



UNIVERSITY OF
CALGARY

Energy Innovations for Today and Tomorrow

Energy Research Strategy
September 2013

Delivering safe, clean, secure energy supplies for the world

By 2035, with the global population reaching 8.5 billion people and assuming no change in patterns of energy use, the world will require energy at a level 1.5 times greater than in 2010. Meeting this demand is a daunting challenge and calls for innovative research if future generations are to enjoy sustained prosperity with minimal environmental impact, including dramatically reduced carbon emissions.

Through the implementation of a new and comprehensive Energy Research Strategy, the University of Calgary will take a leadership role in developing the next generation of energy innovations that the world so urgently needs.

The university has **significant capacity** to address the fundamental challenges associated with ensuring safe, clean and secure energy supplies. The university has made significant investments; we now count more than two hundred faculty members conducting research and training graduate students and postdoctoral fellows. We have created new research centres, developed infrastructure to support energy research and attracted some of the best minds in the energy field. We have the largest academic geosciences program in Canada, world-renowned expertise in chemical and petroleum engineering and some of the top scholars in the legal, economic and policy aspects of resource development.

The Energy Research Strategy will advance the area *Energy Innovations for Today and Tomorrow* of the university's Strategic Research Plan, which identified four research themes directly related to shaping our energy future. The themes are known collectively as **DEEP**:

- Discover new sources
- Extract with minimal environmental impact
- Export to markets
- Plan for the future

A set of four **Grand Challenges** cut across these themes and draw on disciplinary and interdisciplinary strengths at the university:

- Unconventional hydrocarbon resources
- Hydraulic fracturing
- Toward low-carbon energy
- Cumulative effects of energy-related processes

A **'confederation of scholars'** will leverage interdisciplinary collaboration to advance research on both local and global scales. The university will provide \$1 million in matching funds to assist these scholars in developing partnerships and competing for external funds. The university will also recruit over 30 new assistant professors, postdoctoral scholars and research chairs to work on priority energy research topics. A further \$1 million from external sources will be used to fund activities to **build research collaborations and share our research outcomes** with our community.

The University of Calgary's Energy Research Strategy will deliver world-leading research results and technological innovation to achieve lasting economic and environmental benefits for Canada.

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The University of Calgary is strategically located at the core of Canada's multi-billion-dollar energy industry.

Building a global hub for energy innovation

Canada is a leader in secure and sustainable energy supply, use, and innovation. The energy sector accounts for 6.9% of the country's GDP and 25.4% of export trade revenue (\$113.7 billion)¹. It is the world's sixth-largest producer of oil, the third-largest producer of natural gas and hydro-generated power, and the second-largest producer of uranium. Canada counts more than 75% of its power generation as 'non-emitting' and offers immense renewable and clean-energy potential.²

The province of **Alberta** is Canada's energy hub, with the sector employing nearly one in every six workers.³ Energy revenues from crude oil, natural gas, coal, hydro, wind and biomass accounted for 73% of provincial exports in 2011 (or 27.6% of provincial GDP).⁴ As a leader in technology and research on oil sands and heavy oil, Alberta is at the forefront of technologies such as gasification, upgrading, carbon capture and storage, enhanced recovery, water use, tailings management and alternative energy. Alberta's oil sands position Canada third behind Venezuela and Saudi Arabia in terms of global oil reserves.⁵ Our researchers, entrepreneurs, and businesses are setting international standards for reducing environmental impacts and supporting the development of greener communities.⁶

The city of **Calgary** boasts one of the top-performing economies in North America and hosts the head offices of nearly every major oil and gas company in the country as well as the sector's major trade associations and Canada's national energy regulator—the National Energy Board. This concentration of industry makes Calgary a global leader in project design, exploration, production, finance, processing, transportation, marketing and management. The city is also a globally recognized centre for financing, designing, constructing and operating affordable, sustainable and renewable sources of energy.⁷

The **University of Calgary** is located at the core of the energy industry of Canada, benefiting from unparalleled access to corporations, decision-makers and technology receptors. This access gives rise to a unique opportunity and responsibility for our university to be the leader in Canada—and one of the few leaders in the world—in high-impact energy research.⁸

¹ Canadian Energy Overview 2011: Energy Briefing Note (National Energy Board website)

² Natural Resources Canada

³ Government of Alberta

⁴ Canadian Centre for Energy Information

⁵ Oil & Gas Journal, Dec 2012

⁶ Government of Alberta

⁷ Calgary Economic Development

⁸ University of Calgary Strategic Research Plan, 2012

Matching our strengths with opportunities

For over three decades, the University of Calgary has been transforming heavy-oil and oil-sands research by contributing to a ground-breaking process. The steam-assisted gravity drainage (SAGD) process allowed industry to unlock 170 billion barrels of *in situ* bitumen reserves from previously inaccessible Athabasca reservoirs.

The university's role in helping to develop SAGD technology led a paradigm shift in the industry, resulting in a new understanding of heavy oil and oil sands physical operations. Today, the University of Calgary is embracing the opportunity to lead the next great energy innovations.

The primary goal of our energy research conducted by our faculty, staff, and students is to advance knowledge creation, applications, and translation to address major energy system challenges. Our research will help ensure an energy future that balances supply and demand, in a context of responsible resource development that addresses social, human, environmental and economic constraints. The magnitude of the challenges is enormous and we will be global research leaders in key areas where we have the capacity to make significant advances.

Our research tackles critical questions about global energy supply and demand, and addresses issues that are of direct relevance to the local communities that we serve and lead, by examining energy and its impact from the points of view of technology innovation, influence on and by human systems, and the environment and ecosystems.

This Energy Research Strategy aims to deliver world-leading research results and technological innovations to support the necessary shift to sustainable economic energy production globally, and providing substantial economic and environmental benefits to Canada.

The university has tremendous capacity to address the fundamental challenges associated with ensuring safe and secure energy supplies while safeguarding our environments.

We count more than 200 faculty members who conduct energy research and train more than 550 graduate students and 40 postdoctoral fellows, as well as select undergraduate students. We have invested in and raised funds for the creation of new research centres, the development of infrastructure and space related to energy research, and the attraction of the best minds in the energy field.

Our university has a high concentration of professors and chairs working within energy-relevant disciplines. We support more than 30 externally funded chairs in disciplines such as pipeline engineering, petroleum microbiology, heavy oil, unconventional gas and light oil, alternative energy, natural resource law, and public policy. This commitment has resulted in the successful generation of new research programs.

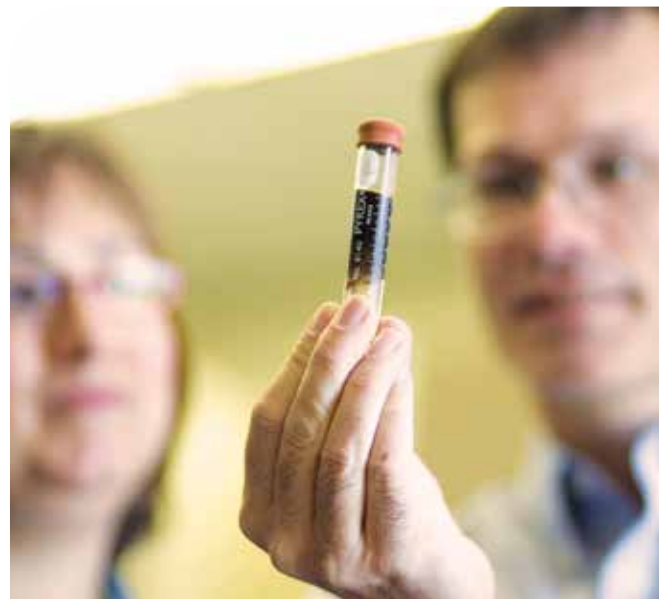
The university's significant investment in energy-related graduate-student programs has resulted in increased enrollment over the past five years. More than 80 students now graduate each year from heavy oil and oil sands research programs—the largest such cohort worldwide. Our geosciences program is the largest in Canada and our expertise in chemical and petroleum engineering is world-renowned. We have some of the best legal scholars, economists, and policy analysts in the resource sector. In addition, we are committed to increasing our

WE
COUNT
MORE
THAN **200**
FACULTY
MEMBERS

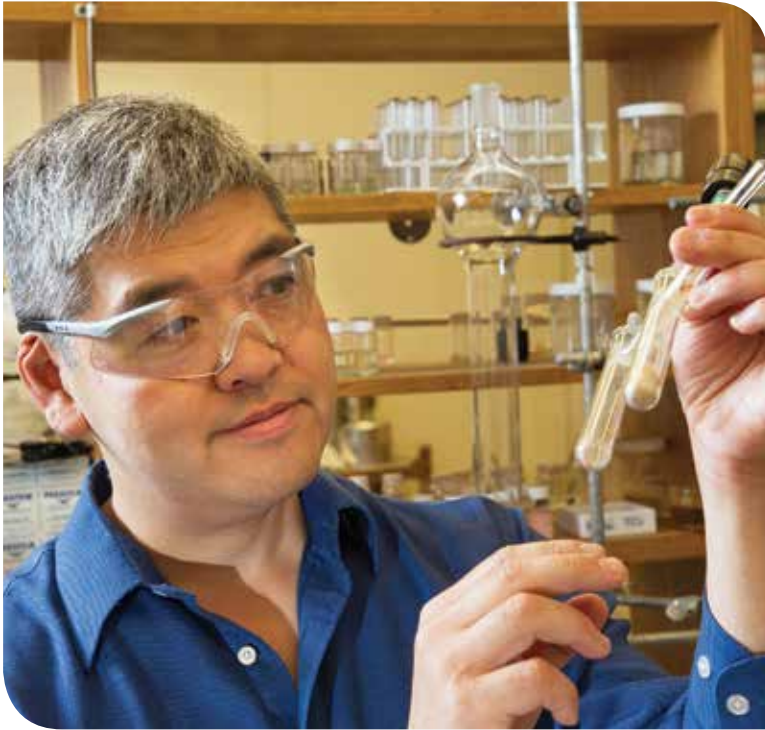
IN ENERGY RESEARCH
WHO RESEARCH + TRAIN MORE THAN

550 + **40**
GRADUATE **POSTDOCTORAL**
STUDENTS **FELLOWS**

+ SELECT UNDERGRADUATE STUDENTS



Our primary goal is to advance knowledge creation, applications, and translation that will address major energy system challenges.



The University of Calgary supports more than 20 institutes, centres and groups in key areas of energy technology and policy research.

research capacity by recruiting new assistant professors and postdoctoral scholars in energy-related disciplines.

Energy research at the University of Calgary is strengthened through many research centres and institutes, partnership institutes, and through participation in networks of centres of excellence and other strategic networks. Currently the university supports more than 20 institutes, centres and groups in key areas of energy technology and policy research. These structures greatly enhance the success of interdisciplinary approaches to the solution of research problems and to the understanding of complex phenomena. They also ensure that the quality and impact of the research is at the highest possible levels.

The University of Calgary continues to create and transfer technology. In the last five years alone, researchers have generated several spin-off companies and have been issued more than 50 oil sands recovery patents. Several formal collaborations exist with industry, private and public organizations in various areas of energy research. Our new strategy includes vehicles to expand industry and academic partnerships.

Our university takes pride in and rewards the quality of individual scholarship, and encourages diversity of approach and thought. Disciplinary strength and depth are essential for our success as an institution on the international stage.

Research as fuel for energy transition

Energy cannot be created or destroyed, only transformed to fuel our needs. Production of energy, through transformation of resources (whether renewable or non-renewable), consumes energy and materials, and the by-products of these transformation processes enter the environment with potentially harmful effects.

Economic factors, such as cost, price and markets are at the forefront of many policy and investment decisions and play a large role in individual fuel choices and access to energy services.

Non-economic factors also influence energy systems, such as impacts on local populations and societal systems, urbanization, public health, rights of indigenous people, innovation and inter-generational equity.

Past energy transitions (for example from biomass to coal, and from coal to petroleum) involved complex interactions of innovation, economic and social drivers, and impacts on the environment and quality of life. The future transition to low-carbon and renewable energy is likely to present similar or greater challenges and to require insightful research.

Partnering on key energy research

Alberta Sulphur Research Ltd.

This not-for-profit research organization is affiliated with the Department of Chemistry at the University of Calgary and conducts research in the science and technology of sulphur and its compounds, with particular emphasis on the production, processing and utilization of sour natural gas, sour crude oils, oil sands and related products. ASRL is in its 50th year of operation and is supported by a cross-section of companies from the energy sector and sulphur production/supply businesses from North America, Europe, the Middle East and Asia. chem.ucalgary.ca/asr



Pipeline Engineering Centre

The Pipeline Engineering Centre at the Schulich School of Engineering leads the advancement of knowledge in pipeline engineering to meet the needs of the domestic and global pipeline industry through a broad multidisciplinary approach. The centre is active in education and research that crosses all departments in the engineering school, including civil, chemical, mechanical, geomatics and electrical engineering. It works collaboratively with industry regionally and internationally to provide training and technology transfer that solves problems and advances the industry. The centre is a leader in pipeline integrity, maintenance, and management; new pipeline technologies; and project management.

The Pipeline Engineering Centre develops collaborative research initiatives, coordinates

research, and builds research infrastructure, all with links to industry at both the national and international level. Research areas include:

- Creating improved algorithms for data processing
- Multi-phase flow
- Improvements in safety and environmental control
- Integrity management
- Hydrogen transmission
- Carbon dioxide transmission
- Efficiency in fluid and gas pipeline flow
- New coatings synthesis

schulich.ucalgary.ca/PEC

Canadian Energy Research Institute

This independent, not-for-profit research organization brings together industry, academia, and government to provide relevant, independent, objective economic research in energy and related environmental issues. The University of Calgary is one of the sponsor organizations—and the only university—represented on the board of directors.
ceri.ca



Canadian Institute of Resources Law at the University of Calgary

As the leading national centre of expertise on legal and policy issues related to Canada's natural resources, the Canadian Institute of Resources Law pursues a mandate of research, education and publication. The institute initiates projects and responds to requests from the public and private sectors and from non-governmental organizations. ucalgary.ca/cirl

Carbon Management Canada Inc.

This national network is working to find commercially feasible ways to address carbon management challenges in the fossil energy, renewable fuels, chemical, cement, mining and metallurgical processing industries. CMC, which is hosted at the University of Calgary, has committed \$22 million to 44 research projects across Canada and funds 30 researchers at the university.

cmcghg.com



School of Public Policy at the University of Calgary

Supported by more than 100 academics and researchers, the work of the School of Public Policy and its students contributes to a more meaningful and informed public debate on policy issues to improve Canada's and Alberta's economic and social performance. Under its energy and environmental policy portfolio, the school publishes practical, timely research in the areas of resource taxation, royalty analysis, regulation and sustainability. It also hosts numerous public events and roundtable discussions featuring world-class speakers with expertise in energy and environmental issues.

policyschool.ucalgary.ca





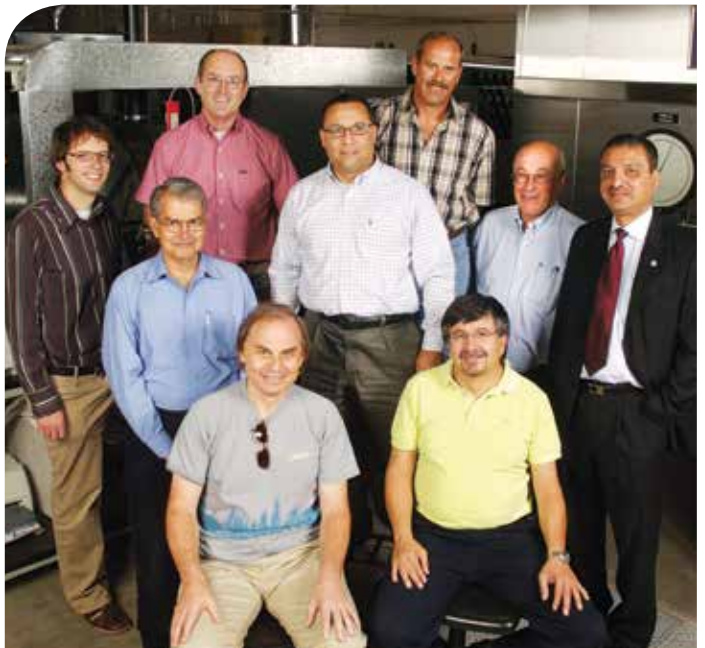
Creating a confederation of scholars

The complex problems around securing a safe and prosperous energy future require contributions from multiple disciplines to arrive at powerful, robust, and broadly applicable solutions. A major element of our Energy Research Strategy is the formation of a self-organized 'confederation of scholars' to generate interdisciplinary collaboration that can advance energy research on both local and global energy challenges.

We will support our scholars to engage in active discussions, energy roundtables, and national and international workshops and conferences. We will also fund major initiatives to help secure provincial, national, and international research grants, prizes, and awards.

Scholars will advance their own energy research agendas and build collaborative networks, taking advantage of funding opportunities from government, industry and other sources. The deliberate bottom-up approach inherent in the confederation of scholars, with strong support from the university, will promote a dynamic and productive research environment by fully engaging our researchers.

We believe this will provide a competitive advantage over the traditional faculty-centred research model.



Building on our research platforms

Our energy research will draw on and contribute to all of the seven platforms identified in our Strategic Research Plan:

Research stations: We are developing a new Geoscience Field Research Site (GFRS) that will be an international stage for research on carbon capture, CO₂ containment and monitoring. This platform will play a key role in several of the Grand Challenges.

Synthesis and visualization: Advances in many disciplines, using both qualitative and quantitative data, are limited by our abilities to synthesize these data and visualize them to aid our understanding. This platform will play a key role in all four themes as well as several Grand Challenges.

Analytics and simulation: We will support various decision frameworks and the development of alternative models for energy systems analysis that will be used to understand the impact of trade-offs, economic factors, and technological innovations on the whole energy system.

Research enablers: We will evaluate the contributions of research enablers to determine how they can be mobilized to support our energy research. Organizations such as the Enbridge Centre for Corporate Sustainability (at the Haskayne School of Business) will examine strategies that consider the social, economic, and environmental dimensions of business decisions and actions.

Commercialization: We will actively support the commercialization of new technology applications emerging from energy research projects.

Knowledge translation: We will translate and mobilize knowledge gleaned from energy research to help improve resource stewardship and public health.

Policy creation: The output from all of our energy research projects will provide essential evidence needed to inform public policy development and decision-making, and we will highlight new opportunities that will drive policy research.



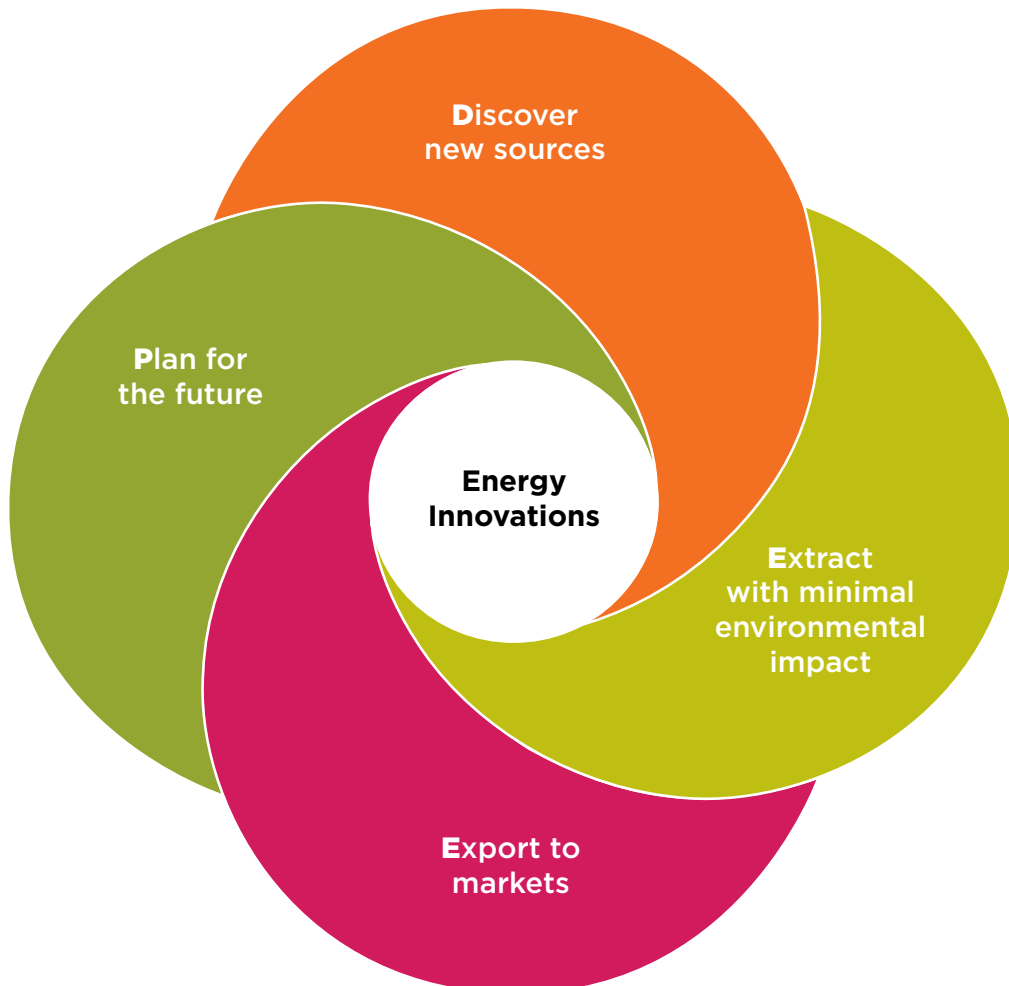
Getting 'DEEP' into energy research

Our Energy Research Strategy will advance the thematic area *Energy Innovations for Today and Tomorrow* of the university's Strategic Research Plan.⁸ We will focus on four research themes that directly relate to envisioning, understanding, influencing, and shaping our aspirational energy future.

The themes, known collectively as **DEEP**, cut across energy generation and use, and incorporate human and environmental dimensions. The university has a critical mass of researchers in

each of the four themes, and will draw on these disciplinary and interdisciplinary strengths to create new knowledge that will promote prosperity while demonstrating responsible environmental stewardship. Thematic teams from the confederation of scholars will seek solutions.

⁸ University of Calgary Strategic Research Plan:
<http://www.ucalgary.ca/vpr/files/vpr/StrategicResearchPlan2012.pdf>



D Discover new sources



Whether it is to find new or efficiently develop existing fossil resources or develop novel ways to produce green or alternative energy, the University of Calgary offers tremendous strengths that build on past accomplishments. Research teams with active industrial collaborations seek to understand the Earth's conventional and unconventional energy resources from the Arctic to the deep biosphere, encompassing disciplines including petroleum geology and engineering, geophysics, geochemistry, sedimentology, paleontology, hydrogeology, basin analysis, materials science, and biogeoscience.

In parallel, breakthroughs are being sought through green chemistry and engineering in renewable and alternative energy fields such as solar energy conversion, fuel cells, and hydrogen and CO₂ capture and storage.

E Extract with minimal environmental impact

Fossil energy extraction operations are of crucial importance to Alberta's economy. But many current approaches to extraction and conversion are not sustainable. Improved and game-changing extraction technologies are required to increase efficiency and reduce environmental footprint. Many University of Calgary researchers are tackling industrial and environmental challenges in the oil sands, *in situ* heavy oil, hydraulic fracturing, upgrading, shale gas, and tight oil; they are applying innovations from physics, chemistry, petroleum microbiology, metagenomics, and sensor and environmental monitoring technologies. Novel extraction processes are being advanced, such as *in situ* upgrading and smart steam-



assisted gravity drainage (SAGD) hybrids. A wide range of scientific approaches, from the water cycle to applied geochemistry, are being applied to the full monitoring of the environmental impact of the oil sands and other resource extraction activities. The potential from major advances in metagenomics and petroleum microbiology is being explored with the aim of realizing a step change in the environmental performance of energy extraction.

E Export to new markets



Canada is a major energy producer on the world stage and exports of energy products contribute significantly to national prosperity. Transportation of oil and gas to markets must be done safely, reliably and with minimal impact on the environment and local populations. The University of Calgary houses the Pipeline Engineering Centre and produces internationally recognized corrosion research instrumental to advancing

safe transportation technology. The business, policy and regulatory aspects of energy exports are complex and are evolving. University research groups in law, business and public policy investigate and analyze issues of current interest to inform the public and leaders in government and industry.

P Plan for the future



Our future will be deeply influenced by the energy choices we make today. Thoughtful analysis must consider more than specific resources or technologies, but the complete 'cradle-to-grave' energy system with full accounting of economic, social and environmental impacts. Engineering, social science, business and legal scholars at the university investigate the past and the present in order to better plan the future, using best

practices in energy systems analysis and life cycle assessment. Their research outcomes are sought by decision-makers in government and business to inform the strategies and policies that will shape tomorrow.



Addressing four Grand Challenges

We have identified four Grand Challenges, built on a foundation of significant existing or emerging research strength at the University of Calgary that will mobilize the confederation-of-scholars model to make major research advances over the next three to five years:

1 Unconventional Hydrocarbon Resources (UHRs)

UHRs are the future of the fossil fuel industry in North America and likely globally. A variety of resource types are classified as ‘unconventional’, including heavy oil and oil sands energy resources (HOOSER); unconventional gas (UG); and light-tight oil (LTO) and liquid-rich shale (LRS), which together are referred to as unconventional light oil (ULO). These resources are the priority exploitation targets in North America, with interest increasing globally—but not without controversy. What they have in common is that the hydrocarbon mobility in the reservoir is very low, requiring advanced, non-conventional petroleum extraction methods (e.g., hydraulic fracturing for UG/ULO, thermal stimulation for heavy oil) to increase fluid mobility in the reservoir to enable flow to the extraction point. Even with advanced technologies, hydrocarbon recovery is typically very low, and the impact of extraction and processing techniques on the environment can be great. Sustainability in unconventional resource development can only be achieved if environmental impacts are mitigated. The research programs at the university are therefore designed around improving understanding of resources, developing methods and technologies to increase recovery, and minimize environmental impact.

Of the UHRs, UG has the lowest carbon footprint and provides a promising transitional hydrocarbon-based fuel that could replace coal as the most prevalent energy source for power generation, while lowering CO₂ emissions. However, there are challenges related to expanding the market for gas, safely transporting it, and reducing the environmental and human impact of development. To increase recovery, we need to advance our understanding of fluid storage and transport processes, and improve hydraulic fracturing techniques. Furthermore, with the decline in conventional gas reserves in Canada, new sources

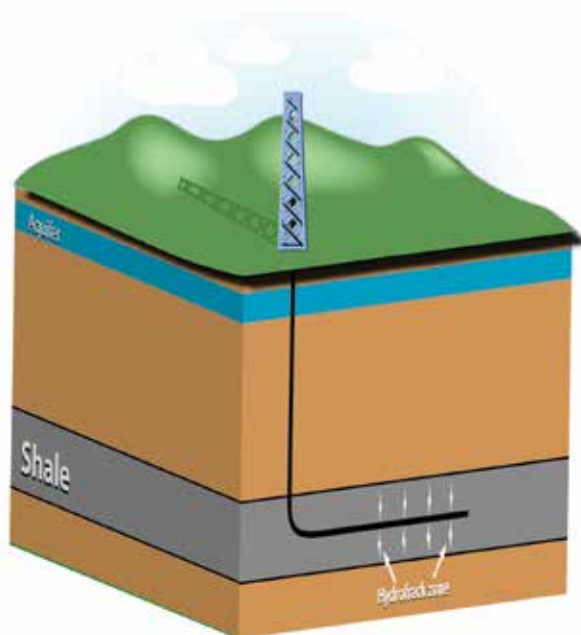
of UG must be found if it is to be effective as a transitional fuel, such as gas derived from microbial gasification of kerogen, coal, oil, and bitumen. Novel microbial routes for gas-to-liquid technologies are also potential game-changing solutions.

Key areas of investigation:

- Fundamentals of fluid flow and storage in UG/ULO reservoirs—analysis and development of predictive models
- Characterization of the subsurface—petroleum and groundwater system, including evaluation of reservoirs, source rocks and migration dynamics
- Characterization of the surface—impacts on ecosystems and communities
- Development of production analysis and reservoir simulation methods for UHRs to improve forecasting
- Improvement of existing recovery technologies
- Development of next-generation *in situ* technologies for recovery of currently inaccessible resources
- Development of new play and prospect techniques for UG/ULO
- New sources of UG and novel gas-to-liquid conversion strategies
- Evaluation of markets for UG including transportation and power generation
- Reduction of environmental footprint and enhancement of safety
- Improve efficiency in production and reduce costs, analysis of cost over-runs on major projects
- Regulatory framework, policy development, and engagement

2 Hydraulic fracturing

Hydraulic fracturing has been used for more than 50 years to accelerate hydrocarbon production and increase recovery. Now applied with horizontal wells and over large areas, this technology has enabled commercial production of oil and gas from low-permeability rock formations, changing the energy landscape in North America. Modern surveillance technology, such as micro-seismic monitoring, has revealed that hydraulic fractures, particularly in unconventional reservoirs, have complex geometries that are difficult to predict. While hydraulic fracturing is designed to maximize petroleum production from the target formation, the possibility does exist that some fractures may penetrate non-target zones and/or generate seismic events. This has raised concerns about contamination of shallow aquifers, emissions to the environment, land use, and well integrity and safety. As long as hydraulic fracturing continues to be an important enabling technology for resource development around the world, the urgency to address these concerns will grow. The University of Calgary is uniquely positioned to perform basic and applied research to address important scientific, environmental, economic and societal issues associated with hydraulic fracturing.



Key areas of investigation:

- Hydraulic fracture monitoring and characterization
- Hydraulic fracture design and optimization
- Assessment of the effects of hydraulic fracturing on water, atmosphere and terrestrial environment qualities
- Use of hydraulic fracturing to simultaneously enhance oil recovery and sequester CO₂ in the subsurface
- Comparison of Canadian play life cycles to those in the U.S.
- Development of new methods to forecast long-term production for hydraulically-fractured horizontal wells
- Water usage and recycling of water in hydraulic fracturing
- Improved assessment and monitoring of wellbore integrity pre- and post-hydraulic fracture
- Assessment of health risks to society and wildlife
- Legal and regulatory framework, disclosure requirements for fluid compositions
- Policy development and stakeholder relations: how to engage people in the decision-making process
- Development of new social science models to quantify the benefits and costs of hydraulic fracturing
- Business plan to export technology to U.S. and other nations with current or planned usage of hydraulic fracturing
- Communication strategies to explain scientific results to the public and education of the public in understanding technical risk

To successfully undertake the field-based research topics outlined above, a national field research facility will be established, ensuring a national and international profile for this research initiative.

3 Toward low carbon energy

Transformative changes are needed in Canadian and global energy systems to quickly and deeply cut greenhouse gas (GHG) emissions and thus to mitigate the risk for rapid climate change. Although fossil fuels will continue to be the primary source of energy for some time to come, there is a critical need for research to discover and prepare for the energy systems of the future.

Significant technology innovation is required to develop and deploy lower-carbon energy supplies, improve efficiency, and reduce CO₂ emissions from fossil-based supply. In addition, new technologies that promise to reduce environmental impacts from the energy sector also add complexity in the form of new economic, environmental and social trade-offs.

Researchers must not only develop new energy technologies that are carbon-neutral at competitive costs, but they must also aim at near-zero environmental/ecosystem impacts and develop more efficient systems for managing and integrating technologies and processes. Decisions about energy systems must focus on managing demand for energy services, hurdles associated with new entrants into entrenched energy markets, changing needs resulting from an aging energy infrastructure, and heightened concerns about social, cultural, and environmental risks. The University of Calgary is strategically positioned to carry out research that will move us toward low-carbon energy.

Key areas of investigation:

- Solar energy
- Wind energy
- Storage of renewable energy
- Biofuels
- Geothermal energy
- Technologies to enable low-carbon communities including building design and transportation
- Reducing CO₂ emissions from transitional hydrocarbon-based supply with CCS technologies
- New CO₂ utilization
- Research on geological storage of CO₂ and the Geoscience Field Research Site (GFRS)
- Novel carbon-capture and storage techniques
- CO₂ pipeline monitoring
- Energy efficiency and demand-side management
- System design, analysis and control
- Public policy and regulatory frameworks and public engagement



4 Cumulative effects of energy-related processes

Cumulative effects, defined as changes in or effects on natural, social, economic, and cultural environments caused by past, present and foreseeable future actions, are often used to describe any outcomes or effects of industrial development that accumulate and produce observable impacts on the environment and human health. Assessing, measuring, predicting and monitoring cumulative effects are increasingly required as components of regulatory approvals. Providing a sound analytical and scientific basis for such assessments and understanding the equity and intergenerational dimensions of decisions based on cumulative effects determinations is critical.



The University of Calgary harbours a network of research strengths relevant to the study of the cumulative effects of energy-related processes and emissions. Fundamental and applied research is required to enhance environmental sustainability of industrial processes, inform policy on energy production, and assure healthy ecosystems and populations. Since Alberta has a huge stake in fossil energy, cumulative effects research will focus on, but not be limited to, this form of energy.

Key areas of investigation:

- Risks of energy production and cumulative pollutant effects to human and ecosystem health, society and economy
- Economic and social costs of risk in the energy industry and translation into best business practices
- Effective communication of risk to aboriginal and other affected populations, the general public and regulators
- Ways to improve government and private decision-making by providing a better understanding of risk and associated trade-offs of technologies
- Use of life-cycle analysis in the energy industry to assess cumulative effects
- Development of sensors for use in populated and remote areas for air, land and water measurements
- Development of electrical-based and biological-based sensors
- Development of data collection software and integration databases for optimal assessment
- Advances in toxicity assessment
- How acquired data translate into corporate responsibility, legislation and engagement of affected populations
- Discovery of new technologies to mitigate risk/cumulative effects of energy production
- Development of novel and innovative contaminant-remediation technologies
- Development of novel pollution-prevention technologies and integration with monitoring
- How new remediation and pollution prevention technologies translate into legislation, regulation and social license to operate

Introduced in 2011, the University of Calgary's *Eyes High* strategic direction sets a clear direction to become one of Canada's top five research-intensive universities by 2016, grounded in innovative thinking and teaching, and fully integrated with the community of Calgary.

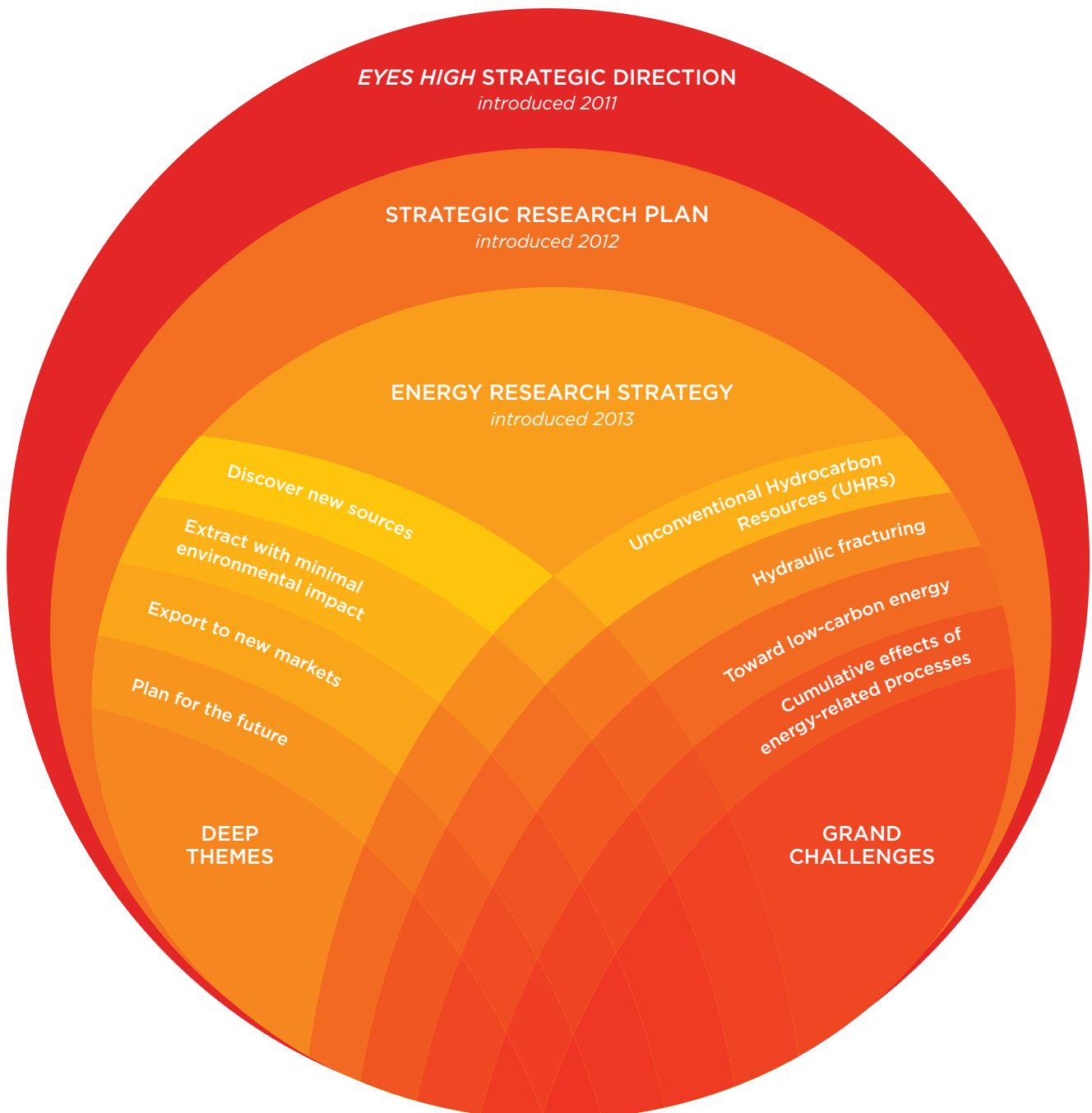


As one of the roadmaps that deliver on this direction, the Strategic Research Plan (introduced in 2012) is about inspiring and supporting discovery, creativity, and innovation across all disciplines. The plan focuses on three major priorities: matching our strengths with opportunities, increasing our research capacity, and creating a dynamic research environment to promote research excellence.



Energy Innovations for Today and Tomorrow is one of six multidisciplinary research themes that are guiding us towards our *Eyes High* goals. This Energy Research Strategy (developed in 2013 under the leadership of Ed McCauley, Vice-president, Research) details how we plan to deliver on that theme.

Ed McCauley, Vice-president, Research at the University of Calgary, is one of the world's foremost researchers in the field of population ecology.





Promoting commercialization and knowledge transfer

Engagement with all of our community stakeholders and partners is essential to ensure that recipients of our research output provide their perspectives on the Grand Challenges we are addressing. This engagement will also identify synergies in research and development activities across all partners.

Within our confederation of scholars, energy research teams will bring together faculty members with a range of disciplinary backgrounds to focus on questions that address the Grand Challenges. Knowledge transfer and commercialization will be key components in practically implementing the results of our research projects.

The University of Calgary will strongly support the energy research teams in building industry alliances and close partnerships with private and public organizations to assist in solving issues related to the Grand Challenges. The university will also engage with partner universities and research organizations—nationally and internationally—to access the most advanced knowledge and expertise on global issues.

Bringing research to market

University of Calgary researchers create and transfer technology, generating spin-off companies that deliver benefits to society as a whole. For example:

Gushor Inc., a Schlumberger company

Gushor was spun out of research conducted by the Canada Research Chair in Petroleum Geology and a team in the Department of Geoscience. It is a fluid analysis and reservoir engineering company that provides innovative geochemical and reservoir engineering solutions to practical production and exploration problems in the heavy oil and oilsands industry by integration of geology, fluid properties, geochemistry and reservoir simulation. gushor.com

Profero Energy Inc.

This oil-and-gas technology company's proprietary technology is based on biodegradation research by researchers at the University of Newcastle and the University of Calgary. Profero's technologies are designed to recover additional energy assets from existing heavy-oil wells that are no longer economically viable. The company is focused on recovering stranded heavy oil by microbially converting it to

natural gas. Profero's technology has the potential to significantly increase the recovery of heavy oil from reservoirs already fully exploited by conventional recovery methods. proferoenergy.com

nFluids Inc.

nFluids is leveraging the work of two university researchers who developed a proprietary nanoparticle oil and gas drilling fluid additive that reduces fluid losses during drilling, increases lubrication, and strengthens the well bore. These benefits allow operators to reduce the total energy requirements and cost of their drilling process, while also reducing the associated environmental impact. nfluids.com

FireWater Fuel Corp.

Firewater is advancing the hydrogen economy through a game-changing breakthrough in catalyst technology developed by two chemistry researchers. The company uses alternative energy sources such as solar and wind power to produce clean hydrogen fuels that can be used on-demand by consumers. fwfuel.com

Matching funds to advance energy research



As our scholars work together on the DEEP research themes and the Grand Challenges, they will seek major funding opportunities from provincial, national, and international sources. Competing successfully for these large grants requires support for grant development and liaison with industry partners and other post-secondary institutions. In 2013-2014, the university will provide \$1 million in matching funds to assist the confederation of scholars to compete for major external funds.

Support and expertise in identifying funding opportunities, defining research questions, developing partnerships and alliances, and preparing grant proposals will be provided through the Vice-President (Research) Office to ensure high rates of success in implementing these major initiatives. There will be an emphasis on developing new collaborative research opportunities with public- and private-sector partners. The overall objective is to increase the impact of research at the University of Calgary through the creation of strategic partnerships that foster innovation and facilitate knowledge transfer and commercialization.



Increasing our expertise and capacity

Based on the expertise of our faculty members, we have substantial research capacity already in place to tackle the four Grand Challenges:

Unconventional hydrocarbon resources:
152 faculty members / 24 research chairs

Hydraulic fracturing:
130 faculty members / 18 research chairs

Toward low-carbon energy:
122 faculty members / 17 research chairs

Cumulative effects of energy-related processes:
128 faculty members / 16 research chairs

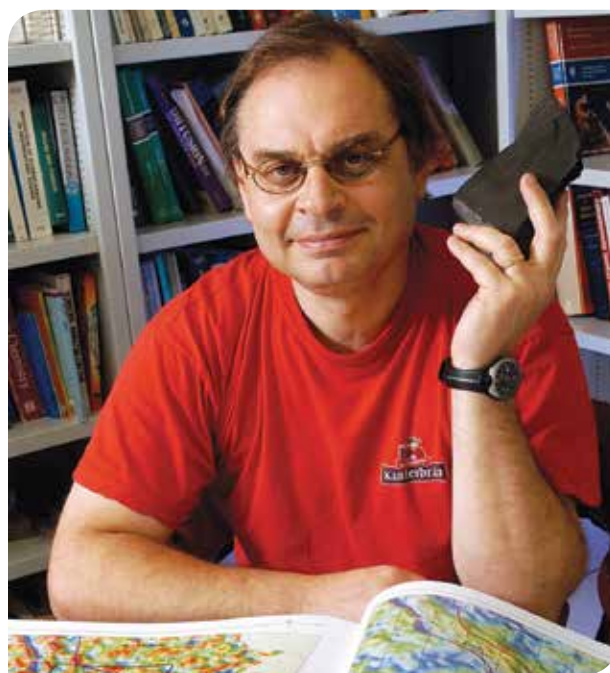
Over 2013-14, we will increase our energy research capacity in three ways:

- Recruit 10 new assistant professors in energy research, three in the area of pipeline engineering and seven in natural resource law, energy economics and policy.
- Recruit more than 20 postdoctoral scholars from around the world to join faculty members to work on and explore priority energy research topics.
- Increase the number of research chairs in energy via provincial and national programs.



Through the Campus Alberta Innovates Program (CAIP), we are recruiting two world experts in the area of metagenomics applied to energy research. The CAIP Chair and Professorship in the Faculty of Science will bolster our strength in petroleum microbiology and reservoir engineering. We are also recruiting two new Canada Research Chairs in Energy Research in the Schulich School of Engineering and the Faculty of Arts.

Finally, we are recruiting a Canada Excellence Research Chair (CERC) in new-materials engineering for unconventional oil research. As one of the most prestigious research awards in Canada, the CERC will be the nucleus of a dynamic research team, supported by new investments of over \$25 million that will integrate materials science, petroleum reservoir engineering, chemical engineering, and bioengineering to find transformative research breakthroughs and commercial opportunities not possible within any one discipline alone. The CERC will also engage the heavy oil industrial sector to explore and field-test new recovery solutions that minimize water use and environmental impacts.



Fully engaging our communities, building the confederation of scholars

The university has secured funding in excess of \$1 million for supporting activities that will foster networking and collaboration at the regional level, national and international levels, with the goal of establishing research and commercialization collaborations that will connect the university with industry, government and other external partners. These activities are framed within the University of Calgary's emerging new energy research strategy and the broader *Eyes High* strategy:

Research workshops: one-day research workshops during which participants will draft roadmaps for research and commercialization activities associated with each of the Grand Challenges. Each workshop will include researchers from the University of Calgary, invited researchers from across Canada, prominent researchers in each of the challenge areas, and experts from industry, government, and community partners.

International research conference: this two-day conference in Calgary will be framed on the Grand Challenges and will serve as a 'test bed' for the research roadmaps produced at each of

the preceding research workshops. Discussion panels will be comprised of local, national and international researchers and external experts drawn from industry, government and other partners in the community.

Research breakfasts: this 'Energy Leaders' breakfast series will take place on campus, encouraging collaboration and sharing amongst scholars who work across the disciplinary lines of energy and environment research. The focus will be on advances in research, especially in areas with demonstrated or potential commercialization activity.

Urban Energy and Environment Issues seminar series: this lunch-hour seminar series will take place at the university's downtown campus and will cover energy and environment issues of interest to people living in a large urban setting. The seminars, which support the Urban Alliance initiative (see below), will identify key considerations for each issue and stimulate dialogue among investigators and practitioners responsible for finding and implementing solutions.

Urban Alliance

The Urban Alliance is a research partnership between the City of Calgary and the University of Calgary. It was created to coordinate a seamless transfer of leading research between the city and the university for the benefit of all our communities.

Its focus is to deliver sustainable quality of life to Calgary and Alberta and is making real impacts on quality of life in Calgary, particularly in areas related to our Energy Research Strategy, including:

- Transportation systems optimization
- Urban energy footprint
- Urban form, density and social connectivity
- Alternate energy
- Greenhouse gas reduction in landfills
- Urban infrastructure investment planning for climate change

Distinguished speakers series: the university will host internationally recognized experts in globally important areas of energy and environment. This activity is an important way for the University of Calgary to give back and engage the public on globally important issues: each visit will include meetings, informal gatherings, public lectures, meals and receptions to facilitate interaction with members of the energy and environment community in Calgary.

Energy and Environmental Systems seminar series: this series of technical research talks on campus will take place throughout the 2013-14 academic year. Intended for specialized researchers in the energy and environment fields, with a primary focus on students and postdoctoral trainees, the series will provide them with professional development and engage them in research, while promoting collaboration and potential commercialization opportunities.

Communications tools: in addition to a suite of promotional materials, a new web space will showcase the progress of our energy research and related activities and provide a means of communication between researchers within the confederation of scholars and the external community.

Expert advice and assistance with commercialization: Innovate Calgary is a full-service organization offering technology transfer and business incubator services to researchers, entrepreneurs and businesses within the advanced technology sector. It is dedicated to accelerating the commercialization of emerging technologies, facilitating and supporting the creation of technology-based companies, and assisting in the growth of existing technology companies in southern Alberta. The university will contract Innovate Calgary to conduct a comprehensive evaluation of energy and environment research projects that have been completed or are in progress at the university, identifying opportunities for commercialization and providing guidance on how to protect intellectual property, license the technology, and/or create a related company.

Innovate Calgary

Innovate Calgary is a full-service organization that fosters the advancement of technology business for researchers, entrepreneurs, technology companies and investors within the advanced technology sector.

Innovate Calgary is the technology-transfer and business-incubation centre for the University of Calgary and works closely with the research services office and the office of the vice-president, research. It provides expert advice and assistance with:

- Intellectual property management/licensing
- Company creation and incubation
- Analysis of commercial potential for technologies
- Mitigation of financial and resource risks relative to commercialization
- Leasing/tenancy opportunities (Alastair Ross Technology Centre and the Research Transition Facility)
- Entrepreneur development services and programs

innovatecalgary.com



The University of Calgary is a leading Canadian university located in the nation's most enterprising city. The university has a clear strategic direction to become one of Canada's top five research universities by 2016, where research and innovative teaching go hand in hand, and where we fully engage the communities we both serve and lead. This strategy is called *Eyes High*, inspired by the university's Gaelic motto, which translates as 'I will lift up my eyes.'

As part of the roadmap to achieve these goals, the university's Strategic Research Plan identifies six research themes that will leverage our distinct capabilities while addressing the unmet needs and challenges of our society as a whole:

- Brain and mental health
- Human dynamics in a changing world: smart and secure cities, societies, and cultures
- New earth-space technologies
- Engineering solutions for health: biomedical engineering
- Infections, inflammation and chronic diseases in the changing environment
- Energy innovations for today and tomorrow

Learn more about the University of Calgary's Strategic Research Plan and Energy Research Strategy.

Contact the Office of the Vice-President (Research) at vpr@ucalgary.ca



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