

**WHY BIOPROCESSES FOR
INDUSTRIAL ENERGY EFFICIENCY
AND WHY NOW?
A CANADIAN PERSPECTIVE**

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Energy Efficient Bioprocesses
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PRESENTED BY

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PURPOSE OF PRESENTATION - BACK TO THE FUTURE!

- **Outline key forces and special circumstances that are once more catalyzing / galvanizing renewed government and industry consideration of bioprocess utilization for enhanced energy efficiency**
- **Introduce candidate and promising bioprocess techniques currently under consideration at the domestic and international level**

PURPOSE OF PRESENTATION(2)

- **Identify sector specific areas within Canada where bioprocesses are expected to improve energy efficiency + reduce ecological footprint**
- **Set the stage for discussions with you on your complementary visions for the development for future policy agenda, appropriate R & D activities, collaborative mechanisms, and strategic planning necessary for this to happen**

CATALYSTS FOR PRESENTATION (1)

“Over the course of a lifetime, the average Canadian will use 124.8 million litres of water; travel 698,412 kilometres in motor vehicles; consume the equivalent of 643,410 cubic metres of natural gas, 1.1 million kilograms of coal or 575,898 litres of crude oil; generate 38,220 kilograms of garbage; and produce 1.3 million kilograms of greenhouse gases..energy consumption in Canada rose by 13% between 1990 and 1999 and GHG emissions rose by 17%”

Statistics Canada 2002, OECD 2002, Suzuki Foundation 2002

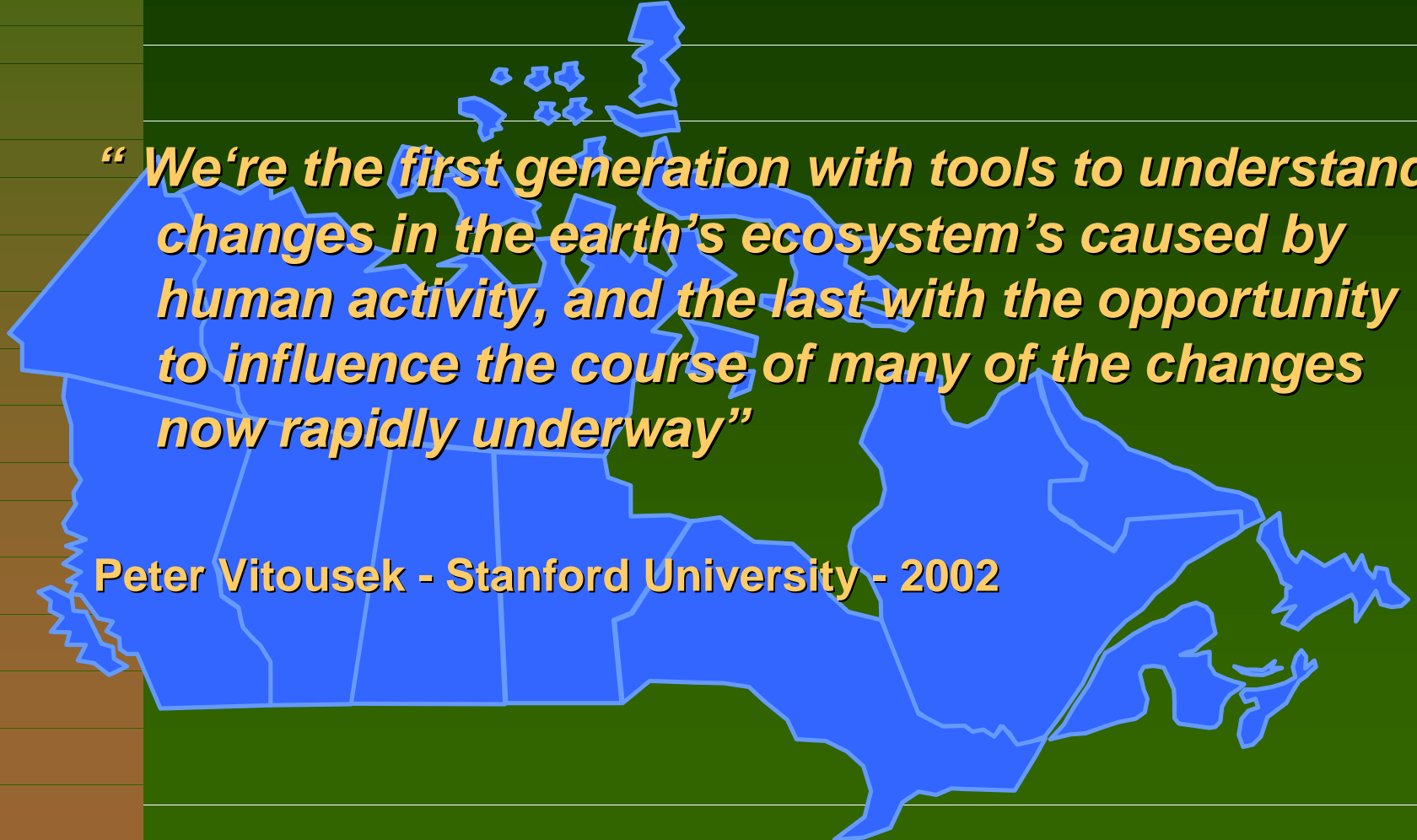
CATALYSTS FOR PRESENTATION(2)



“If every individual in the world consumed as much as the average Canadian citizen, we would need at least two additional planet earth’s to produce the resources and process the wastes”

David Boyd POLIS Project 2002

CATALYSTS FOR PRESENTATION (3)



“ We’re the first generation with tools to understand changes in the earth’s ecosystem’s caused by human activity, and the last with the opportunity to influence the course of many of the changes now rapidly underway”

Peter Vitousek - Stanford University - 2002

PROBLEMS WITH CONVENTIONAL INDUSTRIAL PRACTICES

- **High temperatures to achieve high conversion rates (which may lead to high rates of byproduct production)**
- **Extremes of pH to achieve acid / base catalysis (with production of large quantities of salts when neutralizing reaction mixture)**
- **A wide variety of highly reactive chemicals**
- **Organic solvents in synthesis and purification**
- **Utilize large quantities of clean water**
- **Strong reliance on non renewable sources of energy and starter materials**

BIOPROCESSES AS INSTRUMENTS FOR IMPROVING INDUSTRIAL COMPETITIVENESS

- **Providing industry and consumers with many new and improved products**
- **Diversifying selected industries and increasing their international competitiveness**
- **Creating unprecedented new demand for primary products of agriculture, forestry, and fisheries**
- **Building increasing chemical and self reliance in Canada**
- **strengthening rural economy in Canada**
- **Reducing the risk due to international supply disruptions and currency fluctuations**

UTILIZATION OF BIOPROCESSES TO MINIMIZE ENVIRONMENTAL DAMAGE

- Value added processes which convert renewable feedstock or waste into useful product (production of fatty acids from carbohydrates)
- End-of-pipe processes in which waste is purified
- Process innovation and new biologically mediated processes to minimize waste generation;
- New biomaterials and manufacture of new materials that are biodegradable and replace petroleum based feedstocks

COMPETITIVE ADVANTAGES PROVIDED BY BIOPROCESSES

- As processing aid - to enhance the performance of industrial processes and household practices
- As an extension or addition to existing processes-to accelerate and reduce the cost of conventional processes, extract materials
- As a core technology-for the energy efficient and potential eco-efficiency synthesis of new bioactive ingredients, monomers, intermediates
- As a remediation tool for contaminated wastes, soil, water, and air

CANDIDATE BIOPROCESSES UNDER DEVELOPMENT / CONSIDERATION

- **Biocatalysis**-use of enzymes to drive chemical reactions in microorganisms, plants, animals, and industrial processes
- **Metabolic engineering** - genetically engineering microorganisms for improved process engineering, productivity, and system efficiency
- **Molecular farming** - the use of plants to produce biobased chemical intermediates, biopolymers, and bioactive substances
- **Nanobiotechnology**- conducted at the subcellular level which focuses on biological systems and new materials
- **Bioremediation** - microbial processes for the remediation and restoration of contaminated sites
- **Phytoremediation** - use of plants for the sequestering, remediation, hyperaccumulation of inorganic materials

PREMISE OF PERD STUDY OF BIOTECHNOLOGY FOR CLEANER INDUSTRY

To determine if there was a basis for bioprocesses to enhance industrial energy efficiency by:

- **reducing quantities of GHG produced;**
- **increasing reliance on renewable sources of industrial feedstocks;**
- **reducing quantities of wastes by-products in emission streams;**
- **demonstrating greater energy efficiency in the utilization of fossil fuels;**
- **reducing quantities of water utilized; and,**
- **possibly reducing the incidences of industrial accidents due to attributes of specific products**

CANDIDATE CANADIAN INDUSTRIAL SECTORS UNDER CONSIDERATION

- Pulp and Paper
- Forestry
- Chemicals and Plastics
- Energy
- Mining

RATIONAL FOR SELECTION

Sectors account for:

- ~40% of total current industrial energy use (NRCan 2000);
- ~50% of industrial pollutants released to the Canadian environment (NPRI 2000)
- ~60% of total industrial greenhouse gas emissions (Climate Change Bureau 2000);
- are profligate water consumers;
- contribute extensively to Canadian economic growth and prosperity
- stand to benefit from complementary research internationally

PROJECTED ENERGY DEMAND IN SELECTED CANADIAN INDUSTRY SECTORS (in petajoules)

Sector	2000	2005	2010	2015	2020
Pulp & Paper	395.5	411	442	477.6	502.8
Forestry	10.4	10.6	11.1	11.4	11.4
Chemical	286.1	307.5	340.7	384	424.8
Mining	150.5	155.8	164.3	177.2	190.3
Smelting & Refining	232.5	262.4	281.4	298.2	311.7
Petroleum Refining	311	290.5	302	318.1	334.6
Total for above	1386	1437.8	1541.5	1666.5	1775.6
Total industrial	3561.3	3734	3963.1	4174.2	4386.5
Ratio of totals (%)	38.9	38.5	38.9	39.9	40.5

PROJECTED GREENHOUSE GAS EMISSIONS IN SELECTED CANADIAN INDUSTRY SECTORS (in megatons CO₂ equivalent)

Sector	2000	2005	2010	2015	2020
Pulp & Paper	12.1	12.4	13.3	13.6	13
Forestry	0.7	0.7	0.7	0.7	0.7
Chemical	20.2	22.1	23.1	25.3	27
Mining	6.9	7.5	7.7	8	8.5
Smelting & Refining	12.8	12.9	12.6	12.9	13.2
Petroleum Refining	21.3	22.3	23.2	24.9	26.8
Total for above	74	77.9	80.6	85.4	89.9
Total industrial	125.3	130	137.8	144.1	152.5
Ratio of totals (%)	59	60	58.5	59.3	59

KEY RESULTS FROM PERD STUDY

Bioprocesses have the potential:

- **In the petroleum sector to save energy, remove sulfur, reduce viscosity of heavy oil etc.**
- **In the chemicals and plastics sector to reduce energy consumption, waste generated, and provide product substitution,**
- **In the mining sector to replace high temperature processes such as roasting and smelting with bioleaching and bio-oxidation at ambient temperatures**
- **In the forestry sector for integrated pest management, select faster growing and disease resistant stock**
- **In the pulp and paper to reduce water use, as a substitute for chlorine bleaching, and for deinking**

KEY RESULTS FROM PERD STUDY(2)

- **Canada has a strong research base in the chemicals and biological sciences as well as in related engineering disciplines**
- **There exists a critical mass of technology development companies with life science expertise**
- **Major receptor industries are present in all five industrial sectors**
- **There are a full range of appropriate funding programs that can support basic and applied research**
- **Canada has major plant and microbial biomass resources**

BIOPROCESSES CONUNDRUM

“ Given that all the ingredients appear to be present for the accelerated development, acceptance and integration of bioprocesses into mainstream Canadian industrial activities - why is this only occurring in a disjointed , incremental, and slow manner?”

POINTS TO CONSIDER(1)

INSTITUTIONAL CAPACITY APPEARS PRESENT!

“Canada has the elements to be the ideal place for the development of the next generation of green resources, chemical and energy industries which utilize bioprocesses to achieve eco-efficiency and productivity required for long term sustainability...,

POINTS TO CONSIDER (2)

STARTER MATERIALS APPEAR ABUNDANT!

“ the potential of microbial processes has largely yet to be realized for the commercial synthesis of large numbers of commodity organic chemicals biomass feedstocks, the availability of appropriate organisms, and also, therefore the appropriate enzymes do not currently limit the applications of bioprocesses ”

Source Klass (2000)

POINTS TO CONSIDER (3)
HUMAN CAPITAL APPEARS READY!

*“Dear God
I pray on bended knees,
That all of my syntheses,
Will never be inferior,
to those conducted by bacteria.”*

Source Anonymous

RECOMMENDED “NEXT STEPS” FROM PERD PROJECT

- **Review of international developments - complement existing work with a more systematic overview of international activities (nb in cleaner biotechnology) and documented studies where benefits have been received;**
- **Technology Roadmapping**
- **Development of a plan of work (including pilot projects, development of strategic alliances, business case development, and international collaboration)**
- **More focused consultations, with industry, the research community, and the public**

IMPETUS FOR THIS WORKSHOP

- **Increasing public concern in Canada on deterioration of environment and resultant pressures on industry**
- **Gradual industry responses in modifying existing processes / creating new processes for cleaner production**
- **Potential for biobased products and processes as key tools in the cleaner production “arsenal”**
- **Current “ecological footprint” of selected Canadian industrial sectors**
- **Recent empirical data PERD project and from OECD (augmented by excellence of Japanese, US and APEC research) on selected industrial bioprocesses R & D**
- **Potential of extrapolation from successful international experiences to Canada situation**

**KEY FACTOR AFFECTING RATE OF BIOPROCESS
DEVELOPMENT / INTEGRATION INTO MAINSTREAM
CANADIAN INDUSTRY**

“Our collective ability to identify steps necessary to demonstrate capability of biobased systems to make large, reliable, immediate, and sustainable contributions to reductions in energy demand at competitive costs with minimum environmental disruption”

SUGGESTED QUESTIONS FOR BIOPROCESS OPPORTUNITY / CHALLENGE AGENDA FOR GOVERNMENT / INDUSTRY (1)

- **Market opportunity-do markets exist and can they be created and be made to be sustainable?**
- **Impact of successful commercialization - will impact be high enough to overcome likely industry reluctance?**
- **Competitive strengths - do Canada's and industry's strengths match factors likely to be important in the future?**
- **Receptor capacity- is it / will it be there?**
- **Strength of Canada's S & T Capacity - do we need to reorient / tweak our current S & T focus?**
- **Synergy across sectors - is there potential to leverage successful results from one sector to another?**

SUGGESTED QUESTIONS FOR BIOPROCESS OPPORTUNITY / CHALLENGE AGENDA FOR GOVERNMENT / INDUSTRY(2)

- **Are bioprocesses too “new and unproven” under representative Canadian conditions?**
- **Are benefits to “conjectural and uncertain” in terms of products and implications for manufacturing?**
- **Are the bioprocessing techniques to “unfamiliar” to management, process engineers, and facility operators?**
- **Is there perceived “high risk” in terms of public and regulatory acceptance?**
- **Are bioprocesses “uneconomic” considering all risk and market factors**