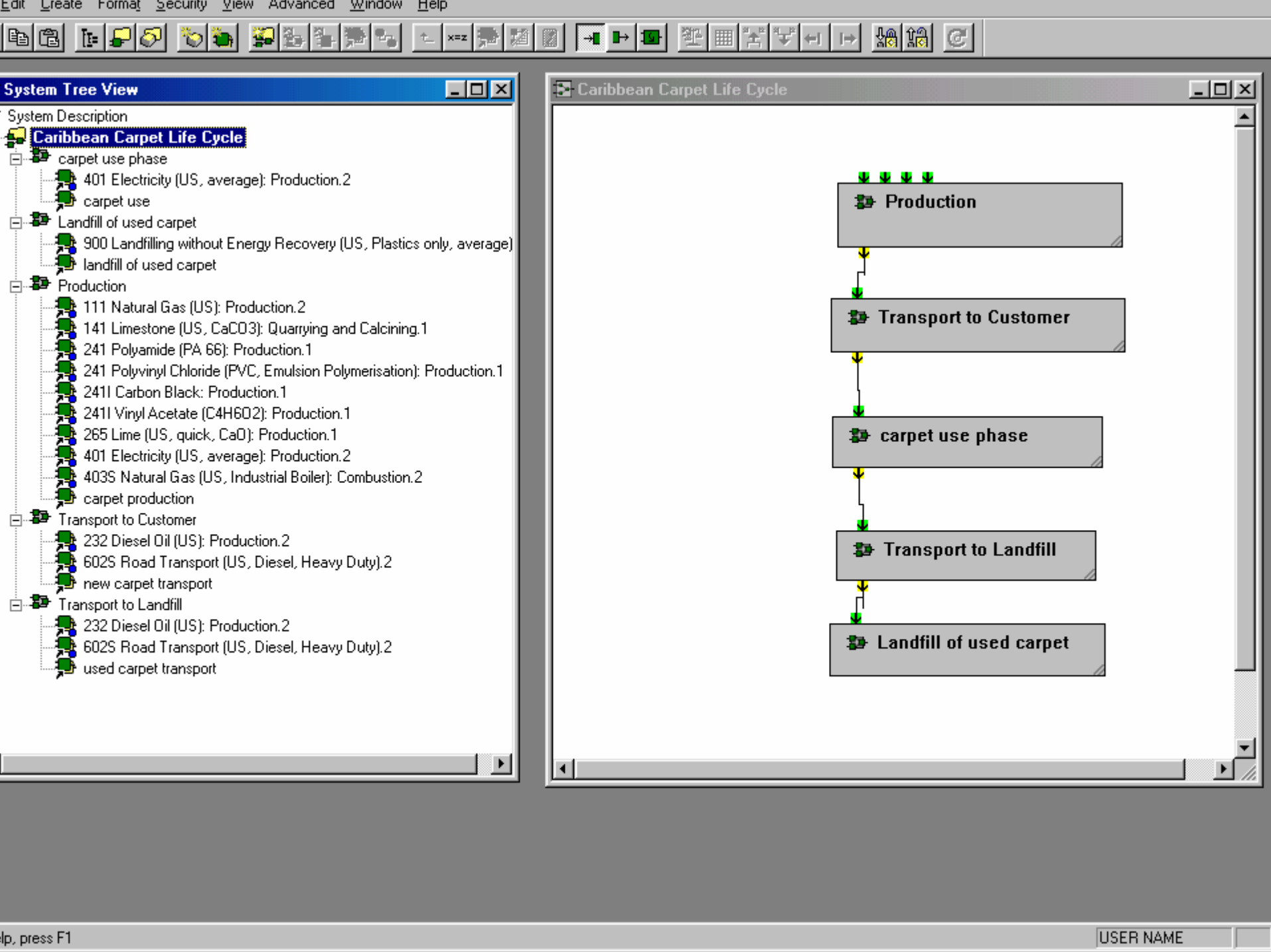
Indicators to be added/consolidated for biobased products

- Land Use (agriculture)
- Water Intake
- Global Warming (C sequestration)
- Ecotoxicity, Human Toxicity (pesticides)

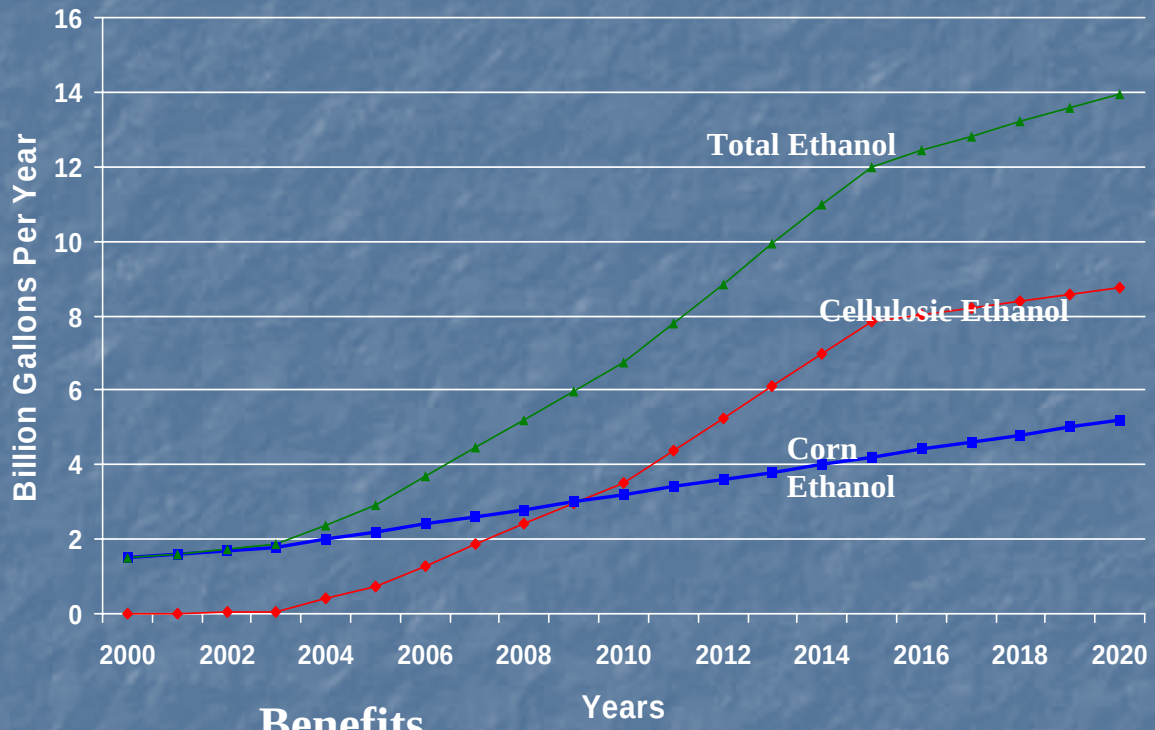


Summary of Indicators




Edit Create Format Security View Advanced Window Help
System Tree View
System Description
Caribbean Carpet Life Cycle
carpet use phase
401 Electricity (US, average): Production.2
carpet use
Landfill of used carpet
900 Landfilling without Energy Recovery (US, Plastics only, average)
landfill of used carpet
Production
111 Natural Gas (US): Production.2
141 Limestone (US, CaCO3): Quarrying and Calcining.1
241 Polyamide (PA 66): Production.1
241 Polyvinyl Chloride (PVC, Emulsion Polymerisation): Production.1
241I Carbon Black: Production.1
241I Vinyl Acetate (C4H6O2): Production.1
265 Lime (US, quick, CaO): Production.1
401 Electricity (US, average): Production.2
403S Natural Gas (US, Industrial Boiler): Combustion.2
carpet production
Transport to Customer
232 Diesel Oil (US): Production.2
602S Road Transport (US, Diesel, Heavy Duty).2
new carpet transport
Transport to Landfill
232 Diesel Oil (US): Production.2
602S Road Transport (US, Diesel, Heavy Duty).2
used carpet transport
Caribbean Carpet Life Cycle
Production
Transport to Customer
carpet use phase
Transport to Landfill
Landfill of used carpet
lp, press F1
USER NAME

Biofuels Technologies - Projected Ethanol Usage



Benefits

- Oil import reduction
- Oxygenate/Octane enhancer (MTBE replacement)
- Agricultural residues (corn stover, wheat straw, rice straw)
- Rural economic development

System Description – Crop production (Corn, Wheat, Cotton, Soybean, Rice Straw, Starch from Potatoes, Canola)

Inputs

- Fertilizers (synthetic, organic)
- Pesticides
- Energy
- Water

- Tillage
- Fertilizer application
- Operations
- Pesticide (Insecticide, Herbicide, Fungicide) application
- Irrigation
- Fermentation (rice)
- Nitrogen fixation (soybean)
- Harvesting
- On-site residue management (burnt, plowed under)
- Carbon sequestration
- Transportation

Outputs

- Air emissions (combustion of energy, volatilization N, fermentation, …)
- Water run-offs
- Crop
- Co-products: residues
- Waste transported outside the field

Functional Unit: Harvesting one acre during one year

Note: this definition gives the latitude to utilize any part of the plant (crop, residues), in any proportion for further processing. Allocation rules will be suggested.

Land Use / Biodiversity – Habitat Indicators

	Biodiversity Indicators	Proposed Measures
1	Protection of priority habitats/species	Area of habitat that is physically protected (i.e.; through fencing or other methods); habitat to be identified as including • 100 feet each side of rivers; • maps with location of T&E species
2	Soil characteristics: soil health	Concentration of organic carbon in the soil
3	Proximity to & protection of high priority vegetative communities	Area of habitat set aside (not farmed) that is identified as "high priority" in Natural Heritage vegetative maps
4	Interface between water and terrestrial habitats/buffer zones	Total linear space of aquatic habitat (i.e. river, lakeshore, etc) protected via physical means vs. total area managed
5	Assimilative capacity of water and land (TMDL process); hydrological function;	Depletion of water resources (annual use versus recharge rate)
6	Percent coverage of invasive species (within protected areas)	For physically protected areas, density of non-native vegetation (area percent)
7	Road density	Miles of road per square mile
8	Percent native-dominated vegetation	Area in native species dominated areas/total area managed
9	Restoration of native vegetation	Area newly returned (in last 12 months) to native habitat
10	Adoption of Best Management Practices linked to biodiversity objectives	Number of Best Management Practices adopted
11	Distribution (patchiness; evenness, etc.)	Size of native-managed acres vs. total area managed Size of native-managed area vs. average field size
12	Connectivity of native habitat	Number of Adjacencies for areas managed as native habitat

- Information known by farmers
- Linked to the global warming indicator
- Information not known by farmers
- Linked to the water intake indicator

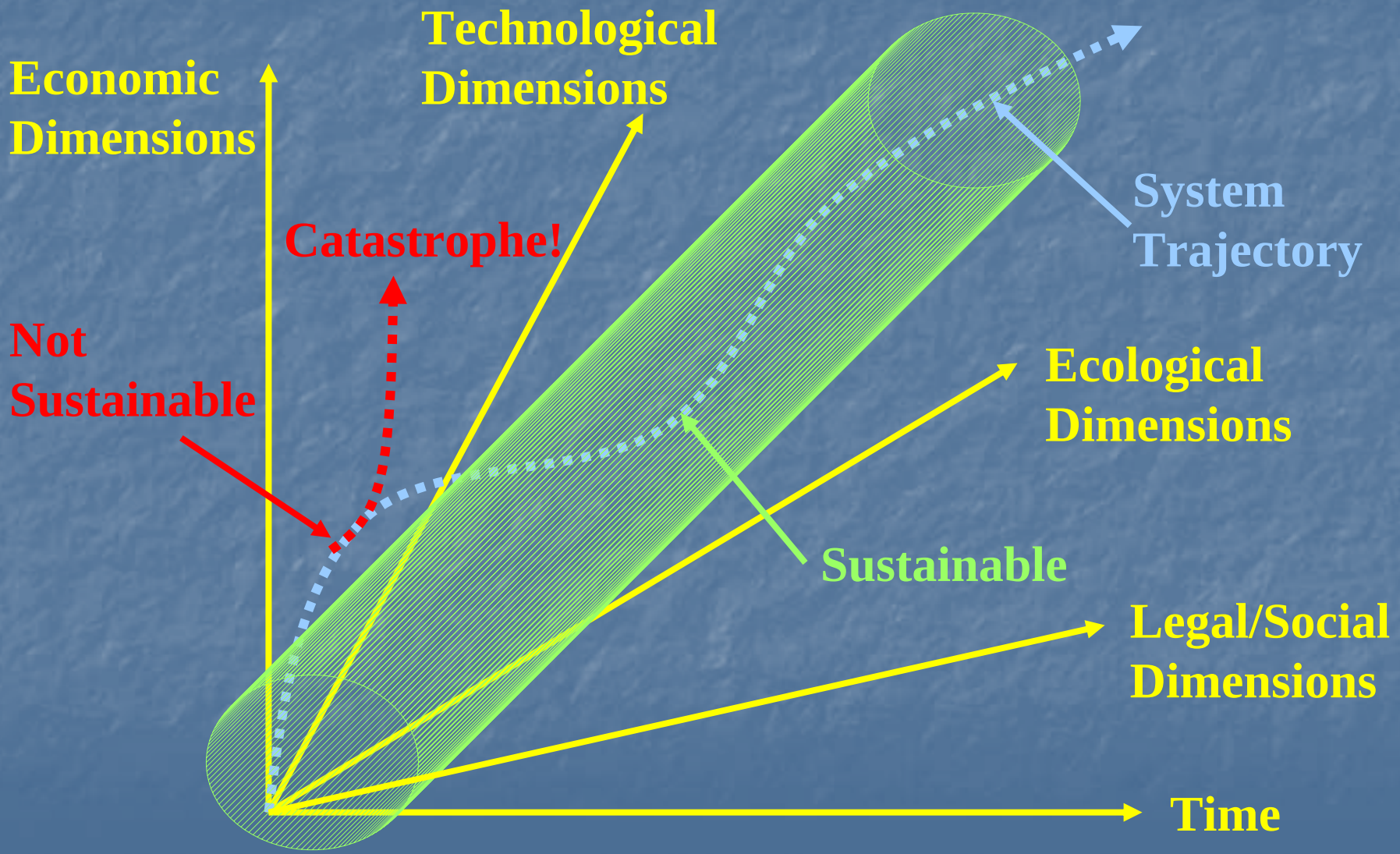
Questions

- How to relate site indicators to product approaches

- How do indicators relate to environmental performance?

R. Schenck, 2002

Sustainable Systems Path



Credit: Herbierto Cabezas