



*2004-05 Research Activities
from the Office of the Vice President for Research*





President

America's place in the global economy, the security of our nation and the quality of life of our people all depend on the creation of new knowledge through basic research. The growth of our research capacity is one of the pillars of Purdue's strategic plan. We are committed to increasing support for research, to providing the facilities and re-

sources to keep the University a world leader and to broadening our interdisciplinary efforts. Purdue also is determined to facilitate the transfer of new knowledge to the marketplace in order to create new economic opportunities in Indiana. Research efforts are important not only to the University, the state and the nation, but also to our students. Many of them are directly involved in these exciting initiatives, and all students benefit from being in an environment that is energized by these highly creative endeavors. Excellence in research is essential to the greatness of our University.

— Martin C. Jischke, President



Provost

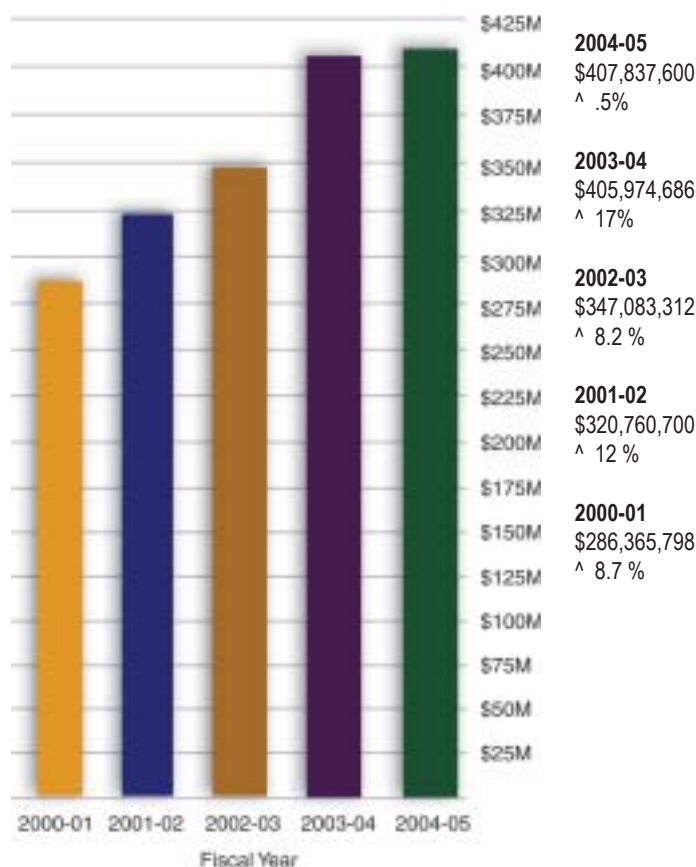
The natural evolution of discovery at Purdue University has included building new facilities, increasing our overall infrastructure, hiring a wide range of new, very talented faculty, and engaging more and more of our students, both graduate and undergraduate in the discovery process.

The pace of activity here at Purdue has increased substantially over the past four years, and that is intentional. We're proud of the role we're playing in helping rebuild the Indiana economy, and I'm especially proud of the initiatives we are undertaking in the Discovery Park. Great colleagues and outstanding students are impacting our abilities to conduct basic and applied research in very positive ways. They bring a creative and entrepreneurial spirit that will continue to drive Purdue forward in the coming years.

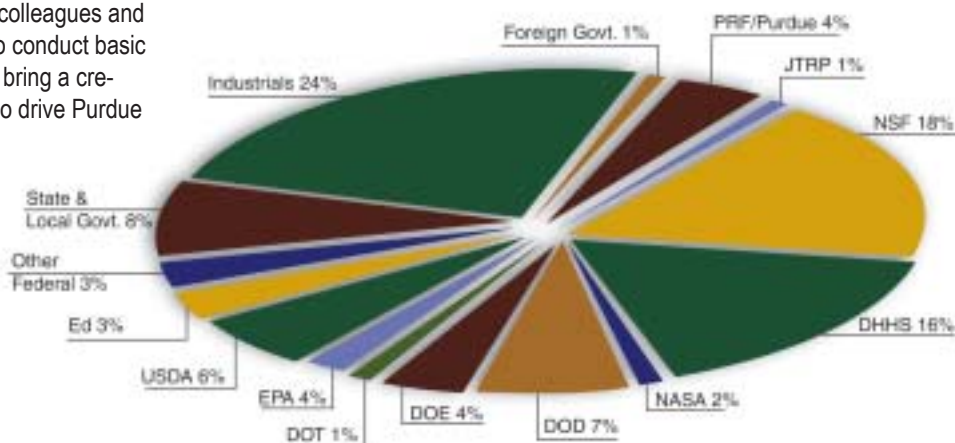
— Sally Mason, Provost

2004-05 Research Expenditures

Systemwide Research Expenditures



Sources of Research Funding by Sponsor





Vice President for Research

Researchers at Purdue University have been productive in efforts to address many of the challenges confronting today's society and to advance the boundaries of discovery. Purdue's sponsored program awards exceeded all expectations with an increase of more than 20 percent in the total dollar value of awards received during FY 2004-2005.

This year's annual report highlights some of Purdue's research in energy — what many consider to be the “grand challenge” confronting our world today — and introduces the newly formed Energy Center in Discovery Park where energy-related technologies move toward commercialization. A \$2.5 million investment to establish the Energy Center, from the \$25 million Lilly Endowment for Discovery Park, has in less than six months already garnered nearly \$5 million in research funding.

New discoveries in energy resources require vital partnerships between industry, government and research institutions. At Purdue, these partnerships are producing innovations in areas of combustion engineering, new catalyst designs that promote desirable chemical reactions for a cleaner environment, and nanotechnology-based enhancements of solar cells.

Researchers specializing in energy-related topics are spread across Purdue's campuses. Our colleges are actively seeking answers to grid security and transmission control, researching clean coal technologies that could reduce emissions to near-zero, and analyzing new technology acceptance and public awareness. The multidisciplinary framework of the new Energy Center brings together these scientists, engineers, political scientists, and economists in new levels of collaboration that will result in more efficient use of our natural resources.

Partnerships are the cornerstone of the successful research endeavors happening at Purdue today. We look forward to increased opportunities in collaboration that inspire students and researchers to seek solutions to the challenges we face together.

— Charles O. Rutledge, Vice President for Research

*Energy —
the grand challenge.
Petroleum and natural gas
supplies may peak in this
century and their use is
challenged by global warming,
environmental and geopolitical
considerations.*

*This challenge offers us
an opportunity to build
partnerships between
academia, industry, and
government that are focused on
finding energy solutions that
will assist in the transition from
conventional fossil fuels
to renewable and clean
fuel sources.*

Jay Gore,
Interim Director of Purdue's
Discovery Park Energy Center



Research in renewable *Bio Energy*



A new, more effective strain of yeast developed in Purdue's Laboratory for Renewable Resource Engineering (LORRE) generates 40 percent more ethanol from agricultural waste. Nancy Ho, senior research scientist and leader of the molecular genetics group, developed this yeast strain for converting corn waste to ethanol, and Purdue has issued the first license for the yeast to the biotechnology company, logen Corp.

logen obtained a non-exclusive license from the Purdue Research Foundation for the yeast and related patents. Its Ottawa, Canada, demonstration facility is the first plant in the world to produce ethanol from cellulosic materials. logen is using the Purdue yeast to produce ethanol from the sugars the company derives from wheat straw. An ethanol-gasoline blend can then be used as a fuel without any modifications to the vehicle.

"Also known as ethyl alcohol, ethanol can be used as fuel by itself or blended with gasoline. Ethanol is environmentally friendly and a cleaner fuel than gasoline," said Mike Ladisch, director of LORRE. "logen's efforts are beneficial to companies in Indiana and the U.S. by providing an industrial test bed ... hence, speeding its development for uses on a range of crops and crop residues."

Typically, ethanol is produced from food crops such as cane sugar, corn and other starch-rich grains. "These crops are expensive and in limited supply and are unable to yield sufficient amounts of ethanol for transportation needs," Ho said. "Cellulosic materials derived from agricultural residues such as corn or wheat stalks, however, are less expensive but more difficult to convert into ethanol."

Purdue's yeast strain is the first in the world to simultaneously ferment the two sugars,

glucose and xylose, found in these cellulosic materials. An added advantage of the yeast strains developed by Ho is that they are environmentally safe, based on the *Saccharomyces* yeast that is used in bread and wine making.

Another leader in the development of biofuels is Professor Bernard Tao, Purdue's named Indiana Soybean Board Professor in Soybean Utilization Research at Purdue University. The professorship was funded in partnership with the Indiana Soybean Board (ISB) to help create value-added products from soybeans through the Department of Agricultural and Biological Engineering.

"The use of renewable, domestic resources, such as soybeans, to replace petroleum fuels, chemicals and polymers can help national energy security and can also develop a new bio-based economy for Indiana," Tao said. "Soybeans are particularly promising due to their technical versatility and productivity as one of Indiana's largest cash crops."

Tao's research projects include making aviation jet fuel and home heating fuel from soybean oil, developing biodegradable coatings for food and industrial uses from soy proteins, creating inexpensive and environmentally safe airline de-icers, and developing laundry additives to improve fabric life.

"Our work is targeted at making Indiana a national center for bioprocessing technology and allowing industry to develop energy and industrial materials that utilize renewable, domestic sources such as soybeans," Tao said.

For more information, please visit these Web sites: <http://news.uns.purdue.edu/UNS/html4ever/2004/040628.Ho.ethanol.html>

<http://news.uns.purdue.edu/html3month/2004/040409.Tao.soybeans.html>

http://axe.agriculture.purdue.edu/agricultures/past/spring2001/features/feature_01.html

energy sources at Purdue

Hydrogen Energy

In his 2003 State of the Union address, President Bush committed \$1.2 billion dollars towards developing hydrogen as a potential long-term energy resource when he announced the "hydrogen fuel initiative." A future economy using hydrogen as an energy source could someday power fuel cells for transportation, residential electricity, and industrial use. However, several technical challenges must be overcome in order to develop this proposed new hydrogen economy.

A report, *The Hydrogen Economy: Opportunities, Costs, Barriers and R&D Needs*, written by Purdue Professor Rakesh Agrawal, Exxon Mobile Corporation retired executive and Purdue alum Michael Ramage, and Martin Offutt from the National Research Council, details the technical challenges in the production, distribution and storage of hydrogen. The U.S. Department of Energy adopted several recommendations from the report.

To produce hydrogen, you must use energy to extract it from other compounds. Sustainable methods to produce hydrogen by using renewable sources such as solar cells, wind

power, or agricultural products are part of the research effort being carried out at Purdue. The transportation and storage of hydrogen also are a challenge because it is such a light weight gas. In addition, the fuel cells needed to convert hydrogen into

energy require the discovery of inexpensive catalysts and materials.

In 1962, Herbert C. Brown, professor and Nobel Laureate from Purdue, developed the first method to liberate hydrogen from Sodium Borohydride. This method continues to be the basis for most of the developments in this area. Today, Purdue Professor P.V. Ramachandran studies the controlled generation of hydrogen from Sodium Borohydride in the Herbert C. Brown Center for Borane Research. His research has attracted the attention and support of General Motors, who rates Purdue as one of the top three groups

in the world working to solve the challenges of a future hydrogen economy. Partnerships with industry play a vital role in today's university research efforts.

H.C. Brown's chemistry to extract hydrogen also has inspired a new method to produce hydrogen for fuel cells that will automatically recharge batteries in portable electronics. Devised by Professor Arvind Varma, research scientist Evgeny Shafirovich, and postdoctoral research associate Victor Diakov, the environmentally benign and credit card-sized cartridges contain the hydrogen-releasing material and could someday replace batteries. Their discovery was published in the December 1, 2005 issue of *Industry Week: Technologies of the Year*.

Purdue is developing provisional patents and a significant intellectual property portfolio in new hydrogen and fuel cell technologies.

Wind Energy

Professor Sandy Fleeter, an expert in turbine technology, works to develop high-efficiency wind turbines by incorporating the physics of unsteady aerodynamic phenomena to

improve the performance and decrease the noise of conventional wind-turbines.

The Department of Energy predicts that wind power will

provide more than 6 percent of U.S. electrical supply by 2020. Wind power could revitalize farms and rural communities by "double cropping" or leasing wind rights while continuing to grow crops at the base of the turbines. Discussions with Cinergy are underway to explore joint projects for creating wind turbines suited to Indiana's Class 3 and 4 winds.

Eager to support the targets of the 2005 Energy Policy Act, Fleeter says, "The wind farms you see out west are gigantic and too expensive for Indiana's wind. But our idea is to develop wind farm capabilities suitable

for Indiana, whose support structure is not so massive, with flexible airfoils that take advantage of unsteady flow phenomena."

Solar Energy

The development of highly efficient solar cells could be within reach in the next five-years. Purdue Professors Richard Schwartz and Jerry Woodall are part of a consortium of universities and corporate research teams to receive the largest award in history to date aimed at solar energy research. The goal is "to develop and produce 1,000 Very High Efficiency Solar Cell prototypes that are affordable and that operate at efficiencies of at least 50 percent."

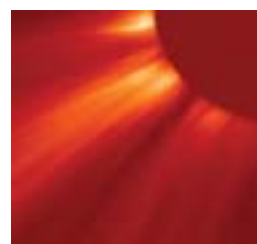
"When successfully completed, the Very High Efficiency Solar Cell technology will be a breakthrough in providing portable power to the soldier in the field," says Douglas Kirkpatrick, program manager for DARPA. Applications for residential and commercial rooftop solar cell systems could also be explored.

The Purdue research team will be involved in developing prototypes, modeling and simulation of the proposed new solar cell technology.

Schwartz, former dean of engineering at Purdue, is an expert in photovoltaic cells and has been conducting solar-energy research for over 40 years. He

has served as a consultant to a number of corporations and as the chairman of the Science and Technology Advisory Committee for the Department of Energy's National Renewable Energy Laboratory (NREL).

Woodall, a Purdue University distinguished professor, spent 31 years as a researcher in IBM labs, has been issued 67 U.S. patents, started three companies, and received a National Medal of Technology from George W. Bush in 2001 for his work on high-efficiency heterojunction cells. He is also a member of the National Academy of Engineering.



Discovery Park

Energy Center

The Energy Center is a multidisciplinary academic community of over 120 researchers, scientists, engineers and economists who together significantly contribute to the energy solutions that states, nations, and the world are currently seeking as we prepare for the eventual transition from fossil fuels to other energy sources.

Areas of Concentration

Social, Economic, and Political Aspects of Energy Use and Policy

Interpersonal communications, mass media, product cost and convenience all influence consumer's choices of energy-consuming and energy-generating products. Technology acceptance analysis will be performed at the same time new energy technologies are being developed.

Clean Coal Energy

A Coal Transformation Laboratory (CTL) will be established within the Energy Center and will focus on technology for converting coal into combustible gases and liquids that can be cleanly burned to meet the exploding demand for electric power, heating, and transportation.

Bio Energy

The Energy Center will assist with innovative research technologies that transform renewable plant materials into transportation fuels.

High Efficiency Wind Turbines

Current technologies for wind power are based on conventional propeller technology. The Energy Center will explore the development of innovative new wind-turbine technology that offers significant advantages over conventional designs.

Advanced Electrochemical Systems

Advanced electrochemical-based energy systems can significantly change the way we generate, store, and use energy. This project

will explore solar hydrogen, electrosynthesized materials, photo-bio-electro-chemical hydrogen generations, fermentation of biomass-based hydrogen production, and bio-fuel cells.

Electric Machines and Power Electronics

The Energy Center power electronics team will focus on creating the technology required to significantly reduce the cost of power electronics and electric machines. The team will also focus on developing tools that solve issues related to the integration of power electronics in large-scale systems. These projects have the potential to have a tremendous impact on U.S. power-transmission and delivery systems.

Hydrogen Energy Systems

The Energy Center will construct a vehicle-scale hydrogen storage and utilization laboratory that will be known as the Purdue Hydrogen Storage and Utilization Systems Laboratory. This lab will allow Purdue chemistry and chemical engineering researchers to study promising new technologies essential to the realization of the hydrogen economy.

Future Nuclear Energy

Purdue researchers are currently contributing to research on a breakthrough design concept for nuclear power plants known as Modular Boiling Water Reactor (MBWR). Nuclear reactors built using this technology are inherently safe and include built-in proliferation-resistant characteristics. The Energy Center will allow further research of this technology.

Solar Energy

Solar energy holds the promise of being inexhaustible. It also produces hydrogen without emitting greenhouse gases. The Energy Center solar team is researching novel solution chemistry processing routes that will enable the fabrication of low-cost, high-efficiency thin-film solar cells that can store energy.



Last October, Purdue dedicated the opening of the Birck Nanotechnology building in Discovery Park. Located on the west edge of campus, it is considered one of the best university facilities of its kind in the nation. The Birck Nanotechnology Building enables experts from a variety of disciplines to work side by side and discover solutions that will address the grand challenges of our times. Nanotechnology is an emerging science in which new materials and tiny structures are built atom-by-atom, or molecule-by-molecule. Nano is a prefix meaning one-billionth, a nanometer is one-billionth of a meter. New solar cell technologies and other energy-related technologies will likely be explored in the laboratories of the Birck Nanotechnology building.

Research Partnerships

Purdue is determined to be a leader in collaborative research and technology transfer. The Office of Industry Research and Technology Programs continues to explore new collaboration models to make these partnerships an optimum experience.

Some of the new or enhanced partnerships are: Indiana Advanced Aerospace Manufacturers Alliance, Raytheon (Fort Wayne and Indianapolis), Indiana National Guard, Med Ventures, Ethicon, Mueller Industries, Chemtura, Savannah River National Laboratories, and Delphi Delco Manufacturing. These partnerships are the result of our outreach efforts in homeland security, our response to partner's needs and Purdue's strong research reputation.

The four new Discovery Park Centers established last year are leading to several new collaborative opportunities. The Energy Center alone had over 40 companies provide letters of support. The State of Indiana provided a grant to get it initiated along with the resources from the Lilly Foundation and the federal government. Several companies are already collaborating in projects in hydrogen, wind energy and bio fuels. A gift was given to the Center to create a student intern program to help produce graduates for industry with knowledge in energy needs.

Indiana 21st Century Research and Technology Fund

With the advent of the Indiana Economic Development Council (IEDC), the Fund has made significant directional changes. The emphasis is now on helping small and start-up companies and less on break through/innovative research. Purdue is still in a great position to participate because of our broad industry contacts, reputation for collaboration, faculty with skills and resources and a willingness/desire to be a partner. The administration of the Fund expects Purdue to be a major participant.

Office of Technology Commercialization

2004-05 has been a highly successful year for the Purdue Research Foundation in the arena of technology commercialization. The Office of Technology Commercialization (OTC) continues to establish itself as a strong and committed partner to Purdue's efforts to become a preeminent technology transfer organization. The office has capitalized on the changes in personnel and practice that have resulted in an organization that is ready to take on the challenge of delivering on the President's vision of Purdue as an important driver of economic development and value for the State of Indiana.

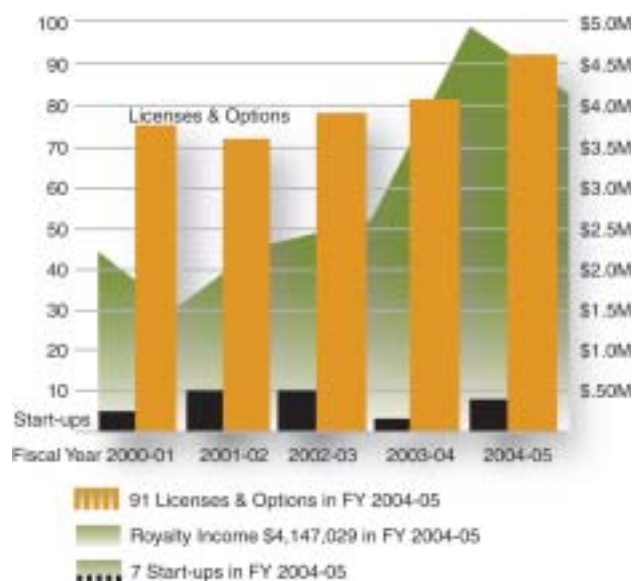
The office has reached or exceeded targets set in the strategic plan and is poised for a year of growth and positive impact.

Discovery to Commercialization

Energy related technologies under development:

- Soy Heating Oil
- BioBattery™
- Increasing Energy Coefficient of Animal Feed
- Energy Efficient Refrigeration and Heat Pump Systems
- Corn Processing for Ethanol Production
- Vegetable Oil as Residential Heating Fuel
- Cloud Point Depression of Soy Methyl Esters
- Ericsson Cycle Heat Pump
- Soy Aviation Fuel
- BioMass Pretreatment Heat Recovery System
- Catalytic and Recyclable Hydrogen (H₂) Production from Organic Silanes
- Chemical Mixtures for Hydrogen Generation by Combustion
- Integrated Biomass to Energy Converter
- Maize Germplasm for Improved Bioprocessing
- Solar-Thermionic Energy Conversion via Carbon Nanotube Arrays
- Synthesis of Amine-boranes, including Ammonia-borane

2004-2005 OTC Fiscal Year Summary



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This annual report is not intended to be a comprehensive summary of energy related research activities at Purdue University.

Purdue University News Service, Agriculture Communications, and the Engineering Communications Office contributed to this report.
Please visit the urls listed below for more information on research activities at Purdue.

<http://news.uns.purdue.edu/>
<http://www.agriculture.purdue.edu/agricultures/>
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