Genomics in Canada's Energy & Mining Sectors

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ABSTRACT

This document serves as an update to Genome Canada's Energy & Mining Sector Strategy to reflect the priority challenges and opportunities of Canada's industries in 2019.

PREPARED BY

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Introduction

Since inception, Genome Canada and its regional Genome Centres have managed a collective investment of more than $54 million building genomics[1] research capacity to serve Canada's Energy & Mining industries[2]. Significant advancements have been made in our understanding of the biological processes that impact the sector activities. The guiding principles as outlined in the Energy & Mining Sector Strategy document, prepared in 2013, provided the groundwork for the integration of genomics discoveries into existing energy and mining operations and regulations to generate environmental, industrial, and performance benefits.

On November 8th, 2019, the Canadian Genomics Enterprise (Genome Canada and its affiliated Regional Genome Centres), in partnership with the Petroleum Technology Alliance of Canada (PTAC), organized a Sector Strategy Workshop on the role of genomics, microbiology and life sciences in Canada's Energy & Mining sectors in preparation for an upcoming research funding opportunity, the 2020 Large-Scale Applied Research Project Competition: Genomic Solutions for Natural Resources and the Environment. The workshop brought together stakeholders (industry, academia, regulators, and government) to compile an up-to-date portrait of the challenges facing Canada's Energy & Mining sectors. The first half of the workshop provided a foundational overview of applications of genomics in both sectors while the second half of the workshop was used to obtain an update on the collective understanding of industry priority areas for future research investment. This document summarizes the outcomes of the workshop and will serve as a supplement to Energy & Mining Sector Strategy document, in guiding the investment strategy for future funding opportunities.

[1] Area of research that aims to decipher and understand the entirety of the genetic information in an organism's DNA that encodes production of RNA, proteins, and ultimately metabolites.

[2] For the purpose of this document "mining" refers to industries engaged in the extraction of metals and minerals and does not include coal and hydrocarbon-based energy resources such as bitumen, while "energy" refers to industries that extract coal and hydrocarbon-based energy resources such as oil/gas/bitumen.

Current State of the Art

GENOMIC APPLICATIONS IN ENERGY

The energy sector is very important to the Canadian economy. It is estimated to employs 819,500 Canadians and is the largest private employer of Indigenous Peoples. In 2018 the sector produced $132.2 billion in exports and 11.1% of the Canadian GDP[3]. Demand for oil & gas is expected to moderately increase in the coming decades while production from existing assets will naturally decline. Genomics can and should be an important part of the toolkit available to the industry as it works to keep pace with demand in an economically, environmentally, and socially acceptable manner.

Previous investments in genomics research have already had an impact in a number of areas.

Control of pipeline corrosion and well souring – Improved understanding of the microbes involved in souring/corrosion and the development of technology to mitigate negative outcomes and extend the commercial life of aging assets.

Development of new extraction technologies – Microbiological conversion of residual and hard to access deposits to value added products.

Better effluent clean-up – Optimization of bioremediation by microbial and plant communities tailored to specific locations and types of effluent.

Improved environmental risk assessment, monitoring and compliance – Analysis of free DNA in the environment (eDNA) to establish detailed baselines, monitor fluctuations, and assess cumulative impacts.

Clean up of hydrocarbon and oil spills – Understanding the role and identifying areas to influence the naturally occurring hydrocarbon degrading

[3] NRCan Report – Energy and the economy. https://www.nrcan.gc.ca/science-data/data-analysis/energy-data-analysis/energy-facts/energy-and-economy/20062

organisms in soil, freshwater, and marine, and arctic ecosystems.

Production of bioenergy – Biological feedstocks and microbial processes to generate biomass-based fuels, electricity, and value-added products.

Reduction of greenhouse gas and carbon emissions – GHG producing and consuming microbial communities have the potential to convert harmful methane emissions to methanol or value-added products

Exploration geomicrobiology – Mapping the distribution of naturally occurring oil-degrading microbes as a tool in locating new hydrocarbon reservoirs.

Canada has world-leading expertise in hydrocarbon and petroleum microbiology, along with plentiful natural resources and processing infrastructure that provide for an internationally competitive research & development ecosystem. Successful breakthroughs will require integration across scientific, societal and commercial boundaries while balancing realistic short-, medium-, and long-term research goals.

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GENOMIC APPLICATIONS IN MINING

Canada is a reliable and responsible source for over 60 minerals and metals. The direct and indirect impacts of the mineral mining industry were valued at $96.5 billion (5% of GDP) in 2017[4]. Canada's mining industry is an attractive place for foreign investment where firms can take advantage of Canada's expertise in research, development and deployment (RD&D) programs and collaborations with Canadian-based research organizations. Investments in genomics research have the potential to improve production, sustainability, and public perception for this sector. Previous studies have identified a number of topics/targets that offer potential economic benefit resulting from the optimization of biological processes using genomics.

Bioreactors and bioleaching – A better understanding of the microbial dynamics in these processes and the tolerance of microbial communities involved to different ore feeds.

Water treatment (active and passive methods) – Use of genomics to unmask the underlying biological mechanisms at play, inform engineering design, and provide confidence in discussing system behavior with stakeholders.

Exploration geology – Mapping of key microbial groups in the field as a tool in locating new ore deposits.

Acid rock drainage (ARD)[5] – Better understanding of the biooxidation process responsible to enable effective early management decisions and prevent environmental damage.

Baseline studies – Faster, cheaper, and more detailed environmental baselining and monitoring of target sites.

Reclamation and remediation – Better understanding of the inputs and parameters required to stimulate the development of natural biological covers in the reclamation of mine sites.

The role for genomics in the mining-industry is only limited by the number of mining-biology interactions that can be identified. There is significant potential to improve project economics while lowering a project's

[4] NRCan Report – Minerals and the economy. https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/minerals-and-economy/20529

[5] Acid Rock Drainage (ARD) – a mineral oxidation process often catalyzed by microorganisms that can result in degradation of the local environment

risk. At the same time, the importance of opening up the 'black box' of biological sciences to an unfamiliar audience is essential for the tools to deliver on their potential.

GENOMICS AND SOCIETY

In parallel to scientific and technological advancements in the area, research is needed to investigate the factors that influence the adoption of new technology into practical application. It is critically important that potential barriers are identified early on so that strategies to overcome those barriers are developed alongside the scientific research plans. This field of research is called **GE^{3}LS**[6] and is an integral part of Genome Canada's research funding strategy.

Of particular importance to the energy and mining communities is the responsible integration of new knowledge and research tools with traditional and First Nations perspectives. This requires data access and interpretation guidelines for all stakeholders including First Nations.

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[6] GE^{3}LS – an acronym that stands for *Genomics and its Ethical, Environmental, Economic, Legal and Societal aspects*. GE^{3}LS research activities are integrated directly into all Genome Canada funded large-scale scientific research projects but may also be funded as a stand-alone project.

Workshop Outcomes and Updates

Four questions were posed to stimulate discussion:

Q1. Do you feel that the presentation missed any topics or opportunities? Are there any topics that should be excluded that were discussed today?

Q2. What do you consider the key non scientific factors that may facilitate or hinder the effective translation of research, and the uptake of genomic-based applications?

Q3. The energy and mining industries are under considerable pressure to operate in a more sustainable way. How can investments into genomics/microbiology best contribute towards improving the industry's performance in this regard?

Q4. Considering the potential mechanisms for industry to participate presented, what are the biggest impediments or barriers to participating in academic-industry research partnerships?

The ensuing discussion highlighted a number of areas including;

Non-technical factors – Non-technical factors can be addressed in part through an integrated GE^{3}LS research component in Genome Canada funded projects. In selecting GE^{3}LS topics to address, research teams need to focus on those factors that could thwart the success of the project in achieving its goals. Genome Centres have resources available to help research teams ask the most appropriate questions and can match-make with appropriate research capacity to address selected issues.

Transformation of tailings ponds – Previous work funded by Genome Canada has identified biological processes at play in oil sands tailings ponds and their impact on nearby ecosystems and GHG release. Today, industry is interested in transforming past tailings ponds into ecologically acceptable wet lands, end-pit lakes, and other end-goals that are usually stated in biological factors. There is plenty of opportunity for genomics to contribute to this effort.

Companies are already sponsoring some relevant research within universities.

Reclamation – There are many industry-disturbed sites in Canada that could provide unique opportunities to better understand the biological processes at play in different reclamation/remediation initiatives. Industry can play a unique role in research partnerships by providing contextual data, access to sites, and samples form their sites. Reclamation trial sites in northern areas deploying alder tree species with different combinations of *Frankia* symbionts planted provide one example. Some of these plots are nearing 20 years old and are performing very well. These sites could provide a unique opportunity to investigate the communities that have developed over time. Elsewhere "fixing" approaches (membranes, bioadsorbents etc.) are being developed to capture both metals and acids. Genomics could be used to assess treatment efficacy and explore how the bioadsorbents, after use, could be incorporated back into soils or used in other applications such as biomaterials.

Environmental DNA – Analysis of eDNA was raised several times in the discussion as an emerging area of opportunity. Several new technologies have come online in recent years that allow for cheaper, faster, and more portable analysis of environmental DNA samples such that robust analysis can be done with minimal equipment and expertise in the field at a much greater depth than traditional approaches. Mining and oil & gas disturbances coming to closure in the coming years will require new innovations for effective monitoring of the closure process. Three interrelated challenges need to be addressed: 1) demonstration of the technology in real-world operations, 2) development of standardized widely applicable approaches and 3) regulatory and decision maker buy-in.

Sustainability & climate change – Industry is under increasing pressure from investors to present a convincing plan for company sustainability. Mine closure and reclamation are critical issues in this respect. Genomics can play a part in understanding the operating site (e.g. biomonitoring) and controlling residual risk to the environment when a site goes into closure (e.g. revegetation, water processing). Because regulators and other stakeholders may not be familiar with genomics, extra effort may be needed to demonstrate the value of genomic information and its role in developing and executing sustainability plans.

Ongoing changes in temperature, water flow patterns, permafrost levels and so on due to climate change may pose an additional challenge, particularly in northern latitudes. An outstanding question in this topic is how to distinguish the impacts of resource development from the background impacts of climate change. Both technical and non-technical research may be needed to resolve issues and find appropriate solutions.

Regulator acceptance – It is important to have effective pathways to update the industry standards used by many regulators in determining regulatory actions and writing new regulations. By influencing primary standards one can have a big effect on the acceptability of new ideas. Good success has been seen in the area of corrosion where the National Association of Corrosion Engineers International (NACE International) has been incorporating genomic approaches into industry standards for failure assessment, monitoring, and mitigation of corrosion. A pressing issue is the inconsistency of genomic analyses currently available through commercial laboratories. These laboratories use slightly different methods for DNA extraction, processing, and sequencing and different bioinformatics tools and databases for interpretation. This is an area where the genomics community should work with major industry players to developing standard operating practices (SOP's) for the genomic analysis.

Hydraulic fracturing – An area of opportunity that was not explicitly captured in previous discussions was the influence of microbial communities in hydraulic fracturing of tight oil and gas bearing formations. Fracking requires the injection and back production of very large volumes of water. In some cases, microbial activity in the water phase causes microbiologically influenced corrosion and well-souring through the production of hydrogen sulfide. With an increased emphasis on water re-use, microbial issues can be magnified. There is an opportunity for the academic community to deploy genomic tools to identify problems and develop appropriate solutions.

Communication barriers – One significant barrier to the translation of research results from academia to industry is the simple fact that academia participates in scientific conferences and publishes and reads scientific journals specific to their areas of interest, while industry participates in industry conferences and reads and publishes in technical journals directly relevant to their industry. There needs to be more incentive for academics to publish and present in industry relevant venues and more frequent communication forums where the two groups can interact. If highly qualified personnel (HQP) trained through academic research projects subsequently take positions in industry, they can play an invaluable role in bridging the communication gap and enabling technology transfer. Enhancing the skill sets of HQP that make them attractive candidates to industry should be encouraged. Another area of opportunity to help bridge the gap is through the service companies that advise and provide expertise to the large operators. These companies are usually nimbler, are plugged into the latest technical developments, and interact with large operators on a regular basis. They can serve as a conduit to deliver technology from academia to the broader industry.

Opportunities for Industry

By participating in academic-industry research partnerships, like those being developed for the 2020 LSARP competition, companies will have a significant advantage in obtaining benefits from minimal investments. Companies will gain:

- A "front-seat" with access to cutting-edge technologies/datasets that are not publicly available
- The opportunity to negotiate a benefit sharing agreement, depending on their contributions.
- An ability to influence research directions that align with their priorities.
- Recognition as a participant in leading edge, visible, large-scale research projects that have been judged to be of excellent quality by external review/assessment.
- Direct interaction with leading research groups and with their peers in the subject area.

A common factor for successful translation of research results is the joint development and execution of research plans between academic and industry. For example, companies can provide:

- Real-world samples, operating experience, field data, and/or access to other ongoing operations. This all counts as in-kind contributions to projects.
- Cash contributions in specific research activities that are of high importance. This increases their negotiating power for sharing benefits and access to relevant research results.
- Guidance through end-user advisory committees that participate in project development and monitor progress.
- Access to equipment and expertise not generally available in industry laboratories.

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GenomeAlberta

15 years of powering genomics research in Alberta

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