Strategic Project Grants Target Area Descriptions

1. ***Advanced Communications and Management of Information***
2. ***Biomedical Technologies***
3. ***Competitive Manufacturing***
4. ***Healthy Environment and Ecosystems***
5. ***Quality Foods and Novel Bioproducts***
6. ***Safety and Security***
7. ***Sustainable Energy Systems (Production, Distribution and Utilization***)

1. *Advanced Communications and Management of Information*

Researchers are encouraged to submit proposals addressing the following STIC sub-priorities: new media, animation and games, wireless networks and services, broadband networks and telecom equipment.

If the sub-priority does not correspond exactly to one of the research topics below, researchers may take advantage of identifying an "exceptional opportunity" within the target area.

Context

Few fields have experienced the same rate of change as communications and information management. Further paradigm shifts will be driven by increasing machine intelligence, advances in signal processing and improved materials. To lead future developments, Canadian researchers need to address strategic challenges in areas such as advanced networks (wireless and optical), software for communications, enabling technologies, emerging and non-traditional devices, heterogeneous and homogeneous photonics and electronics, and information management. Advances in these areas will strengthen the quality and capacity of communications infrastructures and result in the introduction of valuable new products and services.

The success or failure of many new technologies will depend upon how humans interact and adapt. Where a more holistic approach to the research can enhance the impact of a project, applicants are encouraged to incorporate co-applicants and aspects outside the natural sciences and engineering into their applications.

Research Topics

(a) Network-Intensive Applications

In Canada's technologically advanced society, economic and social outcomes depend to a great extent on the capacity of individuals to rapidly find and manipulate information from diverse and distant sources.

The goal of this topic is to stimulate cutting-edge research that will lead to new network-intensive applications. For example, research can include simple intuitive user interfaces, improved access to and manipulation of information, transparent access to centralized or distributed secure information management systems, and new or more effective uses of the capabilities of ubiquitous, intelligent networks.

Research within this topic will be limited to:

- distributed, interactive gaming;
- machine learning;
- tele-presence; and
- user interfaces that are sight and/or voice based, haptic, multimodal and hands free.

(b) Ubiquitous Networks

Future networks will need to be more ubiquitous, mobile, agile and secure than they are today. They will also need to support new applications that continuously push bandwidth and accessibility limits. The goal of this topic is to stimulate research at the systems and technology levels in ubiquitous wireless, wireline and optical networks. Researchers are encouraged to focus on developing next-generation wireless and optical networks and embedded communications networks while addressing broadband connectivity, machine-to-machine connectivity and other issues.

Research within this topic will be limited to:

- intelligent signal processing;
- embedded optical and electronic systems;
- sensors and actuators;
- heterogeneous/integrated photonic and electronic devices and systems;
- optical/wireless/wireline interfaces;
- RF and millimetre wave components;
- tera-hertz technologies;
- programmable platforms; and
- dynamic spectrum allocation.

(c) Management of Information in a Networked Environment

Networks can quickly distribute massive amounts of data to any number of users. Data such as health records, business information and other types of sensitive information must be kept secure yet made available in the right context to users from any location using different devices. Users depend on this data to be accurate, available, properly managed and securely transmitted.

To receive funding under this topic, the proposed research must aim to enhance the accessibility, management, security or privacy of information in a networked environment.

Research within this topic will be limited to:

- intellectual property rights management (e.g., to detect infringement or collect royalties);
- indexing and watermarking of audio and video content;
- secure management of user-created content (e.g., Blogs, Wikis, Flock);
- secure data mining (such that, for example, new insights and opportunities can be extracted from agglomerated data without revealing secure data to unauthorized users);

- location independence;
- data organization;
- search capabilities;
- security and privacy; and
- geospatial information systems (GIS) and Web GIS access.

(d) Adaptive/Cognitive Networks

By definition, adaptive/cognitive communication networks can adapt their performance to accommodate factors such as interruptions, changing environmental conditions and fluctuations in traffic load. Software designed to garner network intelligence is used to detect and adapt to the operating habits of the network and its users with the objective of optimizing established services and offering new ones.

The goal of this topic is to stimulate research that will produce new findings to support network transparency and generate new applications and services. These applications and services will be predetermined and established through network-assisted learning.

Research within this topic will be limited to:

- network- and edge-interface learning algorithms;
- seamless mobility (e.g., wireline, optical and wireless, including cognitive radios);
- location-based technologies (e.g., indoor positioning, network-assisted location);
- abstracted position and authority-based secure content delivery;
- intelligent signal processing;
- dynamic spectrum allocation;
- programmable and learning platforms through enabling technologies (e.g., software, sensing and actuation); and
- enabling security technology (e.g., deep-packet inspection).

(e) Advanced Materials, Devices and Supporting Tools

These projects explore new opportunities for the creation of radically different device technologies towards platforms for next-generation computers and communications networks. These technologies could address higher device speeds, or potential for enhanced functionality, or economical mass-production. Proposals must contain at least one explicit communications or computing application of the proposed technology, which is of interest to the supporting organization(s), to be retained in the competition.

Research within this topic will be limited to:

- parallel systems and programming;
- molecular electronics and computing;
- optical and electronic devices and materials;
- novel electro-optical phenomena usable for computing;
- RF and millimeter wave components; and

- tera-hertz technologies.

(f) Software and Computing Systems

The goal of this topic is to investigate leading-edge infrastructure, methods and tools, which will lead to a substantial improvement of software engineering practices, with respect to quality, evolvability, understandability and overall cost-effectiveness of reliable, long-lived software systems. Of particular interest is the potential for innovative software advances in relation to hardware or middleware and resultant system-level improvements.

Research within this topic will be limited to:

- quantum computing;
- grid computing;
- heterogeneous computing;
- adaptive architectures and self-managing systems; and
- service oriented architectures and composition of services.

2. *Biomedical Technologies*

Context
In the coming years, Canada's aging population will demand greater access to improved health care and biomedical technologies. Natural sciences and engineering research is required to overcome major challenges in the early detection of disease, real-time monitoring of dynamic events in living systems, and the development of "intelligent" medical devices and interactive biomaterials. Research is also required to improve accessibility to health care devices and technologies and make such devices and technologies easier to use.

The intended outcome of research in biomedical technologies is to generate improved or new technologies to support health care, diagnosis and treatment. Technological improvements will reduce the burden on the health care system and increase quality of life. Canada's economy will benefit from the reduction in health care costs and the commercialization of the resulting technologies.

One of the underlying themes of this target area is to build on Canada's strengths in the natural sciences and engineering to overcome barriers to major advancements in biomedical technologies. For example, researchers are encouraged to build on Canada's advanced communications research capability to increase opportunities for remote or home-based care and to improve quality of care through more effective yet less invasive diagnostic tools. Another underlying theme is that advances in biomedical technologies can decrease costs yet increase the functionality of devices and systems so that health care technologies become more widely available and easier to use.

NSERC will **not** fund research involving clinical trials conducted on humans. If your proposed research includes randomized controlled trials (RCT), please submit your application to the RCT program of the Canadian Institutes of Health Research (www.cihr-irsc.gc.ca/e/22388.html).

Research Topics

(a) Detection Methods for Use in Whole Organisms

Early detection of disease is critical to successful treatment or reducing the impacts of the disease. There have been significant advances in technologies that could be exploited for the detection and tracking of molecules, signals or dynamic cellular events in living systems. The challenge is to advance these technologies further to enable the early detection of disease and to monitor disease progression and therapeutic efficacy.

Given the importance of developing non-invasive, cell-specific detection and monitoring methods, researchers are encouraged to develop low-cost, widely accessible, real-time detection and sensing technologies for living systems.

Research within this topic will be limited to:

- new imaging modalities;
- reagent-free spectroscopy;
- minimally invasive detection technologies;
- image guidance technologies for treatment;
- cost-effective, low-maintenance biosensing and/or imaging devices;
- new technologies to break current barriers in spatial and temporal resolution in imaging;
- novel sensors for diagnostics in whole organisms; and
- miniaturized systems for point-of-care diagnostics.

Research involving the development of new gene arrays or new chemical agents will **not** be considered under this research topic.

(b) Computational Tools for Real-Time Signal Processing and Analysis

One of the biggest obstacles to moving diagnostic technologies from the laboratory to the health care system is the tremendous computational burden of transforming measurements into meaningful information that health care providers can use. Canadian scientists and engineers are encouraged to develop computational techniques and analytical tools for the real-time processing of diagnostic data or for complex patient-monitoring systems. They are also encouraged to address a related challenge: incorporate computational techniques and tools into intelligent feedback systems that control complex robotic systems, remote systems or prosthetics.

One of the objectives of conducting research in this area is to find ways to provide meaningful diagnostic or monitoring information that can be captured efficiently, reliably, and in real-time. Such advances will make health care services more efficient, improve patient care and safety, reduce health care costs and/or create opportunities for remote care.

Research within this topic will be limited to:

- computational tools for dealing with large amounts of real-time diagnostic data coming from living systems;
- intelligent diagnosis, i.e., real-time analysis of diagnostic data from living systems;
- intelligent feedback systems for robotics, complex instrument control and prosthetics;
- point-of-care diagnosis;
- real-time image processing;
- computational tools for signal extraction/processing; and
- computational modeling of living systems as a predictive tool for therapy.

(c) Biomaterials and Tissue Engineering

Research within this topic should focus on the key challenges standing in the way of advancing the science of tissue regeneration, specifically keeping cells viable within scaffolds and modulating the immune response to implants. Research that builds on Canada's strength in biomaterials to develop target-specific delivery systems will also be included within this topic.

Research within this topic will be limited to:

- combination strategies to enhance survival of implanted cells/materials in vivo;
- improved methods for functional vascularization and/or innervation of artificial tissues;
- innovative and interactive biomaterials for tissue engineering;
- biomimetic materials for tissue replacement;
- "smart biomaterials" (i.e., biomaterials, including stimuli-responsive materials and signal-initiating materials, that can communicate with the body); and
- target-specific delivery strategies for biomaterials alone or in combination with cells or therapeutic molecules.

Research toward the development of new non-interactive biomaterials for prosthetics will **not** be considered under this research topic.

(d) Technologies for Independent Living and In-Home Care

Given Canada's aging population and our nation's commitment to help older people and people with disabilities live independently, research into technologies that will support independent living has become a national priority. Research in this area could help to generate new, accessible technologies to help older or disabled people remain in their homes, and to improve access to health care for those living in remote regions of Canada.

Natural scientists and engineers are encouraged to conduct the research required to develop new technologies that are affordable, reliable, compact, portable, safe and easy to use. Human factors must be included in the design of instrumentation and monitoring equipment for use in the home or in the health care system.

Research within this topic will be limited to:

- new technologies in communications, monitoring and detection for managing disease or disability in the home;
- human-machine interfaces to make medical technologies easier to use and safer;
- assistive technologies to aid mobility or mitigate sensory impairment;
- technologies to support formal or informal care-giving in the home; and
- rehabilitation engineering.

3. *Competitive Manufacturing*

Context

To compete successfully in the rapidly changing global economy, Canada needs to develop new value-added products and use flexible, lean, clean and cost-effective production processes. In light of these challenges, research in this target area will focus on:

- advancements in manufacturing processes or material design that contribute to new and/or competitive products coming to market; or
- increasing manufacturing productivity and flexibility, reducing energy costs and environmental impacts (operational improvements or integrated production systems for a broad range of manufacturing will be considered).

Research Topics

(a) Automation Workflow Improvements

The goal of research proposed under this topic is to develop automated workflow improvements to assist companies to design, analyze and build manufacturing factories, lines and cells that are capable of providing improved productivity, space utilization, logistics, cost reductions, repeatability and process stability.

Examples of research within this topic include:

- process integration techniques that reduce the number of processes and/or reduce the need for secondary operations;
- flexible and reconfigurable production lines and tooling and material manipulation;
- intelligent sensors (vision, proximity, chemical, thermal, etc.) that can connect to closed loop control for automated process adjustment and pass fail analysis; and
- robotics for speed improvements and minimum airtime, extended service life and ease of use focusing on HMI and other process elements.

(b) Functional Materials

Materials have traditionally been developed for their structural, mechanical or biological performance. An increasing number of new and modified materials with specific features or capacities are being developed and introduced in industry where they are used to support catalysis, energy storage, magnetics, biocompatibility, bioactivity, piezoelectric activity, etc.

The functional performance of materials can be improved by controlling and optimizing their chemical, biological and physical structure. Improving functional performance often requires significant developments in areas such as synthesis, bioengineering, surface chemistry, micro/nanostructure determination and control, materials physics, electrochemistry and other areas of research.

Under this topic, proposed research must focus on the development of novel or improved materials and their manufacturing processes.

Examples of research within this topic include:

- novel biological structures such as bionanoparticles (virus like particles, liposomes, etc.);
- MEMS platform technologies applicable across several application areas; such as advanced functional materials development, micro-fluidics (either for semiconductor device cooling or for biomedical instrumentation realization and the like), MOEMS photonic interconnection capabilities between components/systems; base semiconductor process development and the like;
- development of materials or structures that enable or provide advantaged catalytic performance;
- development of materials or structures that respond to the environment in a useful way so as to produce enhanced physical properties or provide measurement or sensing capability;
- materials used in battery and other energy storage or energy conversion technologies;
- magnetic materials;
- light-emitting materials for: low energy consumption, high light output but low heat emission, and wavelength-specific applications (UV for sterilization, grow light for enhanced photosynthesis); and
- materials for industrial and medical lasers.

(c) Green Manufacturing

The objective of this research area is to invent and develop technologies which will lower the carbon footprint or the environmental impact of manufacturing processes and product life cycles. One specific area is the conversion of Canada's biomass (both forest and agriculture based) through efficient manufacturing to sustainable and recyclable materials. Another area is the drastic reduction in either the energy consumption of manufacturing processes or in the carbon footprint of the manufactured products over their life cycles.

Examples of research within this topic include:

- the substitution of biomass for petroleum based feed stocks to manufacture chemical intermediates and/or to make recyclable biopolymers;
- the manufacture of low environmental impact construction systems for residential and non-residential applications;
- the reduction of plant energy consumption through more efficient processing, improved process flows, or fossil energy substitution;

- the elimination of health hazardous chemicals and waste generation in manufacturing processes;
- zero emission processing; and
- product design which increases the reusability and recyclability of the product.

(d) Hybrid Composite Materials

The goal of the research proposed under this topic is to add value to Canada's manufacturing industry by developing materials with specific functionality that demonstrate high strength and low weight, at an affordable cost. The topic relates to materials comprising a matrix reinforced with fibres or particulates, which meet the criteria above and/or demonstrate other specific properties like, but not limited to, electrical/thermal conductivity, corrosion and chemical resistance, and impact resistance or damage tolerance. The topic includes hybrid materials optimized for specific properties incorporating various material forms and constructions, which may include surface coatings or sandwich configurations. Materials may also be optimized for specific processing including, but not limited to, automated manufacture, liquid composite molding, compression molding, injection molding, etc. Other features of interest would include materials configured for low energy processing like out of autoclave, reinforced thermo-plastics, etc.

(e) Inspection/Measurement

The goal of the research proposed under this topic is to add value to the critical quality/process inspection and measurement control facet almost universally needed by Canada's Manufacturing industries.

The objective is to invent new platform capabilities with significant manufacturing impact, preferably applicable across a broad range of end market applications.

Examples of research within this topic include:

- ADR (automatic defect recognition);
- NDT(non-destructive testing);
- chemical detection or analysis;
- hardware and/or software algorithmic development for 3D imaging;
- sub-surface imaging using x-ray, or IR, or IR and 3D imaging;
- laser acoustics; and
- vibration modal analysis.

An outcome of the above will be a robust solution leading to new methods, prototypes and capabilities that improve on resolution, recognition, accuracy and speed of capture suitable for a manufacturing environment, allowing real time in-line process or product monitoring.

(f) Joining Technologies

The goal of this research is to develop new, or enhance existing, joining methods and processes involving similar or dissimilar material components used in Canadian Manufacturing Industries.

Examples of research within this topic include:

- development of new joining techniques and technologies;
- using existing joining methods to develop or expand joining process parameters to enhance productivity and/or joint quality; and
- develop/enhance efficient process control technologies to test the joint during process and provide automated feedback to the joining process (e.g., adaptive weld technologies – closed loop process control).

The developed joining methods and processes require testing of joint capacities and shall maintain the integrity of material/physical properties of the adjacent parent materials.

(g) Near-Net-Shape Processes

The low labour costs of some of Canada's international competitors and the rising cost of raw materials have affected the ability of Canada's manufacturing sector to compete globally. One way to help Canadian manufacturers compete is to develop superior manufacturing processes; for example, by creating parts or components with minimal wasted material. Near-net-shape processes significantly reduce product cost in two ways: by requiring dramatically less raw material per part; and by requiring significantly less finishing (e.g., machining and grinding).

Examples of part manufacturing processes that can potentially deliver near-net-shape components include casting, metal injection moulding, forging, powder metallurgy, laser sintering and sheet metal processing. Each process has its own research challenges:

- *Casting:* increase yields and as-cast properties, achieving thinner walls;
- *Metal injection moulding:* develop feedstocks and metal injection moulding processes for different alloys, targeting consistent dimensions and final material properties;
- *Forging:* develop methods to achieve closer final shapes with good control of dimensions and properties;
- *Powder metallurgy:* develop advanced powder materials and new technology for producing components that will have higher density and will meet higher stress requirements; develop better compaction methods to enable perfect cavity fill; develop new non-destructive methods for testing powder metal components where inherent residual porosity is ignored;
- *Laser sintering:* increase the impact of laser sintering by improving processes that target dimensional results and final material properties; and
- *Sheet-metal processing:* improve the processes of spinning, shear forming, flow forming, deep drawing, hydroforming, stamping, rolling and incremental forming in order to seize more manufacturing opportunities and compete more effectively in a wide variety of industries.

The challenges lie in further developing these and other processes to deliver parts cost-effectively with the required material properties in the final configuration.

(h) Process and Product Modeling

Manufacturing industries that develop processes to modify the shape or properties of materials or assembly of materials to a precise specification (e.g., parts, systems, feedstocks, chemicals or fibers) will gain a sustained competitive advantage by perfecting their production processes. To gain this advantage the industry must start with accurate, reliable models of key processes, be they mechanical, electrical, thermal, chemical, etc.

The development of products or materials which meet specific performance criteria can be accelerated and optimized if models can be developed that describe the structure-property relationships as well as the process-performance relationships. For example, models for the production of chemicals, polymers, fuels, paper or other basic materials would focus on the impact of processing variables on process efficiency and product quality; while Multi-disciplinary Design / Process Optimization will focus on combinations of:

- minimum weight of products;
- physical, mechanical, chemical properties of materials;
- improved production schedule;
- material costs;
- process cost; and
- environmental impact, etc.

Researchers are encouraged to exploit Canadian expertise to create modeling tools that integrate a high number and wide range of variables in order to enhance or enable the optimization of processes, materials or products. Validation of models with data relevant to industrial application will be a critical aspect and should be included in the project scope and work plan.

4. *Healthy Environment and Ecosystems*

Researchers are encouraged to submit proposals addressing the following STIC sub-priorities: water (health, security), Arctic climate change adaptation.

If the sub-priority does not correspond exactly to one of the research topics below, researchers may take advantage of identifying an “exceptional opportunity” within the target area.

Context

A continually growing economy/population increases the competition between humans and other species that share Canada’s ecosystems, for the energy and material resources within those systems. Canada’s science and engineering community can play an important role in helping policy makers understand the long-term ecological consequences of disturbances such as industrial activity or climate change. This strategic target area seeks better ways to protect and conserve Canada’s natural resources through research to enhance and maintain healthy environments and ecosystems that are better able to adapt to these disturbances. The targeted natural resources include groundwater, estuarine and coastal waters, rivers, lakes, soil, air and forests within managed and/or natural ecosystems.

Research is required to:

- determine ecological processes that are sensitive indicators of ecosystem health, particularly those with promise to guide environmental policy relative to the impact of resource utilization activities such as urbanization, agriculture, fisheries, mining and forestry;
- determine specific interventions that could significantly help ecosystems adapt to disturbances such as changing climate and economic activities with particular attention to the biodiversity of plants and animal life;
- determine ways to significantly improve our ability to effectively and sustainably use water resources in anticipation of local climate change variability; and
- determine better and more effective ways to manage wastes and remediate contaminated soil and groundwater.

Various social, economic and political conditions may impact the implementation of the research results. In order to effect change in policy and human behaviour, to innovate new technologies and to better inform decision makers, applicants are encouraged to incorporate co-applicants and aspects outside the natural sciences and engineering into their proposals. For example, studies of past successes and failures of environmental policies related to the research topics may be beneficial.

Climate research is not included in this target area; however, research designed to better prepare the environment and ecosystems to adapt to common scenarios for future climate change is encouraged.

Proposals that focus on *Strategic Issues in Resource and Ecosystem Sustainability* in Capture Fisheries and *Ecosystem Health and Environmental Interactions* in Aquaculture should apply to the Quality Food and Novel Bioproducts target area.

Research Topics

(a) Ecosystem Adaptation and Interventions

Researchers are invited to investigate ecosystem response to human intervention and climate change, and develop quantitative analytical methods that link environmental quality with ecosystem change. Researchers are encouraged to develop strategies incorporating sensitive indicators of ecosystem health, particularly those that could guide environmental policy relative to the impact of resource utilization activities such as urban land consumption, agriculture, fisheries, mining and forestry. This may involve quantitative models that better represent present or future processes and interrelationships at the ecosystem scale to simulate how anthropogenic disturbance affects ecosystem functions relative to resource utilization (e.g., reduction of ecosystem size, fragmentation, annual forest cut), soil properties, water quality and biodiversity. Researchers are encouraged to investigate the mechanisms and processes most sensitive to increasing levels of human utilization that alter forests, freshwater and coastal systems and could be expected to be early indicators of natural processes of ecosystem adaptation under anticipated scenarios for climate change, as well as the short- and long-term consequences of these adaptations to the Canadian economy and society.

Within this target area there is a need to address:

- how human utilization activities alter forest, freshwater and coastal ecosystems relative to their capacity to adapt in a manner not detrimental to the economy nor societal expectations; and
- how specific interventions may help ecosystems better adapt to climate changes through, for example, maintaining or enhancing biodiversity.

Research within this topic will be limited to:

Adaptation Strategies

There is a need to develop ecosystem level strategies that will ensure that our ecosystems remain sustainable despite increasing levels of human demands on their energy flows and material resources. Researchers are encouraged to identify and assess the industrial practices or human interventions that would be more effective in helping ecosystems and/or significant components within an ecosystem adapt to change. A goal is to recommend those practices or interventions that will help to maintain or enhance the benefits we gain from forests, freshwater and coastal ecosystems, while maintaining or enhancing biodiversity.

Impact of Climate Change on Forests, Freshwater and Coastal Ecosystems

Researchers are encouraged to develop quantitative experimental studies and/or quantitative models to determine the mechanisms and processes more sensitive to the impact of climate change on forest and freshwater ecosystems. These include recommended management practices and interventions that are specifically designed to better prepare ecosystems for climate change and that could be used to guide environmental policy and guidelines.

(b) Water Resources

As water resources become further stressed through increasing levels of societal demand, the pressure to recycle and reuse water will increase. Also, small rural communities face special challenges in ensuring safe water supply and effective wastewater treatment. There is a pressing need for innovative technologies to protect and treat water to higher standards and to more cost-effectively remediate contaminated water resources. Proposals for research targeting incremental improvements to existing technologies will **not** be considered for funding.

Within this target area there is a need to address:

- better and more fully/efficiently integrated water resource utilization; and
- new water treatment technologies better able to cost-effectively treat wider concentrations and types of contaminants

Research within this topic will be limited to:

Supply Protection and Management

Researchers are encouraged to develop methods and tools for quantifying water resources, protecting water quality and managing watersheds, taking into account the factors that control

source, supply, resource utilization and natural ecosystem function within the watershed. For example, research is needed to better understand how shallow and deep groundwater resources interact with surface waters; how resource utilization affects water quality and availability; and how intercepting and redirecting water affects recharge and discharge patterns and ecosystem function.

Treatment, Reuse and Remediation

Researchers are encouraged to develop innovative new technologies, methods and analytical tools for treating water and wastewater, and for remediating contaminated water sources. Examples include biological wastewater treatment, physical-chemical wastewater treatment, drinking water treatment, and *in-situ* and *ex-situ* remediation of contaminated groundwater resources.

(c) Waste Management and Site Remediation

Canada has a large number of industrial brownfields and other contaminated sites that are affecting ecosystems and limiting land use. We need to remediate these sites and find ways to avoid future contamination of land. Researchers are encouraged to develop new approaches to site remediation technologies (e.g., soil remediation), the analytical tools required to evaluate the performance of site remediation, and assess the feasibility and effectiveness of new waste management alternatives.

Within this target area there is a need to address:

- better measures of the effectiveness (including ecological costs) of waste management methods;
- better site remediation methods (particularly for brownfields); and
- better links between microbial activity and contaminant geochemistry.

Research within this topic will be limited to:

Brownfield Remediation

Research to develop innovative, less-intrusive and less-costly approaches to the remediation of brownfields, resulting from all types of past industrial activity, are encouraged.

Analytical Tools

Research to develop innovative analytical tools for site characterization that will more accurately define the extent and nature of the contamination and the success of remediation technologies and/or approaches that may be applied to them.

Systems Engineering

Research on systems engineering approaches are encouraged to better manage municipal, industrial and construction wastes in ways that better protect the environment and ecosystems. Those approaches designed to ensure that toxic materials of emerging concern (e.g., nanotechnology wastes, catalytic wastes [flue gas desulphurization] and novel organic materials) do not enter ecosystems in quantities that may be detrimental are of particular interest.

5. *Quality Foods and Novel Bioproducts*

Context

While Canada's agricultural and food production systems are among the most efficient and highest quality in the world, the prices our commodities fetch are subject to world forces we cannot control. Because of this fact, improvements to our existing food production systems will not necessarily increase revenue in Canada's food commodities sector. To increase revenue, Canada needs to rise above its global competition by introducing high-quality "functional" foods (i.e., with proven health benefits), novel feedstocks and value-added products derived from biological materials, be they plants, animals or microorganisms. Canada could also boost this sector by investing more in research in aquaculture, a new industry relative to traditional crop and livestock production, but with the potential to contribute more to Canada's future food economy. Ensuring and maintaining a safe and high-quality food production system is also of prime importance to Canadians.

Researchers are encouraged to create or develop novel technologies, processes or products that can be applied to food quality and safety, functional foods and nutraceuticals, novel bioproducts, aquaculture and capture fisheries.

Please note that NSERC will **not** fund clinical trials or cohort studies with humans.

Research Topics

(a) Food Quality and Safety

"Food quality" encompasses several attributes, including food safety (microbiological, chemical and/or physical); nutritional quality (amount and availability of major and minor nutrients); sensory quality (appearance, flavour, texture); maintenance of quality (after packaging and during storage) and functionality (suitability for processing and end use). These attributes are increasingly important with respect to consumer acceptance and international trade and, consequently, commercial success. Consumers are also demanding more information on the history of a food right back to point of origin to increase their confidence that a problem in the food production system can be properly traced and then contained or dealt with.

Researchers are encouraged to strengthen Canada's capacity to market superior quality foods here and abroad by developing increasingly reliable and commercially affordable methods and/or technologies that will assure food quality and safety.

Research within this topic will be limited to:

- methods for the analysis, traceability, and authentication of food and food products (e.g., nutrient status, presence of contaminants and/or pathogens, verified composition);
- methods to verify feed quality (e.g., for poultry, livestock, fish);
- preservation technologies (as they affect quality attributes);
- rapid, sensitive and accurate methods for microbial assessment;
- application of risk analysis techniques (mathematical modeling, data acquisition); and
- simple tests for functionality.

(b) Functional Foods and Nutraceuticals

The objective of this research topic is to increase the availability and delivery of food and nutritional components with specific health benefits to humans, livestock, farmed fish and companion animals. These food or nutritional components could be derived from conventional or new food sources of any biological origin. Researchers should attempt to clarify the mode of action of the specific component, in the form in which it is typically consumed, and demonstrate a clear link between the component and health.

Research within this topic will be limited to:

- identifying functional components, determining how they interact, and clarifying their mode of action in disease prevention and health promotion;
- developing methods to enhance the presence, or functionality, of known nutritional or nutraceutical components with recognized functional benefits in food and food products;
- enhancing the functionality of food or food products through improvements in levels, digestibility or bioavailability of active components;
- eliminating anti-nutritional and/or allergenic components from food; and
- developing a production chain in which the functionality of foods will be preserved or increased through production, transportation, storage and, if required, further processing.

(c) Novel Bioproducts

Biological materials, whatever their origin, can be the source of a wide range of new feedstocks and other products, including new medicines. By using the metabolites and metabolic pathways of diverse organisms, scientists and engineers could create “biological factories” to produce novel, high-value products for industrial, nutritional or pharmaceutical applications. Similarly, by using biochemical processing and fractionation, scientists could eventually derive high-value products from ordinary “commodity” starting materials.

Researchers are encouraged to focus on improving sources of non-food bioproducts through genetic or biochemical modification, and developing novel bioprocessing technologies, as described below.

Genetic and Biochemical Improvement of Sources for Non-Food Bioproducts

The objective is to genetically or biochemically modify organisms so that they can be used to produce bio-fuels, pharmaceuticals, industrial feedstocks and other useful products. Success in

this area will help Canada derive far more value from our land and aquatic resources, for example, in providing alternatives to fossil fuels and in reducing the economic impact of declining prices for traditional agricultural commodities.

Research within this topic will be limited to the genetic or biochemical improvement of sources of non-food bioproducts with the goal of raising the levels of desirable compounds or products (e.g., oils, proteins, polymers, starches, fibres, secondary metabolites).

The compounds or products could be either precursors or intermediates requiring further processing, or end products. Gene shuffling, directed evolution, or related technologies to develop new production platforms, or genetic and metabolic engineering toward the development of new host species are all among the approaches researchers could use.

Development of Novel Bioprocessing Technologies

Canada's large land base generates a great deal of biomass. With novel processing, this biomass could become the source of new industrial products that could eventually replace oil, gas and other petroleum-based products in our economy. Canada has an opportunity to lead the world in developing new industrial products from biomass, which will reduce our dependency on non-renewable resources.

Research within this topic will be limited to:

- developing and optimizing biology-based processing methodologies to derive valuable materials from renewable bio-resources; and
- solving issues that emerge from scaling up biology-based processing.

Proposals that focus on developing new processes for producing energy from biological sources or co-products from biofuels should be directed to the Sustainable Energy Systems (Production, Distribution and Utilization) target area.

Proposals that focus on wood processing should be directed to the Competitive Manufacturing target area.

(d) Aquaculture

Aquaculture (the farming of fish, shellfish, algae and aquatic plants) is expected to account for more than half of all global seafood production by 2030. Despite Canada's aquatic resources, seafood processing infrastructure and proximity to markets, Canada has not yet developed a significant aquaculture industry. Researchers are encouraged to develop projects aimed at improving the production efficiency and environmental sustainability of the aquaculture industry.

Research within this topic will be limited to:

Ecosystem Health and Environmental Interactions

Research is required to improve the understanding of the interaction of the culture organisms with and upon their environment. For example, research could focus on pest management, wild and farmed fish interactions, effects of harmful algae, disease interactions, ecosystem indicators and pathways of effects.

Fish and Shellfish Health and Wellness

Healthy fish are indicative of a healthy environment and good husbandry conditions. Environmental conditions can vary widely in the variable climates associated with culture across Canada such that the physiological limits of the organisms can be tested at times in terms of performance. Movement away from inshore protected sites towards more dynamic open ocean conditions could lead to new pressures on the health of the cultured organisms. Effective methods of dealing with exposure to wild pathogens on species in aquaculture production will be required. There is a need to define the interactions of the farmed organisms in terms of health, environment, and to develop mitigation options for maintaining fish health.

Technological Advances

There is an ongoing requirement to improve production technology for shellfish, finfish and seaweed farming to reduce environmental impacts, maintain or improve farmed organism health, to adapt to new and variable environments, and to maintain industry competitiveness in the global economy.

Genetics and Husbandry

Farmed products require well developed broodstocks, adapted to the conditions in the environment. A thorough understanding of farmed animal production attributes through genomics and proteomics approaches is required to advance selective breeding programs to improve shellfish and fish performance for existing species, such as salmon, trout, mussels, oysters and for emerging species such as cod, sablefish, geoduck and abalone.

(e) Capture Fisheries

The Canadian capture fishing industry is large and diverse, with commercial operations off three marine coasts as well as in inland waters and exports about 80 percent of its production. Fishing operations are fuel cost sensitive. Research is needed to assist the industry maintain its competitiveness in an increasingly difficult business situation. Researchers are encouraged to augment current research or develop innovative new projects, directed at addressing the challenges and priority research areas identified by the capture fishing industry.

Research within this topic will be limited to:

Operational Efficiency and Technology Development in the Capture Fishery

Research is required to improve operational efficiency and promote innovation in the Canadian capture fisheries industry. Research under this topic will include technology development to improve the economic performance and support innovation within the harvesting and processing components of the fishing industry to maintain and improve competitiveness. This is essential to relieve the pressure of rising fuel and operational costs and the threat to foreign export markets from aggressively developing fish product exporters around the world. Research might include improved fuel efficiency on vessels, more cost-efficient fishing gears, waste management, and traceability of Canadian seafood products.

Research related to gear and/or methods adaptation to improve ecosystem sustainability could also be included, such as modifying gear to reduce bycatch and decrease the impact of fishing gears on benthic habitat and technology to facilitate fisheries monitoring and control.

Strategic Issues in Resource and Ecosystem Sustainability

Research is required in a wide range of biological, ecological, and ecosystem science related to resource and ecosystem sustainability. Sustainability is achieved by appropriate management measures informed by sound understanding from a science base. Additional basic and applied science is needed to help ensure that Canadian capture fisheries are sustainable, in order to secure the future of our natural resources, the businesses that depend upon them, and to be in a position to demonstrate to others that this is the case. Research under this topic will include biology and ecology of exploited species, habitat impacts of fishing and ecosystem interactions with fishing operations, for example:

- *Enhanced Knowledge of Habitats and Ecosystems*
  Managing for sustainability places additional demands on the need to ensure that the health of the ecosystem and its constituent populations and components are well understood. A range of research is required to address key gaps in our understanding of the biology and ecology of exploited Canadian fishery resources.
- *Ecosystem Impacts of Fishing*
  Fishing industry activities may have an impact on the ecosystem or the status of populations, including exploited resources, biodiversity, and aquatic habitat. Attention has focused on the need to understand the impact that types of fishing activities can have on the ecosystem where the fishery operates. These issues often arise when a sector applies for eco-certification and to meet the requirements for maintaining its certification status. Considerable research is required to understand the fragility and resilience of resources and ecosystems, key indicators of ecosystem status in relation to fishing and the short-, mid-, and long-term effects of fishing. Equally important is research focused on the mitigation of fishing impacts on the ecosystem.
- *Ecosystem-based Management Practices and Resource Enhancement Initiatives*
  Resource enhancement initiatives have been widely undertaken in Canada, and the implementation of ecosystem-based management practices such as closed fishing areas or marine protected areas is increasing. Research is required to develop, support and test new approaches and to understand the success, effectiveness and benefits to the ecosystem and the fisheries involved of existing initiatives.

6. *Safety and Security*

Researchers are encouraged to submit proposals addressing the STIC sub-priority of water security.

If the sub-priority does not correspond exactly to one of the research topics below, researchers may take advantage of identifying an "exceptional opportunity" within the target area.

Context

As stated in *Securing an Open Society: Canada's National Security Policy*, there can be no greater role for a nation than to protect its citizens. But, as Canadians know, we live in an increasingly complex and interconnected world where threats such as terrorism, industrial accidents, the global spread of disease, and natural disasters such as hurricanes and earthquakes, can have devastating consequences.

Individuals, communities, private sector organizations and governments must, in a coordinated fashion, be able to assess security risks and prioritize measures to reduce these risks. Canada needs to do far more to ensure effective emergency management in the face of growing risks.

The four pillars of emergency management are:

- *mitigation and prevention:* sustained actions to reduce or eliminate the impacts and risks associated with natural and human-induced disasters;
- *preparedness:* developing policies, procedures and plans for effectively managing emergencies;
- *response:* actions taken during or directly after an emergency occurs; and
- *recovery:* efforts to repair and restore communities after an emergency.

Researchers are encouraged to develop new ideas and solutions to help ensure the safety and security of Canada and Canadians. While preparing their applications, researchers should pay careful attention to the overall significance of their projects on the area of safety and/or security. Preference will be given to applications intended to address a significant threat, where that threat has a reasonable likelihood of occurring. That is to say, research focusing on safety and security situations that occur frequently and yet are very small in scale, or research addressing extremely unlikely events of such enormity that no conceivable response would have an effect, although important, will not have a high likelihood of being approved.

In order to develop a more holistic approach to emergency management, collaboration with experts who work in fields other than natural sciences and engineering is encouraged, where appropriate.

Proposals that focus on secure management of information should be directed to the Advanced Communications and Management of Information target area. Proposals that focus on food safety and security should be directed to the Quality Foods and Novel Bioproducts target area.

The following research topics focus on mitigation and prevention, given that other federal funding programs already support emergency preparedness, response, and recovery.

Research Topics

(a) Risk and Vulnerability

Decisions pertaining to safety and security must be based on an in-depth understanding of risks and vulnerabilities, and must be seen by citizens as rational, transparent, and defensible. Researchers are encouraged to focus their proposals on the development of techniques, tools and systems that strengthen our capacity to identify and measure risks and vulnerabilities, weigh and compare different types of risks, determine risk levels and inform decision-makers.

(b) Resiliency of Systems

Research is needed to improve the design, engineering and operation of critical infrastructure systems to ensure they function properly during deliberate or accidental interference, natural disasters or other emergencies. Resiliency is interpreted to mean protection from failure, or assurance of service continuity for all types of critical infrastructure (e.g., water, transportation, electrical, internet), including fragile and aging systems. To make systems more resilient, researchers will need to consider, for example, systems' interdependencies, adaptation, redundancy, safe-failure and rapid reconstitution, and containment, as well as isolation of system components.

(c) Event Detection

Canadians must be protected as much as possible from the consequences of natural disasters (e.g., floods, earthquakes, storms), deliberate attacks (e.g., terrorism, criminal, cyber), or accidents (e.g., train derailments, blackouts). Research is needed to develop better surveillance, detection, and identification technologies so that citizens can receive early warning of such events and benefit from measures to reduce their impact. For a technology to be effective, it should allow for disastrous events to be predicted or detected early enough so that measures can be taken to reduce or eliminate dangerous consequences.

7. *Sustainable Energy Systems (Production, Distribution and Utilization)*

Researchers are encouraged to submit proposals addressing the following STIC sub-priorities: energy production in the oilsands, Arctic resource production, biofuels, fuel cells, water energy, cleaner methods of extracting, processing and using hydrocarbon fuels.

If the sub-priority does not correspond exactly to one of the research topics below, researchers may take advantage of identifying an "exceptional opportunity" within the target area.

Context

To a great extent, our standard of living depends on reliable, low-cost and high-quality energy, available as electricity and hydrocarbon fuels. However, we now face pressures that could affect the supply, quality and reliability of these traditional forms of energy. More research is required if Canada is to develop sustainable and affordable energy sources. To receive funding through this target area, researchers should focus on emerging technologies that can be applied to the development of sustainable energy systems.

Sustainable energy systems are best approached from a systems-engineering perspective – a holistic approach that addresses technical issues (e.g., efficiency in energy conversion and use), as well as political and societal concerns (e.g., safety, cost, and environmental impact). In devising this holistic approach, applicants are encouraged to incorporate co-applicants and aspects outside the natural sciences and engineering into their proposals.

Research Topics

(a) Integrated Systems Approach to Electrical Power Grids (Modeling, Lifecycle Analysis, Design, Optimization, Interoperability)

The Canadian electric power system is the aggregate of provincial and territorial systems that have been designed and adapted to meet the local needs of provinces and territories. Each of these systems has its own characteristics and operates independently, a fact that affects the efficacy and uniformity of our national power grid. Researchers are encouraged to focus on improving the efficiency of the national power grid, taking advantage of the resources some provinces have that may meet the needs of others, and forming a complementary, integrated whole. Researchers are specifically encouraged to enhance the mix of options for generating electricity, take advantage of the massive latent storage capacity of our large hydro assets, and seamlessly integrate distributed generation sources into electricity grid systems.

It will be important for researchers to be able to simulate the control and performance of the national power grid and ensure the quality of power it will deliver.

Research within this topic will be limited to:

Optimization of the Electricity System

Research under this topic must focus on optimizing the electricity grid system across Canada (i.e., improving its short- and long-term reliability, reducing its environmental impact, and ensuring that its component technologies work seamlessly and effectively together in the Canadian setting). Research could include the design and operation of an electricity system that integrates centralized and distributed generation, electricity storage, active monitoring, dispatch, fault limitation and power quality control.

Improving the Efficiency of the Distribution Systems and Demand Management Programs

The objective is to encourage an effective demand response to optimally reduce the energy consumption by consumers directly. For example, efforts should be placed on the automation of the distribution system and control response.

Proposals that focus on the protection of the energy infrastructure from natural disasters or terrorist acts should be directed to the Safety and Security target area.

(b) Energy Storage

The capacity to store energy is currently an underdeveloped component of Canada's management of energy. For example, most of today's electricity systems generate and immediately deliver electricity, without storing a portion of it for later use. Although designed to respond to fluctuating demand, these systems face peak period stresses that could be relieved by stored electricity. The transportation sector could also benefit from stored energy sources.

Researchers are encouraged to develop approaches that draw on Canadian expertise in fuel cells, as well as novel energy storage systems.

Research within this topic will be limited to:

Storage of Electricity

The goal is to develop a high-capacity storage system that can easily be integrated into the local grid where it will respond instantly in a power outage and operate seamlessly without a noticeable decrease in the quality of power. Ideally, such a system should be scalable to meet different demands (i.e., mobile and fixed applications such as transportation, building and community uses).

Storage of Hydrogen

The goal is to develop a container with a high weight-percentage storage capacity that can easily be shaped and incorporated into existing transportation systems and that will be cost-effective when mass produced.

(c) Fuel Cells and Clean Transportation Systems

Improving Fuel Cell Performance

For transportation and stationary applications, the goal is to specifically address reliability, durability and efficiency; strategically lowering the cost of fuel cell development by incorporating new engineering ideas; and addressing cost reduction in novel ways (e.g., more cost-effective materials or system components, lower cost to production, lower assembly costs.)

Transportation Systems

The goals are to develop electric drive components for plug-in hybrid electric vehicles; the optimization of new power trains; and to develop advanced clean fuels (including novel pathways for sustainable hydrogen production) and emission reduction technologies.

(d) Biomass Conversion and Co-Product Optimization

Researchers are encouraged to improve the bio-refinery core processes for conversion of biomass to energy (e.g., fermentation, anaerobic digestion, esterification and transesterification, pyrolysis, gasification, Fischer-Tropsch synthesis, as well as pre-treatment technologies [e.g., enzymatic, physical or thermal aspects]). Canada would derive economic and environmental benefits if more

and different types of feedstocks, especially waste biomass, could be used in biomass conversion; if conversion processes, particularly involving waste lipids or waste cellulose, could be optimized; and if the co-products of conversion could also be applied to energy or chemicals production.

Research within this topic will be limited to:

Expanded Sources for Energy

Biodiesel: Researchers are encouraged to solve the problems that arise when biodiesel is produced by one of the core processes from waste lipid or biomass rather than higher-value raw materials (e.g., canola, soybeans).

Bio-oil: Researchers are encouraged to solve the problems that arise when bio-oil is produced from heterogeneous biomass sources (e.g., waste wood from building construction, forestry slash), and to address the challenges of bio-oil use related to harvesting its energy or chemical content.

Co-Product and Waste Biomass Use and Value Optimization: Researchers are encouraged to discover more effective ways to use bio-refinery process and waste biomass co-product materials (such as glycerol from biodiesel production or agricultural and municipal waste cellulosic biomass sources) to generate either bio-fuels or value-added carbon-based products for non-fuel uses.

(e) Systems Engineering Approach to the Extraction, Conversion and Utilization of Fossil Fuels

Much of Canada's infrastructure depends on fossil fuels, and a great deal of energy is consumed in extracting them. By incorporating alternative energy sources (including the waste products of processing) into the extraction and refining of hydrocarbons, the industry could conserve energy, reduce waste and save money.

Research within this topic will be limited to:

Optimizing Hydrogen Supply and Utilization in Bitumen and Heavy Oil Processing

The goal is to generate hydrogen cost-effectively and improve the hydrogenation of bitumen and heavy oil molecules.

"Cleaner" Combustion of Bitumen and Oil Sands Processing Waste Products

The goal is to use waste products (e.g., hydrocarbons in sludge or the asphaltene bottoms, coke) as fuel in processing oil sands and in heavy oil *in-situ* production, co-generation and upgrading (combustion technology and carbon dioxide [CO_2] sequestration).

Integrated Energy Recovery from Fossil Fuel Production and Use

The goal is to reduce energy consumption by recovering the energy created by the production and refining of hydrocarbons, and reusing it in other processes.

Expanding Canada's Energy Supply

The goal is to develop extraction methods for gas hydrates and intermediate depth oil sands.

(f) Clean Coal and Carbon Capture and Storage

Researchers are encouraged to advance technologies to enhance the performance and efficiency of energy conversion systems utilizing coal and coal-derived fuels; to advance technologies to capture CO_2 from coal-fired boilers, oil sands operations and other large point sources; and to sequester the gas safely in subsurface and other storage media.

(g) Low Emission Industrial Systems

The goal is to provide Canadian industry with the technologies that will allow them to achieve state-of-the-art performance with respect to energy efficiency, criteria air contaminant (CAC) and greenhouse gas (GHG) emissions while remaining economically competitive. These consist of highly energy efficient technologies for the conversion of fuels into energy used by industry and for conversion of feedstock into finished materials. Emphasis will be placed on the foremost industrial sub-sectors that are responsible for the majority of air emissions and energy use. These sub-sectors include Iron and Steel, Mining and Smelting, Cement and Lime, Pulp and Paper, Chemicals, Petroleum Refining and Other Manufacturing.

(h) Other Renewable Energy Sources

Research is needed to expand the knowledge base and range of technologies developed for production and use of renewable energy sources such as wind, solar and ocean (wave and tidal). Emphasis will be placed on opportunities where Canada can compete as a global leader or where there are particular operational challenges in a Canadian context (e.g., cold climate).