

INSTITUTE FOR OIL SANDS INNOVATION AT THE UNIVERSITY OF ALBERTA

Breakthrough Energy Research | Advanced Environmental Technologies



Annual Report 2017-2018

Vision

Oil sands operations with a reduced environmental footprint by minimizing water use, consuming less energy, lowering greenhouse gas and other emissions, yielding high quality products at lower cost.

Mission

To promote, to build capacities and to fund breakthrough research that leads to environmentally, economically and socially sustainable development of Canada's mineable oil sands resources.

Values

- **Partnerships, collaboration and teamwork** – we seek to provide an environment in which ideas can surface and be acted upon. We constantly look for innovative solutions that will add value to our stakeholders and investigators. We strive to improve the efficiency and effectiveness of our Institute's operation to deliver best value services. As a learning organization, we are constantly increasing our intellectual capital and improving our business practices and procedures through teamwork and a desire to excel.
- **Effective communication** - we strive to foster a culture that stimulates free and open communication. We commit to communicating definable and measurable goals.
- **Fairness, transparency and accountability** – we take accountability for the Institute's mission and resources entrusted to us. We conduct our business operation in a fair manner that meets or exceeds all legal, ethical and public expectations.
- **Excellence** – we focus on advancing our technical competencies and delivering services of the highest quality consistent with established standards and best practices.

Executive Summary

The aim of the Institute for Oil Sands Innovation (IOSI) is to revolutionize the productivity and sustainability of oil sands operations by focusing on delivering breakthrough technology for cleaner, cheaper oil sands development, while also contributing to the development of tomorrow's top-flight researchers and industry leaders. IOSI's groundbreaking research contributes to social, economic and environmental excellence in extraction and upgrading processes - now and for future generations.

Since 2006, IOSI has established a vibrant, multi-disciplinary institute dedicated to the development of new technology for the oil sands. Comprising of researchers from universities across Canada, as well as the United States and the Netherlands, the institute has made significant advances in the basic understanding of the chemistry, interfacial behaviour, and physics of oil sands materials. IOSI continues to nurture strong partnerships with Alberta Innovates, Imperial and the Canada's Oil Sands Innovation Alliance (COSIA).

The four main themes of the research program are extraction, product cleaning and partial upgrading, on line instrumentation, and tailings fundamentals. In each theme area, IOSI researchers are working together to advance the basic science and to explore technologies for the mineable oil sands industry.

Imperial Oil Resources Ltd. has contributed a total of \$25 million over 13 years to the Imperial Endowment fund as well as \$500 thousand per year in in-kind support to IOSI. The Imperial – U of A Foundation Agreement was amended and renewed for another 5 years effective November 1, 2018 and ending on October 31, 2023. The in-kind support has included time devoted by highly knowledgeable staff from Imperial Oil Resources Ltd. who have contributed significantly to the quality of research.

The partnership has been successful in attracting significant funding and in-kind support from the Province of Alberta through Alberta Innovates (AI) with \$6.0 million from the former Alberta Ingenuity Fund and \$10.0 million from the former Alberta Energy Research Institute. AI committed \$5.86M of funding from 2013 to 2017, and in April 2018, renewed support for 5 years with a total funding of \$2.5M to IOSI to March 31, 2023.

IOSI also receives project-related funding from the Canada Foundation for Innovation, the Canada Research Chairs program, and the National Science and Engineering Research Council (NSERC).

COSIA was launched on March 1, 2012 to foster innovation and collaboration in research and development relating to the environmental impact of oil sands development. The Tailings Environmental Priority Area (EPA) is the successor to the former Oil Sands Tailings Consortium (OSTC). Each company has pledged to share its existing tailings research and technology and to remove barriers to collaborating on future tailings R&D. The research activities on tailings fundamentals carried out by IOSI are part of the fundamental research working group of the COSIA Tailings EPA and funding is shared by all the member companies.

Again, IOSI continues to receive project-related funding from COSIA. The total funding received from COSIA for 2017-18 was \$0.29M.

IOSI has successfully attracted 24 principal investigators (PIs) from the departments of Chemistry, Civil & Environmental Engineering, Chemical and Materials Engineering, Electrical and Computing Engineering, Geotechnical Engineering, and Renewable Resources at the University of Alberta. IOSI's PIs also include members of the Department of Environmental & Fluid Mechanics at the Delft University of Technology in the Netherlands, the Boreal Research Institute at the Northern Alberta Institute of Technology (NAIT), the Centre for Oil Sands Sustainability at NAIT, the School of Sustainable Building and Environmental Management at NAIT, the Department of Enhance Oil Recovery and Agronomy at Purdue University, the Department of Chemistry at the Universities of British Columbia and Montreal, the Atlantic Centre for Green Chemistry from St. Mary's University in Halifax, the Department of Chemical & Petroleum Engineering from the University of Calgary, the Department of Civil, Environmental, and Geo-Engineering at the University of Minnesota, the Department of Chemistry at the University of Ottawa, the Department of Chemical Engineering at Queen's University, Deltares (the Netherlands), InnoTech Alberta, Coanda, the National Research Council of Canada and the National Institute for Nanotechnology.

IOSI approved 16 new research projects in 2017 and 14 new research projects in 2018 (not all of them have commenced).

IOSI project leaders are able to access the world class nanotechnology research tools provided on the University of Alberta campus through a partnership with the National Institute for Nanotechnology (NINT) – available nowhere else in Canada.

IOSI is able to provide unique training and research experience as a result of the exceptional project leaders and facilities available. Imperial's partnership with IOSI provides invaluable industry experience to students. In all, IOSI has grown from the participation of six individuals in April 2006 to close to 130 today.

Goals and Achievements

1. Research Excellence

IOSI is committed to providing research breakthroughs enabling the long-term sustainable development of the oil sands in Alberta. Research focuses on solving some of Alberta's most pressing concerns when it comes to oil sands development. IOSI's areas of research are divided into four themes, as revised in early 2014: extraction, product cleaning and partial upgrading, on-line instrumentation, and tailings fundamentals.

IOSI's call for letters of intent (LOI) in December 2016 resulted in 78 LOIs which were reviewed by the Scientific Advisory Committee (SAC) in April 2017. SAC invited 23 of the 78 LOIs for full proposals. Out of the 23 full proposals, 16 were recommended by SAC to the Executive Management Committee (EMC) in 2017, which were approved as the 16 new projects for 2017. These included one new extraction project, three online instrumentation projects, one new product cleaning and partial upgrading project, and 11 new tailings process fundamentals projects.

The call for LOIs in December 2017 was successful with a record 125 LOIs received in December 2017. These were reviewed by SAC in February 2018 which led to 33 full proposals. Of the 33 full proposals, 14 were recommended by SAC to EMC to approve as the 14 new projects for 2018. These include one project on instrumentation, three on product cleaning and partial upgrading, and ten on tailings fundamentals.

The following are the highlights of progress in each of the four themes:

Theme One: Extraction

Current extraction technologies are based on mining the oil sand then contacting it with warm water, which generates large volumes of high water content tailings. These tailings are expensive to store in ponds, there are technical challenges associated with effective dewatering, and the tailings ponds are a risk to the environment. IOSI supports research leading to water-free processing of oil sands, and technologies that use a significantly smaller volume of water.

The technology for oil sands recovery and processing is controlled by the behaviour of the bitumen and its interactions with the minerals and water present in the ore. Understanding this behaviour is challenging because the oil sands are an extraordinarily complex mixture of components that, so far, defy complete analysis. In order to provide a foundation for new non-aqueous technology, IOSI supports research on bitumen composition, molecular behaviour such as aggregation of the asphaltene components, interfacial interactions between bitumen components and mineral surfaces. Although this theme is focused on non-aqueous technology, water is always present in the oil sand ore, and in small quantities can be useful in binding the fine solids to the sand. Research on bitumen behaviour at oil-water interfaces supports this effort.

Highlights of the research

Project IOSI2011-12: Asphaltene precipitation kinetics and oil sands processing

PI: Harvey Yarranton (University of Calgary)

Accomplishments:

The project has offered new insights into asphaltene aggregation in paraffinic solvents, in particular, that the aggregates grow within a few seconds and then lose their stickiness and will not re-flocculate. This information is crucial for determining the impact of upstream shear conditions on settling; in this case, little impact. The project also provided the data and models for asphaltene precipitation/aggregation and settling in n-alkane diluted bitumen. The models have direct application to non-aqueous oil sands extraction processes. For example, the model can be used to determine the minimum dilution ratio for a particular solvent to settle asphaltenes and solids to produce a clean bitumen product. The project is about to end.

Project IOSI2015-06: Direct in-situ chemical-specific microscopic imaging of extractions

PI: Albert Stolow (National Research Council)

Accomplishments:

Statically measured fluorescence lifetime imaging (FLIM) (within 2 min) of solvent extracted partial agglomerates showed that the aggregates adhered to the sand grain surface.

Project IOSI2016-04: Biodegradation of cyclohexane under different redox conditions

PI: Tariq Siddique (University of Alberta)

Accomplishments:

The project has successfully cultivated cyclohexane degrading microbial communities originating from fluid fine tailings under aerobic conditions. There is evidence of degradation of both cyclohexane and cyclopentane in microcosms containing non-aqueous solids. These active bottles have been inoculated with fluid fine tailings and biostimulated with nitrogen and phosphorus.

Project IOSI2016-05: Removal of hydrophobic bitumen-coated fine solids from NAE bitumen using water droplets with modified interfacial chemistry and bio-inspired polymers

PI: Hongbo Zeng (University of Alberta)

Accomplishments:

Completed the systematic study of surface properties (e.g., surface chemistry, wettability and nanomechanical properties) of the bitumen-coated fine solids collected from the extracted bitumen to understand behaviors of these fine solids in the organic media during the non-aqueous extraction. Developed an easy and effective methodology for characterizing the distribution of adsorbed bitumen on the mineral solids surface using AFM force mapping and Peakforce QNM imaging.

Investigated the adsorption behaviors of bitumen to mineral solids surface and interaction behaviors between two mineral solids in different organic media (i.e., cyclohexane and heptane) by virtue of two state-of-the-art nanomechanical techniques, QCM-D and colloidal probe AFM, with implications for an improved understanding of the behaviors of hydrophobic bitumen-coated fine solids in NAE process.

Investigated the performances of several chemical additives on destabilizing the suspended fine solids in organic media using sedimentation batch tests and unraveled the underlying interaction behaviors among the fine solids and additives, aiming to find an effective and practical strategy to the removal of fine solids from the NAE bitumen. Findings demonstrate that a small amount of water can trigger the generation of solids agglomerate and significantly accelerate the initial settling. The presence of amphiphilic polymers can

flocculate the solids, modulate the surface properties of hydrophobic fine solids and facilitate migration of fine solids to the water/oil interface, ultimately reducing the solids content in the oil phase.

One additional project (IOSI2017-01) has been approved but has not started.

Theme Two: On-line Instrumentation for Oil sands

This is IOSI's newest theme. Research will investigate the development of novel sensors or adaptation of existing sensors from other industries for the rapid real-time online measurements of pertinent operational parameters in oil sands extraction and froth treatment process streams. These sensors must be capable of maintaining performance while operating in a challenging process environment such as streams with high solids contents, bitumen fouling, heterogeneous flows, erosive flows, among other conditions. Examples of such operational parameters include particle size distribution with capabilities to detect ultrafines (less than 0.5 microns) even when mixed with water and/or bitumen; mineralogical composition including clay minerals; tailings stream density (water, clay, bitumen); asphaltene content; viscosity of multiphase flow systems; water chemistry (pH, soluble ions); froth quality; slurry composition (water, bitumen, solids, clays); and ore composition by non-contact methods.

Highlights of the Research

Project IOSI2015-04 and IOSI2018-01: Online monitoring of clay, water and bitumen contents using multiple-wavelength differential light radar

PI: Ken Chou (University of British Columbia)

Accomplishments:

Built a fluorescence differential light radar (LiDAR) and demonstrated that LiDAR has the potential to offer real-time bitumen content monitoring with a good signal-to-noise ratio, independent of the background light intensity and the water contents in oil sands. To validate the accuracy of the LiDAR built in the University of British Columbia, 10 samples from IOSI were tested. Compared with the measurements carried out by the AGAT Labs using the conventional Dean-Stark analysis, the difference was 7% (RMS). The technique will be tested on continuous flow sample streams in a newly approved project IOSI2018-01.

Project IOSI2017-02: Ultra-wideband microwave imaging system for rock and metal detection upstream of the crusher

PI: Rambabu Karumudi (University of Alberta)

Accomplishments:

Project started early 2018, and the lab facilities are set up and the researchers are hired to start the research work.

One additional project (IOSI2017-16) has been approved and is in the final stage of contract negotiations.

Theme Three: Product Cleaning and Partial Upgrading

Processing of the bitumen from the oil sands adds to its value, enables transportation by pipeline, and makes it more attractive to many petroleum refineries. The current technologies use heat to break up the largest

molecules in the bitumen and high-pressure processing with catalysts and hydrogen to remove the sulphur and other contaminants. These technologies require very large capital investments and give significant emissions of greenhouse gases. We support research on new approaches to separate desirable from undesirable components, reaction of bitumen feeds, catalysis, and production of value-added products. The emphasis of the research is to improve value and at the same time reduce energy consumption and the release of greenhouse gases. The theme includes fundamental research on the molecular structure of bitumen components, on new catalysts for processing bitumen and derived distillates, and new reaction pathways.

Highlights of the Research

Project IOSI2015-03: Multifunctional non-precious upgrading catalysts

PI: Natalia Semagina (University of Alberta)

Accomplishments:

Developed unconventional Earth-abundant catalyst for hydrotreatment and a colloidal Earth-abundant catalyst with a potential for partial upgrading.

Project IOSI2016-06: Non-thermal plasma assisted catalytic bitumen partial upgrading under methane environment

PI: Hua Song (University of Calgary)

Accomplishments:

Project was started early 2018. The PI has recruited a PhD student and a postdoctoral fellow, and completed the fabrication and shakedown of the non-thermal plasma assisted catalytic reactor system.

Project IOSI2017-15: CO₂ assisted paraffinic froth treatment

PI: Qi Liu (University of Alberta)

Accomplishments:

Project started in May 2018. The postdoc and the MSc student have been hired, and the lab facilities have been set up. Asphaltene precipitation onset condition studies have begun.

Three additional projects (IOSI2018-02, IOSI2018-03, and IOSI2018-13) have been approved but have not started.

Theme Four: Tailings Process Fundamentals

Warm water is a low-cost medium for extracting the bitumen from the oil sands, but the clays in the oil sands ore become suspended in water. When these fine particles settle, they form wet tailings which contain the fine particles along with about 70% water by weight. The high water content of the tailings makes the current mining operations net consumers of water, and water used for extraction processes is not returned to streams and rivers.

The oil sands industry faces new regulations that require much more rapid treatment of the tailings, giving a

significant reduction in the volume of tailings associated with each mine. IOSI supports the development of new methods for the rapid dewatering of tailings, and integration of extraction and tailings management. Rather than optimizing the water chemistry and additives to maximize bitumen recovery, at the expense of tailings management, we seek an integrated approach.

In the future, the industry will need to treat the water released from tailings and mining sites. New processes are needed to remove the water-soluble components from the oil sands to enable the safe release of this process water. In addition to demonstrating proof of concept on new processing options, the theme includes work aimed at a more fundamental understanding of the interactions of aqueous phase components, minerals, and residual bitumen with additives such as polymers.

The oil sands industry has placed such a high priority on new technology for handling tailings that all of the companies agreed to share all intellectual property in this area, and collaborate on future research and development efforts. The growing importance of tailings is leading to growth of this theme within IOSI in collaboration with the COSIA Tailings EPA. Representatives of the Tailings EPA are actively involved in selecting the new projects within this theme.

Highlights of the Research

There are 13 projects underway in this theme area. The work is being conducted with investigators from six different post-secondary institutions and three engineering firms.

Project IOSI2015-01: Connecting microstructure and rheology for enhanced oil sands tailings reclamation

PI: Milana Trifkovic (University of Calgary)

Accomplishments:

Investigated the correlation between the microstructures of flocs measured by confocal laser scanning microscope and the rheology of the flocculated system.

Project IOSI2015-02: Novel hyperbranched functionalized polyethylenes for densification of oil sands tailings

PI: João Soares (University of Alberta)

Accomplishments:

Synthesized several highly branched co-polymers based on polyethylene backbone and tested their flocculation effect on diluted mature fine tailings. The branched polymers worked more effectively than the straight chain polyethylene.

Project IOSI2016-01: Laboratory investigation of transport, segregation and deposition of TSRU tailings in subaerial beach environments

PI: Jeffrey Marr (University of Minnesota)

Accomplishments:

The project is focused on conducting flume experiments with TSRU tailings material to observe the transport and deposition processes associated with the particles within the TSRU. The facility was constructed in 2017

and has been used to carry out six experiments using a surrogate tailings material. The research team has been working with project stewards to receive a large volume of TSRU tailings so that experiments can be carried out with actual material. It has taken a year to work through the details of transfer of materials and the safety plan for working with TSRU tailings. The test runs will be completed by early 2019.

Project IOSI2016-08: Optimizing the usage of Tubifex to enhance densification and strength of oil Sands tailings: building on recent laboratory test success, towards pilot

PI: Miguel de Lucas Pardo (Deltares, The Netherlands)

Accomplishments:

The project has demonstrated with data, that Tubifex can live and reproduce in oil sands tailings when kept under the correct and cost effective circumstances. As well, the project demonstrated that Tubifex improved the dewatering properties (i.e. higher solids content and higher permeability) significantly in lab environment, when compared to conventional treatment.

Project IOSI2016-09: Bugs and veggies as tailings management tools

PI: Amanda Schoonmaker (NAIT)

Accomplishments:

The project has found that willows can effectively establish in both thickened tailings and centrifuge cake and can convert 20-40cm of the thickened tailings to a soil like texture within the first growing season. Significant strength gain is observed in columns containing vegetation (especially willows) relative to non-vegetated columns. The project team has identified tailings amendments that appear to be beneficial to plant growth and development.

The team has successfully managed the complexities of a very multidisciplinary project. Many different streams of science have been drawn upon to pull this project together including microbiology, chemistry, plant physiology, geotechnical engineering. It has been no small task to ensure that different researchers understood enough of the science from each discipline so that we could collectively execute this study.

Project IOSI2016-10: Technology for in-situ real time measurements of solids content in settling tailings

PI: Ying Tsui (University of Alberta)

Accomplishments:

The project started in late 2017 and one research assistant and two MSc students have been recruited. Most activities associated with the project are on schedule or ahead. Two papers will be presented to the International Oil Sands Tailings Conference in December 2018.

Project IOSI2016-12: Development of rapid screening methods to screen and classify mature fine tailings

PI: Cliff Johnston (Purdue University)

Accomplishments:

The project team is developing optical and thermal analysis methods to predict key performance indicators with an aim to develop rapid methods to predict bitumen and water content, along with mineralogical proxies. The emphasis has been on sample presentation, sampling, mixing and statistical analysis.

Project IOSI2017-06: Minimization of GHG emissions in froth treatment tailings by manipulation of electron acceptors

PI: Juliana Ramsay (Queen's University)

Accomplishments:

Using fluorescence spectrometry as a rapid tool to quantify naphtha appears promising. Experiments will be performed to compare naphtha degradation via fluorescence spectrometry and GC/FID.

Project IOSI2017-08: Enhancing prediction of depositional flow and segregation of non-Newtonian slurries. Phase II of the ongoing "A research trajectory towards improving fines capture prediction: verification, application and improvement of Delft3D"

PI: Arno Talmon (Deltares, the Netherlands)

Accomplishments:

The project team has developed Delft3D-slurry that can simulate non-Newtonian rheology and sand segregation, as well as executed conceptual 3D simulations of tailings deposition and example case studies. A graphic user interface has been added to the model and the model is now ready for use by the operator (assuming knowledge of limitation and necessary developments forward).

Project IOSI2017-10: Effects of shearing on dewatering and compressibility of treated tailings

PI: Clara Gomez (Coanda, Vancouver)

Accomplishments:

The project is in early stages with two of two of the four laboratory experiment sets completed and long-term measurements ongoing. The other two sets of experiments started in late October 2018.

Project IOSI2017-11: Evaluation of granular cap success conditions and failure potential on treated fine tailings

PI: Philip B. Solseng (Barr Engineering, Calgary)

Accomplishments:

The cap advance modeling is nearly complete for subaqueous capping of treated tailings and shows combinations of tailings strength and cap thickness that succeed and fail.

Project IOSI2017-12: From slurry to soil: creating soil from oil sands tailings

PI: Heather Kaminsky (NAIT)

Accomplishments:

The contract was signed in September 2018 and the project is now starting.

Project IOSI2017-14: Towards integrating micro- and macro- scale processes and tools to improve dewatering and rheology assessments in soft and ultra-soft tailings

PI: Milana Trifkovic (University of Calgary)

Accomplishments:

The contract was signed in August 2018 and the project starting.

Additional ten projects (IOSI2018-04, IOSI2018-05, IOSI2018-06, IOSI2018-07, IOSI2018-08, IOSI2018-09, IOSI2018-10, IOSI2018-11, IOSI2018-12, IOSI2018-14) were approved and are currently in contract negotiation. They will start in 2019 in accordance with COSIA's budgeting cycle.

2. Funding and Partnerships

Funding

In 2017 the institute received \$1M from Imperial to IOSI's endowment fund. The Foundation Agreement of IOSI between Imperial and University of Alberta was amended and renewed for another 5 years, effective from November 1, 2018 to October 31, 2023.

Since 2007, the Government of Alberta's Access to the Future Fund has provided a total of \$8.16M to IOSI as an endowment. The spendable allocation from this endowment has partially supported the institute's operational overhead.

IOIS has attracted \$6.0M of investment over five years by the Alberta Ingenuity Fund (now part of AI) and an investment by the Alberta Energy Research Institute (also part of AI) of \$10M over 5 years commencing in February 2008. AI has committed \$5.86M of funding since 2013 with \$500K being received in fiscal year 2017-18. In April 2018, Alberta Innovates renewed its support to IOSI with a total of \$2.5M over 5 years from April 1, 2018 to March 31, 2023.

As of January 11, 2017 a total of \$851K was invested in research and innovation projects through grants to various project leaders, representing 27.67% of IOSI's 2016-17 approved annual budget (\$3.07M).

Personnel Support

Imperial has placed a high priority on IOSI, engaging the Vice President of Upstream Engineering, Dr. Cheryl L. Trudell and the Heavy Oil Mining Research Lead Dr. Christopher Lin in the governance of the institute. Dr. Trudell chairs IOSI's Executive Management Committee (EMC), while Dr. Lin co-chairs the Scientific Advisory Committee (SAC) and is a member of the EMC. Further emphasizing their commitment, Dr. Lin has deployed thirteen research scientists from Imperial and ExxonMobil to help steward IOSI research projects. This has been a very important partnership between University faculty and students and the Imperial staff, who have the knowledge and the vested interest to fully interact with each of IOSI's projects and project personnel.

Alberta Innovates has also placed a high priority on the Institute with Mr. Bryan Helfenbaum, Executive Director, Energy Technologies, Dr. Shunlan Liu, Director, Upgrading and Mr. Kirk Rockwell, General Manager, Basic Research all sitting on IOSI's Executive Management Committee. Dr. S. Liu also sits on IOSI's Scientific Advisory Committee.

Canada's Oil Sands Innovation Alliance (COSIA) Tailings EPA has partnered with IOSI to bring together the shared experience, expertise and financial commitment to find new technologies and solutions to tailings. Mr. Dave Corriveau, Director of the Tailings EPA, Mr. 'Deji Dunmola and Mr. Abu Junaid, Chair and Co-Chair of the Tailings Research Working Group, now participate in the selection of IOSI tailings projects. The tailings EPA

has also deployed fifteen individuals from the industry members of COSIA to help steward IOSI tailings research projects. As with Imperial, this has been a very important partnership between the researchers, students and industry personnel who have the knowledge and expertise to fully interact with IOSI's tailings projects and personnel.

The University of Alberta has also invested resources in the institute. Dr. Fraser Forbes, Dean of the Faculty of Engineering, and Dr. Ken Cadien, Chair of the Department of Chemical and Materials Engineering, sit on the Executive Management Committee. Dr. Qi Liu, the Scientific Director of IOSI, co-chairs the Scientific Advisory Committee. Dr. Natalia Semagina serves as the Associate Director of IOSI and also sits on the SAC. Drs. Ying Tsui, Associate Dean of Research for the Faculty, and João Soares also sit on this committee. The University of Alberta employs 89 of the 130 research and administration personnel currently working in IOSI.

Additional personnel come from St. Mary's University in Halifax, NS, University of British Columbia, University of Calgary, University of Ottawa, Université de Montréal, the National Institute of Nanotechnology in Edmonton, National Research Council in Ottawa, Northern Alberta Institute of Technology (NAIT), Queen's University, Deltares, Coanda, Barr Engineering, Purdue University, University of Colorado, University of Minnesota, and Delft University of Technology, in Delft, Netherlands. In addition, the University provides all of the research facilities used by IOSI in its operations.

Research Partners

At a time when Alberta's oil sands development needs to cause a smaller environmental footprint, IOSI provides a superb capacity building environment coupling the best research facilities – the National Institute of Nanotechnology, nanoFAB – with able research leaders – 1 Canada Excellence Research Chair, 3 Canada Research Chairs, 1 NSERC Industrial Research Chair, 52 respected research scientists, 20 graduate students and 1 undergraduate student. IOSI currently funds projects at fourteen universities, 2 institutions and 2 companies as listed: DELFT, Deltares, Barr Engineering, Coanda, NAIT, NINT, NRC, InnoTech Alberta, Purdue, SMU, UBC, Queens, UdeM, UofA, UofC, CarltonU, UofT, UVic, UofColorado, UofMinn and UofO.

The Institute is housed at the University of Alberta, but it has attracted a number of researchers from other universities who are essential to its mandate. IOSI is expanding Canada-wide, with research projects being conducted at campuses across the country. These include NAIT, St. Mary's University, the University of British Columbia, University of Calgary, Université de Montréal, University of Toronto, University of Victoria, Queens University, Carlton University and University of Ottawa. Internationally the institute partners with the Delft University, Purdue University, University of Minnesota, and the University of Colorado.

IOSI continues its partnership with InnoTech Alberta, the National Research Council, the National Institute for Nanotechnology, and at arm's length with CANMET Energy Technology Centre in Devon, Alberta. IOSI currently partners with Deltares, an independent institute for applied research in the Netherlands, and two engineering companies: Barr Engineering and Coanda.

3. Training and Development

IOSI involves both engineering and science disciplines within its study program. At the University of Alberta, the departments of Chemistry, Chemical and Materials Engineering, Earth and Atmospheric Science, Electrical & Computer Engineering, Renewable Resources and the National Institute of Nanotechnology are currently involved in the program.

IOSI provides an outstanding environment for training of graduate students in oil sands research. In addition to the direct supervision provided by the project investigators, graduate students gain the following experience:

- Direct interaction with industry researchers, as part of the project monitoring process.
- Participation in interdisciplinary conferences and workshops.
- Leadership development activities.
- Training on research equipment in the IOSI Analytical Lab, supervised by the IOSI technical staff.

The result is a high level of scientific preparation combined with a significant understanding of the research needs of the oil sands industry.

Workshops

IOSI organized five workshops on oil sands processing during 2017 and 2018, and invited researchers from various government offices and laboratories, industry and academia. These workshops were designed to bring together current IOSI researchers with prospective researchers and industry experts to identify specific knowledge gaps and research needs for oil sands. These workshops were:

1. The 2017 Alberta Innovates – CanmetEnergy – IOSI joint bitumen partial upgrading workshop (October 3, 2017, Calgary). More than 40 participants from government (Alberta Innovates, Alberta Petroleum Marketing Commission, InnoTech, NRCan), academia (University of Alberta, University of Calgary, University of Saskatchewan), and oil sands companies (Cenovus, CNRL, Husky Energy, Imperial, MEG Energy, Nexen, Suncor, as well as engineering and consulting companies (ASRL, ETX Systems, Fractal, Upgrading Solutions, IHS) attended the workshop. Both the technological and economic challenges were reviewed and discussed, and a summary document of the discussion was prepared to guide the partial upgrading research and development in the future.
2. IOSI’s “Tailings Project Stewardship and Knowledge Dissemination Review” Workshop (November 9, 2017, Calgary). Researchers from University of Alberta, Deltares, University of Montreal, and University of Calgary reported results of 10 ongoing or just-completed tailings projects to COSIA member companies and industry stewards.
3. The 2018 Alberta Innovates – CanmetEnergy – IOSI joint bitumen partial upgrading workshop (June 20, 2018, Calgary). This was a follow-up workshop to the 2017 joint partial upgrading workshop, to explore potential new, early stage technology opportunities that industry should be aware of and considering, with an emphasis on step-out technologies rather than incremental improvement. The Workshop was

attended by 60 participants from government, industry and academia similar to the 2017 workshop, with additional participants from Saskatchewan Research Council, Etaltexx, LTE Oil.

4. IOSI's "Oil Sands Tailings Project Dissemination Review" Workshop (November 15, 2018, Calgary). Based on the positive feedback of the 2017 tailings project dissemination review, the tailings project dissemination review workshop was held again at Imperial in Calgary on November 15, 2018. More than 50 participants attended the meeting, mostly from the 5 oil sands operators (CNRL, Syncrude, Suncor, Imperial and Teck) who are members of the COSIA Tailings EPA. A total of 11 oil sands tailings projects were showcased in the workshop in this one-day event. The workshop was again considered to be well organized and the reported tailings projects presented connections of the different aspects of the IOSI/COSIA's tailings research from fundamental clay surface and colloid chemistry to biological tailings treatment technologies for potential field implementation.
5. IOSI's "Mining Instrumentation" Workshop (November 20, 2018, NAIT Main Campus). This workshop was attended by about 30 participants from Imperial, InnoTech, NAIT, Spartan, UBC and University of Alberta, and is the first effort of IOSI to initiate IOSI's Technology Accelerator program.

Secondary Education

IOSI supported the development of high school level educational materials for the study of bitumen and oil sands development in collaboration with Frank Jenkins and Art Bauer in the Faculty of Education, at the University of Alberta through the Centre for Mathematics, Science and Technology Education (CMASTE). They developed a teaching module on oil sands extraction and made kits available to high schools in the Edmonton region for hands on classroom experiments. IOSI continues to talk with Frank Jenkins on the development of a module on bitumen upgrading; this is still in progress. Details of the current teaching materials are posted on the CMATSE website, linked to the IOSI website.

4. Governance and Management

The IOSI management structure consists of two committees, the Executive Management Committee (EMC) and the Scientific Advisory Committee (SAC). EMC is chaired by Dr. Cheryl L. Trudell, Vice President Upstream Research of Imperial. The EMC provides strategic direction, monitors progress, approves budgets, research plans and intellectual property proposals, and recommends research areas for faculty appointments to the Dean of Engineering. Mr. Bryan Helfenbaum from AI and Christopher Lin from Imperial joined EMC; Natalia Semagina from the University of Alberta has been appointed as IOSI's Associate Director from November 19, 2018 and serves as a SAC member as well as an ex-officio member on EMC. All other members on both EMC and SAC have remained the same.

The EMC held two strategic meetings in June 2017 and November 2018 and conducted an environmental scans to identify changes in the sector, assess external factors and determine current oil sands research needs. The group discussed ways to align research with industry needs, and approved in principle a

“technology accelerator” program to emphasize on research results for commercialization.

In April 2017, the SAC reviewed 78 letters of intent and invited 23 of them to submit full proposals. Sixteen of the 23 full proposals were recommended by SAC to the Executive Management Committee for funding as 16 new IOSI projects for 2017.

The committee conducted multiple stewardship meetings over the last year to review the progress of, and provide guidance to the research projects. The formal stewardship meeting was held in May and the informal stewardship meeting was held in November. The feedback following the stewardship reviews continues to indicate their value to the research process.

In February 2018 the committee reviewed 125 letters of intent from across all four themes. From the 125 letters of intent, 33 full proposals were developed and reviewed by SAC. Of the 33 full proposals, 14 were recommended by SAC to EMC for approval as new IOSI projects for 2018.

Governance Structure

Executive Management Committee Membership:

| CHAIR | MEMBERS: | EX-OFFICIO |
|-----------------------------|-------------------------------------|---|
| Cheryl L. Trudell, Imperial | Christopher Lin, Imperial | Qi Liu, Scientific Director |
| | Fraser Forbes, U of A | Natalia Semagina, Associate Director |
| | Ken Cadien, U of A | Jagvir Singh, Manager Research Operations |
| | Kirk Rockwell, Alberta Innovates | |
| | Bryan Helfenbaum, Alberta Innovates | |
| | Shunlan Liu, Alberta Innovates | |

SAC organizes calls for research proposals from universities across Canada, reviews and screens proposals, and works with researchers to align proposals with existing work and strategic direction and areas. The SAC proposes projects to the EMC to be funded, and conducts “gate reviews” on research projects. At the initial stages of a project, these reviews help ensure that each research proposal is aligned with the objectives of IOSI and the business needs of the oil sands industry. As research progresses, these reviews will determine which projects are ready for further technology development.

Scientific Advisory Committee Membership:

| CHAIR: | MEMBERS: | EX-OFFICIO |
|----------------|---|---|
| Qi Liu, U of A | Christopher Lin, Imperial (Co-chair) Shunlan Liu, Alberta Innovates Natalia Semagina, U of A Ying Tsui, U of A João Soares, U of A Adedeji Dunmola, COSIA (Tailings) Abu Junaid, COSIA (Tailings) Dave Corriveau, COSIA (Tailings) | Jagvir Singh, Manager Research Operations |

Institute Staff

Jagvir Singh, Manager Research Operations (hired November 2018)
 Xiaoli Tan, Research Associate and IOSI Lab Manager
 Lisa Brandt, Research Technician
 Brittany Mackinnon, Research Assistant
 Lynette Hussain, Administrative Financial Assistant

Research Support

The IOSI technical team consists of a research associate and two research technicians who provide general laboratory support to researchers and scientific support to research projects. Sixty per cent of time is spent on general laboratory support and the remaining 40 per cent on specific research support.

The IOSI technical team manages laboratory resources and provides a safe environment for researchers working in the laboratory. The facilities in the IOSI laboratory include:

- bench-scale separation and preparation equipment for solvent extraction of oil sands, minerals separation, tailings treatment, reactors for upgrading of bitumen, asphaltene separation, and chemical reactions
- extensive analysis capability at molecular level for fundamental research by advanced equipment including: intelligent gravimetric analyser (IGA), gas/residual solvents analyzer (DSMS, QIC), particle size analyzer (Mastersizer 3000, FBRM G400), thermogravimetric analyzer (TGA), Infrared spectrometer (Nicolet 6700), gas chromatograph (Sim Dist, SRI, GC-MS), liquid chromatograph (HPLC, Flash), elemental analyzers (CHNS, CHNS/O), rheometer (Marlvern Kinetic Lab+), tensiometer (Krüss K100), atomic force microscopy (Bruker Innova), and TAM III isothermal microcalorimetry (TA Instruments).
- a series of high temperature/pressure reactors for bitumen product cleaning projects (funded by Future Energy Systems), which expands capacity for bitumen treatment up to 5.5 liters per batch at

high temperature and pressure (up to 500 °C and 5,000 psi) with an incorporation of novel in-situ hot pressure filtration unit (up to 400 °C and 300 psi).

The main activities of the IOSI technical team include set-up and maintenance of labs and equipment; training researchers in analytical equipment and experimental methods; sample inventory and preparation of the IOSI samples bank; procuring research materials; and reciprocal service to other oil sands research groups in the Faculty of Engineering.

In 2017 and 2018, from 49 to 60 researchers including graduate students, postdoctoral fellows, research technicians and research assistants have been working in the IOSI laboratory to carry out different research projects.

The IOSI technical team also contributes expertise by carrying out high-level, complex research activities under the direction of the IOSI director and principal investigators. These activities included designing experiments, research methods, data collection protocols and standards; setting research activities; assisting and coordinating the analysis of results; supervising graduate students and research assistants; proposing new research directions under the IOSI theme areas and research scope; and fostering communication with off campus partners.

Promotion of the Institute and its Research

As part of the D.B. Robinson Distinguished Speaker Series in the Department of Chemical and Materials Engineering, IOSI sponsors the Andrew Main Lecture. Each year, the Andrew Main Lecture features an internationally-renowned engineer and/or scientist who inspires students and faculty members alike. This lecture combines exemplary scholarship and industrial relevance—befitting Dr. Andrew Main.

Dr. Jinwen Chen from Natural Resources Canada presented the 2017 Andrew Main Lecture on “Partial Upgrading: Challenges and Opportunities” on November 2, 2017, and Professor Arthur Mar from the University of Alberta presented the 2018 Andrew Main Lecture on “Accelerating the Discovery of Solid State Materials: From Traditional to Machine-Learning Approaches”.