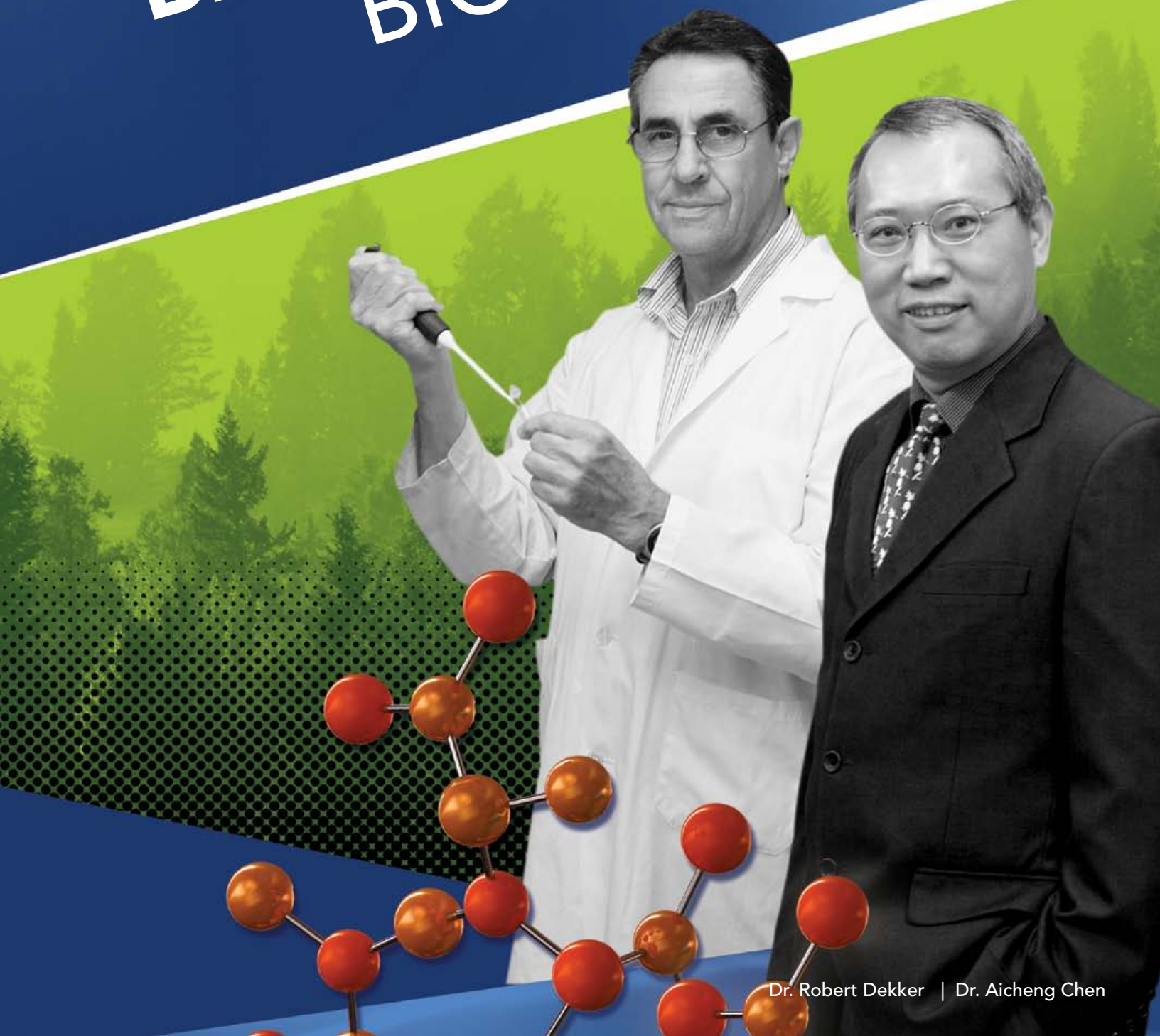
Lakehead
UNIVERSITY

RESEARCH & INNOVATION

# BIOREFINING & BIOPRODUCTS



Dr. Robert Dekker | Dr. Aicheng Chen

Lakehead University is situated in the boreal forest, one of the greatest storehouses of accessible biomass on Earth.

# CREATING THE FUTURE NOW

Using various techniques and processes, biorefining converts plant material into many of the valuable products that are currently derived from non-renewable fossil fuel. These include: bio-fuels (bioethanol and biomethane), bio-materials (fibers, pulp for paper manufacture), and a host of bio-chemicals through downstream fermentation and refining.

Biorefining is a multidisciplinary science that draws upon biology, chemistry, forestry, bioengineering, mathematics, and physics. Its three distinct streams of research activity include: biological conversion, chemical conversion, and natural bioproducts.

Lakehead University's Biorefining Research Initiative (BRI) is developing these techniques and products that will lead to commercial opportunities, and will advance the developing bio-economy. A forest-based bioproducts industry will enhance existing uses of the boreal forest while reducing waste and minimizing pollution.

## TURNING WASTE into wealth

There is black gold in the forests of Northern Ontario – in the form of plant lignin. Research led by Lakehead University's Dr. Aicheng Chen is finding ways of using this lignin in the production of tire rubber.

Millions of rubber tires are produced each year, and a key component of this rubber is carbon black. Carbon black gives the rubber its strength and pigment, and helps reduce thermal damage to the tread and steel belts.

Carbon black currently comes from crude oil, but Dr. Chen believes he has found a better solution. He and his team are using plant lignin to create a direct replacement for carbon black. This will allow Canadian pulp mills to supply the global rubber market with a high-value product that is environmentally friendly and economically beneficial.

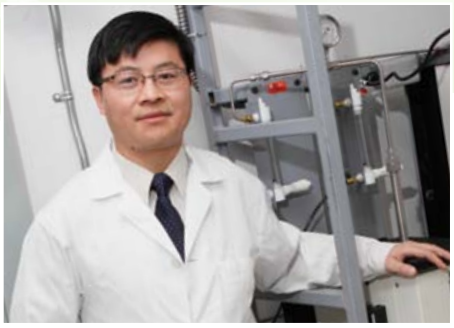
Using electrochemical and photochemical approaches, Dr. Chen is modifying lignin to improve its binding characteristics within the rubber matrix. The challenge is to reproduce the desirable qualities of carbon black, while maintaining lignin's innate beneficial characteristics.

Dr. Chen is an Associate Professor of Chemistry, and holds the Canada Research Chair in Material and Environmental Chemistry.

This project is supported by a Natural Sciences and Engineering Research Council of Canada (NSERC) strategic grant, AbitibiBowater, FPInnovations and Goodyear.

Dr. Aicheng Chen
*Department of Chemistry*

# BIOREFINING RESEARCH AND TECHNOLOGIES ARE REVOLUTIONIZING THE FOREST INDUSTRY — LAKEHEAD IS LEADING THE WAY



## BUILDING THE green economy

Two pathways lead to chemical products in a biorefinery, bioconversion, and thermochemical conversion. Bioconversion – the sugar platform to biofuels like bioethanol – is an area that Dr. Robert Dekker has focused his research on during the last 40 years.

Steps leading to bioethanol production first involves pretreatment of plant biomass (forest and agricultural residues). This is followed by enzymatic saccharification of cellulose, and the subsequent fermentation of the hydrolysis sugars into ethanol.

A successful pretreatment process is steam explosion. This exposes plant biomass fibres to high-pressure steam, which is then explosively discharged to atmospheric pressure. This process also brings about their separation into the constituent components: cellulose, hemicellulose, and lignin, which allows their conversion to value-added chemicals that can replace those presently produced from crude petroleum.

Dr. Dekker is answering this call through his innovative research at Lakehead University's Biorefining Research Initiative (BRI), where he is the Founding Scientific Director and Ontario Research Chair in Biorefining.

Ultimately, Dr. Dekker expects this process will lead to the development of a Biorefinery and greatly expanded value-added uses of Canada's vast boreal forest. Recently, he was awarded a NSERC-CRD grant to explore lignin modification using the biological approach to complement chemical modifications of lignin for polymer applications. This work is supported by the Natural Sciences and Engineering Research Council of Canada (NSERC), FedNor, and the Northern Ontario Heritage Fund Corporation (NOHFC).

Dr. Robert Dekker
*Biorefining Research Initiative*

## LEARNING from nature

A winter walk in the forest is not only good for the soul, it is also good for science – at least if you are Dr. Wensheng Qin.

As a recent immigrant to Northwestern Ontario, Dr. Qin was fascinated to see forest fungi happily digesting plants and trees. This seemingly simple thing is actually a difficult chemical task. This crystallized his idea to create a "super" microorganism – one that can more efficiently break down the tough parts of plants known as lignin.

Using various enzymes produced from certain microorganisms, researchers like Dr. Qin are able to degrade lignin. But to make this commercially viable, enzyme production must be improved.

Dr. Qin's research is attempting to learn from Nature by genetically modifying existing lignin-degrading microorganisms. The goal is to create "super" microorganisms that will produce more efficient enzymes, at much greater volume.

Dr. Qin holds an Ontario Research Chair in Biorefining and is an investigator with Lakehead University's Biorefining Research Initiative.

This research is supported by grants from the Natural Sciences and Engineering Research Council of Canada (NSERC), FedNor, and the Northern Ontario Heritage Fund Corporation (NOHFC).

Dr. Wensheng Qin
*Biorefining Research Initiative*

## CREATING BIO-RESINS from trees

Lignin is a complex carbon molecule that makes up the cell walls of trees and rigid plants. It accounts for 30% of a typical tree, but is currently treated as a waste product of the pulping process.

Now, thanks to leading-edge science being done through Lakehead University's Biorefining Research Initiative (BRI), lignin is being turned from waste into wealth. Instead of simply burning it for heat, researchers are finding new ways to refine lignin into valuable industrial chemicals and products.

Dr. Charles Xu is an Associate Professor of Chemical Engineering, Director of the Green Energy Laboratory at Lakehead, and an active member of the BRI. His work focuses on converting lignin into phenol, and ultimately phenol-formaldehyde resins.

These resins are used in many products such as plywood and particle board. The resins are currently derived from petroleum, making them increasingly expensive.

Using thermal-chemical processes, Dr. Xu and his team can replace up to 50% of the petrochemical phenol with this new biophenol. Dr. Xu expects to reach 100% through this research.

Dr. Xu's work is supported by both the federal and provincial governments, the Ontario Ministry of Agriculture, Food and Rural Affairs, the Northern Ontario Heritage Fund Corporation (NOHFC), and FedNor.

Dr. Charles Xu
*Department of Chemical Engineering*

# LAKEHEAD UNIVERSITY IS POSITIONED TO BE A BIOREFINING LEADER

## The Lakehead Advantage

- 4 Research Chairs, and growing
- $6 Million in seed funding
- State-of-the-art scientific facilities
- Well-established interdisciplinary strengths in forestry, green research, and industry collaborations

*Architect rendering of the proposed BioFor Research Facility*

## WHOLE-TREE mapping

If the current forestry economy is built on optimal tree growth and efficient industrial production, then the emerging bio-economy is being built on knowledge.

Lakehead University's forestry researchers are expanding this knowledge base through the development of new and innovative tree-mapping techniques.

Led by Dr. Reino Pulkki and Dr. Mathew Leitch, Lakehead's forestry researchers are developing ways to map a whole tree, much like the different cuts of beef are plotted to a bovine carcass. This allows the most appropriate sections to be allocated to the most suitable applications, be they solid wood products, composite materials, or feedstock for biorefining.

By providing a detailed analysis of the physical, mechanical, thermal, and bioproduct potential of each part of a tree, Drs. Pulkki and Leitch expect to greatly increase the efficiency of the forest industry. With this information in hand, forest planners and managers can easily and efficiently direct different parts of a given tree to the most effective uses.

This research is being supported by the Natural Sciences and Engineering Research Council of Canada (NSERC), Ontario Ministry of Natural Resources, Ontario Ministry of Northern Development and Mines, and FedNor, as well as by industry partners AbitibiBowater Ltd. and Buchanan Forest Products.

Dr. Reino Pulkki
*Faculty of Forestry and the Forest Environment*

Dr. Mathew Leitch
*Faculty of Forestry and the Forest Environment*

## OPTIMIZING THE NEW bio-economy

Imagine a computer program that cannot only maximize present production and sales of forestry products, but can also predict future demand for a multitude of bioproducts anywhere in the world.

Imagine a tool that helps forest companies integrate and optimize biomass growth with storage, transportation, final markets, and product delivery.

Imagine no more. Dr. Chander Shahi and his team at Lakehead University are developing this computerized decision-making tool.

As part of the University's Biorefining Research Initiative, Dr. Shahi is bringing the power of modern economics to Northern Ontario's evolving bio-economy.

Using Dr. Shahi's multi-variable computer model, the entire supply chain, from raw materials right through to final consumption, will be examined. Global markets will be identified and production will be optimized to meet this demand.

Ultimately Dr. Shahi expects the models to become sophisticated enough to be able to predict future bioproduct demand anywhere in the world. This will allow Northern Ontario's forest industry to make long-term decisions based on predictable market demands. Dr. Shahi's research is supported by the Ontario Centres of Excellence and the Social Sciences and Humanities Research Council of Canada (SSHRC).

Dr. Chander Shahi
*Faculty of Forestry and the Forest Environment*

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