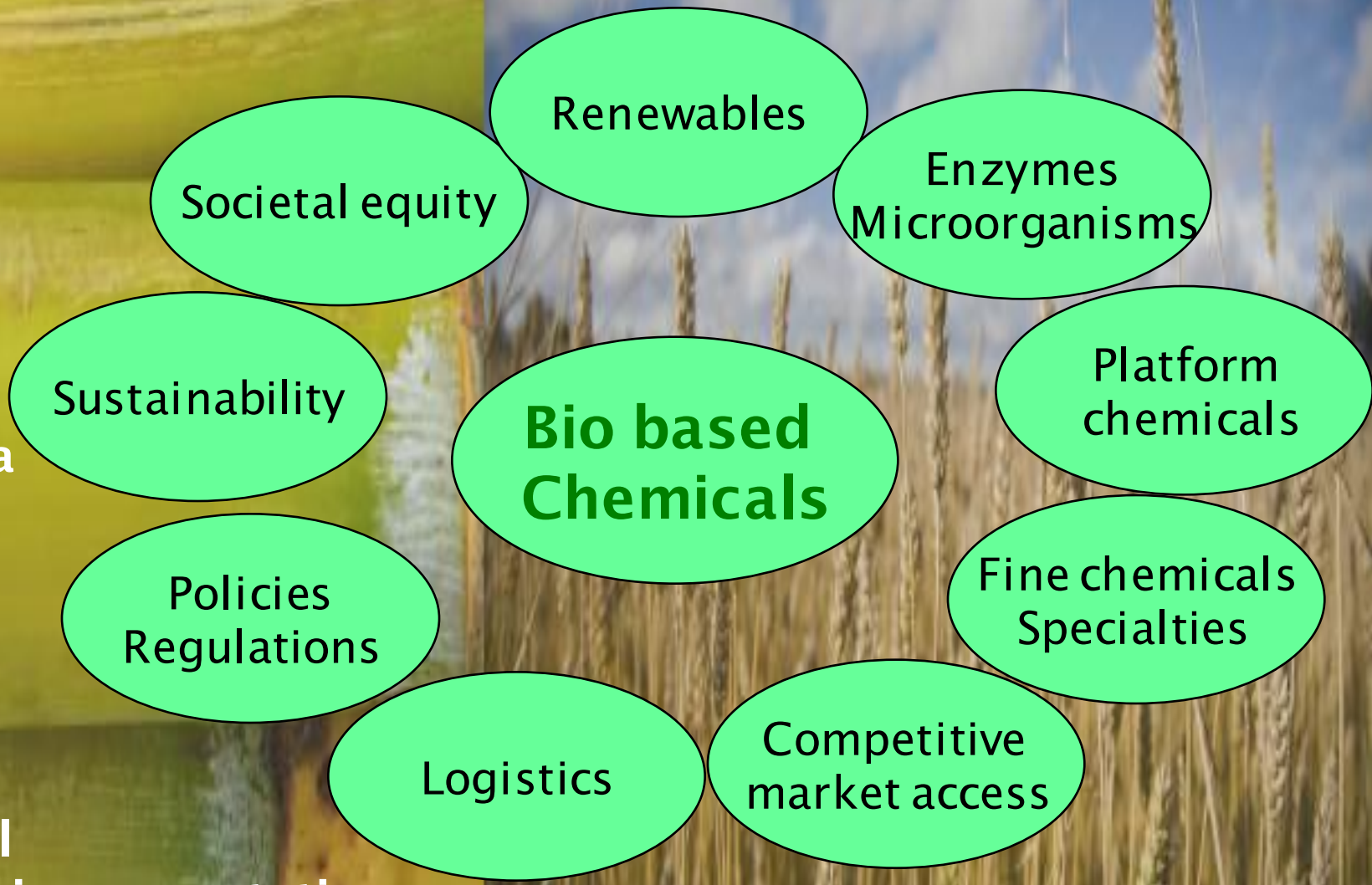
Bio based chemicals industry

Transitions, opportunities, threats



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R.Rajagopal
A KnowGenix presentation

Content

- Key directions in green chemistry
- Transition to a bio based economy
- Markets drivers & influencers
- Global industry trends
- Platform chemicals value chain
- Strategic alliances
- Commercialization barriers
- Future directions

Key directions in GCT

- Waste minimisation
  - Traditional processes
- Green product/process alternatives
  - Replacements for conventional products/processes
- Bio products from renewables
  - Low environmental footprint
  - Incorporates key green chemistry principles

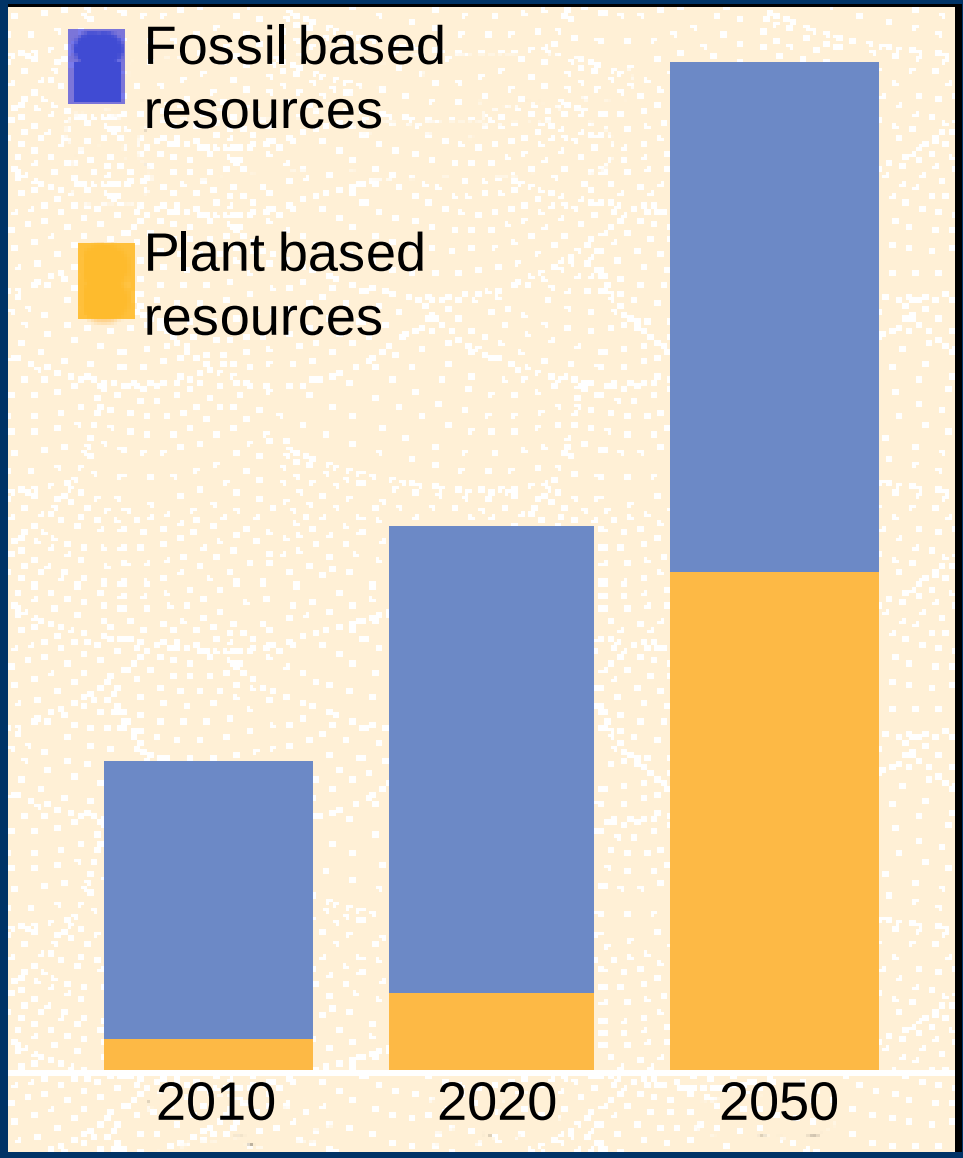
LCA Bio based vs Petroleum based

Company	Product / process	GHG/energy/ inputs	Remarks
Cargill, US	Bio Flexible foam polyols	Energy: 23% GHG : 36%	From vegetable oils/ soyabean oils
Pfizer, US	Biocatalysis	Energy: 83% Input : 80%	Pregabalin [Lyrica] neuropathic drug, water based process
Evonik, Germany	Myristyl Myristate	Emission: 90% Energy : 62%	Enzymatic route to cosmetic ingredients, less wastes, increased yields by around 70%
DuPont, US	1,3-Propane diol	GHG : 20% Energy : 40%	Corn based route
Telles, US	PHA resin	GHG : 200% Energy: 40%	Jv between ADM/Metabolix
NatureWorks, US	PLA resin	GHG : 80-90% Input : 70%	Corn feedstocks Wind power
Hoffman La Roche, Switzerland	Vitamin B2	Air : 50% Input : 75%	Water 66%
DSM Netherlands	Cephalexin	Energy: 65% Input : 65%	Cost reduction 50%, fermentation/enzymatic, water based

USITA IB: Development & adoption by the US chemicals and biofuel industries
Invest No: 338-481 USITC PUB 4020 July 2008

Transition to a bio based economy

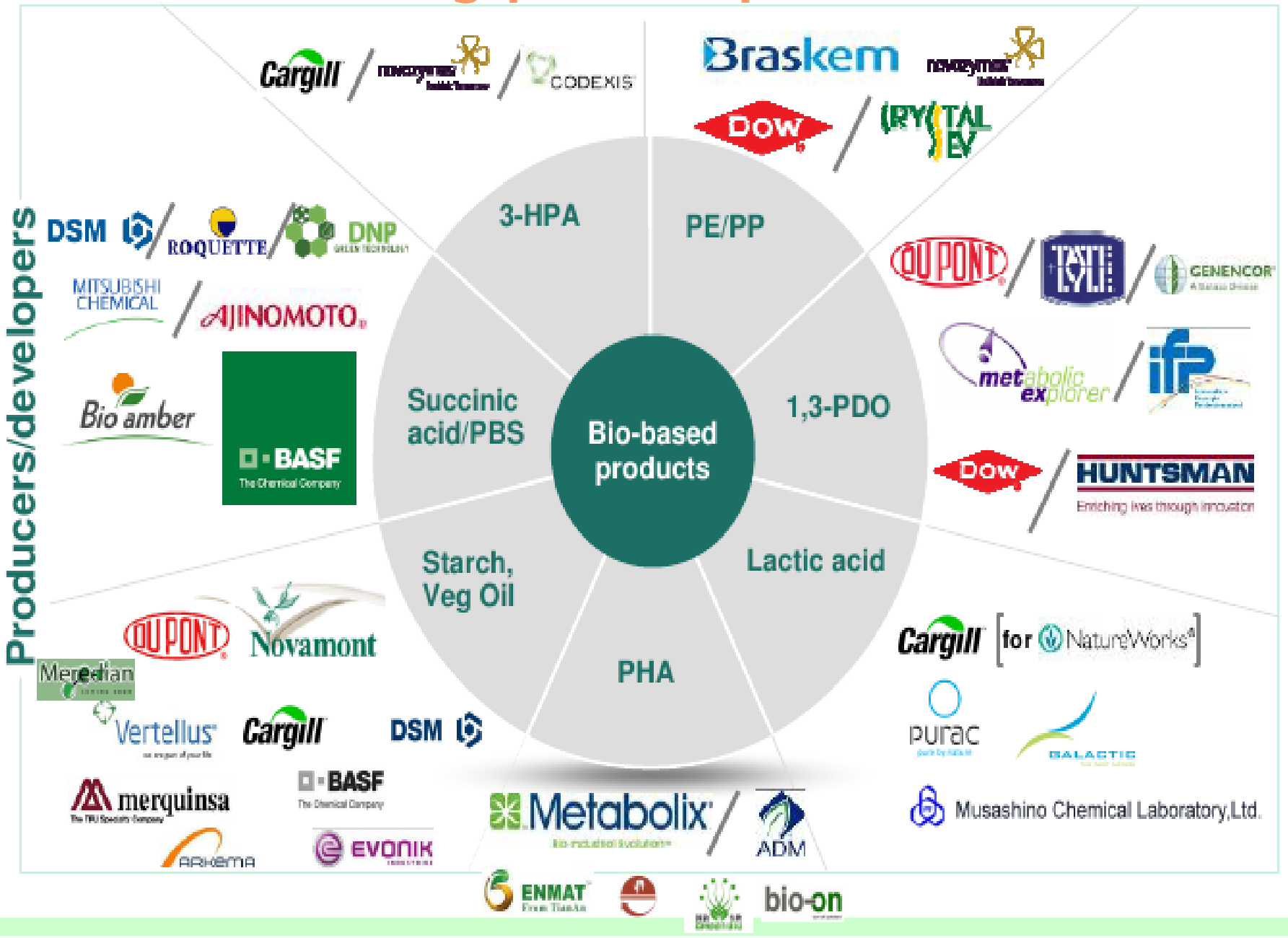
Promise of renewables



Trends in bio based chemicals

- Spate of alliance announcements since 2008
- Venture investments of $ 3.1 bn (since 2004)
- PE/VC funding decline in 2011
  - High risk perceptions
  - Long term profit horizons
- Lack of clarity
  - Status of many projects
  - Market projections
  - Technology capability
  - Feedstocks sourcing
  - Regional markets, policies, regulations

Integrating bio based products into existing product portfolio



Source: McKinsey, Press, Industry Reports

Bio based chemicals ...depends on....

Red Biotechnology

Novel drugs
Vaccines
Stem cell applications

White Biotechnology

Microorganism
Biocatalyst
Biochemistry
Biochem engg.
Fermentation

Green Biotechnology

Discovery/use of Novel genes
Processes
Materials

In plants, crops forestry

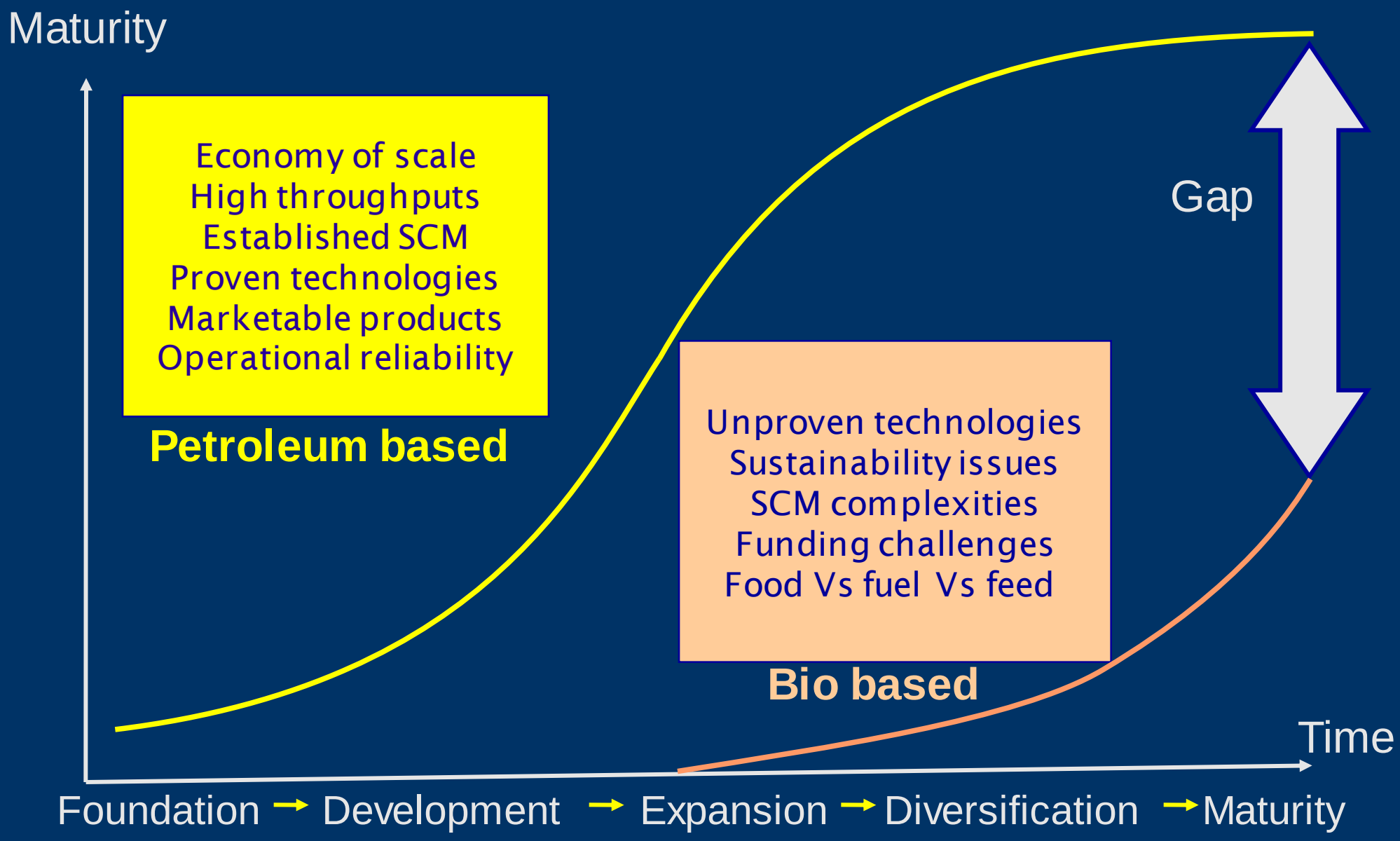
Blue Biotechnology

Discovery/use of Novel genes
Processes
Materials

In marine systems

Complex transitional challenges

Transitional challenges exist



Market drivers & influencers

Primary market drivers

- Rising oil prices & volatilities
- High environmental footprint in fossil based products
- Advances in
  - High volume biomass conversion technologies
  - Biotechnology, genomics, metabolic engineering
- Consumer interest in safer product attributes
- Growing demand for bio based chemicals

Market influencers

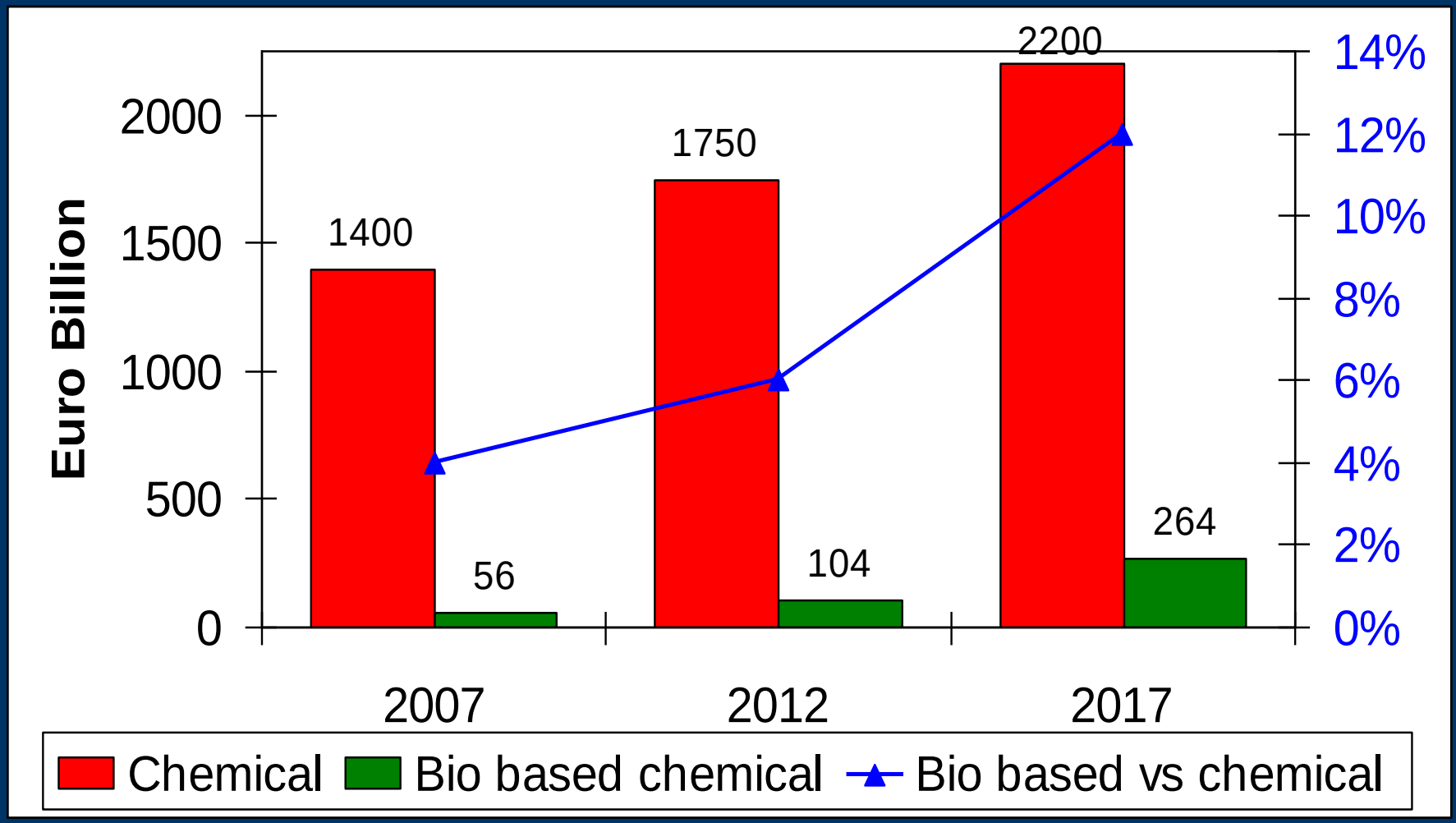
- Traditional feedstocks prices
  - Cost differential between oil/naphtha vs bio products
- Technology
  - Low cost competitive options
  - Easy to scale up/ adopt
- Bio feedstocks supply
  - Food Vs fuel Vs chemicals
- Competition with food
  - Waste by products
  - Feedstocks from non agricultural land

Consumer preference for bio labelled products

Preference for bio-labelled products

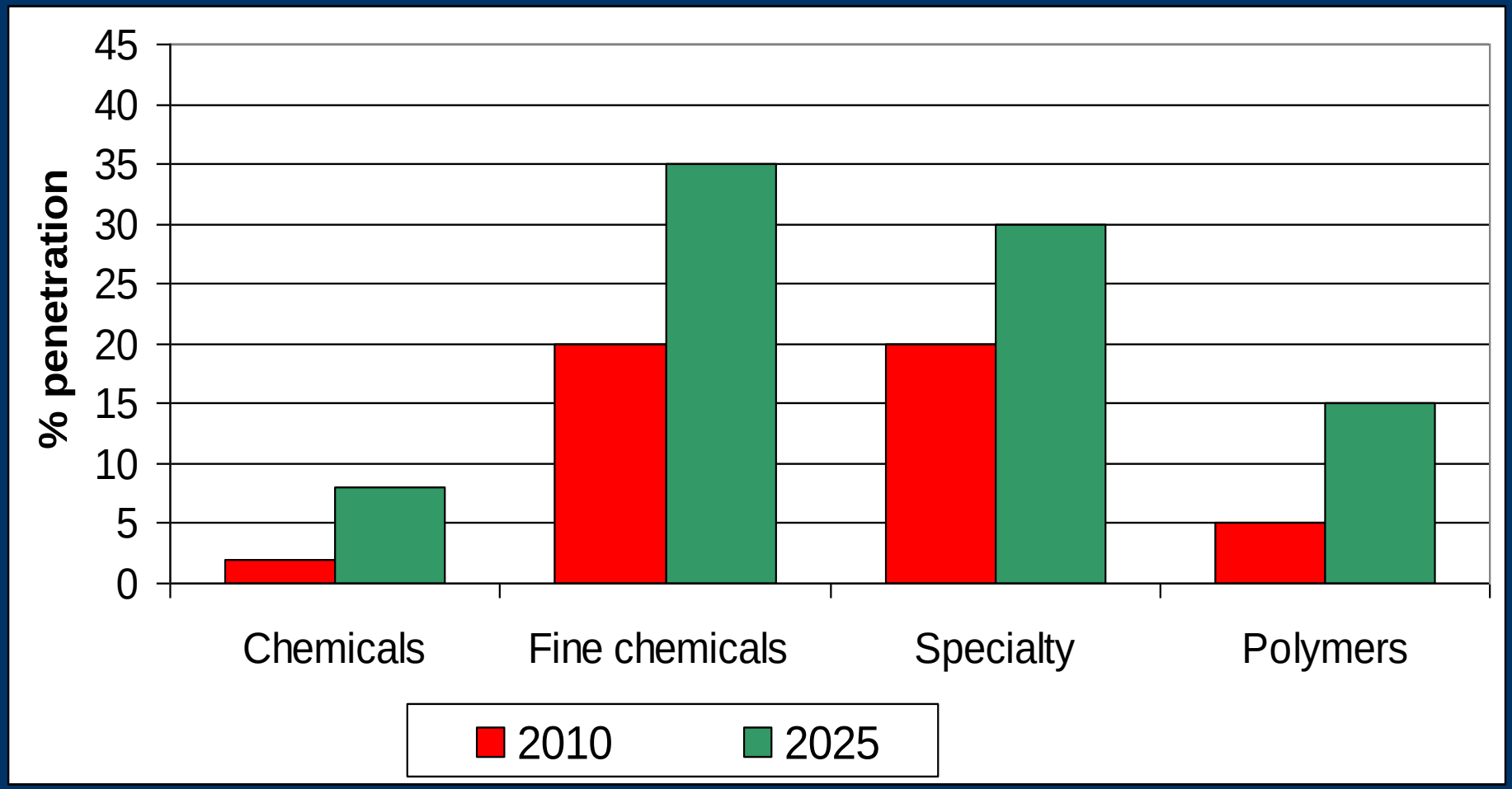
- Biobased
  - Hand soaps
  - Sanitizers
  - Cleaning products
  - Engine oils
  - Lubricants
  - Fibres
  - Food packaging
- Companies
  - Nutek Green
  - Clear Lam Packaging
  - DuPont
  - Green Earth Technologies
  - National Industries for the Blind Agencies
  - NatureWorks
  - Rochester Midland Corporation
  - Bio-Lub Canada

Bio based chemicals: market projections



Source: KnowGenix

World Bio based chemicals: percentage penetration



Source: KnowGenix

Global industry trends

Global trends in bio based chemicals

China	Enzymes, starches, amino acids, vitamins Fermentation: glutamic, citric, lactic acids; Xanthan gums, Vitamin C, PLA , PHA, Epichlorohydrin
EU	Enzymes, bioplastics, bio polymers
Japan	Bio acrylamide, chelating agents, amino acids, palm based methylester sulfonates, genetically engineered enzyme for drugs, PHA,PLA, starch composites
US	PHA, PLA biopolymers, biopropanediol, Sorona biopolymer, BiOH flexible foam polyols, propylene glycol, acrylic acid
Brazil	PHB polymers, Bio PE
Canada	Enzymes, PE/Thermoplastic starch blends, personal care products from oats, animal feed additives
India	Enzymes
Korea	Amino acids, PBS, PLA sheets
Malaysia	Glycerin/ Vitamin E
Philippines	Glycerols, methylesters, diethanolamides, etc.

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Tiers of global players

- Traditional companies
  - Replace fossil chemicals with green alternatives
  - Along existing chemical product trees
  - Within their existing product lines
- New players
  - Production of completely novel products out of biomass
- Technology players
  - Use metabolic pathway engineering
  - Develop technologies like cell factories
  - Existing and novel chemical compounds
  - Without producing the chemicals themselves

Source: A D Little

Key players and products

- Acetic acid
  - Zeachem
- Acrylic acid
  - OPX Biotechnologies
  - Archema
- BIo butanol
  - Green Biologics
  - DuPont / Butamax Advanced Biofuels
- 1,3-Propane diol
  - DuPont/Tate& Tyle
  - METabolic Explorer
- Bio BDO
  - Mitsubishi Chemical and Genomatica
  - Genomatica/Chemtex
  - Metabolix and Davy Process Technology, Myriant
  - Cobalt Technologies/ API
- Isobutene
  - Lanxess/Gevo

Key players and products...

- Levelunic acid
  - Segetis
- Isosorbide
  - Roquette
  - Mitsubishi / PTT
- Glucarates
  - Rivertop Chemicals
- Celluosic ethanol
  - Novozymes/ Mossi Chisolfi Group
- Bio-methionine plant
  - CJ CheilJedang/ Arkema
- Bio greases
  - Elevance Renewable Sciences/ NL Grease LLC
  - Solazyme and Amyris
- Bio Waxes
  - Elevance / ISP
- BioPBS
  - Sinoven Biopolymers (BioAmber)

Top 30 Bio based chemical companies 2011-12

Pure play cos *

Rank 1-10	Rank 11-20	Rank 21-30
Genomatica	Cargill	**Myriant**
Solazyme	Cobalt Technologies	Cosan
Amyris	Waste Management	Mascoma
Gevo	Ceres	KiOR
LS9	**Elevance Renewable Sciences**	DuPont Danisco
DuPont	Dow Chemical	Virent
Codexis	Enerkem	LanzaTech
Genencor	Coskata	POET
Novozymes	**OPX Biotechnologies**	**Metabolix**
ZeaChem	DSM	Honeywell's UOP

Renewable chemicals 7; Strategic investors, suppliers 9; Integrated bio refineries 14

Source: www.biodigest.com

Platform chemicals : value chain

Evolution of technology platforms

- First generation products (commercial)
  - By thermo chemical conversion
    - Propane diol, Polylactic Acid etc.
- Second generation products (pilot)
  - By metabolic engineering and bioprocessing technologies
    - Glycerine, Alcohols, Esters, Caprolactam, Hydroxy Alkanoates, Succinic Acid, 1,4 Butanediol, etc.
- Third generation products (early discovery)
  - Based on plant expression through genetic engineering
  - Chemicals with designed functionality
    - High Oleic oils, Ricinoleic Acid, etc., in canola
    - Epoxy oil crops
    - Lubricants, coatings, polymers

Source: Battelle Research Laboratory, US

Platform chemicals

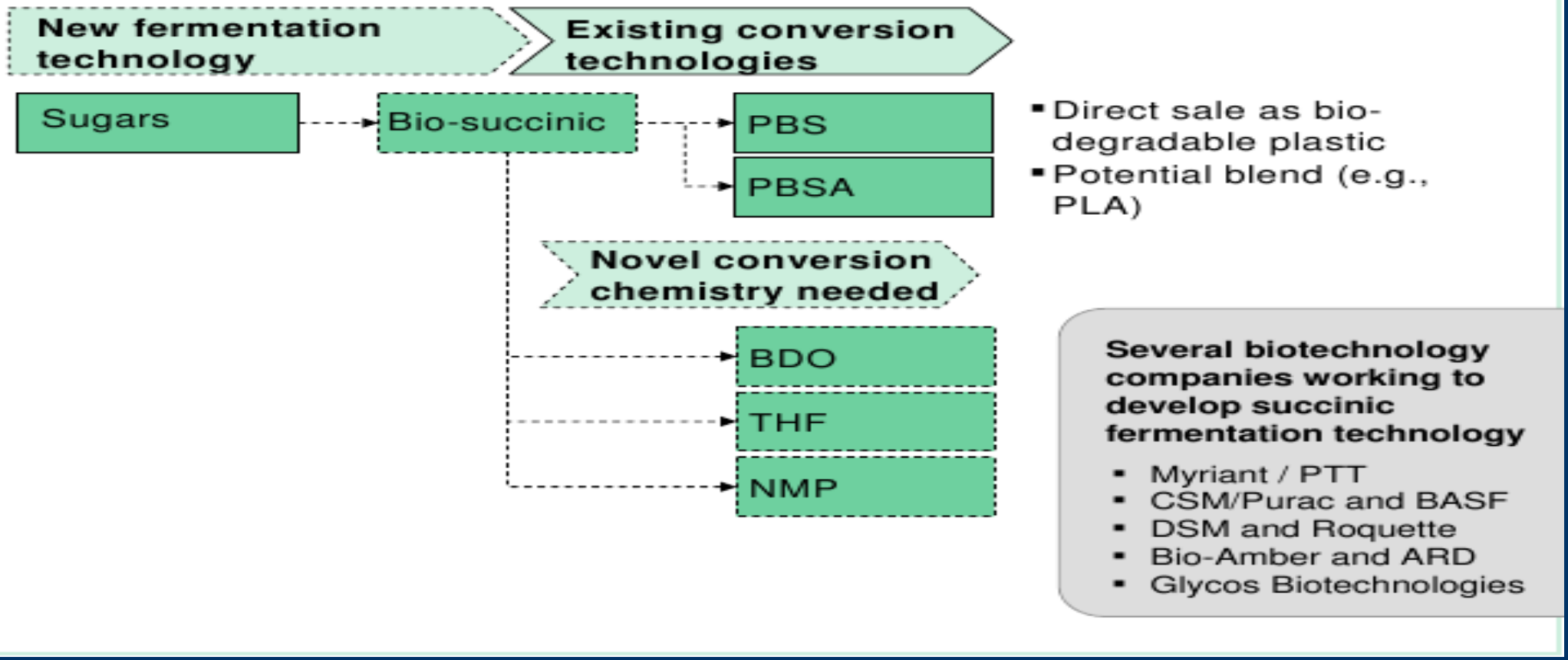
- Sugar based *
  - Glycerol, 3-Hydroxy Propionic Acid, etc., (C3)
  - (Succinic Acid, Fumaric, Malic), Aspartic Acid, 3-Hydroxy butyrolactone (C4)
  - Xylitol, Glutamic, Levulinic, Itaconic Acids (C5)
  - Sorbitol, Glucaric Acid, 2,5 FDCA (C6)
- Oil/ fats based
  - Fatty acids, Fatty Acid Methyl Esters (FAME)
  - Fatty Alcohols, Fatty Amines and Glycerols
- Lignin based
  - Methanol, Dimethyl ether, Olefins
  - Mixed Alcohols

*** Source: Top value added chemicals from biomass Vol 1: US DOE, 2004**

Sugar based platform chemicals: value chain

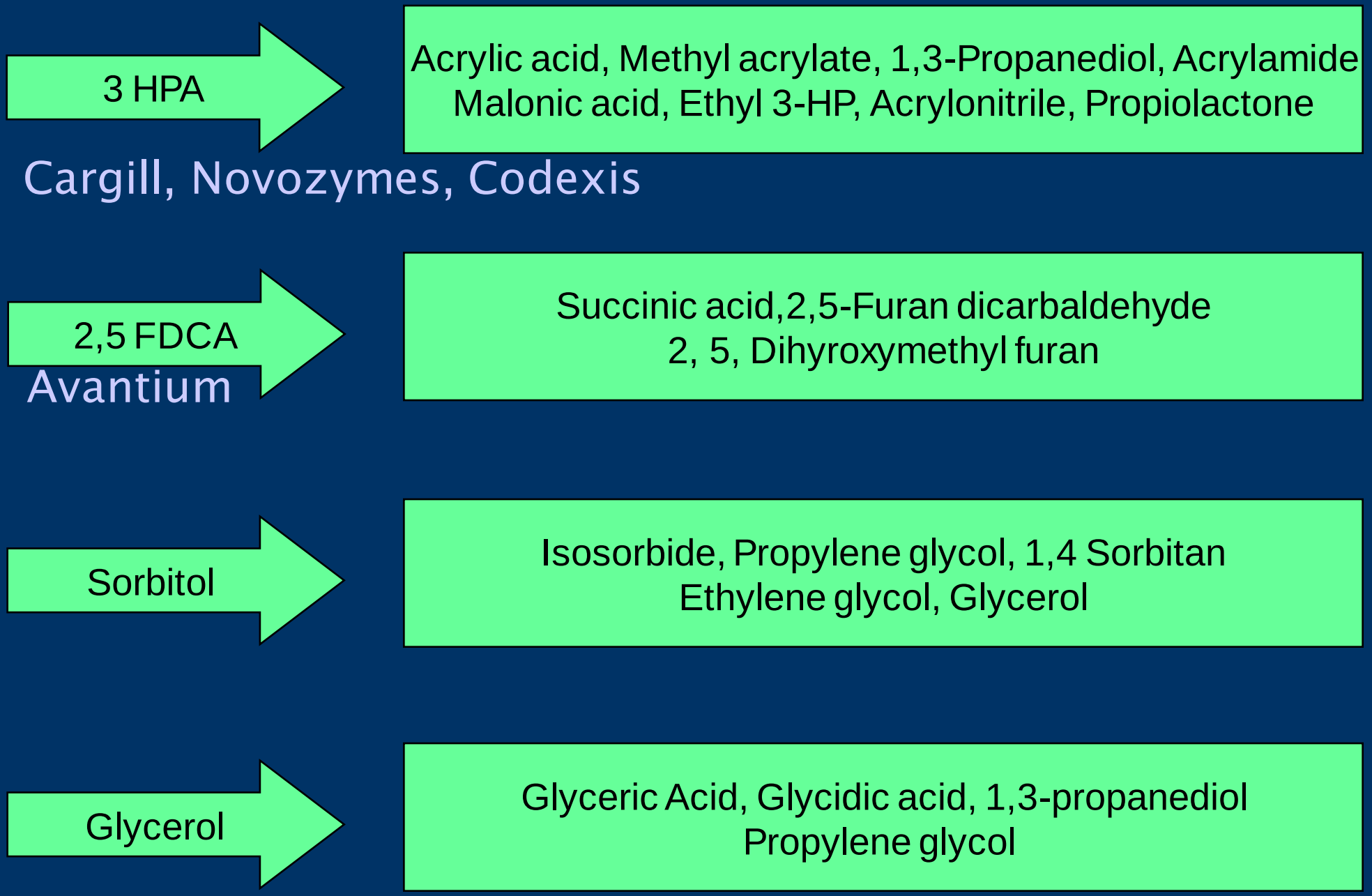
Succinic Acid

Butyrolactone, THF, 2-Pyrrolidone, NMP, Succindiamide, 1,4-Diaminobutane, Succinonitrile . 1.4-Butanediol

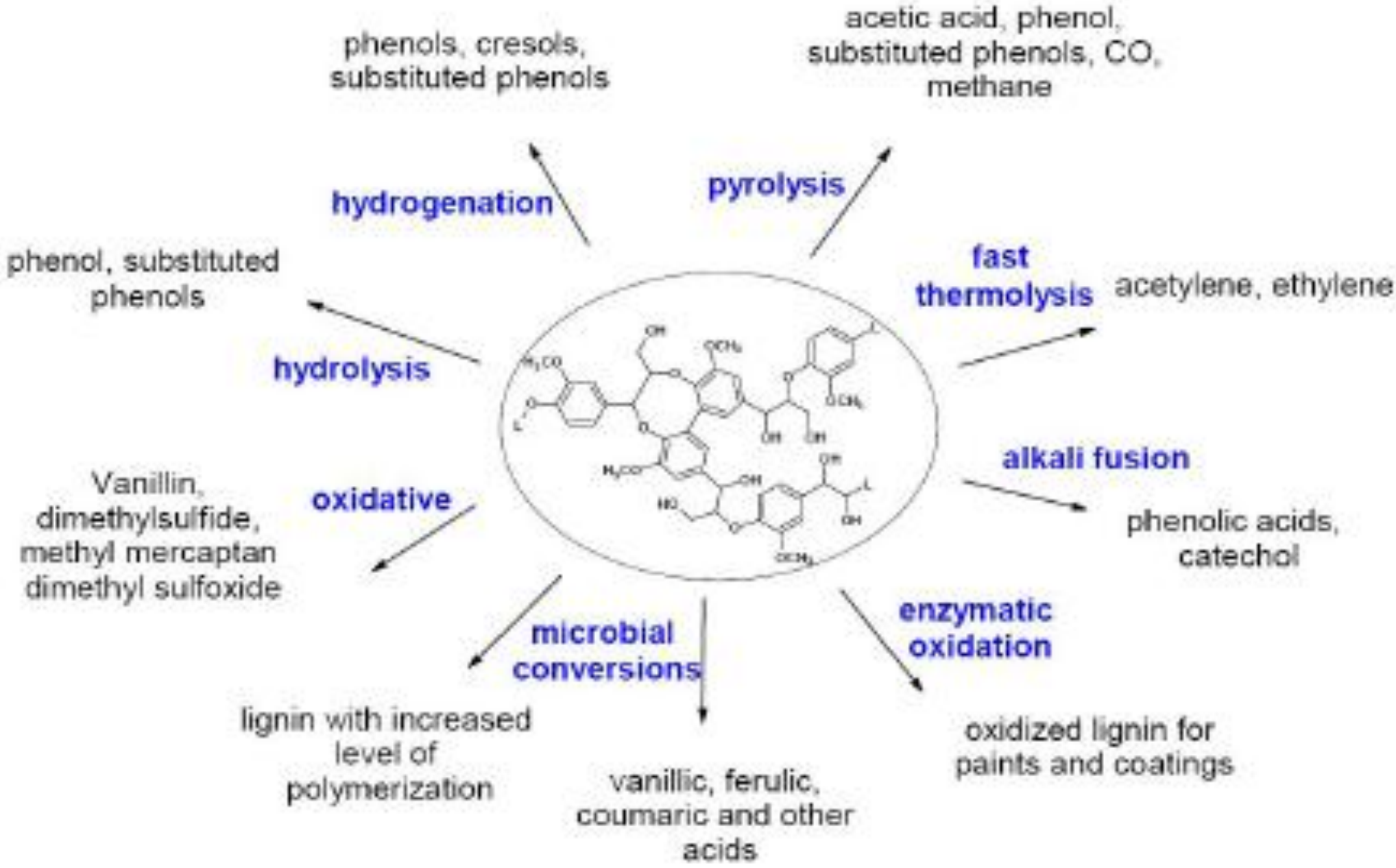


Source: Top value added chemicals from biomass Vol 1: US DOE, 2004;

Mckinsey, Industry reports


3 HPA
Acrylic acid, Methyl acrylate, 1,3-Propanediol, Acrylamide
Malonic acid, Ethyl 3-HP, Acrylonitrile, Propiolactone
Cargill, Novozymes, Codexis
2,5 FDCA
Avantium
Succinic acid,2,5-Furan dicarbaldehyde
2, 5, Dihyroxymethyl furan
Sorbitol
Isosorbide, Propylene glycol, 1,4 Sorbitan
Ethylene glycol, Glycerol
Glycerol
Glyceric Acid, Glycidic acid, 1,3-propanediol
Propylene glycol

Lignin based platform chemicals



source: **US DoE lignin report**

Growth through strategic alliances

Strategic alliances: Drivers

Access to

- New markets
- R&D resources
- Technology
- Domestic markets
- Distribution channels
- Bio feedstocks
- Intellectual property

Enables

- Coordination of global customers
- Cost optimisation
- Risk diversification
  - Sourcing inputs from countries with different research capacities, technologies, regulatory structures

Strategic alliances...

- Amyris & Kuraray
  - Replacing butadiene, isoprene with farnesene
- Global Bioenergies, France and Synthos, Poland
  - Renewable-based butadiene
- Elevance's and Hutchinson Worldwide
  - Bio processing aids in rubber compounds
- Ford and Recycled Polymeric Materials (RPM)
  - Gaskets and seals
- Myriant, Purac, BASF, OPX Biotechnologies,Bio amber, DSM, Roquette,Mitsubishi
  - Bio 1,4-Butanediol
- Global Bioenergies, Gevo and Lanxess
  - Bio-based isobutene
- Novomer/Eastman Kodak
  - Propylene carbonate [PPC]
- Rohm&Haas/ Ceres
  - Methylmethacrylate

Strategic alliances...

- Braskem and Novozymes
  - Green polypropylene
- ChemPro Group Boonton, Mo-Fuel, Dupont Danisco Cellulosic Ethanol (DDCE), Genera Energy
  - Celulosic ethanol
- Metabolix/Meredian
  - Polyhydroxyalkanoates (PHAs)
- Cargill/Novozymes
  - Acrylic acid
- Genencor/Goodyear
  - Isoprene
- Algae based chemicals
  - Dow Chemicals / Algenol Biofuels
  - ExxonMobil/Synthetic Genomics
  - Chevron/Solazyme
  - Valero/Solix
  - Shell/Cellana
  - BP/Martek

Supply chain alliances

- Nature of Alliances
  - Seed companies to develop particular varieties
  - Farm cooperatives for particular crop and biomass
  - Firms providing transportation & storage facility
  - Firms interested in standard and custom co-products
  - National associations for bio-business promotion
  - End products producers
  - Retailers for the marketing of bio-based products

Barriers to commercialization

Diverse consumer attitudes/ preferences

50% of consumers buy green products today

50% of consumers choose not to buy green products for various reasons...

One third of consumers said they would pay 5-10% more for green products.

Sources: BCG Global Green Consumer Survey, 2008; BCG analysis.

Note: About 4,000 respondents from all surveyed countries except China—about 50 percent of the respondents to our survey—were asked to indicate the main reason why they had not recently bought green products. Percentages do not total 100 because of rounding.

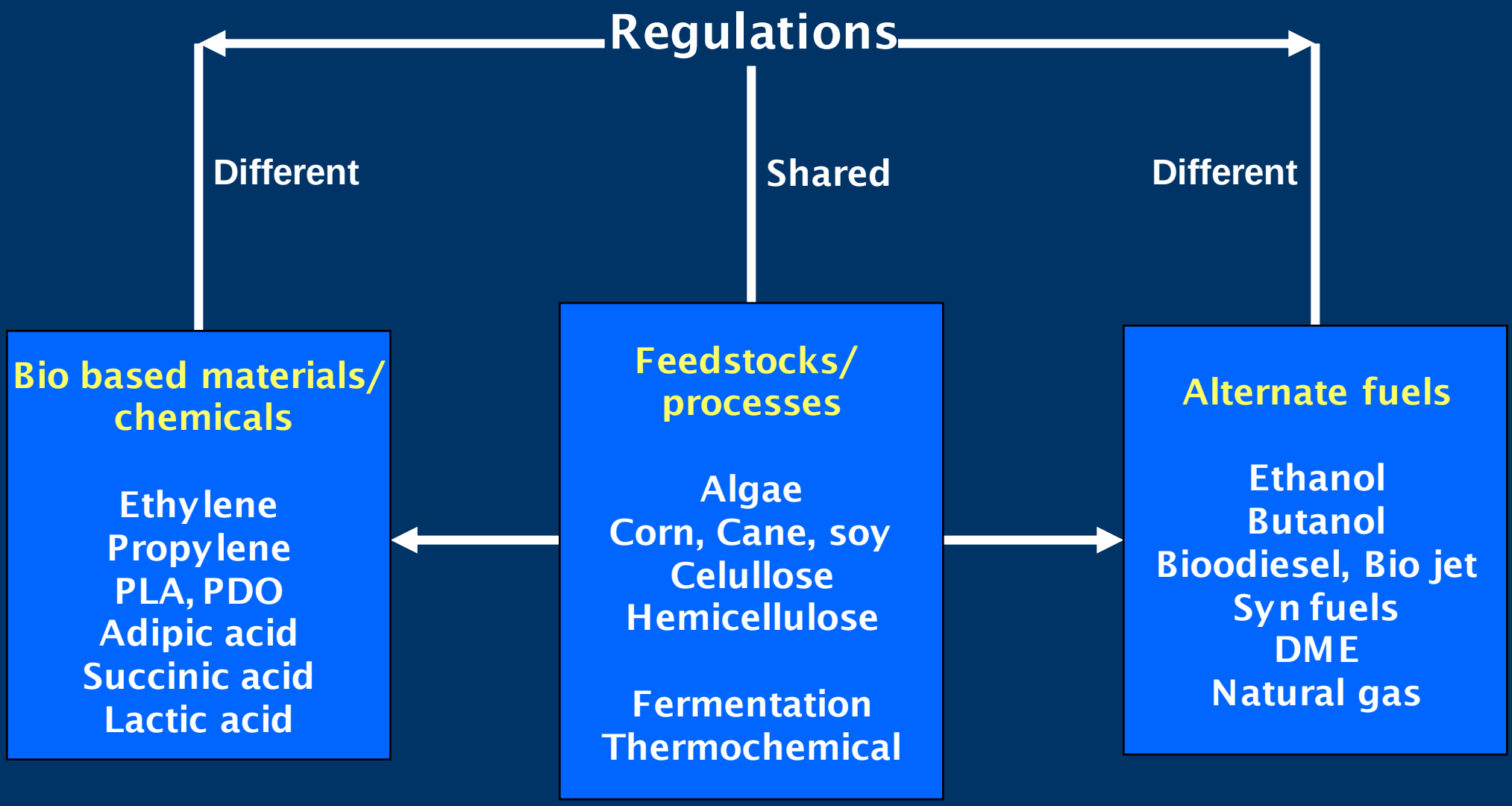
Barriers: Macro level

Feedstocks	Inconsistent crop yields, prices, quality, supplies Lack of new varieties Erratic weather patterns Cross border logistics
Technology	Sub optimal and unproven, Competitive access Operational reliability, Economies of scale
Capital	Lack of funding options, Poor response from PE/VC Stringent funding criteria: IPR, Feedstocks guarantees, Technology capability
Alliances	Cross border relations, language and cultural Host country policies, Multiple intermediaries Complex logistics

Barriers: Micro level

Feedstocks	Optimal crop yields Biomass composition for optimal conversion Feedstocks processing: densification
Technology	High volume biomass conversion Novel catalysis/bio catalysis GM microorganisms Improved separation technologies
Value chain integration	Easy integration [Succinic, Lactic acids] Difficult integration [Levulinic acid] Novel products new properties [PHA, PLA]
Sustainability	GHG emissions Feedstocks choice, land use, synthesis efficiency Bio based carbon content: Measure of sustainability Tools, methodologies, metrics

Regulatory barriers: Micro level



Future directions

Bio based chemicals: Early, high risk stage

- Agriculture technologies
  - In-planta production/ breakthroughs in GM
  - Agricultural productivity
  - Competitive processing of complex biomass
- Bio process technologies
  - Cost effective biocatalyst development
  - Enzyme cultivation techniques
  - High volume biomass conversions
- Developing sustainable strategies
  - Sustainability metrics & measurements
- Managing risks
  - Policy, regulatory, markets, financial, geo climatic/political