GenomeCanada

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Submission from Canada's Genomics Enterprise in Response to Agriculture and Agri-Food Canada's Sustainable Agriculture Strategy Consultation

Executive summary

Climate change poses a significant risk to Canada's agricultural systems, impacting the availability of food and other vital resources, from fuels to the raw materials used to develop everyday products. The federal government is committed to ambitious action to drive sustainability and reduce emissions including in the agriculture sector. New knowledge through transformative genomics science and the application of innovative genomics technologies, products and approaches are required to achieve environmental and climate outcomes, maintain producer productivity and competitiveness, and ensure food security at home and abroad. Canada's Genomics Enterprise—comprised of **Genome Canada and the six regional Genome Centres—**has more than 20 years of deep expertise and experience in delivering impact for sustainable agriculture and food security through genomics. Seizing new opportunities for genomics applications to drive sustainable agriculture and Canada's climate action was a core message from the recently released ***Pan-Canadian Genomics Strategy What We Heard*** report. From the perspective of the Enterprise, the draft *Sustainable Agriculture Strategy* (the "Strategy") being developed by the department must:

1. Be underpinned by Agriculture and Agri-Food Canada's (AAFC) new ***Strategic Plan for Science***. Science and innovation—especially genomics—are key drivers of sustainability and resiliency in the agriculture sector. These two departmental strategies must be aligned and integrated so we draw on the best science and technology to drive Canada's sustainability goals in the agricultural sector.
2. Be flexible and reflect the strengths and diversity of Canada's federated food and research ecosystem.
3. Prioritize both adaptation and mitigation solutions and approaches through a O*ne Health* approach.
4. Prioritize investment in genomics and biotechnology research, tools and technologies that enhance the sustainability and resiliency of traditional breeding practices and processes.
5. Support the development of climate-resilient and lower-carbon novel food systems, such as cellular agriculture, bioproduction and fermentation technologies.
6. Invest in and provide greater support and priority to circularity approaches in agriculture through genomics and biotechnology.
7. Be underpinned by the principles of evidence-based and data-driven tools, programming, policy and decision-making.
8. Address barriers to the adoption of new technologies that can support sustainable agriculture and include support for knowledge mobilization initiatives that enhance broader public acceptance and adoption.
9. Prioritize science-based regulatory modernization to enable smooth implementation and application of new and emerging technologies that contribute to sustainable agriculture goals.

Introduction

Climate change poses a significant risk to Canada's agricultural systems, impacting the availability of food and other vital resources, from fuels to the raw materials used to develop everyday products. The federal government is committed to ambitious action to drive sustainability and reduce emissions including in the agriculture sector.

New knowledge through transformative genomics science and the application of innovative genomics technologies, products and approaches are required to achieve environmental and climate outcomes, maintain producer productivity and competitiveness, and ensure food security at home and abroad.

Canada's Genomics Enterprise—comprised of Genome Canada and the six regional Genome Centres—has more than 20 years of deep expertise and experience in delivering impact for sustainable agriculture and food security through genomics. Seizing new opportunities for genomics applications to drive sustainable agriculture and Canada's climate action was a core message from the recently released *Pan-Canadian Genomics Strategy What We Heard* report.

According to the department upon the launch of its draft *Sustainable Agriculture Strategy*, "now is the time to build on past and current successes and to work together to address ongoing climate and environment challenges in the sector while ensuring productivity continues to meet growing demand for sustainably produced food. The new strategy will help set a shared direction for collective action to improve environmental performance in the sector over the long-term, supporting farmer livelihoods and the long-term business vitality of the sector."

ABOUT US

Genome Canada is an independent, federally funded not-for-profit organization and a national leader for Canada's genomics ecosystem. Working in partnership, and across sectors, we invest in, and coordinate genomics **research**, **innovation**, **data** and **talent** to generate solutions to today's biggest challenges. Genome Canada works closely with the Canadian government to address federal priorities for genomics. We also coordinate with a **pan-Canadian network of Genome Centres**, which enables us to reflect regional and provincial priorities. This network is key to our impact, facilitating regionally focused programs, proactive business development and strong industry connections across the country.

We strongly support the following recommended approaches from the *Sustainable Agriculture Strategy* (hereafter the "Strategy") to help advance the Strategy's goals and outcomes and overcome existing barriers.

- **Knowledge transfer and extension**—activities that increase farmers' access to the information, advice and training they need to effectively implement practices on their farm that advance environment and climate outcomes. For example, agricultural extension, demonstration sites, regional climate risk assessments, on-farm GHG calculators and life cycle analyses.
- **Supporting advancements in clean technology and digital adoption—** approaches that invest in and further incentivize the development, demonstration, commercialization and adoption of clean technology in the sector. For example, zero-emission on-farm equipment or machinery, precision agriculture, artificial intelligence and innovations that enable the use of alternative and bioenergy.
- **Regulations—**amending existing or establishing new regulations that could establish performance standards and/or mandate or prohibit use of a specific agricultural practice to efficiently and significantly scale up the adoption of practices or technologies that currently have low levels of adoption. Climate-friendly new practices, technologies and/or products may also require regulatory approval, along with approaches to address any potential hurdles and prolonged timelines.
- **Science and research—**filling existing knowledge gaps, improving measurement and monitoring, and developing new varieties of crops and livestock to help advance environment and climate outcomes in the sector.
- **Solutions along the supply chain—**supporting solutions along the supply chain that ultimately have a positive impact on on-farm environmental performance, as well as other environmental benefits along the supply chain. For example, advancing the growth of the bioeconomy sector and finding innovative solutions to reducing food loss and waste, and advancing circularity in the sector.
- **Working with Indigenous Partners** — collaborating with Indigenous partners on Indigenous specific policy and programming that supports sustainability in Indigenous agriculture and food systems, including on actions that strengthen Indigenous-led food systems through environmental benefits.

Key points

1) The *Sustainable Agriculture Strategy* must be underpinned by AAFC's new *Strategic Plan for Science*. Science and innovation—especially genomics—are key drivers of sustainability and resiliency in the agriculture sector. These two departmental strategies must be aligned and integrated so we draw on the best science and technology to drive Canada's sustainability goals in the agricultural sector.

- The application of genomics science, tools and biotechnologies can play a key role in supporting the goals of the Strategy and the department's 10-year ***Strategic Plan for Science***. We strongly welcomed the new plan's mission-driven approach to science around four key mission areas: mitigating and adapting to climate change; increasing the resiliency of agro-ecosystems; advancing the circular economy by developing value-added opportunities; and accelerating the digital transformation of agriculture and agri-food. We have been an active participant in departmental workshops in 2023 to support this new approach.
- Canada has world-leading strengths in agricultural genomics science and innovation—this pan-Canadian capacity and expertise driven by investments through Genome Canada and the Genome Centres can be mobilized to support the Strategy and its five themes, especially in collaboration with AAFC's federal living labs sites across the country.
- We have evolved our model to drive a mission-driven approach to genomics research and innovation to meet Canada's biggest challenges. Genome Canada's new ***Climate Smart Agriculture and Food Systems Challenge*** exemplifies this transformative potential and the pan-Canadian delivery of impacts for sustainable agriculture through genomics-enabled research and innovation and multi-stakeholder engagement.

CLIMATE-SMART AGRICULTURE AND FOOD SYSTEMS

Genome Canada's **Climate-Smart Agriculture and Food Systems** initiative is investing a total of close to **$70 million**—through federal and co-funding investment—in cutting-edge genomic research and innovation to reduce the carbon footprint of Canada's food production systems, building their resiliency, environmental sustainability and economic viability. This mission-driven large-scale genomics initiative will support climate change mitigation and adaptation through strategic investments in climate-smart agriculture and food systems. Focused on strengthening the environmental sustainability and performance of Canadian agriculture and food systems, the **initiative will invest in a portfolio of interdisciplinary (fundamental and applied) genomics research and biotechnology development** projects aimed at achieving these goals. A portfolio approach allows benefits from one solution to translate into other production systems or supply chains and cascade impact throughout the broader national food system.

2) The Strategy must be flexible and reflect the strengths and diversity of Canada's federated food and research ecosystem.

- We strongly support the Strategy's principle that "approaches must recognize regional diversity across the country and that there is no "one-size-fits-all" solution to addressing environment and climate issues."
- The reality of Canadian agriculture is one of diversity of landscapes, soil types, weather patterns, farming practices and priorities within provinces, regions and across the country (e.g. large-scale grain crops and livestock in the prairies, vertical farming and greenhouses in BC, Ontario and Quebec, large scale capacity of food and beverage processing in Ontario, regenerative farming in B.C. and elsewhere, smaller scale approaches to food, fibre and fuel in Atlantic Canada, etc.).
- Programs and interventions/incentives may have to be tailored to regional contexts, strengths and realities and should support and elevate provincial agriculture and food strategies, such as for example Ontario's *Grow Ontario—a provincial agri-food strategy*, B.C.'s *Food Security Taskforce* or Quebec's *Agriclimat* pilot program.
- Thanks to strong relationships with provincial governments, the Genome Centres and their programs are aligned in support of provincial and regional agriculture and environmental strategies and programs.
- By working closely with end users or industry partners, the Genome Centres provide boots-on-the-ground local knowledge and relationships that maximize the potential for uptake and implementation of biotechnology solutions.

3) The Strategy must prioritize both adaptation and mitigation solutions and approaches through a *One Health* approach.[1]

- As the COVID-19 pandemic has shown, our health is directly linked to the health of animals and our environment. The *One Health* perspective to understanding the complexity of these interconnections is critical to supporting human health and wellness and addressing the impacts of climate change on our food systems and the health of our water, soil and both farmed and natural environments.
- Taking a *One Health* systems-level perspective requires large-scale, multi-disciplinary approaches to innovation. With genomics as a central, enabling science and bioengineering as the tool for implementation, the Enterprise is uniquely positioned at the interface of human health, agriculture, natural resources, biodiversity and environment.
- There is ongoing value in investing and supporting proven solutions such as breeding for traits to drive mitigation and adaptation in plants and livestock (e.g., nitrous oxide and methane gas reductions).
- There is also value in taking the *One Health* lens to support the development of novel systems, approaches, and technologies to provide low- or no-carbon alternatives to current products and approaches that disrupt the health of our global ecosystem.
- Genomics and biotechnology will be critical to the development of novel antimicrobials to combat the threat and mitigate the impact of antimicrobial resistance (AMR), an existential challenge whose complexity requires a *One Health* lens to convene and effectively connect the research and implementation communities and realize solutions for our immediate- and long-term future.
- The *One Health* lens integrates numerous data streams from across sectors, regions, and products to provide the data required to inform practices and policies. One of the most effective data sources for environmental health monitoring are eDNA (environmental DNA) based approaches. These can economically and quickly capture accurate 'snapshots' of soil, water, and ecosystem health. Coupled with well-established human, animal, microbiome and pathogen sequencing approaches, environmental monitoring provides the glue that connects the

[1] Here we are using the definition developed the One Health High-Level Expert Panel (**OHHLEP**) and published in PLoS Pathogen **One Health: A new definition for a sustainable and healthy future** - "**One Health** is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems. It recognizes the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent. The approach mobilizes multiple sectors, disciplines and communities at varying levels of society to work together to foster well-being and tackle threats to health and ecosystems, while addressing the collective need for healthy food, water, energy and air, taking action on climate change and contributing to sustainable development."

different living systems with each—and with climate, weather, and environment data.

- Genomics and the biotechnology it enables must be leveraged effectively to support these objectives and support the development of a system-level *One Health* approach to human, animal, environmental and economic health. The challenge won't be solved **only** with genomics, but it can't be solved **without** genomics.

GENOME ALBERTA: USING MACHINE LEARNING TO IDENTIFY PIGS WITH SUPERIOR DISEASE RESILIENCE TO IMPPROVE ANIMAL HEALTH AND THE SUSTAINABILITY OF PORT PRODUCTION

Pork production is a highly valuable industry for the Canadian economy at the national and Alberta levels. One of the major threats to robust and sustainable production is disease. Disease resilience is the ability of a host to maintain a reasonable level of productivity when challenged by infection. Vaccination and medical treatments as well as biosecurity and environmental management are strategies used to address the issue, but these approaches have limitations and there is public pressure to reduce the use of antimicrobials in the system. Selection of host resilience is a potential alternative or complement to these existing methods.

The overall goal of the project is to develop a tool for selection of pigs that are resilient in the face of multiple natural infections. To achieve this, detailed data characterizing the physiology, genomics, and health status of pigs will be analyzed by applying various algorithms from machine learning. These algorithms will be used to find patterns that accurately predict which animals remain healthy. Once these patterns are discovered they can inform breeding decisions: pigs that exhibit the disease resilience patterns can be favoured over those that do not, to yield commercial pig populations that remain healthier in the absence of antimicrobials. This ability to better select for disease resilience stands to improve the profitability of the pig industry and the well-being of animals, and to significantly reduce the usage of antibiotics.

GENOME PRAIRIE: 4DWHEAT – DIVERSITY, DISCOVERY, DESIGN AND DELIVERY

Wheat is the most important crop for current and future global food security, as it supplies the most calories and proteins to the global population. Wheat is grown on more land area than any other commercial crop.

Meeting the challenge of increasing wheat production to match the growing demand for food over the next 20–30 years is paramount. Current yield gains are impressive but will not meet the need of a growing population and may become unsustainable due to the lack of genetic diversity in current varieties.

The 4DWheat project will apply the latest genomic strategies to address this gap by focusing on two major challenges: enhancing yield and managing producer risk to important diseases. 4DWheat will apply cutting-edge genomics, resulting in strategies to fully capture diversity in wheat breeding. The project will also quantify the current and future value of wheat genetic resources and examine regulatory networks to promote using new breeding technologies.

GENOME ATLANTIC: REFERENCE GENOME FOR SHORTHORN CATTLE

Growing domestic interest in Canada's relatively small population of Milking Shorthorn dairy cattle has sparked the need for genomic evaluations in the breed. The moderate-sized breed has gained a reputation for its high efficiency in converting forage to milk containing high-valued fat and protein.

Genome Atlantic supported The Canadian Milking Shorthorn Society, headquartered in Kensington, P.E.I., to build a reference population of genotypes—a compilation of the genetic makeup of individual members of the dairy breed in Canada. As a first step, this involved the genotyping of most of the cattle resident in the Maritime provinces.

The work will also provide a template for additional genotyping of other Milking Shorthorn dairy cattle across the country as well as for testing genetic material from existing gene banks.

GENOME ATLANTIC: APPLE GENOMICS

Genomics is a key technology for breeding apples with commercially desirable traits, increasing the likelihood of success in breeding better apple varieties. For many years, Dr. Sean Myles, Dalhousie University Faculty of Agriculture, has been collecting an enormous amount of genomic data and planted more than 1,000 varieties of apples at the Canadian Apple Diversity collection at the AAFC Kentville Research and Development Centre.

Dr. Myles' work has received support from Genome Atlantic, which has now progressed to the identification of several gene-editing targets in apples, of great commercial interest. Genome Atlantic also played a pivotal role in the formation of the National Apple Breeding Consortium, designed to advance the science of apple breeding through innovative technologies like genomics which will enable local breeders across Canada to develop and commercialize varieties suited for growing in their respective regions more quickly.

GENOME PRAIRIE: ENHANCING THE VALUE OF LENTIL VARIATION FOR ECOSYSTEM SURVIVAL (EVOLVES)

Canada is the largest lentil producer and exporter in the world. In 2015, Canadian lentils generated $2.5 billion in export revenue. The industry is seeking to enter the high-value food and ingredients sector and expects future lentil varieties will support this new venture.

The goals of EVOLVES are to: i) accelerate the deployment of specific quality traits through strategic use of genetic variability, and ii) improve the capability and agility of the breeding program so Canada can rapidly capture emerging market opportunities.

Project outputs from EVOLVES will contribute to the Canadian pulse industry's goal of diversifying market outlets and creating price stability. It will also secure Canada as the global leader in all aspects of lentil innovation and as a preferred supplier of high-quality lentils to the world.

4) The Strategy must prioritize investment in genomics and biotechnology research, tools and technologies that enhance the sustainability and resiliency of traditional practices and processes.

- Soil health and the soil microbiome can be one of our greatest opportunities on the pathway to mitigation—this is where genomics research tools and technologies can have a major impact (including in carbon capture potential, soil fertility and providing soil-based resiliency solutions to heat and water stressors).
- Pesticide reduction, fertilizer management, optimizing water management, and improving plant and animal biodiversity can all be improved through genomics research and the application of biotechnological tools and solutions.
- It is possible to use genomics to inform the reclamation of natural grasslands, forests and other managed or farmed ecosystems. Reclamation is a complex process involving myriad interactions at the ecosystem level. This complexity requires the power of genomics to enable the scale and scope of data and machine learning required to secure nature's health. These tools will be even more critical as climate change increases the pressure on food production, biodiversity and natural ecosystems.
- Genomics and biotechnology can support improved carbon sequestration in soil by increasing the amount that is stored and the time period for which it is held.
- The soil profiling efforts led by AAFC can be enhanced with the integration of genomics and metagenomics data to complement AAFC's long history of research in this area. An integrated chemical/biochemical/genetic soil health atlas program would connect these communities to create novel solutions.
- The previously mentioned technology and processes behind environmental DNA (eDNA) monitoring systems are critical to capturing the biodiversity of soil via quality-controlled data adhering to standards required for rapid and responsive policy decisions—not to mention farm-level decisions required of farmers to ensure the success of their season's work.

GÉNOME QUÉBEC: GENOMICS-ENHANCED BIOVIGILANCE TO IMPROVE CROP DISEASE MANAGEMENT AND REDUCE FUNGICIDE USE

Botrytis cinerea is a necrotrophic fungus capable of causing grey mould in hundreds of plant species, many of which are economically important, such as tomatoes, grapevines, potatoes, beans and peas. The disease wreaks economic havoc in fields around the world. At the moment, fungicides are the main weapon available against grey mould caused by B. cinerea. The use of fungicides, however, has resulted in the development of strains of B. cinerea that are resistant to these molecules.

In response, farmers need to use greater quantities of fungicides and apply them more frequently in order to save their crops. Unfortunately, this increased fungicide use compromises the quality of fruit and vegetables and harms the environment. Due to the loss of fungicide efficacy, fighting resistant pathogens has become a major challenge for future agricultural production here in Canada and around the world.

The aim of this research project is to collect a large assortment of isolated B. cinerea strains from all regions of Quebec. This collection will make it possible to analyze the impact of fungicides on the level of resistance and aggressiveness of these strains. Another goal is to use small non-coding RNA as biopesticides and viruses to make resistant B. cinerea strains less aggressive and more sensitive to low doses of fungicides. Farmers would then be able to reduce the massive and frequent use of fungicides.

GÉNOME QUÉBEC: MICROBIOME GENOMICS ARTIFICIAL INTELLIGENCE APPROACHES FOR MORE SUSTAINABLE ALFALFA

Sometimes referred to as the "Queen of Forages", alfalfa is the primary source of fodder for dairy and butchery farmers in Quebec. It offers excellent agronomic performance in addition to being drought resistant and carbon sequestering. Despite all these qualities, alfalfa is finicky in terms of environmental conditions and agronomic practices to reach its full potential.

One of the success factors of alfalfa is the development of nodules that capture nitrogen from the air to feed the plant. The sustainability and optimal performance of alfalfa relies on soil health, the persistence of Rhizobia, and the functional balance of beneficial vs. harmful microorganisms in the alfalfa soil microbiome.

The goal of the project is to apply an integrative microbiome genomics approach to develop a tool for Quebec producers that helps them determine the impact of agronomic management practices and soil health on productivity, quality and the persistence of alfalfa to increase their competitiveness while optimizing carbon sequestration in the soil to reach sustainability goals.

GENOME BC: PRECISION AGRICULTURE

Genome BC is a partner with **Terramera**®, the Vancouver-based agtech leader fusing science, nature and artificial intelligence to transform how food is grown and the economics of agriculture, in a significant project for the Canadian Global **Digital Technology Supercluster**. The **Terramera-led Precision Agriculture to Improve Crop Health** project is designed to leverage cutting-edge technology to prevent pests and protect food crops while reducing pesticide use.

This important project brings together top researchers from Agriculture and Agri-Food Canada, BC Cancer Research, Canada's Michael Smith Genome Sciences Centre, Compression.ai, Genome BC, Sightline Innovation, Simon Fraser University, Trent University and the University of Saskatchewan. The diverse group will focus on solving issues of crop loss due to climate change and the resulting increase in pests, pathogens and viruses. It will start by addressing wheat leaf rust, which threatens Canada’s $7 billion in wheat exports per year, before tackling other devastating crop diseases.

The *Precision Agriculture to Improve Crop Health* project team will develop new pest and pathogen controls through using computational biochemistry, genomics, machine learning and robotics. These technologies will quickly identify and test new pest management formulations and determine their ability to attack specific fungi on specific crops. The tools developed through this work be useful in other fields such as medicine, biotechnology, chemistry and computer science.

GENOME BC: GENOMIC ANALYSIS OF WETLAND SEDIMENT AS A TOOL FOR AVIAN INFLUENZA SURVEILLANCE AND PREVENTION

Avian Influenza (AI) is a viral disease that can cause significant morbidity and mortality in domestic poultry. AI outbreaks, and associated eradication efforts, have negative impacts on the economy and food security. In 2014 an AI outbreak in Canada and the U.S. was estimated to have cost over $3 billion. Wild waterfowl are the reservoir for AI (shedding viruses in their feces) and the focus of AI surveillance programs worldwide. Thus far, these programs have been centered on testing individual wild birds—an approach with significant limitations due to the practical and financial impediments of collecting wild waterfowl samples. These programs were in place during 2014 but failed to predict outbreaks in either country.

In response to the outbreak Genome BC sponsored a pilot study that brought together experts from the Ministry of Agriculture, Foods and Fisheries in partnership and the BC Centre for Disease Control to test a commercial targeted resequencing platform for the isolation and sequencing of a specific set of viral genes to identify the 2014 AI outbreak virus in wetland sediments. This innovative genomic approach demonstrated that the AI virus was widespread in wetlands throughout the Fraser Valley and likely could have been detected in advance of the outbreak had this approach been available.

The follow-on User Partnership Program project was designed to refine the AI sediment surveillance technology and methodology, to validate the sediment surveillance approach in the field, and to identify the optimal combination of AI surveillance techniques for maximum efficiency and efficacy. The multidisciplinary team surpassed these aims by creating and optimizing a novel targeted resequencing platform. The novel methodology was validated in field studies over two years by demonstrating that the detection level of AI sequences in sediment samples was superior to the gold standard approach using difficult to obtain samples from live and hunter-killed birds.

The success of this endeavor was the impetus for a new collaboration among the Ministries of Health, Agriculture and Environment. The longer-term goal of this collaboration is to create a *One Health* Genomics Centre that will dramatically increase genomics capacity in the province and make B.C. a global leader in *One Health* approaches to genomic-based pathogen surveillance.

5) The Strategy must support the development of climate-resilient and lower-carbon novel food systems, such as cellular agriculture, bioproduction and fermentation technologies.

- We cannot produce all the food we need with traditional farming practices and processes. The Strategy must all support approaches that strengthen circular food systems and the bioeconomy. Cellular agriculture and biomanufacturing present a significant global opportunity to diversify food production while complementing and even enhancing existing traditional production approaches.
- Investment in cellular agriculture can drive transformative opportunities for sustainability, food security, resiliency in supply chains and economic growth.
- In fact, Ontario Genomics' s **Cellular Agriculture – Canada's $12.5 Billion Opportunity in Food Innovation** report involving extensive stakeholder consultation, articulated three inter-connected actionable opportunities, below, to inform a policy framework and implementation plan for a thriving Canadian cellular agriculture industry. The report's economic analysis estimated a $7.5 billion per year industry and up to 86,000 jobs by 2030, and Canadian revenues as high as $12.5 billion per year and up to 142,000 jobs in the longer term. To achieve success, the report recommended that Canada must:

    - **Develop a national vision and strategy for a Canadian cellular agriculture industry in the near term**. This is foundational to enable a growing domestic ecosystem and fully realize the benefits presented by this industry. An outcomes-driven national vision and strategy should be developed collaboratively, be inclusive of stakeholder requirements and include a clear plan for implementation in the short-, medium- and long-term.
    - **Establish a clear and transparent regulatory framework for cellular agriculture products in Canada.** Canada is encouraged to proactively develop an agile, iterative and innovative regulatory framework by building on existing processes to support the evaluation and approval of cellular agriculture products in a timely manner, in alignment with Canada's current rigorous regulatory process and excellent food safety standards.
    - **Provide supporting mechanisms for research and commercial development.** Incentivization, through public and private investment and partnerships, and outcomes-driven networks, is critical for a thriving domestic cellular agriculture industry, with infrastructure support for research and development, training, company creation, scale-up and growth, leading to made-in-Canada product commercialization.

ONTARIO GENOMICS: CELLULAR AGRICULTURE

Ontario Genomics and the **Canadian Food Innovation Network** (CFIN) announced in May 2022 the recipients of more than $900,000 in funding through their AcCELLerate-ON competition, Canada's first regional cellular agriculture competition.

One of the four projects, Ardra Inc., is **developing fermentation-based production of heme** as a natural flavour ingredient. A significant focus of the Canadian alternative meat industry is supplying pulse-based plant ingredients. Ontario has an opportunity to support the alternative meat industry and potentially enable more Canadian-produced products by leveraging its engineering biology and biotechnology expertise to supply/create ingredients to enhance these products.

Ardra's project focuses on developing a very well understood ingredient called heme, found in animal blood, which alone provides a core element of the taste of meat. Ardra has demonstrated production of animal-free heme by precision fermentation and has active requests for larger sample amounts from several major flavour companies.

Their objective is to reach pilot-scale for heme production, validation of their key ingredients by these potential customers, and to establish a clear path to market.

GENOME ATLANTIC: ALGAL-BASED PRODUCTION OF NUTRITIONAL LIPIDS

Genome Atlantic is supporting a regional R&D company to further enhance their commercial production of omega-3-rich lipids, such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

These are produced through fermentation by microalgal biotechnology and sold into human and animal nutrition markets, complementing and potentially displacing fish oil in the market. In accomplishing this, the company aims to contribute significantly to global food and environmental security through reduced dependence on unsustainable resources, such as fish oil and high-footprint resources, such as terrestrial oil plants.

Genome Atlantic's support will help to accelerate the process and yield of these products by way of contemporary -omics and syn-bio applications.

6) The Strategy must invest in and provide greater support and priority to circularity approaches in agriculture through genomics and biotechnology.

- We strongly support the principle of circularity in the Strategy: "applying circular economy principles towards an agriculture and food system that is regenerative, resilient, turns waste into a resource, and offers new domestic and international market opportunities." In fact, we would recommend that the principle deserves higher priority in the Strategy by adding it to both the goals and targets, representing a real win-win and value add for the Strategy. Special attention should be given to addressing the gap in pre-farm gate opportunities.
- Canada has deep expertise and new opportunities to apply genomics tools and technologies in the upcycling and valorization of agricultural waste/residue/by-products/biomass for producers, consumers and other stakeholders and for the benefit of other sectors (e.g., biofuels and the emergent bio-energy sector).
- As a complex, systems-level challenge involving the actions of numerous stakeholders and members of diverse communities, the pursuit of circularity in our production systems requires solutions in production, processing, transportation and waste reduction or valorization. All of these aspects of our food system are impacted by genomics and biotechnology. For example:
    - Modern agriculture has been enabled, and continues to be improved, by the application of genomics-enabled plant and animal breeding. Increasing production without increasing emissions requires bio-based solutions.
    - Processing of pea and other leguminous protein, a climate-smart alternative to animal-based protein in packaged goods, results in starch and other waste streams that can be repurposed as the fuel to feed microbes in bioreactors for the production of food ingredients or agricultural products.
    - On-farm transportation and fuel needs can be addressed via on-farm or co-located biofuel production systems that convert farm waste and processing biomass into biodiesel, a drop-in replacement for farm vehicles – reducing carbon emissions and connecting waste-to-fuel in a circular value chain.

GÉNOME QUÉBEC: A GENOMIC PLATFORM FOR OPTIMIZING REPRODUCTIVE CAPACITY AND THE BIOCONVERSION OF FOOD WASTE AMONG BLACK SOLDIER FLIES

Despite one of the strongest residual materials management policies in North America, still less than 25 per cent of the 1.3 million tonnes of organic materials generated annually by the agri-food industry are recycled, and the remains buried. The upcycling of organic matter by insects is an emerging biotechnology that is shaking up conventional systems for managing residual organic matter.

The black soldier fly (BSF) is among the highest and most produced insect species both in Quebec and elsewhere in the world. While there have been significant advances in the practice of BSF production, significant gains are still to be made, particularly in terms of bioconversion and reproductive capacity. In this context, this project aims to develop a platform for the genetic improvement of BSF.

This platform will enable companies to produce, through genetic selection, strains of BSF with a better capacity for recovering organic waste and transforming this waste into entomological proteins. These proteins can then be used as food for animals intended for human consumption; an approach that is fully in line with sustainable agriculture and advancing circular economy approaches.

ONTARIO GENOMICS: WASTECANCREATE UPCYCLING CONSORTIUM

Tackling the dual issues of food waste and plastic pollution, Ontario Genomics has brought together academic and industry partners to form a vital consortium, supported by AAFC.

The organization helps partner organizations convert agricultural waste into bioplastics, a process that intends to lead to lower energy costs, improved performance, and a reduction in GHG emissions.

With funding of up to $1.26 million through the ACT Research and Innovation Stream, Ontario Genomics will manage a consortium to accelerate the optimization of lab processes, pilot commercial processing equipment and produce material test samples for use by industry partners.

7) The Strategy must be underpinned by the principles of evidence-based and data-driven programming, policy and decision-making.

- We strongly support the principle in the Strategy "ensuring that scientific advice guiding decision-making is based on sound scientific principles and empirical data, accepted methodologies, and professional standards."
- Genomics is a big data science. Genomics data collection, generation, sharing and analysis can yield actionable insights to support climate and environmental goals in the agricultural sector.
- Initiatives that support the convergence of big data through drones, robotics and sensors with artificial intelligence applications can advance precision agriculture to inform best practices on sustainability and greater productivity for farmers and producers.
- Génome Québec has pursued significant investments in artificial intelligence and agricultural genomics, which can be leveraged to support sustainable agriculture objectives. It has partnered with Laval University through **Genovalia**, the very first centre dedicated to the production, processing and exploitation of non-human genomic data in Quebec. This initiative will create value by building on the synergy between artificial intelligence and genomic data in sectors such as agrifood, forestry and environmental sciences. The centre will respond to the numerous challenges in genomics, such as improving standardization in data collection, increasing information sharing among different areas of research, growing computational capacity, and developing more efficient analytical tools. Better use of genomic data will provide many advantages for the agriculture industry, help guide public policies and further advance scientific research.
- To support evidence-based data benchmarking, the Strategy should invest in and support continuous measurement and data integration, sharing and management tools such as the ***National Agricultural Sustainability Index*** in which Genome Alberta is a partner.
- The Strategy could also leverage new tools being created by Genome Canada's programs such as the new ***Data Coordination and Collaboration Hub*** in our Climate Smart Agriculture and Food Systems Challenge. Genome Canada is investing $4 million in cross-cutting funding to develop and implement a portfolio-level plan to coordinate data assets, standards and analytics across the Interdisciplinary Challenge Teams in our Challenge.

GENOME ALBERTA: INTEGRATING GENOMIC APPROACHES TO IMPROVE DAIRY CATTLE RESILIENCE: A COMPREHENSIVE GOAL TO ENHANCE CANADIAN DAIRY INDUSTRY SUSTAINABILITY

Global demand for dairy products is set to expand with emerging economies, the need for safe, affordable, nutritious and high-quality milk protein in developing countries and world population expansion. At the same time, the dairy industry is also facing a number of emerging issues important to governments and consumers, related to human and animal health, environmental impacts, sustainability and social acceptability.

The project looks to satisfy increasing demand and ensure the global competitiveness of Canada's dairy cattle industry both on-farm and in exporting Canadian dairy genetics, while ensuring overall sustainability. To address these needs, new datasets and genomic tools will be developed to deliver a more 'resilient' cow, i.e. an animal able to adapt rapidly to changing environmental conditions, without compromising its productivity, health or fertility while becoming more resource-efficient and reducing its environmental burden.

The index for resilience will allow farmers to reduce costs related to poor cow fertility, diseases and animal feed, which represent the largest expenses in milk production, resulting in an estimated annual net savings for the dairy industry of $200 million. At the same time, a more accurate selection for increased fertility, broader disease resistance and environmental efficiency will result in wider benefits to Canadian society, i.e., reduced reliance on pharmacological interventions (antibiotics and hormones), fewer animal welfare concerns, reduced animal wastage, reduced methane emissions and reduced land required for feed production.

This project will collect and standardize new data with applications that will benefit Canada's dairy industry and increase global food security and sustainability.

8) The Strategy must address barriers to the adoption of new technologies that can support sustainable agriculture and include support for knowledge mobilization initiatives that enhance broader public acceptance and adoption.

- The Strategy must support social science and other research to better understand the barriers to adoption to new technologies. Genome Canada and the regional Genome Centres have a long and deep history of supporting integrated research in our programs that aims to understand the implications of genomics in society and provide solutions to **adoption.**
- The Strategy could also leverage new tools being created by Genome Canada programs such as the **Knowledge Mobilization and Implementation Hub** in our Climate Smart Agriculture and Food Systems Challenge. Genome Canada is investing $2 million in cross-cutting funding to develop and implement a plan to coordinate knowledge mobilization strategies across the Interdisciplinary Challenge Teams and support portfolio-level research into the ethical, environmental, economic, legal and social implications of genomics and activities for knowledge mobilization and implementation, including in Indigenous and marginalized communities. This includes support within the initiative for Indigenous knowledge and agricultural practices and meaningful engagement to support technology adoption.
- Securing adoption and implementation of novel technologies on the farm requires that these solutions fit with the logistics and economic realities of food production. Working with farmers to reduce the barriers to on-farm implementation will be critical to link the innovation with the practices and support made-in-Canada technological and commercial development.

ONTARIO GENOMICS: BARRIERS AND OPPORTUNITIES FOR COMMERCIALIZATION OF GENE-EDITED BEEF AND DAIRY PRODUCTS

For years, our understanding of genetics has been used to improve agricultural practices and food production. Conventional plant and livestock breeding have shaped many of the food products we enjoy today. More recent advances in biotechnology are allowing us to address agricultural issues that were inconceivable with standard genetic technologies. One such advancement is the development of gene-editing technologies that may be used to improve the welfare of farm animals, potentially benefiting farmers and broader. However, people have also expressed concern about the use of biotechnology in food production. This concern—as well as supply chain constraints—can lead to resistance to adopting these technologies by producers, processors, retailers, food service and other supply chain stakeholders.

What factors affect societal acceptance of these technologies? The primary aim of this research project is to answer this question, focusing on potentially animal welfare enhancing gene-edited technologies as applied to dairy and beef cattle. The larger objective is to better understand how novel gene-edited food technologies are likely to be perceived.

The proposed research will focus on understanding of perception, trust and adoption among all interested groups from farmers to consumers. A better understanding of perceptions towards gene-editing technologies may allow for improved communication efforts, and potentially result in enhanced trust in the food system. Moreover, Canadian food businesses will be able to more confidently predict which gene-editing technologies are likely find societal acceptance.

9) The Strategy must prioritize science-based regulatory modernization to enable smooth implementation and application of new and emerging technologies that contribute to sustainable agriculture goals.

- The Strategy consultation document states "The challenges facing the agriculture sector are significant and innovation will be vital to inform and support the magnitude of the changes required to ensure food production systems will be profitable, sustainable and resilient...such as gene editing."
- The Enterprise provided its views to the federal government's consultations regarding guidance for plants for **novel traits**. We welcomed Health Canada's publication of updated guidance in May 2022.

- As part of addressing the goal of the Strategy, we now urge the Canadian Food Inspection Agency to publish its *Guidance for Plants with Novel Traits* so that Canada's agricultural sector can capitalize on the opportunities of bio-innovation for climate smart agriculture and eliminate uncertainty about Canada's position on plant breeding innovation in the global marketplace.
- Furthermore, genomics-enabled information and tools will be required to inform the development of policies to enable proactive environmental protection and remediation efforts in the face of climate change impacts. Canada's leadership in soil health science and regenerative agriculture provides us with an unrivaled opportunity to lead the world in the development of innovative policy solutions for environmental engineering – a discipline that stands to improve agricultural productivity and reduce emissions, while providing significant opportunities for commercial innovation and business creation.

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