The Application of Industrial Biotechnology to Pollution Prevention

Presented at
The Environmental Innovations Summit 2002

Bio

BIOTECHNOLOGY
INDUSTRY
ORGANIZATION

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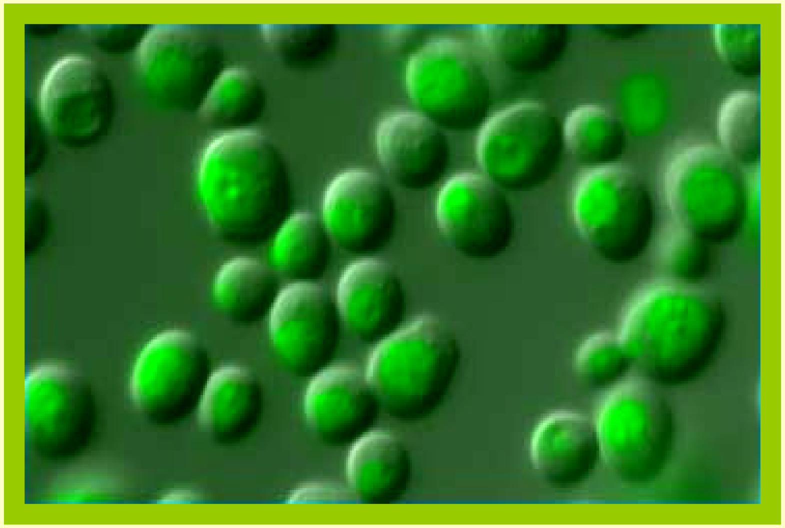
Industrial and Environmental Section

Industrial Biotechnology

- **The application of life sciences in conventional manufacturing.**

- **It uses genetically engineered bacteria, yeasts and plants - - whole cell systems or enzymes**

- **In most cases results in:**
  - **lower production costs**
  - **less pollution**
  - **resource conservation**



Applications of Industrial Biotechnology

Industrial use of biological systems (whole cells or enzymes)

- **Waste recycling**
- **Chiral synthesis**
- **Textile treatment**
- **Food enzymes**
- **etc., etc.**

Applications of Industrial Biotechnology

- Replacement of fossil fuels by renewable raw materials, for example:
  - Cargill Dow polymers - polylactides
  - Eastman and Genencor – ascorbic acid
  - DuPont and Genencor - 1,3-propanediol
  - Biofuels - bioethanol, biodiesel

Organization for Economic Cooperation and Development (OECD)

Headquarters in Paris

Members - the developed nations

OECD Working Party on Biotechnology (WPB)

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Task Force on

Biotechnology for Sustainable Industrial Development

Task Force on Biotechnology for Sustainability Industrial Development

Mission

Study the use of Industrial Biotechnology to Assist Developed and Developing Countries in Achieving Sustainable Development

May 2000, the WPB commissioned the Task Force to prepare a study on this topic

The Application of Biotechnology to Industrial Sustainability

Completed November 2001

Why the latest study?

- No collections of comparable case studies existed, and
- No analysis to-date of the policy implications

Why did we do it?

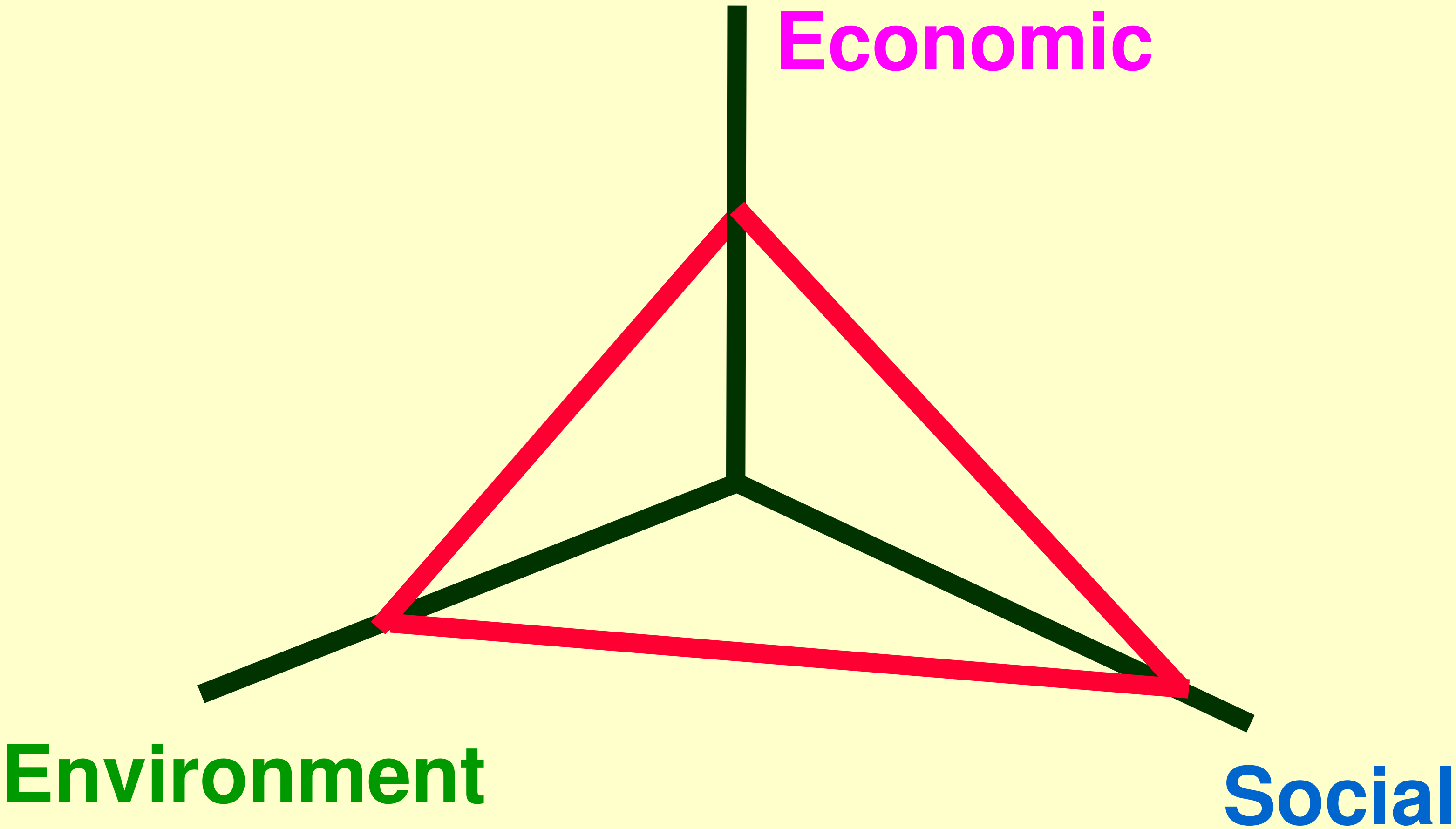
- Sustainability Biotech should be on every industrial agenda--

and on every list of parameters.

Basis of the Study

- Identification of companies which have adopted new biotechnology processes (21 case studies)
- The factors in their decision making
- The policy lessons which emerged

The Triple Bottom Line



Size of triangle = indicator of sustainability

Unanswered Questions

- Some assessments already existed but were
  - academic studies of environmental problems
  - specific in-house analyses of process development

We wanted to know:

- Can biotechnology provide a cheaper option?
- Can economic and environmental improvement go hand in hand?

Two distinct audiences

- Industrial policy makers (senior management)
  - show what others have done and the benefits
  - demonstrate new sustainability strategy to their company

- Policy makers within government
  - see how the "early adopters" have made decisions
  - support guidelines for national financing programmes

Participating Companies

- Avecia
- Baxenden
- Billiton
- Biochemie (Novartis)
- Cargill Dow
- Cereol
- Ciba
- Domtar
- DSM
- ICPET
- Iogen
- Leykam
- M-I, BP Amoco
- Mitsubishi Rayon
- Oji Paper
- Paques (Budel Zinc, Pasfrost
- Roche
- Tanabe Seiyaku
- Windel

Breakdown of Cases by Sector and Country

Industry sector	Pharma	Fine chemicals	Bulk chemicals	Food & Feed	Textiles	Pulp & paper	Minerals	Energy
Austria						1		
Canada						2		2
Germany	2			1	1			
Japan		1	1	1				
Netherlands	1			1			1	
South Africa							1	
UK		1	2					1
USA			1					

Selected Case Study Results

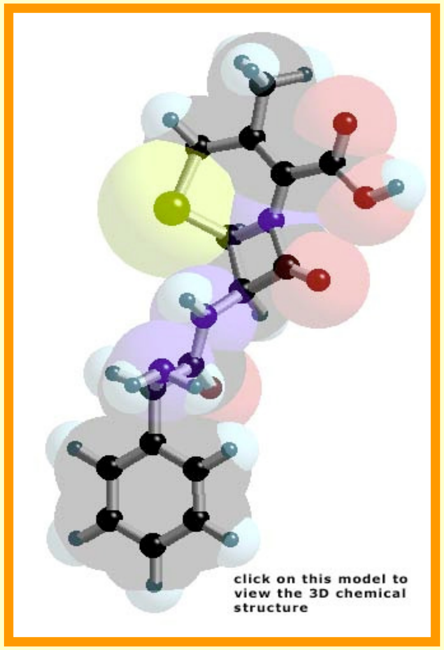
from

“The Application of Biotechnology to Industrial Sustainability”

Manufacture of Vitamin B_2 (Hoffman La-Roche, Germany)

- Substituted multi-step chemical process with a one-step biological process using a genetically modified organism.
- Land disposal of hazardous waste greatly reduced.
- Waste to water discharge reduced 66%
- Air emissions reduced 50%
- Costs reduced by 50%

Production of Antibiotic 7 amino-cephalosporan) (Biochemie , Germany)

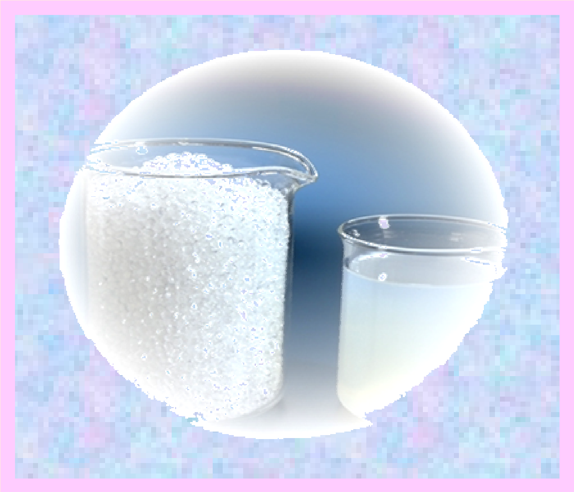


- Converted chemical synthesis to biological process.
- Old chemical route – used chlorinated solvents, hazardous chemicals.
- Biological process – no toxic ingredients.
- Reduced air, water and land pollution discharges.

Production of Antibiotic Cephalexin (DSM, Netherlands)

- Involved conversion from chemical synthesis to biological synthesis.
- Old process produced 30-40kg of waste per 1kg of product.
- New one step biological process--eliminated the need to use methylene chloride.
- Dramatically reduced waste generation and toxic emissions.

Production of Acrylamide (Mitsubishi Rayon, Japan)



- Conversion to enzymatic process reduced levels of all waste products as a result of high selectivity of enzymatic reaction.
- Lower energy consumption for enzymatic process,

  1.9 MJ/kg for old process - 0.4 MJ/kg for new process.
- Enzymatic process produced lower CO_2 Emissions

  old process – 1.5 kg CO_2/kg product

  enzyme process 0.3 kg CO_2/kg product

Synthesis of Polyester Adhesives (Baxenden, Untied Kingdom)

- Chemical process used tin or titanium catalyst at 200^{o}C.
- New enzyme process more energy efficient.
- New process eliminated the need to use organic solvents and inorganic acids.
- Environmental improvements were realized along with improved product quality.

Bio-Polymer Production (Cargill-Dow, USA)

- Production of Polylactic acid (PLA) polymer from corn sugar replaces petroleum feedstock.
- PLA can replace PET, polyesters and polystyrene.
- PLA is compostable.
- PLA is carbon neutral – CO_2 is recycled.
- In the future, PLA will be made from ligno-cellulosic biomass.

Vegetable Oil Degumming (Cerol, Germany)

- Enzymatic degumming of vegetable oils reduced amounts of caustic soda, phosphoric acid and sulfuric acid used compared to conventional processes.
- Enzymatic process reduced the amount of water needed in washing and as dilution water.
- Sludge production was reduced by a factor of 8.

Removal of Textile Finishing Bleach Residues (Windel, Germany)

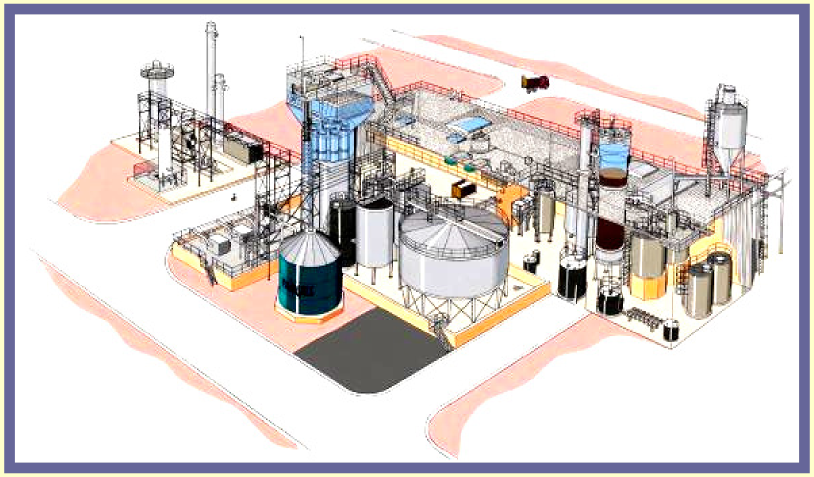
- Hydrogen peroxide used for bleaching textiles usually requires several rinsing cycles.
- New enzyme process -- only <u>one</u> high temperature rinse is needed to remove bleach residues.
- Reduced production costs
- Reduced energy consumption by 14%
- Reduced water consumption by 18%

Wood pulp process (Leykam, Austria)

- In traditional pulping – wood chips are boiled in a chemical solution to yield pulp.
- Biopulping (treatment of woodchips with a fungus) uses enzymes to selectivity degrade lignin and to break down wood cell walls.
- If next step is <u>mechanical treatment</u>, result is 30-40% reduction in energy inputs.
- If next step is <u>chemical treatment</u>, result is 30% more lignin being removed and lower amounts of chlorine bleach used.
- Cost reduction due to savings on energy and chemical costs.

Wood Pulp Brightening (Domtar, Canada)

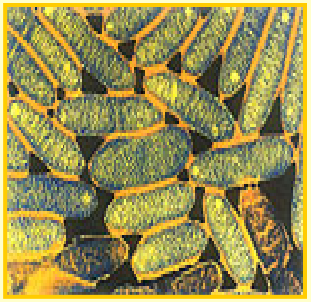
- Wood pulp digestion is followed by bleaching in a multi-stage process to yield bright, strong pulp.
- Two options to reduce chlorine
  1) reduce lignin prior to bleaching (enzymes still in R&D)
  2) change bleaching chemistry
- Enzyme xylanase produced third option - "activating" lignin so less bleach is needed.
- Xylanase treatment reduces the use of bleaching chemicals by 10-15% and reduces toxic dioxin formation.



Zinc Refining (Budel Zinc, Netherlands)

- In old process -- finishing wastewater contains heavy metals, sulphuric acid and gypsum used to precipitate sulphates.
- New biological process was developed using sulphate reducing bacterial enzymes for sulphate reduction.
- This process allows zinc and sulphate to be converted to zinc sulphide which can then be recycled to the refinery.
- As a result, no gypsum is produced, water quality has been improved and valuable zinc is recycled.

Bioleaching of Copper Ore (Billiton, South Africa)

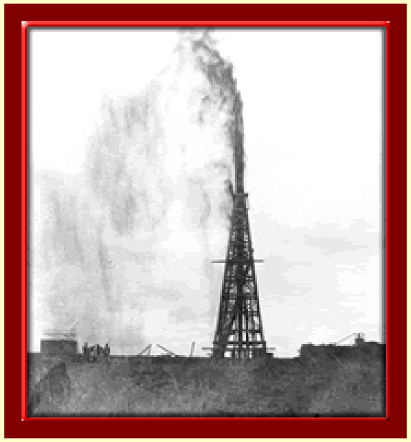


- Copper smelters are generally heavy polluters.
- Bacteria can be used in leaching metals from ores.
- Can treat low-grade ores or concentrates containing problem elements.
- Biological leaching produces environmental benefits, lowers environmental emissions and costs.
- Reduces generation of particulate emissions (dust).
- Using bacteria reduces sulphur dioxide emissions.
- Allows safe handling of arsenic impurities in a stable form.

Ethanol from Biomass (Iogen, Canada)

- Ethanol currently produced by fermenting grain (old technology).
- Cellulose enzyme technology allows conversion of crop residues (stems, leaves and hulls) to ethanol.
- Results in reduced CO_2 emissions by more than 90% (compared to oil).
- Allows for greater domestic energy production and it uses a renewable feedstock.

Oil Well Completion
BP Exploration



- Oil well drilling uses “muds” to lubricate the drilling string and to coat the insides of a bore hole with a layer of “cake”.
- After a well is drilled, the cake must be removed or “broken”. Traditional breakers are strong acids or other harsh chemicals.
- Enzyme breakers were developed especially for advanced horizontal drilling procedures.
- Advantages of enzyme breakers are high specificity, lower risk of formation damage, even degradation of filter cake, and using enzymes reduces acids or petro chemicals in water/mud discharge.

OECD Report Significant Findings

- Biotech invariably led to a more environmentally friendly process.
- It also resulted in a cheaper process

  but….

- The role of the environment was secondary to cost and product quality

  unless….

- Environmental legislation/regulation is driver - then the decision might be change or close!

Significant findings

- Approaches were rarely systematic – each company took a different approach.
- Biotech skills had to be acquired – was helpful to have industrial or academic partners?
- Lead times improved with succeeding developments!
- Cost was primary factor and environmental improvements second.

Key Messages

- Why adopt biotechnology? To cut costs and be environmentally friendly.
- Companies -- be aware of change; find yourself an R & D partner.
- Find a champion; assemble arguments to convince doubters.
- Build your own in-house biotech skill base.
- Companies -- work with government and stay close to the regulators.
- Government -- companies still need help – especially incentives and R & D funding.

Messages

- **If government regulators include industrial biotechnology in pilot programs or innovative pollution prevention strategies they can help promote the diffusion of this green technology into many industrial sectors.**
- **Government can help the private sector prevent pollution AND help companies cut costs significantly.**

Messages

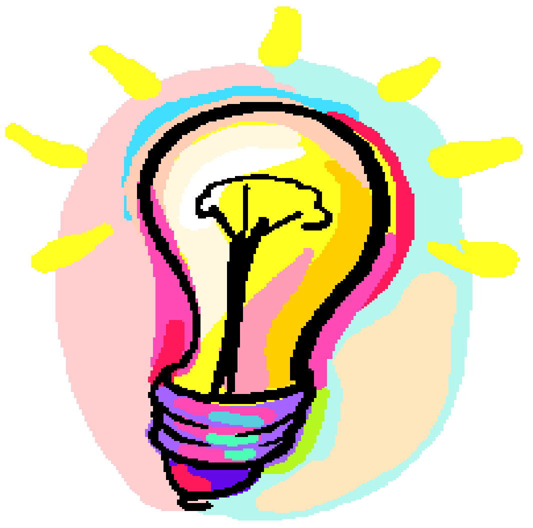
- **Additional Options – regulators -- contemplate identification of industrial biotechnology applications in regulatory frameworks, such as:**
- **Identify industrial biotechnology in <u>guidance documents</u>**
- **<u>Best management practices</u> (BMP's)**
- **Best Available Technology <u>(BAT)</u>**
- **Best Available Retrofit Technology <u>(BART)</u>**
- **Best Available Control Technology <u>(BACT)</u>**

Why Should Regulators Care?

- Because, unlike most command and control pollution control strategies, industrial biotech can reduce/prevent pollution <u>and</u> costs.

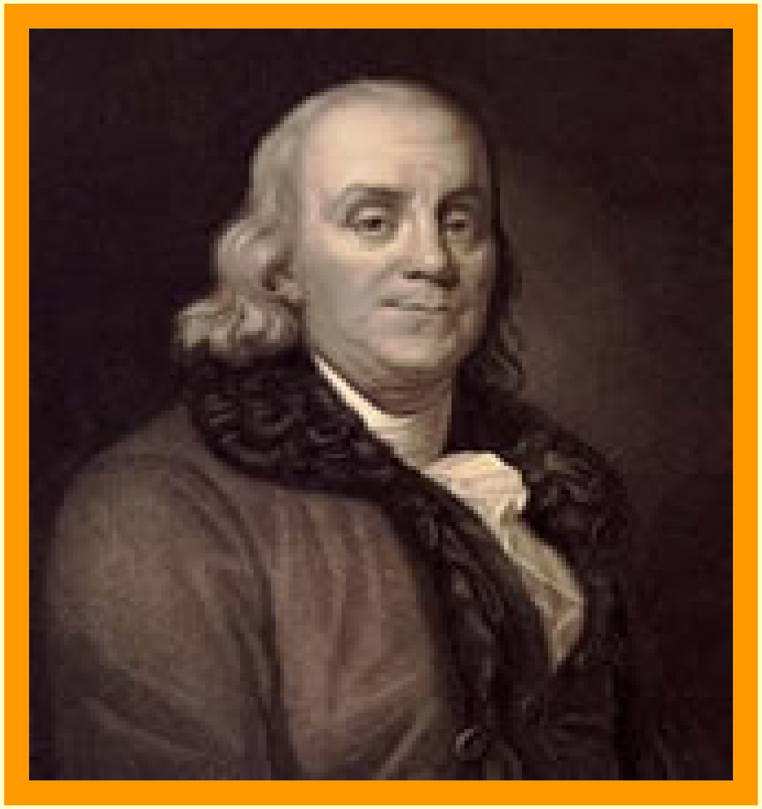
- Industrial biotech would stand up very well in regulatory regimes requiring the calculation of economics - - costs and benefits.

Conclusions



- Industrial Biotechnology is in the early stages of development.
- It's innovative applications are increasing and spreading rapidly into all areas of manufacturing.
- It is already providing useful tools that allow for cleaner, more sustainable production methods and will continue to do so in the future.
- It is in the interest of both business and government to foster the diffusion of these innovative applications into many sectors of the manufacturing economy.

Ben Franklin



“An ounce of prevention is worth a pound of cure.”

If Ben Were Alive Today he might say…

"A pound of pollution prevented is cheaper than an ounce of pollution controlled!"

OECD Task Force Publications

- **"Biotechnology for Clean Industrial Products and Processes"** (OECD, 1998)

- **"The Application of Biotechnology to Industrial Sustainability"**(OECD,2001)

- **to order click on**

www.OECD.org/bookshop