National Occupational Standard for

Process Engineer in Bio-Industrial, Bio-Energy

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Igniting the bio-economy's brainpower

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2 A COMPETENCY FRAMEWORK FOR INDIVIDUALS WORKING IN THE BIO-ECONOMY

2.1 What is a National Occupational Standard?

In Canada, National Occupational Standards are industry-developed and validated documents that identify and group tasks/competencies associated with a particular occupation. They also describe the knowledge and skills that a worker must demonstrate to be considered competent.

The former Alliance of Sector Councils (TASC) outlined 11 guiding principles for creating National Occupational Standards (NOS). NOS for the Canadian bio-economy meet all 11 principles and are developed to meet the current and future human capital management needs of the Canadian bio-economy.

2.2 How are we defining a competency?

We define a competency as ***a set of related behaviors that describe successful performance in a designated area. It is a behavioural expression of how people integrate knowledge, skills, attributes, and attitudes to produce a value-adding result in a defined situation.***

The competency statement includes a description that integrates skills, knowledge, and actions into a sequence of activities that deliver a value-added product or service.

Performance Indicators is the term we use for the behaviours grouped under each competency that describe the level of mastery the incumbent role must demonstrate when executing a task.

For this project, we have organized the competencies into four categories.

Core Competencies are those competencies that describe the "essence of the role" — that is, they are the one to three most critical competencies that may be applicable across multiple roles in a function or job family. All levels of personnel in this function would typically share them. These competencies may also act as qualifiers that differentiate the function from other functions.

Technical Competencies are those competencies related to specific roles or professions that enable an individual to work, function, and succeed in that role. They address the various responsibilities that job incumbents encounter in a role. For example, a surgeon's technical competencies would encompass multiple surgical tools, techniques, and conditions that could be part of the position.

Similarly, technical competencies for a lawyer would contain various legal situations that they encounter in the context of a particular field of practice.

Regulatory Competencies are those competencies that describe compliance with prescribed practices and mandated obligations under applicable laws, regulations, and industry standards. They ensure that critical work processes are implemented and integrated into all work activities. They are of absolute importance where economic behaviours can impact human conditions.

Personal/professional Competencies are those competencies that enable an individual to be successful working with others and fulfilling their responsibilities in a work context. Personal and professional competencies are not necessarily role specific.

2.3 Levels of complexity of work

It is important to recognize how the complexity of work varies along an organizational continuum. At one end of this continuum is low-complexity, clearly-defined, task-driven work. At the other end of the continuum is work that is higher in complexity, not as well-defined, and requires higher-level thinking and decision-making skills and a greater degree of autonomy. Results are recognised over a longer period of time and are more difficult to assess.

Figure 1: Demonstrates how the level of complexity changes with the role responsibilities

Complexity Level	Examples of Work at Different Complexity Levels	Typical Roles/Titles
Most Complex	Construct and pursue worldwide strategic plans in large corporations.	CEOs of the largest trans-global corporations
	Construct and pursue worldwide strategic plans.	C-suite executives at multi-national organizations
	Lead the accumulated impact of multiple business units.	C-suite executive at large, multi-location organizations
	Optimize the function of a single business unit or corporate support staff.	General manager; plant manager
	Manage multiple, interdependent projects; balance resources among departments.	Engineering manager
	Plan and carry out sequential projects while considering contingencies and alternatives.	Maintenance manager
	Accumulate information to diagnose and anticipate problems; proactive; notice trends.	Maintenance technician
Least Complex	Follow predefined procedures; seek help when encountering an obstacle. The ability to anticipate problems is not expected.	Maintenance labourer

We define the complexity levels within the profiles at four levels:

Foundational — performance focus is on the execution of procedures and tasks involving own job role.

Operational — performance focus includes some discretion in the planning and executing of work. The work typically includes assessing the quality of the work outcomes and taking corrective action to ensure quality.

Specialist — performance focus is on translating goals and standards to team members and ensuring that work done under the person's responsibility area complies with all corporate standards.

Strategic — performance focus is on leading work and the accumulated impact of work in an independent business unit or across a whole organization. The impact of work at this level is often not visible until the medium to longer term.

The following example illustrates the different complexity levels within a profile.

Competency Name: Research Ethics **Competency Definition:** Exercises integrity and professionalism to ensure all research is performed responsibly in keeping with the ethical principles of beneficence and nonmaleficence. Competence at this level is demonstrated when the **Research Manager**:			
Performance Indicators			
Foundational	Operational	Specialized	Strategic
Diligently follows research procedures and protocols mandated by legitimate authorities and professional organizations.	Regularly monitors own actions and decisions to ensure they align with professional and organizational values.	Holds self and staff accountable to the organization's values, ensuring compliance with the policies and procedures related to scientific ethics and rules of conduct.	Fosters an organizational culture of integrity and ethical business practices by unwavering personal example.

2.4 Overview methodology for the development of national occupational standards

National occupational standards were developed using a multi-step process.

Step	Description	Result/Output
1	Identify critical roles in the bio-economy through primary and secondary research.	List of 50 key roles
2	Create draft profiles with critical competencies for the roles, performance, and knowledge indicators.	Draft profiles
3	Review the draft profiles with industry subject matter experts to refine the competencies, performance, and knowledge indicators.	Reviewed profile with design inputs from industry experts
4	Further validation and review by industry via online focus group.	Validated profiles by industry experts
5	Broader validation of the draft profiles via national online surveys.	Occupational Standards validated on a national level by experts from the different sectors
6	Addition of the Essential Skills and Canadian Language Benchmark (ES/CLB) ratings.	Nationally validated NOS profiles with ES/CLB profile for each NOS

3 PROCESS ENGINEER IN BIO-INDUSTRIAL AND BIO-ENERGY PRODUCTION COMPETENCY FRAMEWORK

3.1 Competency diagram for Process Engineer in Bio-Industrial and Bio-Energy Production

Competencies		Complexity Level			
		1	2	3	4
Core Competency					
1	Promote Engineering Professionalism				
2	Technical Integrity Assurance				
Technical Competencies					
3	Techno-Economic Feasibility Studies				
4	Process Design				
5	Process Equipment Selection and Specification				
6	Process Control				
7	Solids Handling				
8	Hydraulic Analysis and Optimization				
9	Thermodynamics and Heat Management				
10	Catalyst Usage and Handling				
11	Process Monitoring and Optimization				
12	Technical Problem Solving				
13	Process Safety Assurance				
14	Utilization of Technical Software - Process Engineering Applications				

Complexity Level Legend

1. Foundational
2. Operational
3. Specialist/Manager
4. Expert/Executive

Competencies		Complexity Level			
		1	2	3	4
Industry Regulatory Competencies					
15	Legal/Regulatory Compliance - Process Engineering				
Personal and Professional Competencies					
16	Systems Thinking				
17	Creative Thinking				
18	Critical Thinking/Decision-Making - Process Engineering				
19	Communication and Influencing				
20	Socio-cultural Intelligence				
21	Collaboration				

3.2 Definition of occupation

The Process Engineer position differs significantly across the industry because they often exist in several functions and departments across an organization. Process Engineers design processes for use in various industries, including agricultural, manufacturing, pharmaceutical, petroleum, mineral, food, water treatment, nuclear, metallurgy, mineral processing, and biotechnology to help transform raw materials into valuable everyday products.

Process Engineers and Chemical Engineers are often considered as interchangeable. However, Process Engineers focus not on researching new chemical reactions (like Chemical Engineers), but instead focus on applying known chemical reactions for the purpose of designing production processes, maintaining equipment, and optimizing throughput. There is more emphasis on applying knowledge, mathematics, and physics (specifically fluid mechanics, mass, and heat transfer) than chemistry, so they work more with mechanical engineers.

Although Process Engineers develop new, innovative processes for new facilities, they are also often involved in the analysis, upgrading, and modification/optimization of equipment and production processes that a company is already using.
During this process, they develop project proposals and study protocols, undertake experiments and other tests, analyze the results, conduct theoretical computations, and prepare project reports and publications. They usually must work with people from every manufacturing industry sector, including research and development (R&D) staff (often chemical engineers), production personnel, operations personnel, management, and even customers, in some cases.

Process Engineers create systems to make the best use of workers, machines, materials, information, and energy. They often work on technology transfer and process scale-up from lab to pilot and pilot to full-scale production facilities. These projects can be experimentally based, theoretical/computation/modelling based, or a combination of both.

When they engage in research it may be in fundamental research, such as investigating the underlying basis of chemical processes, bioprocessing, and bioengineering, or it may be more applied, such as:

- developing a specific chemical process to produce existing chemicals more cost effectively or to produce new chemicals,
- developing a specific biochemical process to produce biopolymers, biofuels, bio-solvents, or bio-actives,
- conducting classic and modern genetic research for new strain development,
- conducting fermentation research for fermentation or enzymatic bioprocess development, and
- investigating methods for monitoring and control of bioprocesses.

This role works in the following subsectors:

Applicable To	Bio-Health	Agri-Bio	Bio-Industrial	Bio-Energy
			■	■

The level of complexity of the role is:

Span of Complexity Levels	Foundational	Operational	Specialist/ Management	Expert/Executive
		■	■	

3.3 Level of education, training or designations requirements

Typical Education Required	Secondary	College	Bachelor	Master	PhD
			■	■	
Typical Starting Experience	**0–5 yrs.**	**5–10 yrs.**	**10–15 yrs.**	**15–20 yrs.**	**20+ yrs.**
	■	■			

- Bachelor of Science or Chemical engineering
- OR Master of Science or Chemical engineering
- Training and competency in mathematics, thermodynamics and fluid mechanics, plant design, and commissioning is required
- Competency is required in phase equilibrium and mass transfer, biochemical engineering, industrial chemistry, organic chemistry, environmental engineering, cell biology, reactor design, data analysis for process and product development,

chemical reaction engineering, process dynamics and control, chemical process equipment, unit operations. and particle technology
- Working knowledge of and experience with reading complex engineering drawings, and a good technical product and process knowledge
- Strong technical background in production and the ability to understand basic equipment and process design drawings, equipment, and diagrams
- Strong background in developing processes, lean cell design, and consumables manufacturing
- Ability to handle diverse activities simultaneously
- Ability to work in a matrix organization is an asset
- Interpersonal skills and leadership competencies with strong oral and written communication skills
- Good documentation management skill with an attention to detail is critical
- Proven experience in continuous improvements developing processes and driving change associated changes

3.4 Core competencies list for Process Engineer in Bio-Industrial and Bio-Energy Production

3.4.1 Promote Engineering Professionalism

Applies professional knowledge and judgement to uphold the highest standards of skilled practice and ethical behavior for the service to the public, the engineering peer group, and the profession.

Competency in this role is demonstrated when the individual:

- Models integrity and respect in all related actions and decisions, ensuring own actions and decisions follow the letter and spirit of the professional code of conduct.
- Demonstrates a strong sense of public service with the obligation to protect the health and safety and welfare of the workers and the public.
- Performs services in their competence area.
- Functions with authority and exercises independent judgement in decisions.
- Continually renews knowledge through studies, research, publications, seminars, and conferences.
- Delivers quality of work in accordance with established standards to maintain the right to practice.

Knowledge required for competency at this level:

- Knowledge of the requirements to maintain good standing with any professional certification/licensing body required for legal conduct of company activities, e.g., Society of Professional Engineers
- Working knowledge of the employer's/client's code of conduct.
- Working knowledge of the implications of the general data protection regulation (GDPR) for Canadian businesses
- Ability to stay up-to-date on the Practice Standards, Practice Bulletins, and Practice Guidelines relevant to the discipline

3.4.2 Technical Integrity Assurance

Applies engineering best practices in the design, assurance, and verification of processes, systems, process equipment, and products in order to ensure they meets their design intent and standards.

Competency in this role is demonstrated when the individual:

- Demonstrates a strong integrity and management philosophy in all process engineering work, including setting equipment and operating standards, verifying compliance, and implementing corrective action when required.
- Collaborates and supports the management of operational processes and process equipment integrity in each stage of the asset management lifecycle.
- Develops standards, procedures, and management systems for facility and process operations in order to minimize risk to health, safety, and the environment.
- Ensures asset integrity is maintained through the application and monitoring of engineering controls, including adherence to Technical Operating Envelopes (TOE).
- Completes incident investigation for Safe Operating Limit (SOL) exceedances and acts to prevent recurrences.
- Follows a systematic process to analyze and assess the adequacy of protection layers and acts to implement additional safeguards if required to mitigate process risk.
- Uses/participates in risk management process to identify, mitigate, and control potential risks in relations to operating practices, process safety, and process equipment specifications.
- Collaborates with operations to maintain assets in a fit for service condition while extending the life in the most reliable, safe, and cost-effective manner.

Knowledge required for competency at this level:

- Thorough knowledge of the asset lifecycle management process
- Working knowledge of risk assessment
- Understanding of hazard and operability studies (HAZOP)
- Knowledge of risk management processes and tools

3.5 Technical competencies list for Process Engineer in Bio-Industrial and Bio-Energy Production

3.5.1 Techno-Economic Feasibility Studies

Uses process engineering and business knowledge to complete Techno-Economic Feasibility Studies in order to determine the technical feasibility and financial viability of proposed new process designs or process improvements for the purpose of identifying risks and ensuring projects meet organizational and economic hurdle rates.

Competency in this role is demonstrated when the individual:

- Works with an interdisciplinary team, including operations and maintenance staff, to set and articulate the objectives and parameters of the proposed study.
- Collects information and research related company documents to assist in providing clarifications regarding the accepted hurdle rates for any upgrades and or new projects.
- Collects and analyzes information to understand the market needs regarding the product qualities and to ensure the different process options deliver the required product characteristics.
- Assesses the different technologies, technology providers, reliability of the process technology options, and/or restrictions regarding the identified technology options.
- Confirms the cost/adequacy of the quality and availability of feed materials options.
- Confirms the plant/equipment siting, location, and infrastructure opportunities and constraints.
- Considers all process and equipment design options' capacity and utility requirements and estimates the cost of the different options.

- Estimates and confirms design assumptions regarding the operating costs and requirements.
- Completes design calculations and synthesis and advises decision makers on the technical feasibility, economic viability, and required risk mitigation related the different opportunities.

Knowledge required for competency at this level:

- Understanding of the Techno-Economic feasibility process.
- Ability to execute, acquire, and use cost estimations.
- Knowledge of how to calculate and/or use different economic concepts such as Internal Rate of Returns, Net Present Value, Break Even Ratios, etc.

3.5.2 Process Design

Applies understanding of the applicable technologies, processes, and engineering techniques to design production equipment and process flows that transform materials into selected products and services within set cost, quality, and safety standards.

Competency in this role is demonstrated when the individual:

- Prepares scoping studies for process design projects.
- Establishes design basis (basic engineering data including yield, feed/product specifications, turndown, utility information, specific equipment design requirements, battery limit conditions, site conditions, etc.).
- Completes process flow designs, including early equipment options, material lists, cost analysis, and forecasts.
- Completes the Process and Instrumentation Diagrams with input from other disciplines.
- Identifies the chemical process problems such as scale, corrosion, emulsions, contaminations, and incorporate solutions in order to prevent their occurrence.
- Evaluates and uses process designs results from pilot facilities and completes scale-up designs.
- Ensures that all testing and operational activities are performed in accordance with industry best practices, company documentation related to process engineering, and HSE regulatory requirements.
- Collaborates with technical experts to complete piping and instrument design documentation.

- Prepares a project initiation document to facilitate a smooth hand-off from project design to project planning and implementation.
- Prepares operating procedures and manuals for the training of process operators and assists with startup procedures when applicable.
- Prepares system turnover Process and Instrumentation Diagrams for the systematic turnover of the constructed facilities to operations.
- Checks the completion of the systems in the field before turnover to operations.

Knowledge required for competency at this level:

- Working understanding of the design and manufacturing processes, including Good Manufacturing Practices (GMP)
- Knowledge of the biomass characteristics and applications in biofuels
- Knowledge of engineering process design practices and processes

3.5.3 Process Equipment Selection and Specification

Uses design assumptions, process designs information, and related engineering standards processes in the design and selection of process equipment in order to ensure optimal reliability and operability and revenue targets are met.

Competency in this role is demonstrated when the individual:

- Develops and completes major equipment and line sizing, material selection, P&IDs, PFDs, equipment process data sheets, and other process related documentation to confirm the detail design basis.
- Screens existing and new technologies to select option that best satisfies and optimizes process operations.
- Collaborates with other disciplines to achieve consistency in design and equipment selection.
- Attends design reviews and confirms process and/or technology changes that will influence the process equipment selection and design decisions/standards.
- Ensures all process or technology changes and impacts are documented and implements a process to ensure all changes are communicated and incorporated in all project and operational decisions.

Knowledge required for competency at this level:

- Understanding of asset management methodologies.
- Understanding of management of change process.

3.5.4 Process Control

Applies knowledge of process control for process equipment and systems architecture in order to reduce variability and operate processes at the economic optimum.

Competency in this role is demonstrated when the individual:

- Through continuous improvement and optimization work practices, identifies the potential value to improve process control and advises on process control strategies.
- Interprets operational data and specifies the different variables and their constraint parameters in order to achieve the required process control standards.
- Provides control loops for the process equipment and recommends different control systems equipment.
- Monitors, evaluates, and troubleshoots instrument devices and plant control loop performance.
- Assists in benefit assessment after implementation of the control applications.
- Develops procedures and reviews vendor documentation to advise others on the operation and maintenance of control systems for process equipment.

Knowledge required for competency at this level:

- Detailed knowledge of latest types of process control and the tools, instrumentation, and controller applications
- Knowledge of best practices in alarm management and troubleshooting

3.5.5 Solids Handling

Considers the material qualities in the design of materials handling systems to manage storage and transportation of both hazardous and nonhazardous solids in order to ensure efficient flow rates are maintained in support of optimal production conditions.

Competency in this role is demonstrated when the individual:

- Analyzes and determines the physical and chemical characteristics of the solid materials used in or generated by the process/facility under review.
- Analyzes and determines the considerations in selecting and designing the solid handling equipment to ensure equipment efficiency and reduce waste.
- Troubleshoots less-than-optimal performance of solids handling equipment and specifies system adjustments, process redesign, and equipment changes to improve performance.
- Researches and identifies the best solids handling strategies in order to ensure flowability and suppress the caking propensity of solids in processes, e.g., manufacturing and wastewater management.
- Collaborates with different disciplines to effectively design processes to remove solids when at undesirable levels in suspense.
- Develops strategies and processes to manage, dispose, and reuse solids after extraction and separation from other product streams.
- Works with safety and environmental specialists to make sure that company and industry standards are properly applied to waste management of both hazardous and nonhazardous solids.

Knowledge required for competency at this level:

- Detailed knowledge of technologies surrounding the handling, feeding, and storage of solids
- In-depth knowledge the different biomass characteristics when working in the bioeconomy applications

3.5.6 Hydraulic Analysis and Optimization

Applies knowledge of hydraulic engineering principles to optimize fluid flow in process operations, increase network production, avoid flow obstructions, and ensure pipeline integrity in support of system efficient production operations.

Competency in this role is demonstrated when the individual:

- Collaborates with different discipline experts to set up pipeline hydraulic simulations to predict varied rates of production in process equipment over time in order to reduce time investigating and identifying equipment inefficiencies (e.g., fouling and scaling in pipes and heat exchangers).
- Interprets fouling deposit composition analysis to determine fouling, corrosion, and erosion causes and required control strategies.
- Analyzes equipment parameters and material specifications to provide Technical Operating Limits for safe, efficient pump, compressor operations, and pressure limits.
- Calculates pressure drop and hydraulic parameters through equations, correlations, or by simulation software for various conditions (single-phase and two-phase fluid flow) and redesigns equipment to optimize and maintain hydraulic system efficiency.
- Applies different simulation techniques to change Technical Operating Limits or design specifications.

Knowledge required for competency at this level:

- Working knowledge of dynamic multiphase pipeline modelling
- Understanding of single-phase liquid and vapor flow characteristics
- Understanding of two-phase liquid and vapor flow characteristics
- Understanding of the impact of different types of fluid and vapor flow on pipe sizing, pump, and compressor selection

3.5.7 Thermodynamics and Heat Management

Applies the principles of thermodynamics in establishing design and operating parameters for facility processes and equipment and/or to execute technical problem solving and trouble shooting to ensure plant reliability, optimized production rates, and product quality.

Competency in this role is demonstrated when the individual:

- Applies knowledge of thermodynamics and transport phenomena to determine stages of phase and chemical equilibrium in the design of separations processes and chemical reactors in order to ensure the thermodynamic efficiency of chemical processes.
- Establishes design and plant operating criteria and controls for facility processes and equipment in order to optimize energy and heat management through normal, start-up and shut down operating modes.
- Develops and implements process monitoring to use the information in calculating and forecasting heat transfer equipment performance in order to develop maintenance intervals and procedures.
- Troubleshoots and determines non-optimal performance of processes and equipment to restore performance and improve operating envelopes and Technical Operating limits.
- Provides support to operate, maintain, and troubleshoot all fired and non-fired heaters, boilers, and heat exchangers.

Knowledge required for competency at this level:

- Working knowledge of combustion design and all forms of heat transfer
- Knowledge of emission limits for major boilers and heaters
- Knowledgeo f heater and steam generator instrumentation
- Knowledge of standards for heat exchanger equipment

3.5.8 Catalyst Usage and Handling

Uses and applies knowledge of the interplay between catalyst activity, life cycle, design, and operations to assess and identify the root causes related to material nonconformity, safety incidents, and reduced production rates.

Competency in this role is demonstrated when the individual:

- Assists and participates in interdisciplinary teams to complete failure investigation and root cause analysis of catalytic processes, systems, and materials with reference to fouling, surface damage and pyrophoricity, fires, and explosions.
- Participates in chemical kinetic assessments to optimize the use of catalyst in the production processes of industrial production.
- Interprets the activity, durability, and systems analysis of the catalyst in the production of chemicals to improve process designs and reduce catalyst costs.

- Participates in studies to determine characterization of catalyst in order to extend the catalyst life, self-repairing capabilities, and selectivity, effectively improving the catalyst efficiency rate and lowering production costs.

Knowledge required for competency at this level:

- In-depth knowledge of the different types of catalysts and their applications

3.5.9 Process Monitoring and Optimization

Uses knowledge of the related production processes to monitor plant operations, identify abnormal or non-optimized operating conditions, and effectively troubleshoot or redesign production processes and equipment to improve performance.

Competency in this role is demonstrated when the individual:

- Works with operations and maintenance teams to establish integrated process monitoring strategies to monitor unit as well as equipment health, technical operating envelopes, and performance.
- Uses statistical analysis of historical data in order to anticipate deviations from established trends, process and safety risks, and diminished equipment performance.
- Identifies causes for deviances and bottlenecks and consults with the stakeholders to identify and implement corrective action and continuous improvement strategies.
- Provides the process engineering support to implement process optimizations and equipment modifications/replacements.
- Collects information and improves the process simulation and performance prediction models for process systems optimizations.
- Based on the system diagnosis, operating conditions, and overall process objectives, set new standards for establishing the philosophy and operational scheme of the production system.

Knowledge required for competency at this level:

- In-depth knowledge of process models and simulations

3.5.10 Technical Problem Solving

Uses technical knowledge and expertise to analyze, evaluate, and solve technical problems during production upsets, off-spec production, and unplanned shutdowns in order to restore production in a timely manner.

Competency in this role is demonstrated when the individual:

- Collaborates with the relevant process owners to define the problem and state the goal to achieve.
- Compiles a team of subject matter experts to complete a situation analysis and identify the root cause of the problem.
- Collaborates with the identified experts to identify alternatives and complete the decision analysis in order to decide on the appropriate solutions to the technical problem.
- Develops the corrective action implementation plan and related engineering solutions when required.
- Leads and oversees the solution implementation plan and ensures engineering quality in any manufactured equipment and/or process changes.
- Tests and compares the solution against the goal criteria and/or other constraints in order to modify and improve solution to achieve the required results, if needed.
- Ensures all SOPs and operating manuals are correct and updated to reflect any new standards and to ensure staff is fully trained in changed operating procedures and standards.

Knowledge required for competency at this level:

- In-depth knowledge of standard technical problem-solving processes and tools
- Basic project management knowledge and expertise

3.5.11 Process Safety Assurance

Applies process engineering fundamentals and related production process' design specifications to analyze and assess the integrity of production processes and the adequacy of protection layers in order to mitigate any process safety risks.

Competency in this role is demonstrated when the individual:

- Completes a hazard analysis and considers parameters such as chemical reaction kinetics, maximum heat release, accumulation of heat and unreacted material, heat and mass transfer, viscosity changes, fouling, precipitation, or gas evolution to assess and confirm the integrity and safety of any process design.
- Ensures that Adiabatic Calorimetry is performed and assesses undesired or decomposition reactions.
- Reviews and ensures the required process monitoring and control equipment and technologies are used to monitor and control chemical processes at critical control points.
- Reviews and ensures that the different process steps have adequate mechanisms in place to manipulate parameters such as temperature, pH, pressure, dosing rates, stirring, mixing, solvent type, catalyst, etc. in order to bring process under control when required during runaway reactions or process control equipment failure.
- Reviews and ensures production procedures are correct and that operators are trained to understand and execute the procedures, with specific importance to batch production processes.
- Completes incident investigations and implements corrective actions required to mitigate any process safety risks.
- Ensures emergency equipment, tools, and procedures are available and that all process operations staff are trained in managing process safety incidents.

Knowledge required for competency at this level:

- Knowledge of basic engineering principles as related to the different engineering disciplines qualification programs
- In-depth knowledge of calorimetric analysis and instruments
- In-depth knowledge of process safety management tools and techniques
- In-depth knowledge of process hazard analysis tools and techniques

3.5.12 Utilization of Technical Software - Process Engineering Applications

Uses knowledge and mastery of the full range of digital technologies for information processing, communication, and basic problem-solving in all aspects of the work.

Competency in this role is demonstrated when the individual:

- Takes initiative to adopt and master relevant technologies and software applications, as required.

- Uses digital resources to collect information, structure and analyze data, calculate engineering parameters, and design processes and equipment to increase quality and throughput.
- Applies and uses knowledge of control systems software to ensure process control efficiency and safety.
- Uses digital technologies to simulate and monitor operational risk and to ensure process and equipment health are maintained.
- Uses digital technologies to simplify information and improve communication.
- Uses and applies digital technologies for process simulations.

Knowledge required for competency at this level:

- Comprehensive knowledge and skill in the application of the Microsoft Office suite and Google Analytics
- Full proficiency in process design software such as AutoCAD and process simulation software

3.6 Industry regulatory competencies list for Process Engineer in Bio-Industrial and Bio-Energy Production

3.6.1 Legal/Regulatory Compliance - Process Engineering

Consults and collaborates with compliance engineers, environmental experts, and health and safety experts to develop and maintain a process which ensures that regulatory compliance is maintained in the design, modification, and operation of production processes and process equipment.

Competency in this role is demonstrated when the individual:

- Reviews and comments on the environmental impact assessment studies.
- Follows the permitting plan to be acquired from every regulatory body, starting with regional, municipality, provincial, federal and all the regulatory bodies.
- Confirms regulatory and industry compliance standards and codes, including the specific company compliance policies and requirements as part of all process engineering design specifications.

- Ensures timely completion of qualification and validation reports as and when required for the operationalization of process designs and equipment installations/commissioning.
- Provides updated and correct SOPs and staff training.
- Provides document records as required for the startp and operations of new or modified production processes and equipment.
- Ensures compliance with specific GMPs (Good Manufacturing Practices).
- Participates in the investigation and reporting of all occupational health and safety related incidents, e.g., spills of dangerous substances and out of control process incidents.

Knowledge required for competency at this level:

- Working knowledge of the organization's SOPs and regulatory framework
- Working knowledge of all regulatory requirements relative to the organization's operations from sources such as Environment Canada, the Province, etc., and other regulators, as required
- Working knowledge of different acts regulating equipment use that impact process designs such as the Combustible Dust Act and Energy Efficiency Regulations Act, etc.

3.7 Personal and professional competencies list for Process Engineer in Bio-Industrial and Bio-Energy Production

3.7.1 Systems Thinking

Applies different mental skills to understand the interconnections of the different elements of a process/system to predict the system behavior and then devises modifications that will influence the process' or system's performance in a desired way.

Competency in this role is demonstrated when the individual:

- Competently identifies the different elements in a system to determine the system content and boundaries.
- Demonstrates the ability to identify key connections and relationships between parts of a system.
- Accurately describes how the different elements influence each other and the system's behavior overall in order to define cause and effect relationships.

- Understands the hierarchy of influence in order to derive options to modify and manipulate the systems reactions.
- Applies systems modelling to develop intervention strategies in order to control and direct system or process reactions in specific ways.

Knowledge required for competency at this level:

- Detailed knowledge of systems thinking

3.7.2 Creative Thinking

Uses and applies free thinking outside current constructs and mental models to interpret the same information and or practices in ways that allow for the creation of new ideas and solutions.

Competency in this role is demonstrated when the individual:

- Knows and understands own preferred way to analyze and interpret information to recognise when different ways of thinking are required to create solutions to workplace challenges.
- Uses both convergent and divergent thinking to develop the ability to allow for alternative ways to analyze and interpret information.
- Uses concepts and principles outside the current work experience and discipline to understand cause and effect relationships and applies these new ways in design processes.
- Contributes to the synthesis of information from multiple sources in order to formulate entirely new ideas and products.
- Explores new scientific technologies and approaches to determine their applicability in improving process and equipment efficiencies.

Knowledge required for competency at this level:

- Thorough understanding of different thinking styles

3.7.3 Critical Thinking/Decision-Making - Process Engineering

Analyzes and synthesizes information and data to form sound judgements on technical concepts and to solve problems and make timely decisions that deliver process and equipment efficiencies.

Competency in this role is demonstrated when the individual:

- Engages in scientific discussions with peers to hone critical thinking skills in technical problem solving during process design.
- Seeks opinions from engineers and experts to explore other perspectives on process engineering concepts and solutions.
- Uses experience and logic to evaluate and refine creative options and solutions.
- Recommends a course of action based on an analysis of preliminary and incomplete information when action must be taken immediately.
- Uses creative processes such as mind mapping, brainstorming, and visualization to generate options.
- Contributes to the synthesis of information from multiple sources to formulate entirely new ideas and products.

Knowledge required for competency at this level:

- Working understanding of decision-making tools and techniques

3.7.4 Communication and Influencing

Communicates in ways that create shared understanding, generate support for the achievement of goals and objectives, and facilitate conflict resolution and problem-solving.

Competency in this role is demonstrated when the individual:

- Delivers multi-mode communications that convey a clear understanding appropriate to the target audience and context, e.g., using plain language to communicate technical research details to a non-technical audience.
- Uses persuasive language to ethically advocate for concept process designs options and equipment selection options while allowing others room to share their opinions.
- Invites participative decision-making where appropriate, encouraging input from staff.

- Uses discretion and integrity to resolve conflict with a resistant audience in a manner that maintains a positive working relationship.
- Masters the ability to use scientific presentations to convince stakeholders of technical choices in process design and optimization.

Knowledge required for competency at this level:

- Detailed knowledge in communication tools and techniques
- Working knowledge of influencing strategies and techniques

3.7.5 Socio-cultural Intelligence

Demonstrates the capacity to realize how their behaviors affect workplace interactions and vice versa, and then adapts their interpersonal approach to deal with diversity, manage unproductive relationships, and enhance team performance in familiar and unfamiliar contexts.

Competency in this role is demonstrated when the individual:

- Consistently models ethical conduct such as discretion, personal integrity, and respect for diversity in order to foster cooperation and collaboration with colleagues.
- Works cooperatively with multiple stakeholders, demonstrating tact, diplomacy, and a willingness to consider alternative approaches or ideas that achieve results within ethical guidelines.
- Manages own behaviors to diffuse conflicting relationships in order to overcome barriers in achieving shared workplace goals.
- Addresses emerging organizational, regulatory, and technological concerns in a professional way by focussing on the concerns and solutions.
- Demonstrates resilience by remaining respectful but tenacious and committed to goals even in the face of opposition and ambiguity.
- Has the ability to create constructive collaboration in diverse relationships, acknowledging and using contributions to improve the quality work outcomes.

Knowledge required for competency at this level:

- Working knowledge of emotional and social intelligence
- Understanding of conflict management strategies
- Working understanding of motivational theories

3.7.6 Collaboration

Actively participates in or leads multi-disciplinary, inter/intra-departmental teams to generate ideas and solutions, solve problems, and improve overall organizational performance.

Competency in this role is demonstrated when the individual:

- Actively engages with others to seek and honour their expertise and opinions.
- Applies active listening and emotional intelligence techniques to ensure others are valued.
- Encourages broad discussion and sharing of ideas to generate innovative solutions.
- Openly gives credit to the ideas and participation of others.
- Assumes responsibility if things go wrong.

Knowledge required for competency at this level:

- Knowledge of Emotional Intelligence principles
- Understanding of teamwork and collaboration principles
- Understanding of group problem-solving and decision-making principles
- Knowledge of group dynamics
- Effective communication principles

3.8 Essential Skills for Process Engineer in Bio-Industrial and Bio-Energy Production

Essential Skills (ES) are foundational skills required for all types of work. They are not technical skills, but the core skills people need to acquire knowledge and complete workplace tasks and daily activities.

Understanding the ES requirements for a role can allow individuals to compare their skills to those required, assist training/learning providers in developing appropriate supports to ensure ES levels are developed during training, and provide employers with an additional tool for determining who/how to place in particular roles.

Human Resources and Skills Development Canada has defined Essential Skills as follows:

- Reading
- Document Use
- Numeracy, which is further divided into:
  - Money math; Scheduling, budgeting, and accounting math; Measurement and calculation math; Data analysis math.
  - Several different factors related to estimations, including the presence of a set procedure, the number of items being estimated, the consequences of errors in estimation, the amount of information missing, and the accuracy required.
- Writing
- Oral Communication
- Thinking Skills, which are further divided into:
  - Problem Solving
  - Decision Making
  - Critical Thinking
  - Job Task Planning and Organizing
  - Finding Information
  - Significant Use of Memory
- Digital Skills
- Working with Others
- Continuous Learning

Most of the ES have levels based on complexity, and a role can be analyzed to determine the appropriate levels of ES. The exceptions are noted below:

- "Working with Others" does not have a complexity rating: it simply describes the ways in which the role would be required to interact with other people, either internally within the organization or externally (i.e., with clients, customers, or the public).
- "Continuous Learning" does not have a complexity rating: it describes the types of learning expected in the context of the role (e.g., on the job, being mentored by others, formal training as part of the job, etc.).

NOTE: as of January 2020, ESDC was undertaking a comprehensive review of ES with the intent of adding additional skills, refining existing ones (particularly digital skills) and better aligning ES with similar approaches used in other countries. However the detail was not finalized in time to be used, therefore the profiles developed for this project follow existing standards as of December 2019.

3.9 Canadian Language Benchmark for Process Engineer in Bio-Industry and Bio-Energy Production

Canadian Language Benchmarks (CLB) are a 12-point scale for task-based language proficiency descriptors which were originally developed as a guide for measuring the teaching and assessment of English as a Second Language (ESL) learners in Canada. Since they were originally developed, the Canadian Centre for Language Benchmarks (CCLB) has continued to refine CLB, and it now includes scales for both English and French language proficiency. [1]

The CLB has been validated against both the Common European Framework for Language (CEFL) and the American Council for the Teaching of Foreign Languages (ACTFL) benchmarks and is considered accurate for high-stakes evaluation[2].

[1] Centre for Canadian Language Benchmarks. Theoretical Framework for The Canadian Language Benchmarks And *Niveaux De Compétence Linguistique Canadiens.* CCLB. Ottawa 2015. p8

[2] Centre for Canadian Language Benchmarks. Canadian Language Benchmarks: English as a Second Language for Adults, CCLB. Ottawa 2012 p.II

The ES levels for Oral Communication were developed with reference to the Canadian Language Benchmarks[3]. Comparative work to determine the alignment between the CLB and other Essential Skills has been ongoing, with recent work providing additional alignment with the ES for Oral Communication in both spoken and listening domains, Reading, Writing, and Document Use.[4]

CCLB has developed a set of crossover tables that align CLB ratings with ES ratings for reading, writing oral communication and document use.

Process Engineer ES/CLB Profile

Essential Skills	Equivalent CLB Level	ES Level				
Reading	Reading: 11–12	1	2	3	4	5
Document Use	Reading: 11–12 Writing: 11–12	1	2	3	4	5
Writing	Writing: 9	1	2	3	4	5
Oral Expression	Speaking: 11–12 Listening: 11–12	1	2	3	4	
Numeracy	n/a	1	2	3	4	5
Thinking Skills – Problem Solving	n/a	1	2	3	4	
Thinking Skills – Decision Making	n/a	1	2	3	4	

[3] Essential Skills Research Group. Readers Guide to the Essential Skills. ESDC. Ottawa ND. p57
[4] Canadian Centre for Language Benchmarks. Relating Canadian Language Benchmarks to Essential Skills: A Comparative Framework. 2015, p3

Essential Skills	Equivalent CLB Level	ES Level				
Thinking Skills – Job/Task Planning and Organizing	n/a	1	2	3	4	
Thinking Skills – Significant Use of Memory	n/a	Types 1,2,3				
Thinking Skills – Finding Information	n/a	1	2	3	4	
Digital Skills	n/a	1	2	3	4	5
Working with Others	n/a	See Below				
Continuous Learning	n/a	See Below				

Explanation of the Essential Skills and the Canadian Language Benchmark for Process Engineer

Reading: ES 5 CLB: 11–12

Process Engineers read and interpret a wide variety of dense and complex technical and scientific documentation, including studying research papers and articles in peer-reviewed journals, vendor and component manufacturer documentation, materials specifications, technical and engineering standards, design documents, and commercial documentation (contracts, proposals, patents, etc.) to glean information that can be used to develop and optimize processes and process control procedures.

Document Use: ES 5 CLB: Reading: 11–12, Writing: 11–12

Process Engineers access and interpret information from a wide variety of complex digital and paper-based sources, and use the information gathered to make inferences and draw conclusions within their area of specialization. The must interpret information presented textually, graphically, and numerically and synthesize and summarize information to inform their own work, as well as to inform decisions by others in the organization.

Writing: ES 4 CLB: 9

Process Engineers compose technical and engineering reports related to manufacturing processes and optimization. They document operating procedures for manufacturing departments and create process safety documentation for manufacturing and maintenance personnel. They write internal memos and other routine correspondence aimed at a variety of audiences.

Oral Expression: ES 4 CLB: Speaking: 11–12, Listening: 11–12

Process Engineers work within an interdisciplinary team and must be adept at communicating complex technical information to a wide variety of audiences both inside and outside the organization. They contribute to peer forums, provide information to inform the decisions of senior managers and other stakeholders, instruct junior personnel in techniques and technologies, and solicit feedback from external departments and stakeholders. Additionally, they make presentations to senior management, negotiate with external vendors and providers, instruct others on production processes and techniques, and may be called upon to communicate the details of process technologies, process safety, and process optimization to non-technical audiences.

Numeracy: ES 4 (Money Math: n/a, Scheduling, Budgeting and Accounting: 3, Measurement & Calculation: n/a, Data Analysis: 4)

Process Engineers are responsible for formulating and tracking departmental budgets, as well as tracking expenditures for on-going projects. In the course of their work they will conduct complex calculations with a wide array of dependent and independent variables. In many cases they will analyze data to predict future results in a climate of uncertainty, where the consequences of mistakes can be dire. They develop operating metrics to determine process efficiency, establish tolerances for quality control practices, and use predictive algorithms to develop pre-emptive maintenance and life-cycle cost optimization strategies for production assets.

Thinking Skills:

Thinking skills are subdivided into five domains:

- Thinking Skills — Problem Solving
- Thinking Skills — Decision Making

- Thinking Skills — Job/Task Planning and Organizing
- Thinking Skills — Finding Information
- Thinking Skills — Significant Use of Memory

- Thinking Skills — Problem Solving: ES 4

Process Engineers solve complex, multi-variate problems in the course of their work. They deal with problems of a scientific and technical nature, where the interactions of variables may be unknown or unpredictable, and they must develop a process for solving these problems in order to optimize the outcomes.

- Thinking Skills — Decision Making: ES 4

Process Engineers analyze, synthesize, and evaluate arguments, information, and data and must exercise sound judgement in deciding between alternative courses of action. The decisions they make can have significant financial consequences for their organization, and the decisions are difficult and extremely costly to reverse

- Thinking Skills — Job/Task Planning and Organizing: ES 4

Process Engineers plans their own work, taking into account the availability of shared resources and potential scheduling conflicts with others. They plan and direct the work of their departments, setting priorities and allocating and managing limited resources to optimize their value. They have wide discretion over the what and how of their work, and are expected to manage their time to meet specific milestones in a project schedule. They work within an interdisciplinary team to execute projects that will impact the future profitability of their organization.

- Thinking Skills — Finding Information: ES 4

Process Engineers collect, analyze, and interpret data from a wide array of multidisciplinary scientific and technical resources in the course of their work. Information must be collected and synthesized in order to be used.

- Thinking Skills — Significant Use of Memory: Types 1, 2, 3

Process Engineers must memorize, retain, and use information through one or all of the following methods:

  - Purposeful memorization of procedures, codes, parts numbers, memorization through repetition (Type 1)
  - Remembering information for brief periods, e.g., minutes or hours (Type 2)
  - Unique events in which learning occurs from exposure (Type 3)

- Digital Skills: ES 4

Process Engineers utilize standard office productivity software tools (Word processing, spreadsheets, presentations, etc.), electronic communication tools (email, text, instant messaging, video conferencing, etc.), and a variety of data retrieval and analysis tools and technologies in the performance of their duties. They develop, test, and implement software programs and code for production systems and troubleshoot production problems using specialized and sophisticated data analysis and modeling software, and use other specialized digital tools to design, test, and document production processes.

Working with Others: Work Contexts 2, 3 & 4

The following work contexts and functions are relevant to the Process Engineer role:

- Works independently (Context 2)
- Works jointly with a partner or helper (Context 3)
- Works as a member of a team (Context 4)

They may also be involved in supervisory or leadership activities, as follows: Functions 1–5 & 8–12

- Participate in formal discussions about work processes or product improvement (S/L Function 1)
- Have opportunities to make suggestions on improving work processes (S/L Function 2)
- Monitor the work performance of others (S/L Function 3)
- Inform other workers or demonstrate to them how tasks are to be performed (S/L Function 4)
- Orient new employees (S/L Function 5)
- Select contractors and suppliers (S/L Function 8)

- Assign routine tasks to other workers (S/L Function 9)
- Assign new or unusual tasks to other workers (S/L Function 10)
- Identify training that is required by or would be useful for other workers (S/L Function 11)
- Deal with other workers' grievances or complaints (S/L Function 12)

Continuous Learning: Types of Learning 1, 2, 3 How Learning Occurs: 1, 2, 3, 4, 5, 6

Type of learning may include:

- Training in job-related health and safety (Type 1)
- Obtaining and updating credentials (Type 2)
- Learning about new equipment, procedures, products, and services (Type 3)

The learning may occur:

- As part of regular work activity (Context 1)
- From coworkers (Context 2)
- Through training offered in the workplace (Context 3)
- Through other forms of self-study (Context 4):
    - At work
    - On worker's own time
    - Using materials available through work
    - Using materials obtained through a professional association or union
    - Using materials obtained through worker's own initiative
- Through offsite training (Context 5):
    - During working hours at no cost to the workers
    - Partially subsidized
- With costs paid by the worker (Context 6)

4 REFERENCES

Gathering the data

The development of the National Occupational Standards started with a review of existing information for the role. This review process included: referencing books, job postings, websites, articles, and BioTalent Canada's existing skills profiles to create the first draft. After several iterations via written feedback, focus groups and a national survey with subject matter experts, the National Standards were developed. The following are sources consulted during the creation of the Process Engineer in Bio-Industrial and Bio-Energy Production profile:

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