McKinsey&Company

Making the bio-based economy happen

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Today's industrial products are largely based on oil and gas

Fuel

Paints

Fibers

Bulk chemicals

Specialty chemicals

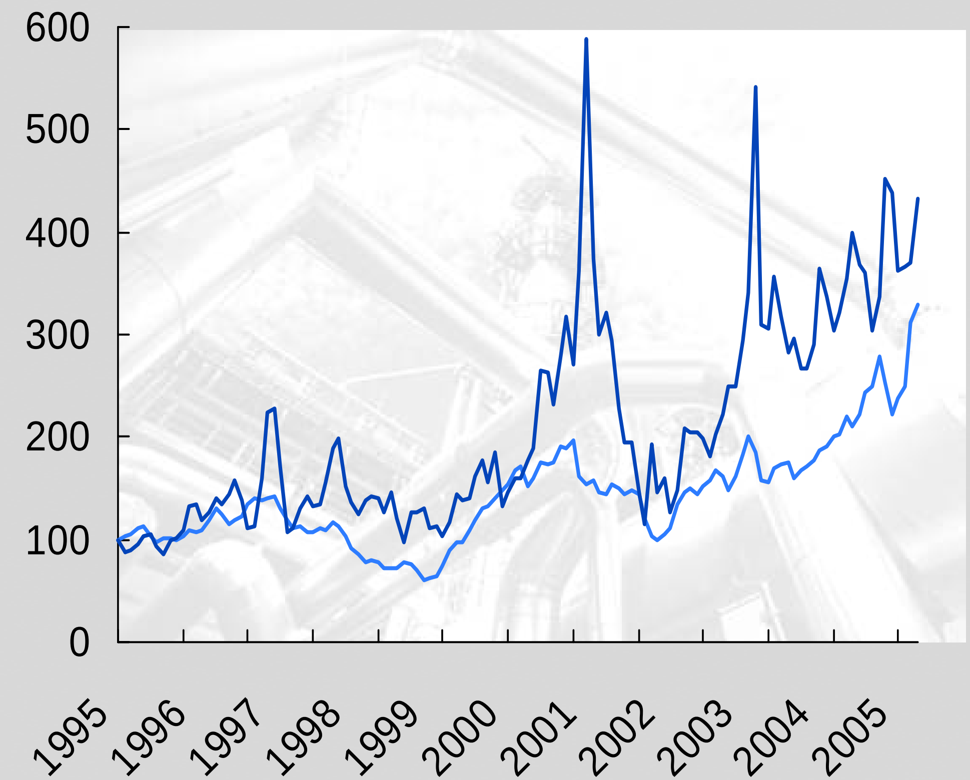
Packaging

Drugs

Recent trends put hydrocarbon feedstock under pressure

Gas
Oil

Volatile and increasing prices



Additional pressure

- Dependency on oil-producing countries
- Consumer activism based on environmental and social issues
- Costs of carbon taxes/ greenhouse gas emission trading

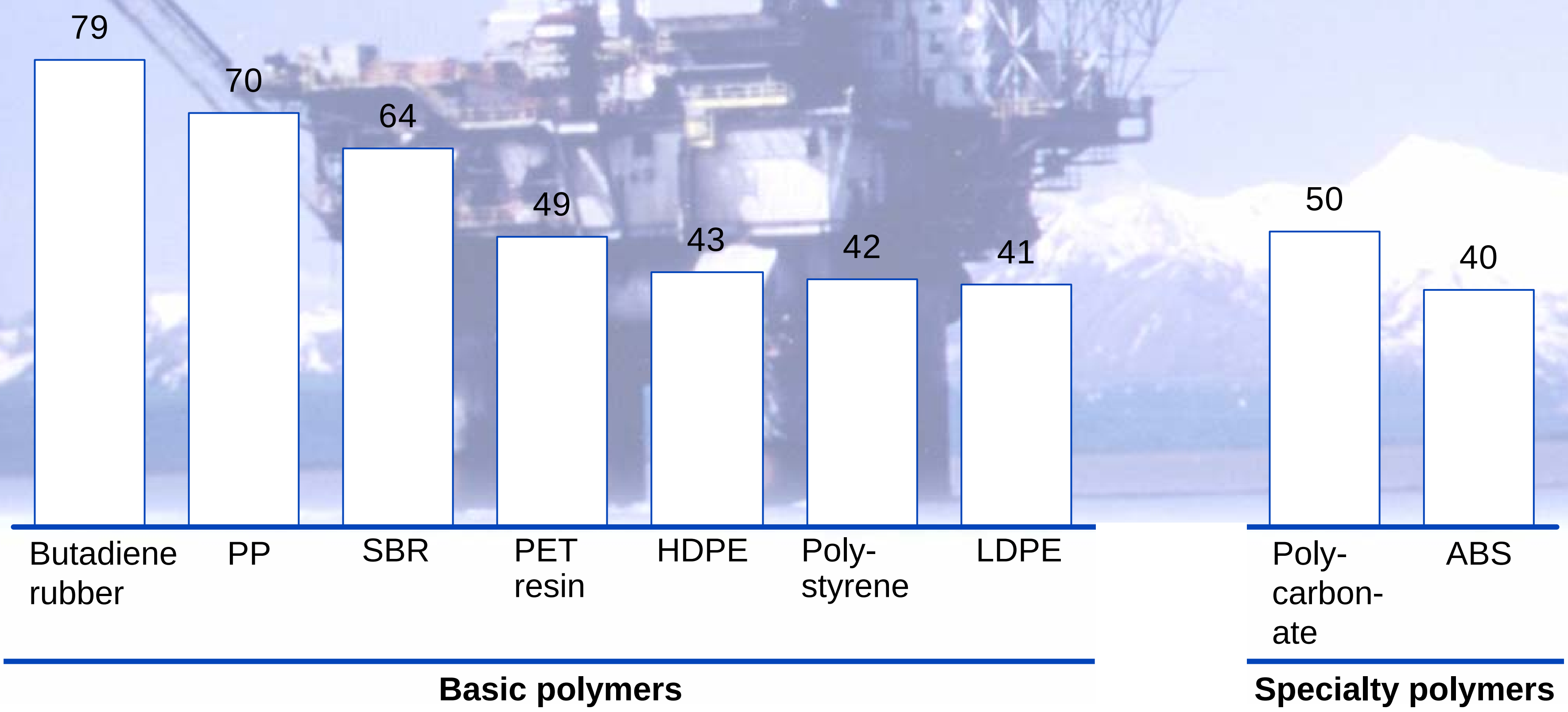
OIL & GAS

Source: CMAI; McKinsey

Today's common polymers have high exposure to hydrocarbon prices

TOTAL HYDROCARBON COSTS AS PERCENT OF PRICE

Percent

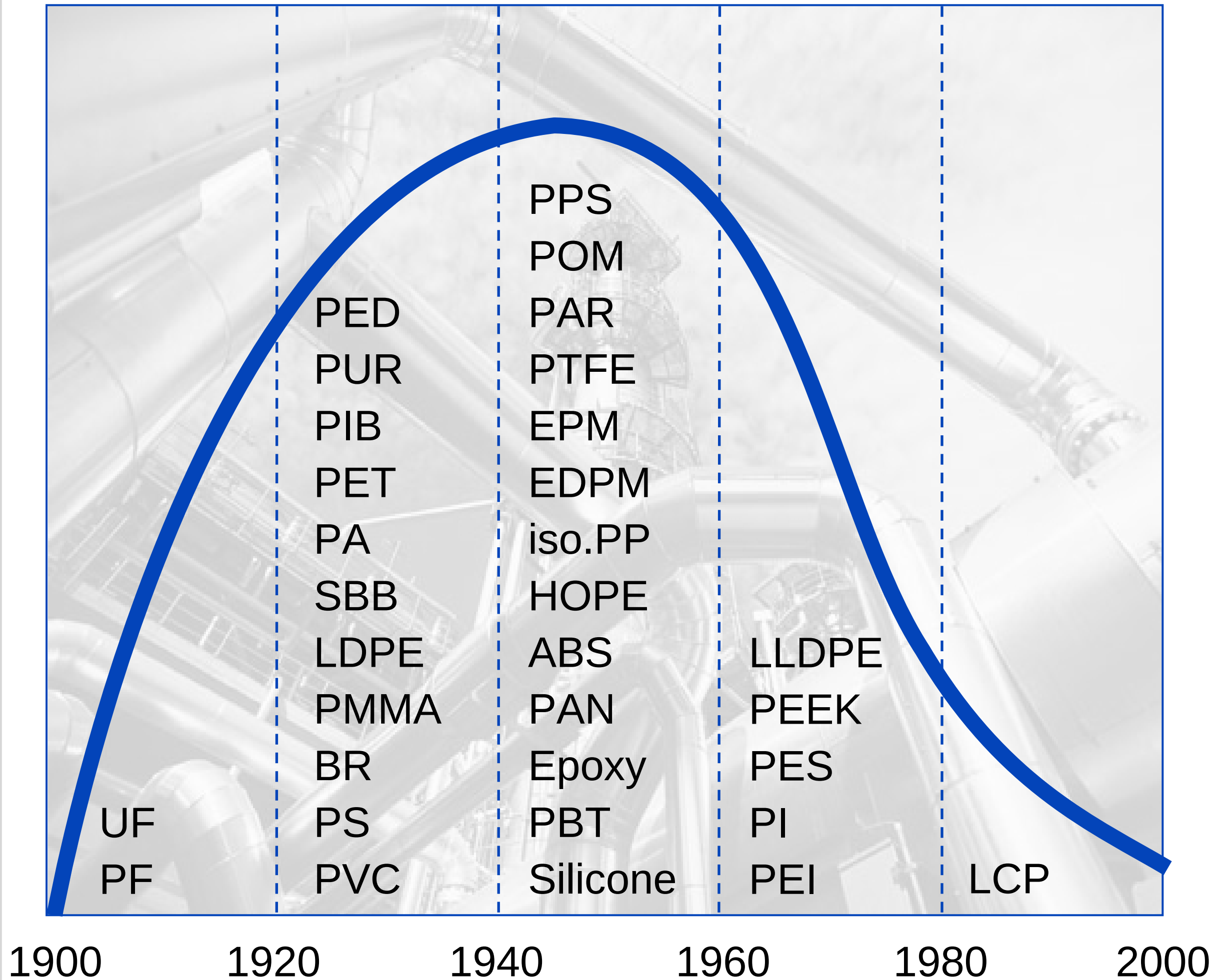


Source: CMAI; McKinsey

The innovation potential of fossil building blocks appears largely exploited

- Ethylene
- Propylene
- Butadiene
- Benzene
- Toluene
- Xylene
- Methanol

Polymer innovation based on fossil building blocks



Source: McKinsey

Chemical industry leaders put much hope on biotech

I expect most **innovation** to come from **biotechnology**

Biotech is the **most advanced new technology** in chemicals, nanotech might be the next

The only area of current **break-through** is **industrial biotech**

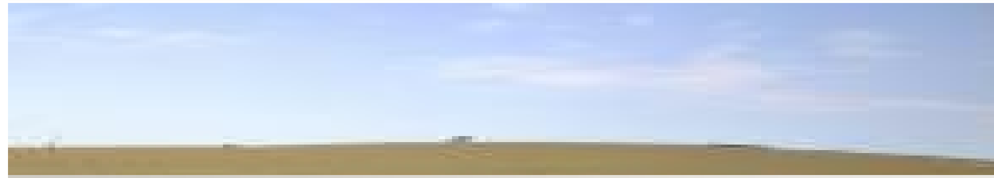
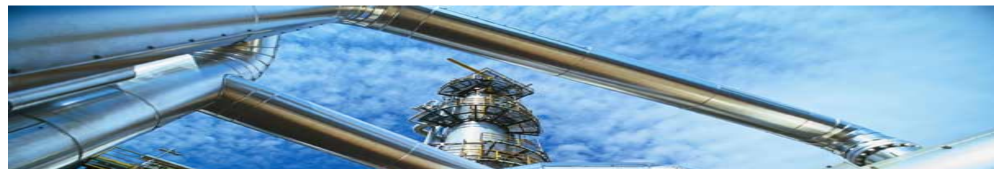
Biotech is a way of maintaining a **competitive edge over the Asian** competition

Key drivers of change

- **Feedstock prices**
- **Innovation**
- Asia
- Service offerings

Source: McKinsey

Industrial biotech should be approached with a broad definition

Definition	Examples
Industrial biotech makes use of	
Biological feedstock	• Sugar crops • Oil crops • Biomass (e.g., straw, stover, switchgrass)
and/or	
Biotechnological processes	• Fermentation • Biocatalysis • In-planta production
for the manufacture of existing or new	
Industrial products	• Biofuel • Biomaterials • Nutritional ingredients • Specialty chemicals • Commodity chemicals

Source: McKinsey

The impact is just emerging and could grow into a discontinuity affecting several major markets

	Total market Sales, USD	**Biotech today*** Sales, USD	**Biotech products** Current examples
Fuel	~ 500 billion	~ 20 billion	• Ethanol** • Biodiesel
Polymers and petro-chemicals	~ 500 billion	~ 1 billion	• PLA, PHA, Sorona • Glycols • Ethylene • Acrylic acid
Specialty chemicals	~ 300 billion	~ 5 billion	• Enzymes • Flavors, fragrances • Oleochemicals
Fine chemicals	~ 100 billion	~ 15 billion	• Pharma intermediates • Amino acids • Vitamins • Citric acid

Already 5% of chemical sales depend on biotech today

Key growth drivers

- Technology breakthroughs
- New bio-based building blocks
- Cheap biomass feedstock
- Regulatory push
- Recognized need for innovation
- Major private investments

Potential for major discontinuities

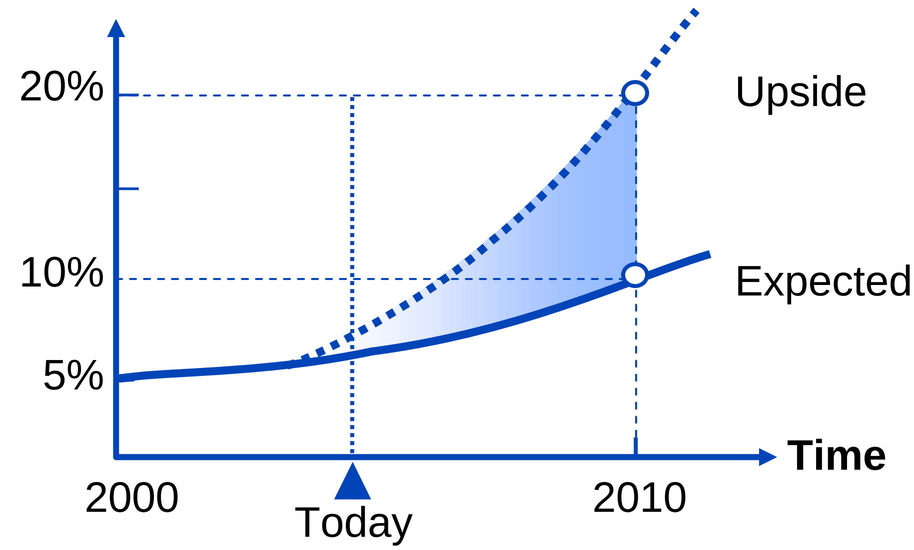
* I.e., fermentation or biocatalysis used for at least 1 production step; in total, 5% of all chemical sales are dependant on biotech today
** Ethanol is also used in non-fuel applications; all ethanol sales accounted for in this category
Source: McKinsey, SRI, press clipping, company publications

Biotech adoption could more than double by 2010

McKinsey approach

- Analysis of technological and market trends in chemical industry
- Inventory of current commercial and R&D biotech activities
- Combined bottom-up/top-down estimate of likely impact by segment
- Interviews and discussions with chemical industry executives

Chemical sales impacted* by biotechnology



Impact depends on

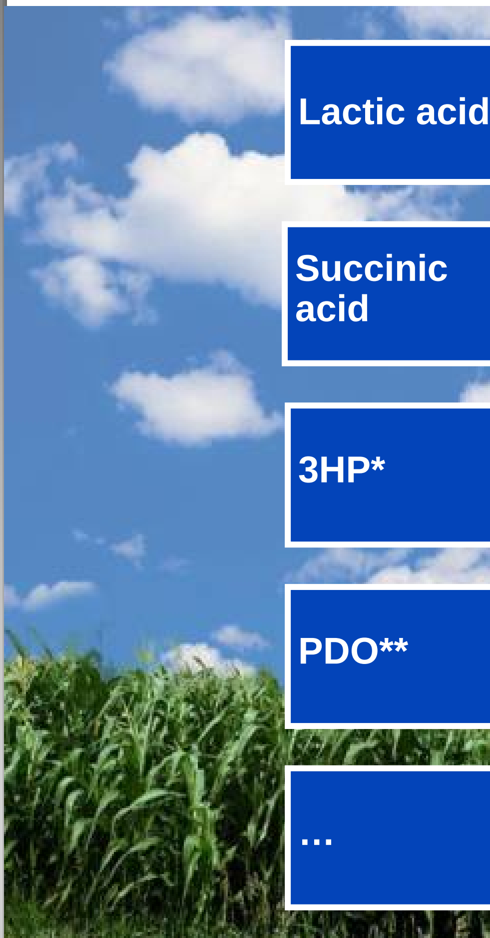
- Feedstock price spread
- Consumer acceptance
- Policy framework
- Investment level/success

* I.e., biotechnology used for at least 1 production step; 100% of sales accounted for in multi-step products

Source: McKinsey

Bio-based building blocks are being developed as a source of new products

Bio-based building blocks



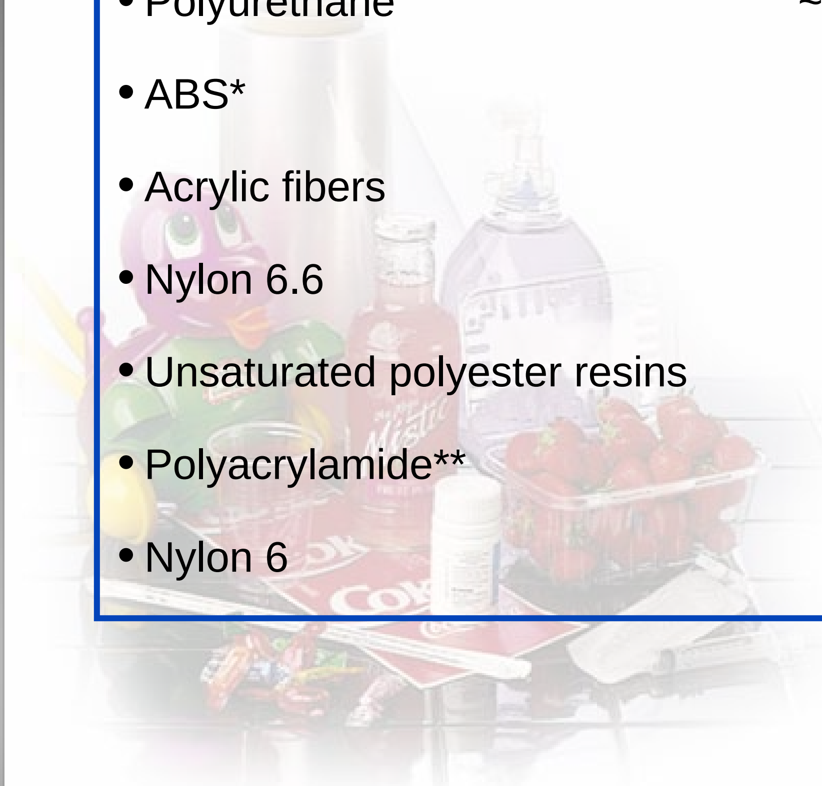
- Lactic acid
- Succinic acid
- 3HP*
- PDO**
- ...

- **Biopolymer (PLA)**
- Chiral drugs
- Acrylic resins
- Food additives
- Solvents
- High-performance chemicals
- Commodity chemicals

PLA is starting to replace polyester (PET) on the basis of costs and performance

* 3-hydroxy propionic
** Propanediol
Source: Cargill Dow; Degussa

Also, existing products can become "bio" by using bio-based intermediates – polymer example



Polymers	Sales USD billions	Biotechnology inroad
• Polyethylene	~ 30	• Ethylene from bio-based ethanol
• Polyurethane	~ 14	• Bio-based polyols
• ABS*	~ 8	• Butadiene from succinic acid
• Acrylic fibers	~ 4	• Acrylonitrile from 3HP
• Nylon 6.6	~ 4	• Adipic acid from succinic acid
• Unsaturated polyester resins	~ 3	• Maleic anhydride from succinic acid
• Polyacrylamide**	~ 2	• Acrylamide from 3HP
• Nylon 6	~ 2	• Caprolactam from fermentation

Technically feasible, but mostly not cost-effective for shut-down economics to date

* Acrylonitrile-butadiene-styrene resins
** Excludes superabsorbent applications
Source: SRI; CMAI; McKinsey analysis

Conversion of waste biomass has the potential to further reduce bio-feedstock cost

Idea

- Convert biomass (e.g., stover, straw, energy crops) into sugars
- Use sugars as feedstock for fermentation for organic chemicals (e.g., ethanol, bio-based building blocks)

Rationale

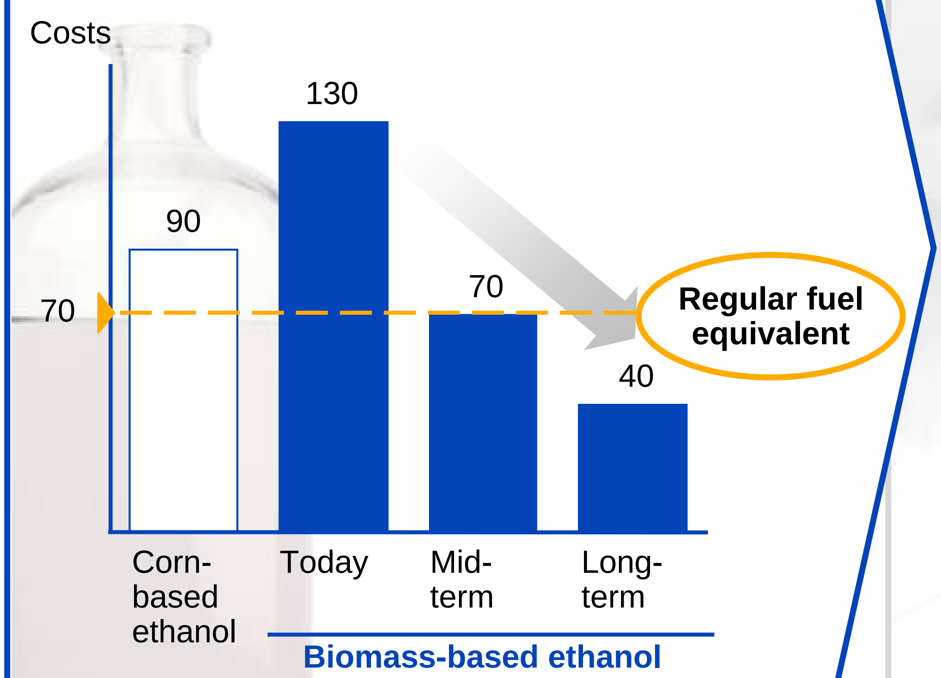
- Abundantly available
- Cheap, mostly discarded today
- Renewable, eco-friendly resource
- Valuable by-products (e.g., proteins, lignin)

- **First semicommercial "biorefinery" onstream in 2003 (Canada)**
- **Government grants USD 400 million in 2003**
- **Technology ready for commercial use in 2 - 4 years**
- **Substantial long-term cost savings**

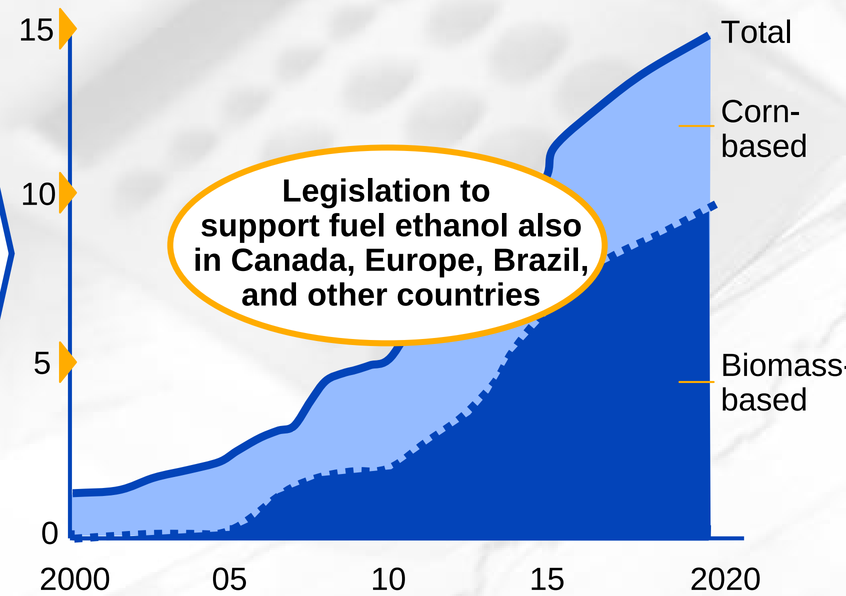
Source: DOE; NSF; USDA; McKinsey

Bio-ethanol is among the first and biggest markets to profit from low-cost biomass feedstock

Cost reduction
US cent/gallon



US market growth (DOE estimate)
Billion gallons



Source: US Department of Energy; GOBI International; NREL; MBI; McKinsey

SIMPLIFIED

Product examples

Potentially integrated in biorefineries

A new value chain is emerging with lots of places to play

Value chain

Enablers

- Logistics
- Technology
- Equipment
- ...

Feedstock provision	Feedstock processing	Primary conversion	Secondary conversion
• Farming • Storage • Distribution	• Grain/seed milling • Biomass pre-treatment and enzymatic conversion	• Fermentation • Chemical conversion • Enzymatic conversion	• Polymerization • Downstream processing • Complex chemical synthesis

Products (examples)

Corn, Energy crops, Soy, Straw, stover	Oil, Sugar, Protein, Lignin	Ethanol, Platform chemicals, Vitamins, Biodiesel	Fine chemicals, Bio-polymers, Specialty chemicals

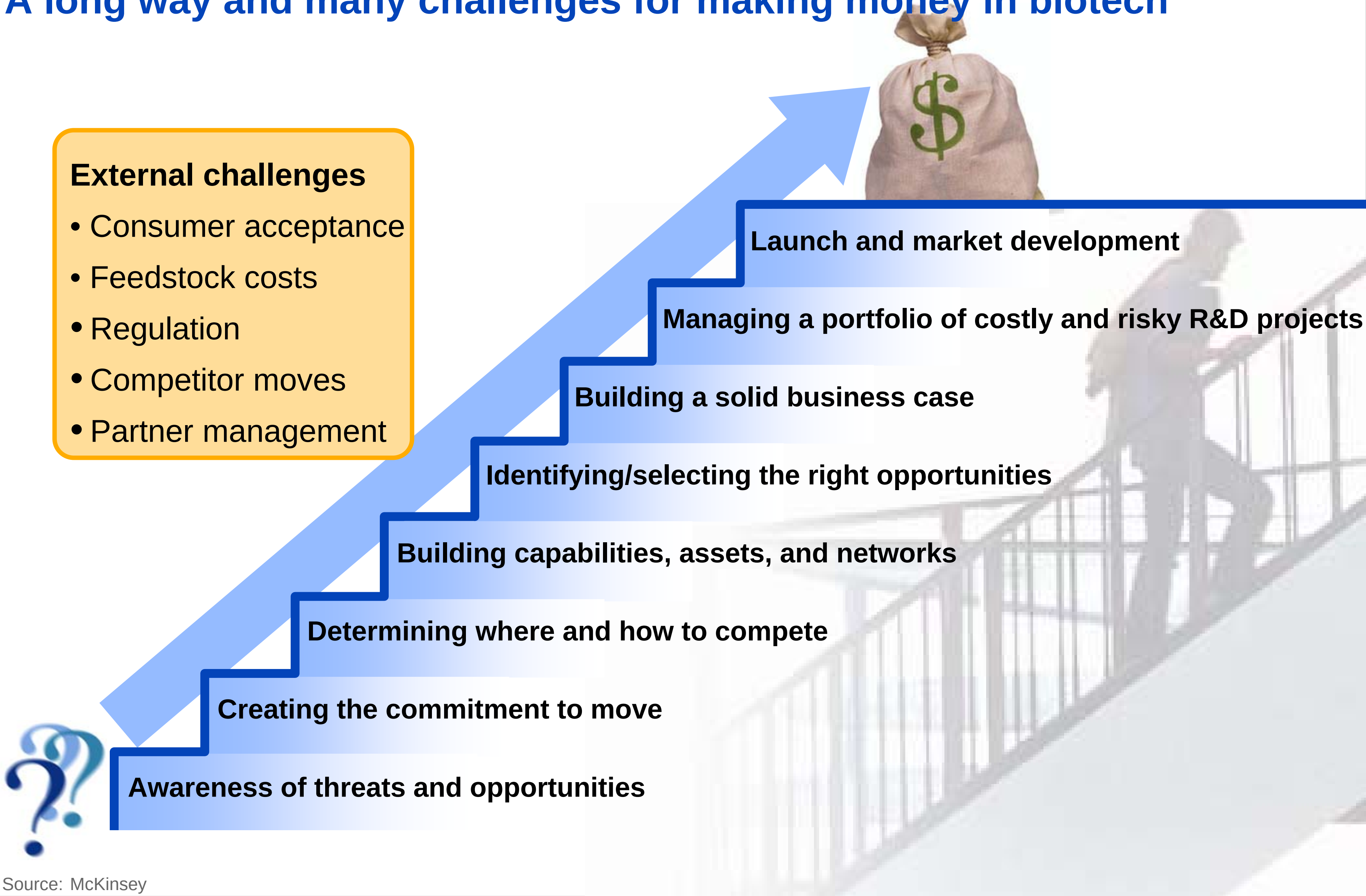
End markets Examples

• Food • Feed • Energy	• Food • Feed • Energy	• Transportation • Pharma • Food/feed • Cosmetics	• Automotive • Electronics • Consumer goods • Pharmaceuticals

A long way and many challenges for making money in biotech

External challenges

- Consumer acceptance
- Feedstock costs
- Regulation
- Competitor moves
- Partner management



Source: McKinsey

Case 1

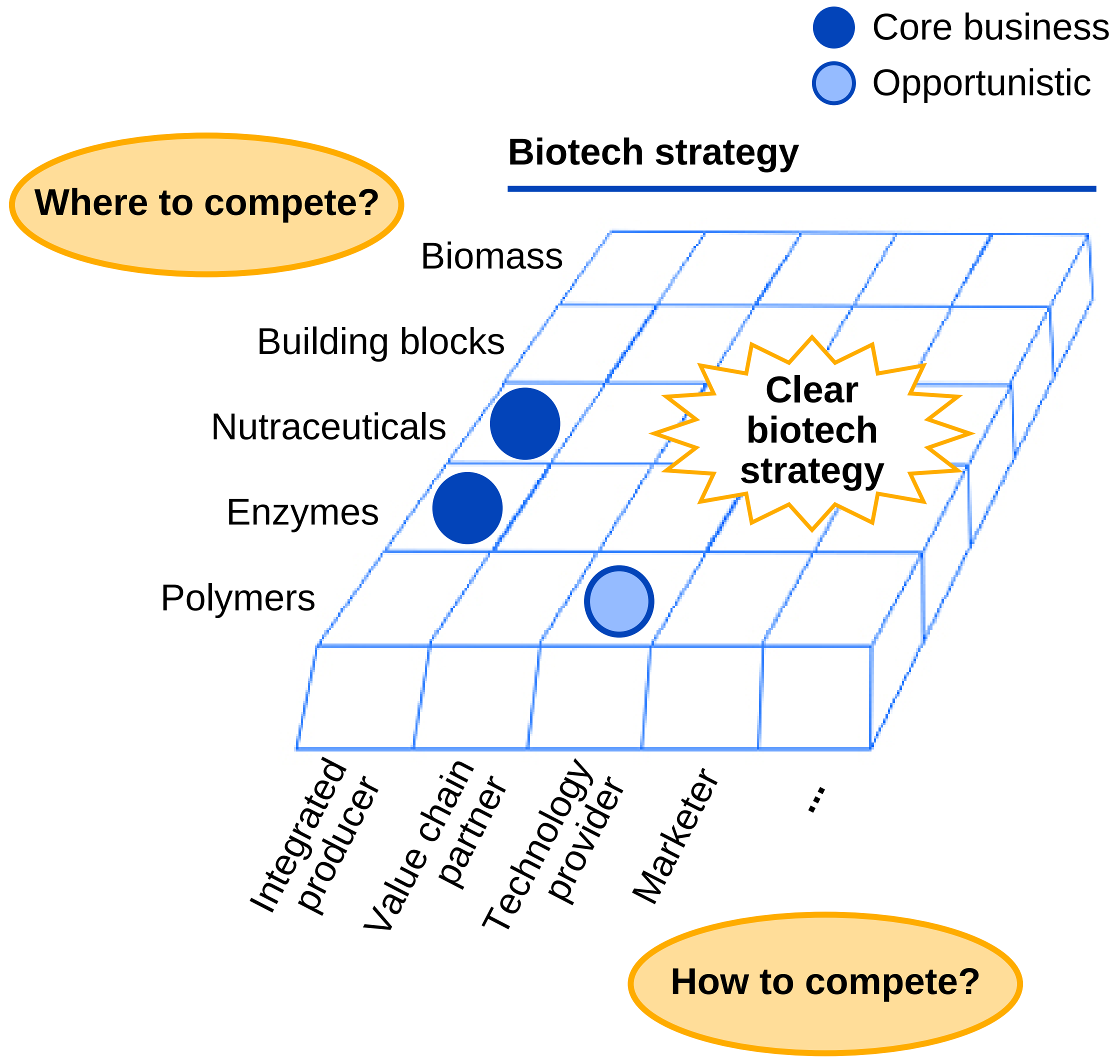
Building the biotech strategy for a chemical company

Overall opportunities and specific threats

Distinctive skills and assets

Room for sustainable competitive advantage

Fit with company's overall strategy



Source: McKinsey

Case 1

Common pitfalls in building a biotech strategy

- **Solution space defined too narrowly along current market needs**
- **External experts and customers either ignored, or followed too blindly**
- **The industry, market and technology context not considered dynamically**
- **Strategic options not pressure tested for some specific business opportunities**
- **Synergies and balances across different initiatives not fully leveraged**

Source: McKinsey

Case 2

Systematic scan for process innovation opportunities

Analysis of core products

- Route scouting teams for chemistry and biotech
- Economic evaluation of different technology and production options
- Assessment in the context of market and industry dynamics

Improvement levers	Cases
Stop production – resell from low-cost producer	1
Incremental improvements in current process/asset	2
Move current process to China	1
New chemical route	2
New enzymatic route	1
New fermentation route	2

- **New R&D road map (incl. termination of ongoing efforts)**
- **New production network**
- **60% cost reduction expected by 2010**

Source: McKinsey

Case 2

Key success factors for evaluating process innovation opportunities

- Think “product strategy”, not “biotech”
- Define aspiration level based on dynamic industry cost curves
- Watch emerging competition, especially from China
- Make a dedicated effort with chemical and biotech expert teams
- Give scientific curiosity and creativity room and time …
- … then model process economics and NPV for decision making
- Include technology or academic partners, if skills not available in-house

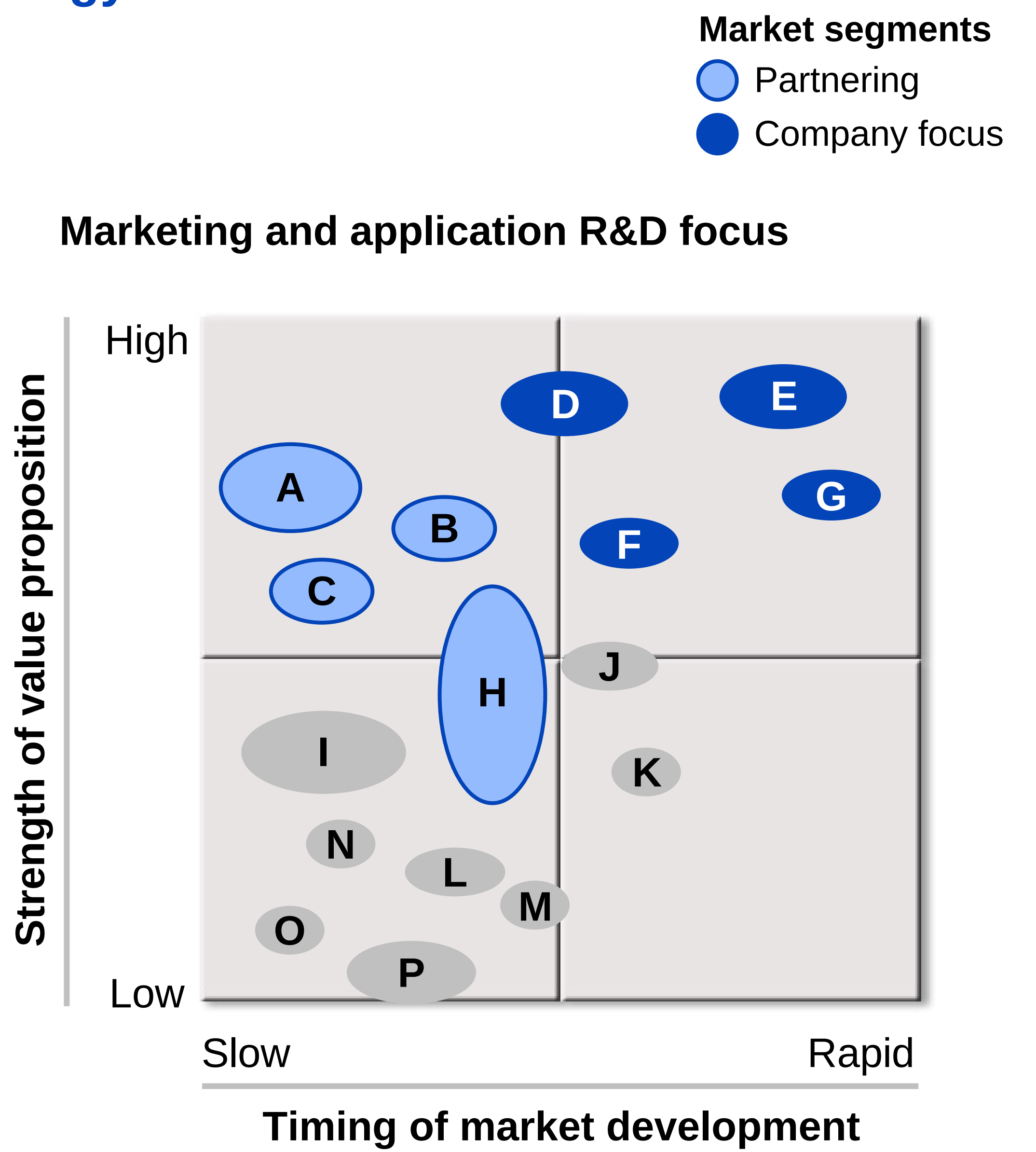
Source: McKinsey

Case 3

Defining the go-to-market strategy for a new bio-based product

- Assessment of product costs and performance vs. incumbent products
- Interviews with end customers and value chain intermediaries for adaption barriers
- Economic evaluation of potential market segments
- Evaluation of different business models, including partnering

Marketing and application R&D focus



Source: McKinsey

Case 3

Key lessons learned for commercializing new bioproducts

- Make sure there is a market for your value proposition: green is nice, but cost/performance is better
- Focus on applications/segments with highest value and lowest hurdles, and try to capture growth rather than substitution
- Do not overestimate the initial production capacity requirements
- Do not underestimate the efforts needed for market and application development
- Identify and address potential adoption hurdles along the entire value chain, thinking about “TCO” and risks
- Prepare the market entry well (e.g., fit-for-use studies, pilots, pricing)

Source: McKinsey

Summary

- Biotech has started to affect the **chemicals and fuel markets** based on cost savings and new functionality. The impact is growing as the fundamentals of biotechnology strengthen, and the **benefits get recognized** more broadly.
- Most notably, new **bio-based building blocks** emerge that could give chemical innovation a boost similar to the introduction of cracker chemistry in the last century. The conversion of **waste biomass** is a prerequisite to secure the availability of low cost carbohydrate feedstock
- A **new value** chain is emerging with many places to play. As with other disruptive technologies, there is the **threat and opportunity** to dramatically change who captures the money
- Despite significant investments, the **track record** of capturing value from biotech is **mixed.** The path to value creation is full of internal and external challenges. However, these **challenges can be managed** with approaches that combine well established management practices with innovative and biotech specific thinking
- **Let's discuss**: Is the potential to transform the industrial landscape and bring about a more sustainable economy real, and what does it take to make it happen?

APPENDIX

Yet, petrochemical companies are well positioned to address hurdles

Hurdles	Opportunities
Low-cost feedstock	• Low-cost biomass (e.g., straw, corn, stover, grass) available for USD 10-30/ton • Conversion to fermentable sugars is already advanced at pilot scale • Large chemical companies can bring the skills for process integration and manage large R&D and capex projects
Technological hurdles	• Bio-tech route to most starting materials (e.g., lactic acid, 3-hp) already works well • Main challenge is the thermochemical conversion into other intermediates or end products (e.g., acrylic acid, PG) • Large chemical companies have the experience to develop these processes
Barriers for adoption	• Chemical companies are best positioned to incorporate biotech products into their value chain • They know how the industry works, have the development/marketing skills/ partners • They can accelerate adoption and adaptation by incentives and lobbying
Strategic commitment	• Large chemical companies have the resources and the time horizon required to work on breakthrough innovation

Source: McKinsey

In particular, the conversion of cellulosic biomass to low cost sugars could substantially improve biotech economics

Concept

- Harvest cellulosic biomass (e.g., paper sludge, corn stover, straw, switch grass)
- Convert the celluloses and hemicelluloses enzymatically into fermentable sugars
- Make use of by-product streams (e.g., lignin for energy, proteins for feed)

Potential impact

- Sugar cost could be reduced to or below levels of Brazil in many part of the world
- According to the USDA* and US DOE*, more than 1 billion ton of biomass available for bio-products in U.S. alone – equivalent to 145 million tons of PE**)

- First semi-commercial plant operating since 2005 (Shell/Logen Canada)
- Government grant worth $40 million issued in 2003
- Several large companies 'testing the waters' are DuPont, Cargill, Shell, John Deere, etc.)

* USDA – US Department of Agriculture; US DOE – US Department of Energy

** Assuming 1.67 ton of ethanol per ton of PE, 300 kg of ethanol per ton of dry biomass and 20% water content in harvested biomass

Source: USDA, US DOE, McKinsey

Window of opportunity for pioneers is here

Pioneer chemical companies…

- **Will obtain competitive advantage.** General perception is that biotech will eventually have a major role in commodity chemicals- pioneers can secure a strong position and avoid the incumbent dilemma
- **Will secure key positions in IP.** IP is the key success factor in this new field. Chemical companies can still decide whether to use IP to develop the product on their own, license the technology or block others from competing
- **Will secure partnership position with other major players**. There are only few strong partners for each step of the emergin value chain (grain producers, enzyme companies, OEMs…)- early movers can secure a position in a "winning team"

But competition is not sleeping

- **Many large petro-/chemical companies already active in R&D and commercialization of bio- products, e.g.,**
  - BASF (major R&D efforts in fermentation and plant-based chemicals, e.g., 1, 4-butanediol)
  - Natureworks/Cargill (commercialized PLA, working on acrylic acid, propylene glycol, soy-based polyols)
  - DuPont (commercializing Sorona,major effort on biomass conversion with John Deer and Diversa)
  - DSM (USD 2 billion sales with bio-based products)
  - ADM (in JV with Metabolix, fermentation route to PHA)

Source: McKinsey