The Transition Accelerator | L'Accélérateur de transition

Workforce Requirements for Advancing a Hydrogen Economy

HYDROGEN WORKFORCE ASSESSMENT TOOL

July 2022

Introduction

Canada is one of the world's largest and lowest cost producers of hydrogen.

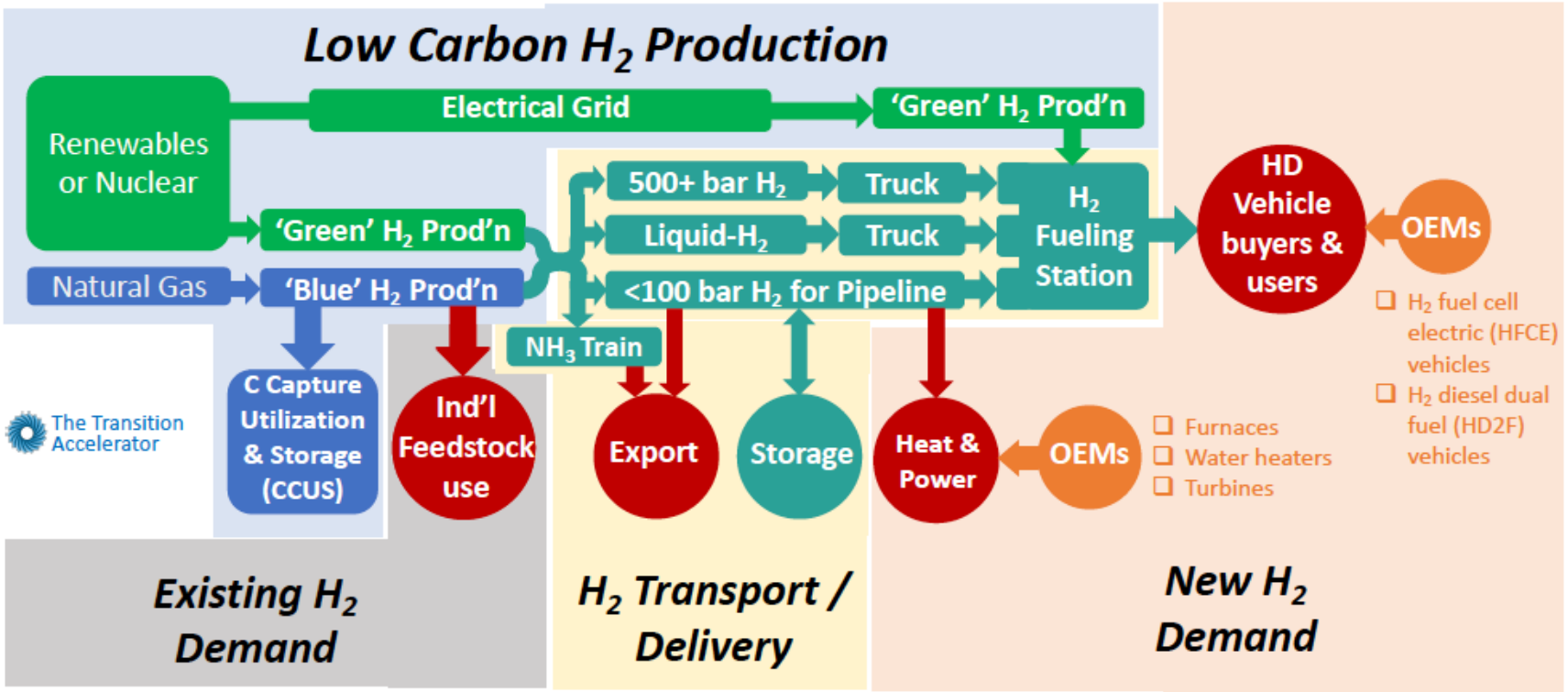
- Strengths in hydrogen production, fuel cell technology, and carbon capture, utilization, and storage (CCUS) can advance our national drive to net-zero by decarbonizing many of the heavy-emitting sectors important to the Canadian economy.
- When combined with a skilled and ready workforce, Canada is in a unique position to become a global leader as both user and exporter of low-carbon hydrogen.

The purpose of this ***Hydrogen Workforce Assessment Tool (Tool)*** is to outline the workforce required to advance Canada's hydrogen economy.

The Tool complements the ***Assessing the Workforce Required to Advance Canada's Hydrogen Economy*** **report** that identifies opportunities to leverage skilled and available labour, the degree to which an additional workforce must be developed and the potential risks to meeting hydrogen's talent needs.

Towards a Low-Carbon Hydrogen Economy

Understanding how Canada's hydrogen economy is being developed provides insights into the pace for which an expanded hydrogen workforce will be required.



Towards a Low-Carbon Hydrogen Economy *cont'd*

- The transition to low-carbon hydrogen will be characterized by deploying technologies to decarbonize production and by creating demand beyond today's industrial uses.
  - The majority of Canada's current hydrogen is produced by reforming natural gas. To be part of a net zero energy system, this type of hydrogen production needs to be coupled with carbon capture and storage (CCS) and is referred to as "blue" hydrogen. Canada has significant CCS expertise and infrastructure to leverage.
  - Electrolyzer technology powered by renewable energy to separate water into hydrogen and oxygen supplies of "green" hydrogen. This type of hydrogen production does not require CCS.

- Today, hydrogen is safely stored as a compressed gas or cryogenic liquid in tanks.
  - Production facilities, including onsite production for fueling stations, have short-term storage onsite.
  - As demand for hydrogen grows, there will be a need to increase storage capacity. Underground salt caverns and depleted hydrocarbon reservoirs are emerging as feasible, large-scale solutions.

Towards a Low-Carbon Hydrogen Economy *cont'd*

- Hydrogen supply and demand value chains are connected by a distribution system of pipelines, roads for truck transportation and rail.
  - Transporting hydrogen by truck is most common. Gaseous hydrogen is transported in compressed tube trailers and liquid hydrogen in super-insulated, cryogenic liquid tankers.
  - As demand for hydrogen grows, there will be a need for safe, low-cost delivery of large volumes of hydrogen across long distances. Expanding the hydrogen pipeline network is a distribution solution but there are challenges that need to be addressed to make this mode of transporting hydrogen technically and economically feasible.
  - Ammonia is an effective carrier for hydrogen because it can be produced using low-carbon methods, has high hydrogen storage density and can be liquefied for transport by rail or ship.

Towards a Low-Carbon Hydrogen Economy *cont'd*

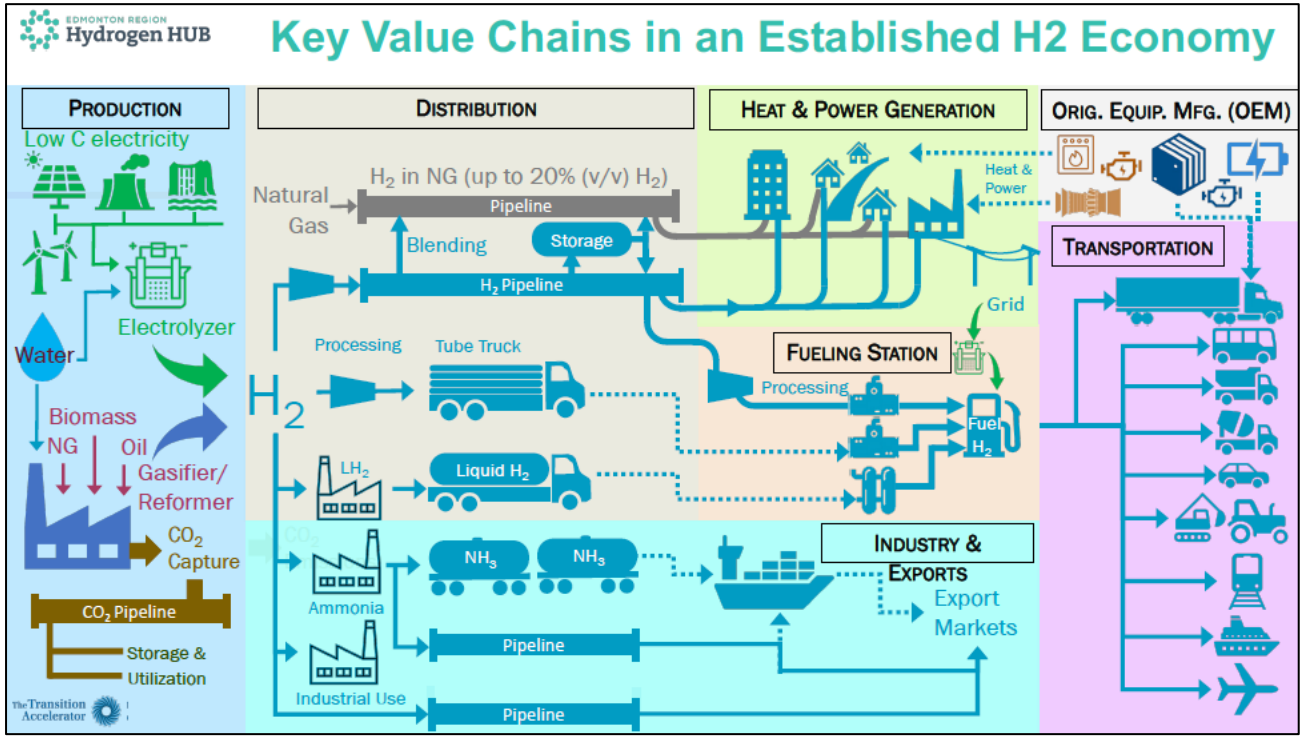
- Expanding existing and creating new markets for low-carbon hydrogen is a pre-requisite to attracting investment in supply infrastructure.
  - Hydrogen as an energy source for the transportation and freight sectors, and heating and power utilities, and as industrial feedstock for steel, cement, and mineral and metal manufacturing.
    - Initially involves retrofitting and conversion of existing systems, equipment and infrastructure to accommodate fuel-switching, co-combustion and blending of hydrogen with other fuels
  - Hydrogen fueling stations are required to enable the use of hydrogen as a transportation fuel.
- The development Canada's manufacturing sector to ensure the availability of hydrogen appropriate equipment and technology is important to derisk the potential for supply chain bottlenecks
  - Expand manufacturing of fuel cells, hydrogen fuel cell vehicles and electrolyzers
  - Manufacturing of appliances and other end-use devices that can use hydrogen
  - Diversify current manufacturing, fabrication and assembly of equipment, components and modules of appliances to include those suitable for hydrogen, and hydrogen infrastructure

HUB Approach for Advancing Low-Carbon Hydrogen

A significant challenge in advancing an affordable low-carbon hydrogen economy is simultaneously building the supply and demand value chains, and the distribution systems required to connect them.

A hydrogen HUB is a region where hydrogen supply and demand can be significantly scaled. Determining if sustainable economics exist includes assessing the availability of:

- Resources needed to produce and supply low-cost, low-carbon hydrogen
- Nearby market demand
- Ability to connect supply and demand through roads, rail and/or pipelines
- Potential to scale without sustained public investment
- Engaged stakeholders including industry, governments and academics



How to use the: *Hydrogen Workforce Assessment Tool*

The ***Hydrogen Workforce Assessment Tool*** has been created to support the HUB approach to assessing the feasibility of building a viable low-carbon hydrogen economy.

The *Tool* details the core occupations required for each hydrogen value chain:

- Typical minimum qualifications
- Key activities carried out by the occupation
- Unique requirements required by that occupations in the hydrogen industry
- Potential talent opportunities and/or risks

Core occupations are defined as those that are key to the industry's ability to sustain operations. They maybe hired in significant numbers or represent occupations that have a significant impact on the business or industry's ability to succeed.

Readers can contemplate a HUB's specific talent needs, opportunities and risks by using the navigation links offered in the following slide to go to the specific value chain and/or technology of interest.

This is a *living document* that will evolve with the development of Canada's hydrogen economy.

Workforce Requirements by Hydrogen Value Chains

Use the following links to read about the detailed workforce requirements at the value chain level:

Low Carbon Production

- Proton Exchange Membrane (PEM) Electrolysis
- Steam Methane Reforming (SMR) & Autothermal Reforming (ATR)
- Carbon Capture & Storage (CCS)

Storage, Upgrading and Transporting

- Underground Storage of Hydrogen
- Hydrogen Pipelines
- Hydrogen Distribution by Truck
- Ammonia as a Chemical Carrier of Hydrogen

Expanding existing and creating new markets for low-carbon hydrogen

- Transportation Using Hydrogen
- Hydrogen Fueling Stations
- Heating Using Hydrogen
- Power Generation Using Hydrogen

Manufacturing for the Hydrogen Economy

Roles Common Across the Value Chains

Low Carbon Hydrogen Production

Hydrogen can be produced using a range of technologies and feedstocks. Innovation continues and pilots and demonstrations of additional production technologies and processes are being tested for commercial viability.

The *Hydrogen Workforce Assessment Tool* focuses on the three commercial production technologies currently found in Canada's hydrogen industry:

1. Proton Exchange Membrane (PEM) Electrolysis
2. Steam Methane Reforming (SMR)
3. Autothermal Reforming (ATR)

Production complexes are often integrated with Storage, Upgrading & Transportation value chains.

Proton Exchange Membrane (PEM) Electrolysis Production

Production of hydrogen using PEM electrolysis technology involves:

- Use of an electrolyzer, powered by renewable electricity, to separate water into hydrogen and oxygen offers the opportunity to increase the supply of “green” hydrogen
- Electrochemically producing hydrogen energy is a pure hydrogen
- From a workforce perspective, requires an understanding of electrochemical reactions and processes
- Need to design and manage interconnection of renewable generation sites to electrolyzer production plant to ensure stable power flow

Electrolysis production facilities are typically smaller scale than SMR and ATR plants, and as a result are more suited to distributed production near sources of demand.

- Likely presents the greatest opportunity for provinces with baseload renewable electricity generation such as hydropower.

Production complexes are often integrated with Storage, Upgrading & Transportation value chains.

PEM Electrolysis: Core Occupations

PEM Electrolysis Production Workforce Requirements	
ENGINEERS	**PLANT OPERATIONS & MAINTENANCE**
• Automation and control specialist • Chemical/Process engineer • Electrical engineer • Electrical & instrumentation engineer • Facility engineer • Measurement specialist • Mechanical engineers: Equipment & piping, Reliability • Process control engineer • Process safety engineer • Production engineer • Renewable Interconnection Specialist	• Control room operator • Lab technician • Maintenance planner • Maintenance trades: Electrical, Instrumentation & control, Mechanical • Plant manager • Plant operator

PEM Electrolysis: Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
ENGINEERS				
Automation & controls specialist	*Multiple pathways to this career:* • Bachelor's Degree: Automation, Instrumentation & Controls or Electrical Engineering • Certificate of Qualification in Instrument technician • Technology Diploma: Instrumentation or Automation Engineering	• Support automation and controls functions including supervisory control and data acquisition (SCADA), programmable logic controller (PLC), remote terminal unit (RTU), distributed control system (DCS), human-machine interfaces (HMI), communications hardware, protocol and programming languages and related technologies. • Configure systems, troubleshooting and support equipment related to process control including leak detection technology	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of automated process systems and controls systems associated with electrolyzers	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Relevant codes and standards • Automated process systems and controls systems
Chemical/Process engineer	Bachelor's Degree: Chemical or Process Engineering or Electrochemistry	• Ensure safe, reliable and efficient operation of the process equipment by applying knowledge of thermodynamics, electrochemistry, fluid mechanics, and materials science • Troubleshoot production and process issues • Oversee plant modifications and upgrades to processes and related equipment ensure comply with regulatory standards • Participate in Root Cause and Failure Analysis	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of electrochemical reactions, processes and hydrogen production using PEM electrolyzers	Experienced talent pool relatively small Expanded use of electrochemical technology for clean energy is likely to drive increased demand

PEM Electrolysis: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Electrical engineer	Bachelor's Degree: Electrical Engineering Experience with renewable energy is preferrable including knowledge of associated codes and standards.	• Provide expertise and leadership in the equipment specification and selection as it relates to high power rectification, harmonic filtering, high voltage and medium voltage power distribution equipment for industrial processes • Optimise Rectification arrangement for Electrolyser plants required for conversion of alternating current (AC) to direct current (DC) • Provide technical guidance on application of codes, standards and project design criteria • Participate in Root Cause and Failure Analysis (RCFA)	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of key high power electrical equipment associated with electrolyzer produced hydrogen • Optimise rectification arrangement for electrolyser plants	Skills/knowledge and industry transferability opportunity with other industrial infrastructure including power generation and cogeneration of oil & gas, chemical, petrochemical, pulp & paper, mining & minerals, etc. Experience with renewable electricity maybe more difficult to find.
Electrical & instrumentation engineer	Bachelor's Degree: Electrical & Instrumentation Engineering	• Design for new or modification of instrumentation, control systems, and electrical projects including Programmable Logic Controllers (PLC) and safety PLCs (SIS), Distributed Control Systems (DCS), fire and gas (F&G) systems • Size and select equipment • Supervise installation and commissioning • Provide technical expertise to resolve issues associated with instrumentation, electrical, and control/safety systems.	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of key instrumentation and electrical equipment and systems associated with electrolyzer produced hydrogen	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match

PEM Electrolysis: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Facility engineer	Bachelor's Degree: Chemical, Process or Mechanical Engineering .	• Provide technical support during routine operations, expansion and optimization, and during planned and unplanned outages. • Assist operations and integrity groups with compliance measures and best practices for process controls such as: MOC, HAZOP, design and repair, reporting and regulatory compliance. • Design and implement large scale facility capital projects	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of electrochemical reactions, processes and hydrogen production using PEM electrolyzers • Appropriate selection, design and maintenance of related production equipment, materials, coatings, etc.	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Operation and optimization of production facilities • Natural gas processing closest match
Measurement specialist	*Multiple pathways to this career:* • Bachelor's Degree: Chemical, Electrical & Instrumentation, Mechanical Engineering • Technology Diploma: Chemical, Electrical, Instrumentation or Mechanical Engineering	• Provide measurement and measurement systems expertise: flow meters, process analysers, flow measurement calculations • Conduct measurement uncertainty analysis and solve issues associated gas measurement including hydrogen, methane, and CO2	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of electrochemical reactions, processes and hydrogen production using PEM electrolyzers • Knowledge of hydrogen gas value-chains	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Modelling experience using process simulators • Data validation and reconciliation

PEM Electrolysis: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Mechanical engineer - Equipment & piping	Bachelor's Degree: Mechanical Engineering	• Design pressure and stationary equipment associated with hydrogen production including electrolyzers, vessels, piping and related auxillary systems • Design rotating equipment associated with hydrogen production including turbines, compressors, pumps and related auxillary systems • Provide technical expertise on the maintenance and repairs of pressure equipment and systems, and rotating equipment to ensure accordance with all applicable codes and standards • Develop expertise in existing and emerging technologies associated PEM electrolyzer production and related processes and equipment • Participate in Root Cause and Failure Analysis (RCFA)	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection, design and maintenance of electrolyzers, vessels, piping systems and fitting, valves and seals to withstand hydrogen pressure (high/low) and temperatures (hot/cold) • Appropriate selection, design and maintenance of combustion, compression, pumping and turbine systems and equipment to withstand hydrogen pressure (high/low) and temperatures (hot/cold)	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • High pressure gas system • Cryogenic/refrigeration system • Piping and pressure vessels • Flammable gas • Compressors • Regulatory inspection requirements and inspection/test procedures for high pressure process manufacturing including ASME / API Pressure Vessel, NBIC

PEM Electrolysis: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Mechanical engineer - Reliability	Bachelor's Degree: Mechanical Engineering	• Lead PEM electrolyzer plant reliability program development and implementation in accordance with all applicable codes and standards • Oversee inspection, maintenance and repair of pressure and stationary equipment associated with hydrogen production including electrolyzers, vessels, piping and related auxillary systems • Oversee inspection, maintenance and repair of rotating equipment associated with hydrogen production including turbines, compressors, pumps and related auxillary systems • Develop expertise in existing and emerging technologies associated with the inspection and maintenance • Participate in Root Cause and Failure Analysis (RCFA)	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection, design and maintenance electrolyzers, vessels, compressors, piping systems and fitting, valves and seals to withstand hydrogen pressure (high/low) and temperatures (hot/cold) • Appropriate selection, design and maintenance of combustion, compression, pumping and turbine systems and equipment to withstand hydrogen pressure (high/low) and temperatures (hot/cold)	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • High pressure gas system • Cryogenic/refrigeration system • Piping and pressure vessels • Flammable gas • Compressors • Regulatory inspection requirements and inspection/test procedures for high pressure process manufacturing including ASME / API Pressure Vessel, NBIC

PEM Electrolysis: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Process control engineer	Bachelor's Degree: Chemical or Electrical & Instrumentation Engineering	• Building, implementing, and maintaining the advanced control applications used to perform facility operations optimization using a combination of regulatory and model predictive control techniques. • Build and deploy advanced process control applications • Develop and test control applications • Process modelling and simulation using software	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of electrochemical reactions, processes and hydrogen production using PEM electrolyzers • Knowledge of electrolyzer hydrogen production plant control systems and advanced control systems for process optimisation	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Plant control systems and advanced control systems for process optimisation • A strong knowledge of plant and equipment design. • Software to build, test and deploy Advanced Control applications

PEM Electrolysis: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Process safety engineer	Bachelor's Degree: Chemical or Process Engineering Significant experience in process equipment, engineering, safety and operational risk management • Process Hazard Analysis techniques (HAZOP, FMEA) • What-If studies, quantitative and semi-quantitative risk assessments (LOPA and FTA/ETA) • Reliability/Survival analysis • Knowledge of OSHA 1910.119, CSA Z767, CSA Z260, ISO 31000, API 1173 and related codes and standards.	• Lead the continual improvement of process safety and risk management processes and methodologies • Analyze and evaluate a wide range of operational risks affecting financial, safety, operational reliability, environmental and reputational receptors • Oversee application of codes, standards, and regulations relevant to process systems and process safety for hydrogen. • Oversee application of cceptable deviations from the approved standards, project specifications and processes • Facilitate the hazard identification and inventory (barrier management) process	• Process engineering and controls skills specific to hydrogen including hazard risk analysis and reviews, mechanical integrity and instrumented system analysis, and operation readiness inspection • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match Specialized role with small talent pool like to make it difficult to fill positions.

PEM Electrolysis: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Production engineer	Bachelor's Degree: Chemical or Mechanical Engineering	• Support of all aspects of day-to-day operations, including troubleshooting plant process problems and lead/execute plant projects • Data analysis and tracking, systems integration, and production equipment and systems troubleshooting and monitoring • Participate in Root Cause Analysis (RCA) investigations to identify and eliminate sources of undesired performance	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using PEM electrolyzers	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match
Renewable power interconnection specialist	Bachelor's Degree: Electrical Engineering Experience with renewable energy is preferrable including knowledge of associated codes and standards.	• Design and manage interconnection of renewable generation sites to electrolyzer production plant • Conduct computer modeling to ensure stable power flow	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of key high power electrical equipment and interconnection applications associated with renewable electricity powered electrolyzer produced hydrogen	Skills/knowledge and industry transferability opportunity with other industrial infrastructure including power generation and cogeneration for industrial plants. Experience with renewable electricity and processes and assemble inputs required for the interconnection applications maybe more difficult to find.

PEM Electrolysis: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
PLANT OPERATIONS & MAINTENANCE				
Control room operator	Typically an experienced plant operator. *Multiple pathways to this career:* • Diploma in petrochemistry, chemical processes, control room operator or power engineering technology • Class A, Class B refrigeration for liquification process	• Oversee day-to-day operations from centralized control room • Assist Plant operator diagnose operational deficiencies using instrument indications • Troubleshoot equipment issues and potential root causes using instrument indications • Support preparation of equipment and systems for maintenance and commissioning • Perform safety responsibilities such as hazard identification, equipment lock-out, emergency response, etc. • Issue work permits to maintenance personnel and ensure that they are aware of the risks associated with the work to be performed	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using PEM electrolyzers	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Plant monitoring and control through distributed control system (DCS) and programmable logic controller (PLC)

PEM Electrolysis: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Lab technician	Post-secondary diploma: • Chemical, Process or Petroleum technology • Laboratory technician	• Conduct quality control testing on process samples and finished products • Properly apply standards, procedures • Document and communicate findings and results • Organize and store all chemicals substances, fluids and compressed gases according to safety instructions • Understand the operation and maintenance of specified lab instruments	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using PEM electrolyzers	Skills/knowledge and industry transferability opportunities: oil & gas, chemical, petrochemicals, pulp & paper, etc.
Maintenance planner	*Multiple pathways to this career:* • Certificate of Qualification in Industrial electrician, Industrial mechanic/Millwright or Instrumentation technician • Bachelor's Degree: Electrical or Mechanical Engineering	• Develop preventive and predictive maintenance plans for the lifecycle of key electrical and mechanical equipment associated with PEM electrolyzer hydrogen production systems and facilities • Contribute achievement of key performance indicators by continuous improvement of maintenance function • Track best practices in preventive and predictive maintenance including leveraging of technology	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection, design and maintenance of electrolyzers, vessels, compressors, piping systems and fitting, valves and seals to withstand hydrogen pressure and temperatures • Appropriate selection, design and maintenance of combustion, compression, pumping and turbine systems and equipment to withstand hydrogen pressure and temperatures	Skills/knowledge and industry transferability opportunities: oil & gas, chemical, petrochemicals, pulp & paper, etc. Experience working with computerized maintenance management systems (CMMS)

PEM Electrolysis: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Maintenance trade - Electrical	Certificate of Qualification in Industrial Electrician • Registered apprentice	• Inspect, repair, install, troubleshoot and modify electrical and electronic equipment and components, AC/DC motors and drives, low and high voltage motors/breakers programmable logic controls (PLC'), control circuits, switchgears, transformers, motors, starters, relays and hydraulic and pneumatic electrical controls • Install or replace electrical wiring, receptacles, switch boxes, conduits, feeders, fibre-optic and coaxial cable assemblies, lighting fixtures and other electrical components • Install, replace or repair generators, alternators and industrial storage batteries • Interpret drawings, blueprints, schematics and electrical code specifications	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection and maintenance of key electrical and electronic equipment and systems associated with an electrolyzer hydrogen production plant	Skills/knowledge and industry transferability opportunities: oil & gas, chemical, petrochemicals, pulp & paper, etc.

PEM Electrolysis: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Maintenance trade – Instrumentation & control	Certificate of Qualification in Instrumentation technician • Registered apprentice	• Inspect, repair, install, troubleshoot and modify process controls, control valves, safety devices, analyzers, programmable logic controls (PLC), instrumentation (pressure, level and flow), process monitoring equipment, nd control circuits and distributed control systems (DCS) • Perform preventive and corrective maintenance on instrumentation and electrical equipment • Troubleshooting, repair, and calibration of plant instrumentation and controls. • Improve equipment performance and/or system reliability/capacity	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection and maintenance of key instrumentation equipment and systems associated with an electrolyzer hydrogen production plant	Skills/knowledge and industry transferability opportunities: oil & gas, chemical, petrochemicals, pulp & paper, etc. Supports digitization across multiple industries; in high demand • Existing skill shortage

PEM Electrolysis: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Maintenance trade - Mechanical	Certificate of Qualification in Industrial Mechanic or Millwright • Registered apprentice In Ontario: Hydrogen Technician (TSSAH2) certification • Obtained by working under our TSSA-H2 technicians	• Inspection, repair, troubleshooting, modification, installation and commissioning of mechanical equipment to such as reciprocating, centrifugal and screw compressors, cryogenic pumps, gear drives, steam turbines, fans and blowers, vessels, heat exchangers, reciprocating and centrifugal expanders and piping systems • Continuously improve machinery condition and reliability	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Maintenance of vessels, compressors, piping systems and fitting, valves etc. to withstand hydrogen pressure and temperatures • Knowledge of appropriate materials, seals, coatings	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match
Plant manager	Likely to be an experienced worker with engineering, maintenance and/or operations experience.	• Manage the day-to-day operations including organizational tasks, assignment of work and meeting production targets and delivery dates • Ensure all plant employees work within occupational health and safety regulations, polices and procedures • Continuously look for ways to improve production process techniques and equipment • Assist with troubleshooting operational and maintenance issues • Coach, mentor, train and develop employees in their job performance; participate in succession planning and hiring activities	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of electrochemical reactions, processes and hydrogen production using PEM electrolyzers • Maintenance of equipment and systems involved in hydrogen production using PEM electrolyzer	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match

PEM Electrolyzer: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Plant operator	*Multiple pathways to this career:* • Technology Diploma in petrochemistry, chemical processes or power engineering • Class A, Class B refrigeration for liquification process	• Responsible for ensuring safe plant operation and the production of hydrogen gas and/or liquid hydrogen • Observe and analyze plant activity to identify potential operational problems, causes and propose appropriate corrective actions • Prepares equipment and systems for maintenance and commissioning • Track daily production and performance data to optimize production and inform equipment maintenance, safety and environmental indicators • Load hydrogen trucks	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of electrochemical reactions, processes and hydrogen production using PEM electrolyzers	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Plant monitoring and control through distributed control system (DCS) and programmable logic controller (PLC)

Back to Value Chains Menu

Or continue on to SMR/ATR Core Occupations

Steam Methane Reforming (SMR) & Autothermal Reforming (ATR) Production

Steam Methane Reforming (SMR) and Autothermal Reforming (ATR) are similar production processes and require the same types of occupations.

- SMR and ATR are thermochemical processes that use high-temperature steam to break hydrocarbons into hydrogen, carbon monoxide (CO) and carbon dioxide (CO_2)
- The main difference between the two processes is that SMR uses air for combustion to create steam, while ATR uses purified oxygen. The pure oxygen for ATR is produced using an air separation unit (ASU)
- Natural gas is the most commonly used feedstock
- High-temperature/high-pressure steam plants are regulated as are the Plant operators employed to run them
    - SMR and ATR hydrogen production plants require a Power Engineer or Stationary Engineer Certificate of Qualification

Since carbon is produced as part of SMR and ATR processes, carbon capture and storage (CCS) technology is required to produce low carbon hydrogen.

Production complexes are often integrated with Storage, Upgrading & Transportation value chains.

SMR & ATR: Core Occupations

SMR & ATR Production Workforce Requirements	
ENGINEERS	**PLANT OPERATIONS & MAINTENANCE**
• Automation and control specialist • Electrical & instrumentation engineer • Facility engineer • Measurement specialist • Mechanical engineers: Equipment & piping, Reliability • Process control engineer • Process engineer • Process safety engineer • Production engineer	• Control room operator • Lab technician • Maintenance planner • Maintenance trades: Electrical, Instrumentation & control, Mechanical • Plant manager • Plant operator

SMR & ATR: Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
ENGINEERS				
Automation & controls specialist	*Multiple pathways to this career:* • Bachelor's Degree: Automation, Instrumentation & Controls or Electrical Engineering • Certificate of Qualification in Instrument technician • Instrumentation Engineering Technology diploma	• Support automation and controls functions including supervisory control and data acquisition (SCADA), programmable logic controller (PLC), remote terminal unit (RTU), distributed control system (DCS), human-machine interfaces (HMI), communications hardware, protocol and programming languages and related technologies. • Configure systems, troubleshooting and support equipment related to process control including leak detection technology	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR • Knowledge of automated process systems and controls systems for SMR/ATR	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Relevant codes and standards • Automated process systems and controls systems
Electrical & instrumentation engineer	Bachelor's Degree: Electrical & Instrumentation Engineering	• Design for new or modification of instrumentation, control systems, and electrical projects including Programmable Logic Controllers (PLC) and safety PLCs (SIS), Distributed Control Systems (DCS), fire and gas (F&G) systems • Size and select equipment • Supervise installation and commissioning • Provide technical expertise to resolve issues associated with instrumentation, electrical, and control/safety systems.	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of key instrumentation and electrical equipment and systems associated SMR and/or ATR production plants	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match

SMR & ATR: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Facility engineer	Bachelor's Degree: Chemical, Process or Mechanical Engineering .	• Provide technical support during routine operations, expansion and optimization, and during planned and unplanned outages. • Assist operations and integrity groups with compliance measures and best practices for process controls such as: MOC, HAZOP, design and repair, reporting and regulatory compliance. • Design and implement large scale facility capital projects	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR • Appropriate selection, design and maintenance of related production equipment, materials, coatings, etc.	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Operation and optimization of production facilities • Natural gas processing closest match
Measurement specialist	*Multiple pathways to this career:* • Bachelor's Degree: Chemical, Electrical & Instrumentation, Mechanical Engineering • Technology Diploma: Chemical, Electrical, Instrumentation or Mechanical Engineering	• Provide measurement and measurement systems expertise: flow meters, process analysers, flow measurement calculations • Conduct measurement uncertainty analysis and solve issues associated gas measurement including hydrogen, methane, and CO2	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR • Knowledge of hydrogen gas value-chains	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Modelling experience using process simulators • Data validation and reconciliation

SMR & ATR: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Mechanical engineer - Equipment & piping	Bachelor's Degree: Mechanical Engineering	• Design pressure and stationary equipment associated with hydrogen production including air separation units, vessels, piping and related auxillary systems • Design rotating equipment associated with hydrogen production including turbines, compressors, pumps and related auxillary systems • Provide technical expertise on the maintenance and repairs of pressure equipment and systems, and rotating equipment to ensure accordance with all applicable codes and standards • Develop expertise in existing and emerging technologies associated SMR/ATR production and related processes and equipment • Participate in Root Cause and Failure Analysis (RCFA)	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection, design and maintenance of air separation units, vessels, piping systems and fitting, valves and seals to withstand hydrogen pressure (high/low) and temperatures (hot/cold) • Appropriate selection, design and maintenance of combustion, compression, pumping and turbine systems and equipment to withstand hydrogen pressure (high/low) and temperatures (hot/cold)	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • High pressure gas system • Cryogenic/refrigeration system • Piping and pressure vessels • Air separation units • Flammable gas • Compressors • Regulatory inspection requirements and inspection/test procedures for high pressure process manufacturing including ASME / API Pressure Vessel, NBIC

SMR & ATR: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Mechanical engineer - Reliability	Bachelor's Degree: Mechanical Engineering	• Lead plant reliability program development and implementation in accordance with all applicable codes and standards • Oversee inspection, maintenance and repair of pressure and stationary equipment associated with hydrogen production including electrolyzers, vessels, piping and related auxillary systems • Oversee inspection, maintenance and repair of rotating equipment associated with hydrogen production including turbines, compressors, pumps and related auxillary systems • Develop expertise in existing and emerging technologies associated with the inspection and maintenance • Participate in Root Cause and Failure Analysis (RCFA)	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection, design and maintenance vessels, compressors, piping systems and fitting, valves and seals to withstand hydrogen pressure (high/low) and temperatures (hot/cold) • Appropriate selection, design and maintenance of combustion, compression, pumping and turbine systems and equipment to withstand hydrogen pressure (high/low) and temperatures (hot/cold)	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • High pressure gas system • Cryogenic/refrigeration system • Piping and pressure vessels • Flammable gas • Compressors • Regulatory inspection requirements and inspection/test procedures for high pressure process manufacturing including ASME / API Pressure Vessel, NBIC

SMR & ATR: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Process control engineer	Bachelor's Degree: Chemical or Electrical & Instrumentation Engineering	• Building, implementing, and maintaining the advanced control applications used to perform facility operations optimization using a combination of regulatory and model predictive control techniques. • Build and deploy advanced process control applications • Develop and test control applications • Process modelling and simulation using software	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR • Knowledge of SMR/ATR hydrogen production plant control systems and advanced control systems for process optimisation	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Steam generation • Plant control systems and advanced control systems for process optimisation. • A strong knowledge of plant and equipment design. • Software to build, test and deploy Advanced Control applications

SMR & ATR: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Process engineer	Bachelor's Degree: Chemical or Process Engineering	• Ensure safe, reliable and efficient operation of the process equipment by applying knowledge of thermodynamics, fluid mechanics, and materials science • Troubleshoot production and process issues • Assist in the resolution of longer-term reliability and maintenance issues involving unusual corrosion, steam quality concerns, fouling of heat transfer surfaces, pre-mature catalyst degradation, breakdown of insulation, and other chronic equipment and performance problems • Oversee plant modifications and upgrades to processes and related equipment ensure comply with regulatory standards • Participate in Root Cause and Failure Analysis	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • High pressure gas system • Cryogenic/refrigeration system • Piping and pressure vessels • Flammable gas • Compressors • Steam generation • Regulatory inspection requirements and inspection/test procedures for high pressure process manufacturing including ASME / API Pressure Vessel, NBIC

SMR & ATR: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Process safety engineer	Bachelor's Degree: Chemical or Process Engineering Significant experience in process equipment, engineering, safety and operational risk management • Process Hazard Analysis techniques (HAZOP, FMEA) • What-If studies, quantitative and semi-quantitative risk assessments (LOPA and FTA/ETA) • Reliability/Survival analysis • Knowledge of OSHA 1910.119, CSA Z767, CSA Z260, ISO 31000, API 1173 and related codes and standards.	• Lead the continual improvement of process safety and risk management processes and methodologies • Analyze and evaluate a wide range of operational risks affecting financial, safety, operational reliability, environmental and reputational receptors • Oversee application of codes, standards, and regulations relevant to process systems and process safety for hydrogen. • Oversee application of acceptable deviations from the approved standards, project specifications and processes • Facilitate the hazard identification and inventory (barrier management) process	• Process engineering and controls skills specific to hydrogen including hazard risk analysis and reviews, mechanical integrity and instrumented system analysis, and operation readiness inspection • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Steam generation Specialized role with small talent pool like to make it difficult to fill positions.

SMR & ATR: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Production engineer	Bachelor's Degree: Chemical or Mechanical Engineering	• Support of all aspects of day-to-day operations, including troubleshooting plant process problems and lead/execute plant projects • Data analysis and tracking, systems integration, and production equipment and systems troubleshooting and monitoring • Participate in Root Cause Analysis (RCA) investigations to identify and eliminate sources of undesired performance	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match

SMR & ATR: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
PLANT OPERATIONS & MAINTENANCE				
Control room operator	Typically an experienced plant operator. Power Engineer or Stationary Engineer Certificate of Qualification	• Oversee day-to-day operations from centralized control room • Assist Plant operators diagnose operational deficiencies using instrument indications • Troubleshoot equipment issues and potential root causes using instrument indications • Support preparation of equipment and systems for maintenance and commissioning • Perform safety responsibilities such as hazard identification, equipment lock-out, emergency response, etc. • Issue work permits to maintenance personnel and ensure that they are aware of the risks associated with the work to be performed	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Steam generation • Plant monitoring and control through distributed control system (DCS) and programmable logic controller (PLC)

SMR & ATR: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Lab technician	Post-secondary diploma: • Chemical, Process or Petroleum technology • Laboratory technician	• Conduct quality control testing on process samples and finished products • Properly apply standards, procedures • Document and communicate findings and results • Organize and store all chemicals substances, fluids and compressed gases according to safety instructions • Understand the operation and maintenance of specified lab instruments	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR	Skills/knowledge and industry transferability opportunities: oil & gas, chemical, petrochemicals, pulp & paper, etc. • Steam generation
Maintenance planner	*Multiple pathways to this career:* • Certificate of Qualification in Industrial electrician, Industrial mechanic/Millwright or Instrumentation technician • Bachelor's Degree: Electrical or Mechanical Engineering	• Develop preventive and predictive maintenance plans for the lifecycle of key electrical and mechanical equipment associated with SMT/ATR hydrogen production systems and facilities • Contribute achievement of key performance indicators by continuous improvement of maintenance function • Track best practices in preventive and predictive maintenance including leveraging of technology	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection, design and maintenance of vessels, compressors, piping systems and fitting, valves and seals to withstand hydrogen pressure and temperatures • Appropriate selection, design and maintenance of combustion, compression, pumping and turbine systems and equipment to withstand hydrogen pressure and temperatures	Skills/knowledge and industry transferability opportunities: oil & gas, chemical, petrochemicals, pulp & paper, etc. • Regulatory inspection Experience working with computerized maintenance management systems (CMMS)

SMR & ATR: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Maintenance trade - Electrical	Certificate of Qualification in Industrial Electrician • Registered apprentice	• Inspect, repair, install, troubleshoot and modify electrical and electronic equipment and components, AC/DC motors and drives, low and high voltage motors/breakers programmable logic controls (PLC'), control circuits, switchgears, transformers, motors, starters, relays and hydraulic and pneumatic electrical controls • Install or replace electrical wiring, receptacles, switch boxes, conduits, feeders, fibre-optic and coaxial cable assemblies, lighting fixtures and other electrical components • Install, replace or repair generators, alternators and industrial storage batteries • Interpret drawings, blueprints, schematics and electrical code specifications	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection and maintenance of key electrical and electronic equipment and systems associated with a SMR and/or ATR hydrogen production plant	Skills/knowledge and industry transferability opportunities: oil & gas, chemical, petrochemicals, pulp & paper, etc.

SMR & ATR: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Maintenance trade – Instrumentation & controls	Certificate of Qualification in Instrumentation technician • Registered apprentice	• Inspect, repair, install, troubleshoot and modify process controls, control valves, safety devices, analyzers, programmable logic controls (PLC), instrumentation (pressure, level and flow), process monitoring equipment, and control circuits and distributed control systems (DCS) • Perform preventive and corrective maintenance on instrumentation and electrical equipment • Troubleshooting, repair, and calibration of plant instrumentation and controls. • Improve equipment performance and/or system reliability/capacity	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection and maintenance of key instrumentation equipment and systems associated with a SMR and/or ATR hydrogen production plant	Skills/knowledge and industry transferability opportunities: oil & gas, chemical, petrochemicals, pulp & paper, etc. Supports digitization across multiple industries; in high demand • Existing skill shortage

SMR & ATR: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Maintenance trade - Mechanical	Certificate of Qualification in Industrial Mechanic or Millwright • Registered apprentice In Ontario: Hydrogen Technician (TSSAH2) certification • Obtained by working under our TSSA-H2 technicians	• Inspection, repair, troubleshooting, modification, installation and commissioning of mechanical equipment to such as reciprocating, centrifugal and screw compressors, cryogenic pumps, gear drives, steam turbines, fans and blowers, vessels, heat exchangers, reciprocating and centrifugal expanders, and piping systems • Continuously improve machinery condition and reliability	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Maintenance of vessels, compressors, piping systems and fitting, valves etc. to withstand hydrogen pressure and temperatures • Knowledge of appropriate materials, seals, coatings	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match
Plant manager	Likely to be an experienced worker with engineering, maintenance and/or operations experience.	• Manage the day-to-day operations including organizational tasks, assignment of work and meeting production targets and delivery dates • Ensure all plant employees work within occupational health and safety regulations, polices and procedures • Continuously look for ways to improve production process techniques and equipment • Assist with troubleshooting operational and maintenance issues • Coach, mentor, train and develop employees in their job performance; participate in succession planning and hiring activities	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of SMR and/or ATR processes and hydrogen production • Maintenance of equipment and systems involved in SMR and/or ATR hydrogen production	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Steam generation

SMR & ATR: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Plant operator	Power Engineer or Stationary Engineer Certificate of Qualification Many plants require a minimum 3rd Class certificate	• Responsible for ensuring safe plant operation and the production of hydrogen gas and/or liquid hydrogen • Control and monitor production process in a highly automated plant • Observe and analyze plant activity and equipment to identify potential operational problems, causes and propose appropriate corrective actions • Prepares equipment and systems for maintenance and commissioning • Track daily production and performance data to optimize production and inform equipment maintenance, safety and environmental indicators	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Steam generation • Starting up, maintaining, shutting down processing facilities • Plant monitoring and control through distributed control system (DCS) and programmable logic controller (PLC)

Back to Value Chains Menu

Or continue on to Carbon Capture & Storage
Core Occupations

Carbon Capture & Storage (CSS)

The majority of Canada's current hydrogen is produced by reforming natural gas. While we have significant expertise in this form of low-cost production, it produces carbon. To be part of a net zero energy system, this type of hydrogen production needs to be coupled with CSS.

With four commercially operating capture facilities and world's largest carbon dioxide gathering and transportation infrastructure system in the Alberta Carbon Trunk Line, Canada has CCS expertise that can be leveraged.

The *Hydrogen Workforce Assessment Tool* looks at employment across four CCS technologies:

1. **Carbon capture:** involves infrastructure and a process of capturing and separating carbon dioxide from exhaust emitted during industrial processes such as stream methane and autothermal reforming methods of hydrogen production
    - CO_2 needs to be dehydrated and purified. Impurities, including water, increase risk of corrosion of equipment and pipelines and reservoir contamination and therefore need to be removed – similar to natural gas processing

Carbon Capture & Storage (CSS) *cont'd*

2. **Pipeline transmission:** in either a gas or liquid state
   - Canada has both gas and liquid CO2 pipelines. Gas pipelines use compression technology while liquid pipelines involve hydraulics
   - Engineering, operations and maintenance knowledge and expertise currently found within Canada's natural gas and liquid pipeline sector
   - State-of-the-art metering systems to account for sales and deliveries; SCADA (Supervisory Control and Data Acquisition) systems for measuring pressure drops, and potential indication of abnormal operation's situation
   - Pipelines in operation are monitored internally by pigs (internal pipeline inspection devices) and externally by corrosion monitoring and leak detection systems

3. **Underground storage:** requires the ability to characterize subsurface geology to ensure permanent storage of CO2 and the drilling and completion of deep injection wells and monitoring
   - Deep saline aquifers or caverns serve as locations for sequestering carbon. Depleted oil and gas reservoirs are also being investigated for carbon storage
   - CO2 injection underground either in liquid or gas form will eventually take a solid mineral form

Carbon Capture & Storage *cont'd*

4. **Measurement, Monitoring and Verification (MMR)** requires atmospheric, biosphere, hydrosphere, geosphere, and well-based monitoring to address health, safety and environmental risks, evaluate sequestration performance and provide evidence that the site is suitable for closure. MMV is central to CO2 sequestration risk management.
    - Monitoring and measurement are surveillance activities necessary for ensuring the safe and reliable operation of a CO2 sequestration project.
        - Use of supervisory control and data acquisition (SCADA) technology and seismic data to demonstrate containment and conformance of the injected CO2 and support emissions accounting and reporting
        - Ongoing modeling and monitoring of storage sites during and after injection to track how CO_2 plume is behaving to detect any changes in subsurface pressure or concentration
    - Verification refers to the comparison of measured and predicted performance, which is also known as conformance.

As with hydrogen, carbon hubs are likely to be developed so that a cluster of companies using carbon capture technology can leverage the availability of carbon pipelines and pore space suitable for carbon sequestration.

Carbon Capture & Storage (CCS): Core Occupations

CCS Workforce Requirements			
Carbon Capture	**CO2 Pipeline Transmission**	**Underground Storage**	**Measurement, Monitoring & Verification (MMV)**
ENGINEERS • Automation & control specialist • Electrical & instrumentation engineer • Facility engineer • Measurement specialist • Mechanical engineer: Equipment & piping, Reliability • Process control engineer • Process engineer • Process safety engineer • Production engineer **OPERATIONS & MAINTENANCE** • Control room operator • Lab technician • Maintenance planner • Maintenance trades: Electrical, Instrumentation & control, Mechanical • Plant manager • Plant operator	**ENGINEERS** • Automation & control specialist • Compression specialist • Corrosion specialist • Electrical & instrumentation engineer • Hydraulics engineer • Measurement specialist • Pipeline engineer • Pipeline integrity specialist • Process safety engineer **OPERATIONS & MAINTENANCE** • Control centre operator • Pipeline scheduler • Pipeline technicians: Electrical &, instrumentation, Mechanical • Station operators: Compression, Pump	**ENGINEERS** • Drilling & completion engineer • Reservoir engineer **GEOSCIENCE PROFESSIONALS:** Geologist, Geophysicist **FIELD OPERATORS** • Drilling crew • Heavy duty mechanic • Reservoir technologist • Service rig crew • Well completions operator • Well completions supervisor	**ENGINEERS** • Measurement specialist • Reservoir engineer **GEOSCIENCE PROFESSIONALS:** Geologist, Geophysicist **TECHNOLOGISTS & TECHNICIANS** • Instrumentation technician • Reservoir technologist • Sampling and analysis technician • Seismic crew

Carbon Capture: Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
ENGINEERS				
Automation & controls specialist	*Multiple pathways to this career:* • Bachelor's Degree: Automation, Instrumentation & Controls or Electrical Engineering • Certificate of Qualification in Instrument technician • Instrumentation Engineering Technology diploma	• Support automation and controls functions including supervisory control and data acquisition (SCADA), programmable logic controller (PLC), remote terminal unit (RTU), distributed control system (DCS), human-machine interfaces (HMI), communications hardware, protocol and programming languages and related technologies. • Configure systems, troubleshooting and support equipment related to process control including leak detection technology	• CO2 properties, behaviour and potential hazards created • Understanding of carbon capture process • Knowledge of automated process systems and controls systems for carbon capture	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Relevant codes and standards • Automated process systems and controls systems
Electrical & instrumentation engineer	Bachelor's Degree: Electrical & Instrumentation Engineering	• Design for new or modification of instrumentation, control systems, and electrical projects including Programmable Logic Controllers (PLC) and safety PLCs (SIS), Distributed Control Systems (DCS), fire and gas (F&G) systems • Size and select equipment • Supervise installation and commissioning • Provide technical expertise to resolve issues associated with instrumentation, electrical, and control/safety systems.	• CO2 properties, behaviour and potential hazards created • Knowledge of key instrumentation and electrical equipment and systems associated with carbon capture, separation, purification and liquefication	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match

Carbon Capture: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Facility engineer	Bachelor's Degree: Chemical, Process or Mechanical Engineering .	• Provide technical support during routine operations, expansion and optimization, and during planned and unplanned outages. • Assist operations and integrity groups with compliance measures and best practices for process controls such as: MOC, HAZOP, design and repair, reporting and regulatory compliance. • Design and implement large scale facility capital projects	• CO2 properties, behaviour and potential hazards created • Understanding of carbon capture, separation, purification and liquefication processes • Appropriate selection, design and maintenance of related carbon capture equipment, materials, coatings, etc.	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Operation and optimization of production facilities
Measurement specialist	*Multiple pathways to this career:* • Bachelor's Degree: Chemical, Electrical & Instrumentation, Mechanical Engineering • Technology Diploma: Chemical, Electrical, Instrumentation or Mechanical Engineering	• Provide measurement and measurement systems expertise: flow meters, process analysers, flow measurement calculations • Conduct measurement uncertainty analysis and solve issues associated gas measurement including hydrogen, methane, and CO2	• Carbon properties, behaviour and potential hazards created • Understanding of measurement equipment and instrumentation associated with carbon capture, separation, purification and liquefication processes • Knowledge of CO2 value-chains	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Modelling experience using process simulators • Data validation and reconciliation

Carbon Capture: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Mechanical engineer - Equipment & piping	Bachelor's Degree: Mechanical Engineering	• Design rotating and stationary equipment associated with carbon capture, dehydration, purification and liquefication including vessels, piping, turbines, compressors, pumps and related auxillary systems • Provide technical expertise on the maintenance and repairs of pressure equipment and systems, and rotating equipment to ensure accordance with all applicable codes and standards • Develop expertise in existing and emerging technologies associated carbon capture processes and equipment • Participate in Root Cause and Failure Analysis (RCFA)	• CO2 properties, behaviour and potential hazards created • Appropriate selection, design and maintenance of vessels, piping systems, cryogenic systems and fitting, valves and seals for CO2 • Appropriate selection, design and maintenance of compression, pumping and turbine systems and hydraulic and pumping systems and equipment	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • High pressure gas system • Cryogenic/refrigeration system • Piping and pressure vessels • Compressors • Regulatory inspection requirements and inspection/test procedures for high pressure process manufacturing including ASME / API Pressure Vessel, NBIC

Carbon Capture: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Mechanical engineer - Reliability	Bachelor's Degree: Mechanical Engineering	• Lead carbon capture plant reliability program development and implementation in accordance with all applicable codes and standards • Oversee inspection, maintenance and repair of rotating and stationary equipment associated with carbon capture, dehydration, purification and liquefication including vessels, piping, turbines, compressors, pumps and related auxillary systems • Develop expertise in existing and emerging technologies associated with the inspection and maintenance • Participate in Root Cause and Failure Analysis (RCFA)	• CO2 properties, behaviour and potential hazards created • Appropriate selection, design and maintenance of vessels, piping systems, cryogenic systems and fitting, valves and seals for CO2 • Appropriate selection, design and maintenance of compression, pumping and turbine systems and hydraulic and pumping systems and equipment	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • High pressure gas system • Cryogenic/refrigeration system • Piping and pressure vessels • Compressors • Regulatory inspection requirements and inspection/test procedures for high pressure process manufacturing including ASME / API Pressure Vessel, NBIC

Carbon Capture: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Process control engineer	Bachelor's Degree: Chemical or Electrical & Instrumentation Engineering	• Building, implementing, and maintaining the advanced control applications used to perform facility operations optimization using a combination of regulatory and model predictive control techniques. • Build and deploy advanced process control applications • Develop and test control applications • Process modelling and simulation using software	• CO2 properties, behaviour and potential hazards created • Understanding of carbon capture, separation, purification and liquefication processes • Knowledge of carbon capture plant control systems and advanced control systems for process optimisation	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Plant control systems and advanced control systems for process optimisation. • A strong knowledge of plant and equipment design. • Software to build, test and deploy Advanced Control applications

Carbon Capture: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Process engineer	Bachelor's Degree: Chemical or Process Engineering	• Ensure safe, reliable and efficient operation of the process technology and equipment by applying knowledge of chemical solvent/ absorption, thermal kinetics, gas separation, gas processing, cryogenics, fluid mechanics, and materials science • Troubleshoot production and process issues • Oversee plant modifications and upgrades to processes and related equipment ensure comply with regulatory standards • Participate in Root Cause and Failure Analysis	• CO2 properties, behaviour and potential hazards created • Understanding of carbon capture, separation, purification and liquefication processes and steam generation processes	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match

Carbon Capture: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Process safety engineer	Bachelor's Degree: Chemical or Process Engineering Significant experience in process equipment, engineering, safety and operational risk management • Process Hazard Analysis techniques (HAZOP, FMEA) • What-If studies, quantitative and semi-quantitative risk assessments (LOPA and FTA/ETA) • Reliability/Survival analysis • Knowledge of OSHA 1910.119, CSA Z767, CSA Z260, ISO 31000, API 1173 and related codes and standards.	• Lead the continual improvement of process safety and risk management processes and methodologies • Analyze and evaluate a wide range of operational risks affecting financial, safety, operational reliability, environmental and reputational receptors • Oversee application of codes, standards, and regulations relevant to process systems and process safety for carbon capture • Oversee application of acceptable deviations from the approved standards, project specifications and processes • Facilitate the hazard identification and inventory (barrier management) process	• Process engineering and controls skills specific to hydrogen including hazard risk analysis and reviews, mechanical integrity and instrumented system analysis, and operation readiness inspection • Knowledge of CCS related regulations, standards and codes • Keep up-to-date with changes to CCS technology, regulations, standards and codes	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match Specialized role with small talent pool like to make it difficult to fill positions.

Carbon Capture: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Production engineer	Bachelor's Degree: Chemical or Mechanical Engineering	• Support of all aspects of day-to-day operations, including troubleshooting plant process problems and lead/execute plant projects • Data analysis and tracking, systems integration, and production equipment and systems troubleshooting and monitoring • Participate in Root Cause Analysis (RCA) investigations to identify and eliminate sources of undesired performance	• CO2 properties, behaviour and potential hazards created • Understanding of carbon capture, separation, purification and liquefication processes and steam generation processes	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match

Carbon Capture: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
PLANT OPERATIONS & MAINTENANCE				
Control room operator	Typically an experienced plant operator. Power Engineer/Stationary Engineer Certification.	• Oversee day-to-day operations from centralized control room • Assist Plant operator diagnose operational deficiencies using instrument indications • Troubleshoot equipment issues and potential root causes using instrument indications • Support preparation of equipment and systems for maintenance and commissioning • Perform safety responsibilities such as hazard identification, equipment lock-out, emergency response, etc. • Issue work permits to maintenance personnel and ensure that they are aware of the risks associated with the work to be performed	• CO2 properties, behaviour and potential hazards created • Understanding of carbon capture, separation, purification and liquefication processes and steam generation processes	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Plant monitoring and control through distributed control system (DCS) and programmable logic controller (PLC)

Carbon Capture: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Lab technician	Post-secondary diploma: • Chemical, Process or Petroleum technology • Laboratory technician	• Conduct quality control testing on process samples and finished products • Properly apply standards, procedures • Document and communicate findings and results • Organize and store all chemicals substances, fluids and compressed gases according to safety instructions • Understand the operation and maintenance of specified lab instruments	• CO2 properties, behaviour and potential hazards created • Understanding of carbon capture, separation, purification and liquefication processes and steam generation processes	Skills/knowledge and industry transferability opportunities: oil & gas, chemical, petrochemicals, pulp & paper, etc. • Natural gas processing closest match
Maintenance planner	*Multiple pathways to this career:* • Certificate of Qualification in Industrial electrician, Industrial mechanic/Millwright or Instrumentation technician • Bachelor's Degree: Electrical or Mechanical Engineering	• Develop preventive and predictive maintenance plans for the lifecycle of key electrical and mechanical equipment associated with carbon capture plants • Contribute achievement of key performance indicators by continuous improvement of maintenance function • Track best practices in preventive and predictive maintenance including leveraging of technology	• CO2 properties, behaviour and potential hazards created • Appropriate selection, design and maintenance of vessels, piping systems, cryogenic systems and fitting, valves and seals for CO2 • Appropriate selection, design and maintenance of compression, pumping and turbine systems and hydraulic and pumping systems and equipment	Skills/knowledge and industry transferability opportunities: oil & gas, chemical, petrochemicals, pulp & paper, etc. • Natural gas processing closest match Experience working with computerized maintenance management systems (CMMS)

Carbon Capture: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Maintenance trade - Electrical	Certificate of Qualification in Industrial Electrician • Registered apprentice	• Inspect, repair, install, troubleshoot and modify electrical and electronic equipment and components, AC/DC motors and drives, low and high voltage motors, programmable logic controls (PLC'), control circuits, switchgears, transformers, motors, starters, relays and hydraulic and pneumatic electrical controls • Install or replace electrical wiring, receptacles, switch boxes, conduits, feeders, fibre-optic and coaxial cable assemblies, lighting fixtures and other electrical components • Install, replace or repair generators, alternators and industrial storage batteries • Interpret drawings, blueprints, schematics and electrical code specifications	• CO2 properties, behaviour and potential hazards created • Appropriate selection and maintenance of key electrical equipment and systems associated with carbon capture plant and technology	Skills/knowledge and industry transferability opportunities: oil & gas, chemical, petrochemicals, pulp & paper, etc.

Carbon Capture: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Maintenance trade – Instrumentation & controls	Certificate of Qualification in Instrumentation technician • Registered apprentice	• Inspect, repair, install, troubleshoot and modify process controls, control valves, safety devices, analyzers, programmable logic controls (PLC), instrumentation (pressure, level and flow), process monitoring equipment, nd control circuits and distributed control systems (DCS) • Perform preventive and corrective maintenance on instrumentation and electrical equipment • Troubleshooting, repair, and calibration of plant instrumentation and controls. • Improve equipment performance and/or system reliability/capacity	• CO2 properties, behaviour and potential hazards created • Appropriate selection and maintenance of key instrumentation equipment and systems associated with carbon capture plant and technology	Skills/knowledge and industry transferability opportunities: oil & gas, chemical, petrochemicals, pulp & paper, etc. • Natural gas processing closest match Supports digitization across multiple industries; in high demand • Existing skill shortage

Carbon Capture: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Maintenance trade – Mechanical	Certificate of Qualification in Industrial Mechanic or Millwright • Registered apprentice Experience as a Pipefitter and/or Class A welder an asset	• Inspection, repair, troubleshooting, modification, installation and commissioning of mechanical equipment to such as reciprocating, centrifugal and screw compressors, cryogenic pumps, gear drives, steam turbines, fans and blowers, vessels, heat exchangers, reciprocating and centrifugal expanders. • Continuously improve machinery condition and reliability.	• CO2 properties, behaviour and potential hazards created • Appropriate selection, design and maintenance of vessels, piping systems, cryogenic systems and fitting, valves and seals for CO2 • Appropriate selection, design and maintenance of compression, pumping and turbine systems and hydraulic and pumping systems and equipment	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match
Plant manager	Likely to be an experienced worker with engineering, maintenance and/or operations experience.	• Manage the day-to-day operations: organizational tasks, assignment of work and meeting production targets and delivery dates • Ensure all plant employees work within occupational health and safety regulations, polices and procedures • Continuous improvement of process techniques and equipment • Assist with troubleshooting operational and maintenance issues • Coach, mentor, train and develop employees in their job performance; participate in succession planning and hiring activities	• CO2 properties, behaviour and potential hazards created • Understanding of carbon capture, separation, purification and liquefication processes and steam generation processes • Maintenance of equipment and systems involved in carbon capture plant	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match

Carbon Capture: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Plant operator	Power Engineer/Stationary Engineer Certification	• Responsible for ensuring safe plant operation • Observe and analyze plant activity to identify potential operational problems, causes and propose appropriate corrective actions • Prepares equipment and systems for maintenance and commissioning • Track daily production and performance data to optimize production and inform equipment maintenance, safety and environmental indicators	• CO2 properties, behaviour and potential hazards created • Understanding of carbon capture, separation, purification and liquefication processes	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Steam generation • Plant monitoring and control through distributed control system (DCS) and programmable logic controller (PLC)

CO2 Pipeline Transmission: Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
ENGINEERS				
Automation & controls specialist	*Multiple pathways to this career:* • Bachelor's Degree: Automation, Instrumentation & Controls or Electrical Engineering • Certificate of Qualification in Instrument technician • Technology Diploma: Instrumentation Engineering	• Support automation and controls functions including supervisory control and data acquisition (SCADA), programmable logic controller (PLC), remote terminal unit (RTU), distributed control system (DCS), human-machine interfaces (HMI), communications hardware, protocol and programming languages and related technologies • Configure systems, troubleshooting and support equipment related to process control including leak detection technology	• CO2 properties, behaviour and potential hazards created • Understanding of CO2 compression and/or liquification processes • Knowledge of automated process systems and controls systems for CO2 pipeline transmition	Skills/knowledge and industry transferability opportunity with natural gas and petroleum liquids pipelines: • Relevant codes and standards • Automated process systems and controls systems
Compression specialist	*Multiple pathways to this career:* • Bachelor's Degree: Aerospace, Chemical or Mechanical Engineering • Technologist Diploma: Aerospace Engineering, Mechanical Engineering	• Provide design, engineering and other technical support for CO2 compression and processing equipment • Model and simulation of complex thermomechanical systems (air flow, compression, heating, cooling, electro-mechanical actuation etc.) • Monitor compressor equipment performance and ancillary equipment such as air compressors, boilers, pumps and electrical equipment; trouble-shoot issues and identify solutions	• CO2 properties, behaviour and potential hazards created • Understanding of CO2 compression properties and processes • Appropriate selection, design and maintenance of CO2 compression, turbine systems and equipment	Skills/knowledge and industry transferability opportunity with natural gas and petroleum liquids pipelines and aerospace.

CO2 Pipeline Transmission: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Corrosion specialist	*Multiple pathways to this career:* • Bachelor's Degree: Materials or Mechanical Engineering • Technologist Diploma: Materials Engineering, Mechanical Engineering Valid driver's license + clean abstract National Association of Corrosion Engineers (NACE) certification	• Apply knowledge of basic engineering principles and corrosion theory to CO2 projects • Inspect, maintain and trouble-shoot pipeline facilities • Provide input into methodology, and pipeline integrity procedures, practices and technologies including cathodic protection equipment and systems and corrosion control systems • Apply corrosion prediction models that are used to assess CO_2 corrosion rates	• CO2 properties, behaviour and potential hazards created • Understanding materials behaviour in high pressure CO_2 • Knowledge of appropriate CO2 material and coating selection	Skills/knowledge and industry transferability opportunity with natural gas and liquid hydrocarbon pipelines: • Corrosion mechanism involved for transporting and storing CO_2 is similar to the mechanism in oil and gas applications
Electrical & instrumentation engineer	Bachelor's Degree: Electrical & Instrumentation Engineering	• Design for new or modification of instrumentation, control systems, and electrical projects including Programmable Logic Controllers (PLC) and safety PLCs (SIS), Distributed Control Systems (DCS), fire and gas (F&G) systems • Size and select equipment • Supervise installation and commissioning • Provide technical expertise to resolve issues associated with instrumentation, electrical, and control/safety systems.	• CO2 properties, behaviour and potential hazards created • Knowledge of key instrumentation and electrical equipment and systems associated with CO2 pipeline transmission including compression and/or liquefication	Skills/knowledge and industry transferability opportunity with natural gas and liquid hydrocarbon pipelines

CO2 Pipeline Transmission: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Hydraulics engineer	Bachelors Degree: Chemical or Mechanical Engineering	• Provide technical expertise for CO2 liquid pipeline • Develop and maintain comprehensive hydraulic models of pipeline systems, Conduct steady-state and transient pipeline hydraulic analyses, incremental volume analysis and other special studies as needed • Identify optimization opportunities • Trouble-shoot and offer recommendations to mitigate overpressure risk	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a liquid state	Skills/knowledge and industry transferability opportunity with liquid hydrocarbon pipelines
Measurement specialist	*Multiple pathways to this career:* • Bachelor's Degree: Chemical, Electrical & Instrumentation, Mechanical Engineering • Technologist Diploma: Chemical, Electrical & Instrumentation, Mechanical, Petroleum Engineering	• Provide measurement and measurement systems expertise: flow meters, process analysers, flow measurement calculations • Conduct measurement uncertainty analysis and solve issues associated gas measurement including hydrogen, methane, and CO2	• Carbon properties, behaviour and potential hazards created • Understanding of measurement equipment and instrumentation associated with CO2 transmission • Knowledge of CO2 value-chains	Skills/knowledge and industry transferability opportunity with natural gas and liquid hydrocarbon pipelines: • Data validation and reconciliation

CO2 Pipeline Transmission: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Pipeline engineer	Bachelor's Degree: Chemical, Civil or Mechanical Engineering	• Lead all aspects for expansion and maintenance capital projects for pipelines and related facilities • Approve and certify design and operations procedures with an engineering stamp ensuring conformation to laws and regulations, company policies and procedures, accepted engineering practice, and upholds public safety • Provide project support including the planning, design, approval and procurement of materials, tendering, constructing, testing and commissioning of the pipelines or related facilities • Prepare Technical Assessments, Material Specifications and/or updates to pipeline construction and maintenance manuals	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a liquid and gaseous state • Understanding materials behaviour in liquid and high and low pressure CO_2 • Materials selection including coatings for CO2 pipeline and related facilities	Skills/knowledge and industry transferability opportunity with natural gas and liquid hydrocarbon pipelines: • Understanding of pipeline design, pipelines systems codes and standards, construction practices and field operations. • Canadian regulations and standards related to pipelines including ASME and CSA 7662

CO2 Pipeline Transmission: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Pipeline integrity specialist	Bachelor's Degree: Chemical, Materials, Metallurgical or Mechanical Engineering National Association of Corrosion Engineers (NACE) certification	• Provide technical expertise in the design, implementation and updating of pipeline asset integrity management programs (IMP's) ensuring compliance to technical, regulatory, and legal requirements • Stay current and compliant with standards, pipeline regulations, industry standards, integrity assessment, monitoring, mitigation and repair methods • Oversee all aspects of pipe integrity, integrity management systems, fracture mechanics, mechanics of materials, risk analysis, pipeline construction, in-line inspection and cathodic protection • Analyze information to assess and manage potential pipeline integrity threats and damage prevention issues	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a liquid and gaseous state • Understanding materials behaviour in liquid and high and low pressure CO_2 • Understanding materials behaviour in liquid and high and low pressure CO_2 • Materials selection including coatings for CO2 pipeline and related facilities	Skills/knowledge and industry transferability opportunity with natural gas and liquid hydrocarbon pipelines: • Understanding of pipeline design, pipelines systems codes and standards, construction practices and field operations. • Canadian regulations and standards related to pipeline integrity and damage prevention including ASME and CSA 7662

CO2 Pipeline Transmission: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Process safety engineer	Bachelor's Degree: Chemical or Process Engineering Significant experience in process equipment, engineering, safety and operational risk management • Process Hazard Analysis techniques (HAZOP, FMEA) • What-If studies, quantitative and semi-quantitative risk assessments (LOPA and FTA/ETA) • Reliability/Survival analysis • Knowledge of OSHA 1910.119, CSA Z767, CSA Z260, ISO 31000, API 1173 and related codes and standards.	• Lead the continual improvement of process safety and risk management processes and methodologies • Analyze and evaluate a wide range of operational risks affecting financial, safety, operational reliability, environmental and reputational receptors • Oversee application of codes, standards, and regulations relevant to process systems and process safety for carbon pipeline transmission • Oversee application of acceptable deviations from the approved standards, project specifications and processes • Facilitate the hazard identification and inventory (barrier management) process	• Process engineering and controls skills specific to hydrogen including hazard risk analysis and reviews, mechanical integrity and instrumented system analysis, and operation readiness inspection • Knowledge of CCS related regulations, standards and codes • Keep up-to-date with changes to CCS technology, regulations, standards and codes	Skills/knowledge and industry transferability opportunity with natural gas and liquid hydrocarbon pipelines: Specialized role with small talent pool like to make it difficult to fill positions.

CO2 Pipeline Transmission: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
OPERATIONS & MAINTENANCE				
Control centre operator	Technology certification in Chemical Engineering, Power Engineering, or Petrochemical Engineering Technology	• Remotely control and monitor pipeline system and operations • Monitor, resolve, and escalate operational and safety issues • Optimize operations by maximizing throughput while minimizing operating costs • Perform emergency corrective action as required • Maintain accurate logs and reports • Provide courteous and precise communications with external and internal customers	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a liquid and gaseous state	Skills/knowledge and industry transferability opportunity with natural gas and liquid hydrocarbon pipelines: • Understanding of SCADA • Pipeline monitoring and control through distributed control system (DCS) and programmable logic controller (PLC)
Pipeline scheduler	Post-secondary certification in business, commerce or or related discipline	• Manage scheduling of CO2 receipt locations and coordination deliveries to downstream connections • Manage daily nominations on pipeline • Communicate any maintenance or other shutdown intel with control room operations and external and internal customers • Gather, analyze and compile data for reporting	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a liquid and gaseous state	Skills/knowledge and industry transferability opportunity with natural gas and liquid hydrocarbon pipelines: • Pipeline logistics • Pipeline hydraulics and/or compression

CO2 Pipeline Transmission: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Pipeline technician - Electrical & Instrumentation	*Multiple pathways to this career:* • Certificate of Qualification in Instrumentation technician or Industrial Electrician • Registered apprentice • Technologist diploma in Instrumentation engineering or Electrical engineering Valid driver's license + clean abstract	• Ensure that electrical and instrumentation equipment and systems are maintained in compliance with regulations and procedure requirements • Trouble-shoot, test, calibrate electrical systems associated with measurement,pumps, motors, valves, switchgear, flow meters, logic controls, motor control centers, compressors, power supplies, etc. • Program and trouble-shoot instrumentation systems including PLC's, RTAP, Flow Computer, and SCADA systems • Communicate with contractors, public, landowners, and government agencies as required	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a liquid state • Knowledge of electrical equipment and instrumentation systems required for pipeline transmission of liquid and/or gaseous CO2	Skills/knowledge and industry transferability opportunity with liquid and gaseous hydrocarbon pipelines

CO2 Pipeline Transmission: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Pipeline technician - Mechanical	*Multiple pathways to this career:* • Certificate of Qualification: Industrial Mechanic (Millwright) • Registered apprentice • Technologist diploma: Mechanical Engineering Valid driver's license + clean abstract	• Ensure that all stationary and rotating mechanical equipment and systems are maintained in compliance with regulations and procedure requirements • Perform inspections, troubleshoot and repair mechanical equipment: pumps, valves, actuators, tank mixers, mechanical seals, motors, fans, compressors, turbines, etc. • Lead pipeline isolation, lock out/tag out activities including blowing down, purging, and pressuring pipelines and the installation and operation of air movers/expellers • Communicate with contractors, public, landowners, and government agencies as required	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a liquid state • Knowledge of stationary and rotating equipment and systems required for pipeline transmission of liquid and/or gaseous CO2	Skills/knowledge and industry transferability opportunity with liquid and gaseous hydrocarbon pipelines

CO2 Pipeline Transmission: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Station operator-Compression	*Multiple pathways to this career:* • Certificate of Qualification: Industrial Electrician or Industrial Mechanic (Millwright) • Registered apprentice • Technologist diploma: Electrical Engineering, Mechanical Engineering	• Operate and maintain all compression facility equipment and systems • Monitor, troubleshoot, and repair dehydration equipment, pneumatic controls, compression, turbines, etc. • Responsible for isolation and permitting activities as required • Communicate with contractors, public, landowners, and government agencies as required	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a gaseous state • Understanding of CO2 compression processes • Appropriate selection of materials, coatings, seals, etc. for the maintenance of CO2 compression facility equipment and systems	Skills/knowledge and industry transferability opportunity gaseous hydrocarbon pipelines • Working with programmable logic controllers, pneumatic and automated operations systems
Station operator - Pump	*Multiple pathways to this career:* • Certificate of Qualification: Industrial Electrician or Industrial Mechanic (Millwright) • Registered apprentice • Technologist diploma: Electrical Engineering, Mechanical Engineering	• Operate and maintain all pump facility equipment and systems • Monitor, troubleshoot, and repair dehydration equipment, injection pumps, plunger lifts, hydraulic controls, etc. • Responsible for isolation and permitting activities as required • Communicate with contractors, public, landowners, and government agencies as required	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a liquid state • Appropriate selection of materials, coatings, seals, etc. for the maintenance of CO2 pump facility equipment and systems	Skills/knowledge and industry transferability opportunity with liquid hydrocarbon pipelines • Working with programmable logic controllers, hydraulic controls and automated operations systems

CO2 Underground Storage: Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
ENGINEERS & GEOSCIENCE PROFESSIONALS				
Drilling & completion engineer	Bachelor's Degree: Chemical, Mechanical or Petroleum Engineering	• Responsible for the design and execution of drilling and completions plans for deep CO2 injection wells and observation/monitoring wells in accordance to company standards and regulatory requirements • Take an integrated approach to well design, drilling, completions, and well construction • Conduct digital field planning and optimization • Design well integrity management plan	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in liquid and gas state • Well design and material choices based on understanding of long-term regulatory environment, CO_2 injection stream properties, changes in CO2 pressure over lifetime of the well and potential corrosive elements	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry Drilling & completion engineers with experience across a number of basins/reservoirs likely to transfer to CCS more easily

CO2 Underground Storage: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Reservoir engineer	Bachelor's Degree: Chemical, Mechanical or Petroleum Engineering	• Conduct detail modelling to evaluation and characterization of the reservoir • Conduct the evaluation, appraisal, development and optimization of safe and reliable carbon storage based on understanding of CO2 characteristics and reservoir, provide technical input into well design and spacing, and injection testing and analysis • Provide input into the project development lifecycle, including integrating surface and subsurface activities, ensuring regulatory compliance • Design reservoir monitoring and surveillance program	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a liquid state • Understanding of reservoir engineering fundamentals for CO2 injection and well testing, pressure and rate transient analysis, fluid characterization • Pressure, voltage, temperature (PVT) characterization and thermal/flow modeling specific to sequestered gas composition • Migration modeling, zone selection and storage design. • Reservoir geochemistry, modeling CO_2-water-mineral interactions	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry • Reservoir engineering fundamentals are same • Understanding of subsurface chemistry, regional distress profiles, and pre-existing faults and fractures of value • Data and tools used for modelling, evaluating, visualizing and contextualizing subsurface opportunities

CO2 Underground Storage: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
GEOSCIENCE PROFESSIONALS				
Geologist Geophysicist	Bachelor's of Science Degree: Geology or Geophysics	• Apply seismic and geoscience databases to identify and assess deep aquifers and cavern for suitability for permanent CO2 storage • Assess subsurface risk to inform reservoir and completion engineering • Conduct storage evaluation to determine capacity, containment and injectivity estimations to optimize operations during injection • Run various Excel-based simulations, including but not limited to: hydraulic simulations, MIT calculation (test pressures, nitrogen equivalent volumes, leak rate calculations) • Support mechanical integrity testing (MIT) and workovers of storage and injection wells • Assist in design of long-term monitoring system and procedures to ensure safety and to satisfy regulatory requirements	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a liquid and gaseous state	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry • 2D, 3D & 4D stratigraphy-focused seismic data interpretation • Competent with different types of seismic data and interpretation software • Data and tools used for mapping, modelling, evaluating, visualizing and contextualizing subsurface opportunities

CO2 Underground Storage: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
FIELD OPERATIONS				
Drilling crew	Leasehand is the entry level position on a drilling crew. Requirements include: • Legally eligible to work in Canada • At least 18 years of age • Possess a valid driver's license • Physically fit • Ability to work safely and plan ahead • Mechanical aptitude • Oilfied safety certifications Must pass pre-employment drug and alcohol test With experience, Leasehands can progress through to: Floorhand, Motorhand, Derrickhand, Driller and Rig Manager positions.	• Operate the machine and equipment used to drill CO2 injection wells and monitoring wells into deep-isolated rock formations.	No unique requirements. CO2 injection wells are a type of deep injection well used for injection into deep-isolated rock formations.	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry Currently a very tight labour market for drilling workforce

CO2 Underground Storage: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Heavy duty mechanic	Certificate of Qualification in Heavy Duty or Industrial Mechanic (Millwright) • Registered apprentice Unrestricted Class 5 driver's license with satisfactory driver's abstract	• Daily repairs and preventative maintenance of drilling and well servicing equipment and service rigs • Trouble-shooting and diagnosing mechanical, hydraulic and/or electrical issues across a variety of equipment including transport tractors and trailers, injectors, diesel engineers, powertrain, pressure pumping equipment, tractors, trailers, and cranes • Maybe shop based or required in the field	No unique requirements	Skills/knowledge and industry transferability opportunity with the oil & gas industry, agriculture, forestry, mining and transportation Current shortage of Heavy duty mechanics/technicians
Reservoir technologist	Technologist Diploma: Chemical, Petroleum Engineering	• Gather, process and integrate many different types of data and information including from satellite, gravity and electromagnetic measurements, 3D/4D seismic imaging, reservoir models and well data to inform CCS project planning and development and ensure corporate and regulatory, safety and environmental compliance • Assist in the interpretation of sub-surface data to evaluate storage potential • Construct sub-surface maps to help monitor wellsite operations	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a liquid state • Understanding of reservoir data as it relates to CO2 injection and storage • Stay up to date on technology and options for CO2 storage and monitoring	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry • Data and tools used for modelling, evaluating, visualizing and contextualizing subsurface opportunities

CO2 Underground Storage: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Service rig crew	Leasehand is the entry level position on a service rig crew. Requirements include: • Legally eligible to work in Canada • At least 18 years of age • Possess a valid driver's license • Physically fit • Ability to work safely and plan ahead • Mechanical aptitude • Oilfield safety certifications Must pass pre-employment drug and alcohol test With experience, Leasehands can progress through to: Floorhand, Derrickhand, Driller and Operator positions.	• Perform maintenance, known as workovers, on CO2 wells • Perform remedial treatments to ensure well integrity is maintained for the life of the well • Well decommissioning at the end of the well's life	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a liquid state • Understanding of appropriate well completion solutions for CO2 given subsurface condition and need for long-term well integrity	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry Currently a very tight labour market for service rig workforce

CO2 Underground Storage: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Well completions operator	Valid Class 1 or Class 3 Driver's licence and clean driver's abstract • Legally eligible to work in Canada • Physically fit • Ability to work safely and plan ahead • Mechanical aptitude • Oilfield safety certifications Comfortable driving off-highway/off-road	• Safely drive equipment to site and engage in activities required to "complete" the CO2 injection and monitoring wells including casing (surface and injection) and cementing the wells. • Perform pre-trip and post-trip inspections by accurately completing corresponding driver log forms while remaining in accordance inspection procedures • Keep paper work up to date including all permits, government regulatory paperwork, iron inspections, and maintenance documentation • Rig-up treating iron, manifolds and recording equipment • Rig-out of all equipment for travel and conduct movement to following site • Perform maintenance on equipment	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a liquid state • Understanding of appropriate well completion solutions for CO2 given subsurface condition and need for long-term well integrity	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry Current shortage of well service operators. In part due to the shortage of Class 1 Drivers

CO2 Underground Storage: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Well completions supervisor	Experienced well completions operator Valid Class 1 or Class 3 Driver's licence and clean driver's abstract	• Oversee well completions operations • Coach, mentor and train operators	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a gas and liquid state • Understanding of appropriate well completion solutions for CO2 given subsurface condition and need for long-term well integrity	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry Current shortage of well service supervisors. In part due to the shortage of Class 1 Drivers

Measurement, Monitoring & Verification (MMV): Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
ENGINEERS				
Measurement specialist	*Multiple pathways to this career:* • Bachelor's Degree: Chemical, Electrical & Instrumentation, Mechanical Engineering • Technologist Diploma: Chemical, Electrical & Instrumentation, Mechanical Engineering	• Provide measurement and measurement systems expertise including evaluate and select monitoring technologies • Ensure sufficient data is collected to provide evidence of: geological containment of CO2 stream and affected fluids within the storage complex, no significant adverse effects to other pore space users within hydraulically connected saline formations, no significant adverse effects of CO2 injection on health, the environment or other resources • Quantify the amount of CO2 sequestered and to support permanent reduction of greenhouse gases • Conduct measurement uncertainty analysis and solve issues associated with CO2 gas measurement • Verify and update models and simulations, and use the results to continually inform capacity estimates and conformance verification.	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a gas and liquid state • Understanding of measurement equipment and instrumentation associated with permanent underground storage of CO2	Skills/knowledge and industry transferability opportunity with other underground storage technologies including those used for natural gas: • Modelling experience using process simulators • Data validation and reconciliation

Measurement, Monitoring & Verification (MMV): Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Reservoir engineer	Bachelor's Degree: Chemical, Mechanical or Petroleum Engineering	• Develop models and execute simulations to evaluate and predict the behavior of the storage complex, and inform risk assessment • Conduct reservoir simulation for historical and predictive flow modelling, including of the plume • Estimate the displacement of a CO2 plume in the reservoir; the potential reactivation of faults due to CO2 pressurization and injection; undesired migration of the injected CO2 plume (leading to leakage to the surface); and reservoir uncertainty. • Monitor and minimize impacts on adjacent saline groundwater systems and other pore space users, including other CCS, oil and gas, minerals, disposal, geothermal, storage, etc.	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a gaseous state • Understanding of reservoir engineering fundamentals for CO2 injection and well testing, pressure and rate transient analysis, fluid characterization, • Pressure, voltage, temperature (PVT) characterization and thermal/flow modeling specific to sequestered CO2 composition • Migration modeling, zone selection and storage design. • Reservoir geochemistry, modeling CO_2-water-mineral interactions	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry • Reservoir engineering fundamentals • Understanding of subsurface chemistry, regional distress profiles, and pre-existing faults and fractures of value • Data and tools used for modelling, evaluating, visualizing and contextualizing subsurface opportunities

Measurement, Monitoring & Verification (MMV): Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
GEOSCIENCE PROFESSIONALS				
Geologist Geophysicist	Post-secondary degree in Geophysics and/or Geology is required.	• Use seismic data to generate maps and cross sections of the subsurface stratigraphy. • Analyze 2D, 3D & 4D seismic data for sub-surface hazard assessment • Design and oversee implementation of an induced seismicity hazard assessment, monitoring, and mitigation program • Develop models and execute simulations to evaluate and predict the behavior of the storage complex, and inform the project risk assessment • Conduct geological and geomechanical modelling to assess injectivity and containment including caprock integrity, stress regime, fault and fracture characteristics, and activation of pre-existing faults and fractures	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a gaseous state	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry • 2D, 3D & 4D stratigraphy-focused seismic data interpretation • Competent with different types of seismic data and interpretation software

Measurement, Monitoring & Verification (MMV): Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
TECHNOLOGISTS & TECHNICIAN				
Instrumentation technician	Certificate of Qualification in Instrumentation technician • Registered apprentice	• Inspect, repair, install, troubleshoot, calibrate and modify CO2 monitoring sensors, equipment and systems • Perform preventive and corrective maintenance. • Improve equipment performance and/or system reliability/capacity	• CO2 properties, behaviour and potential hazards created • Appropriate selection and maintenance of CO2 sensors and monitoring equipment and systems	Skills/knowledge and industry transferability opportunity with the upstream and midstream oil & gas industry Supports digitization across multiple industries; in high demand with existing shortages
Reservoir technologist	Technologist Diploma: Chemical, Petroleum Engineering	• Gather, process and integrate many different types of data and information including from satellite, gravity and electromagnetic measurements, 3D/4D seismic imaging, reservoir models and well data to inform CCS regulatory, safety and environmental compliance as it pertains to underground storage • Construct and interpret sub-surface maps to help monitor storage • Assist engineers and geoscientists process and interpret data to improve CO2 storage performance	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a liquid state • Understanding of reservoir data as it relates to CO2 injection and storage • Stay up to date on technology and options for CO2 monitoring	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry • Data and tools used for modelling, evaluating, visualizing and contextualizing subsurface activity

Measurement, Monitoring & Verification (MMV): Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for CO2	Potential Talent Risk/Opportunity
Sampling and analysis technician	Technologist Diploma: Biology, Chemical or Environmental Engineering	• Collect soil, air and water samples and perform lab testing to investigate and monitor CO2 underground storage sites and ensure regulatory, safety and environmental compliance	• CO2 properties, behaviour and potential hazards created • Understanding of properties and characteristics of CO2 in a liquid state	Skills/knowledge and industry transferability opportunity with the upstream and midstream oil & gas industry
Seismic crew	• Legally eligible to work in Canada • Physically fit • Ability to work safely and plan ahead • Mechanical and electronic aptitude • Oilfield safety certifications	• **prepare, control and conduct seismic tests** to gather subsurface information about CO2 underground storage performance • Data gathered will be used by engineering and geoscience professionals ensure regulatory, safety and environmental compliance	No unique requirement for CO2.	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry Current shortage of seismic labourers and operators

Back to Value Chains Menu

Or continue on to Storage, Upgrading &
Transporting Core Occupations

Storage, Upgrading & Transporting

For the hydrogen economy to reach its full potential, storage, transport and distribution systems connecting supply to demand need to be developed.

The *Hydrogen Workforce Assessment Tool* focuses on four components of the hydrogen distribution value chain:

1. Underground storage of hydrogen
2. Hydrogen pipelines
3. Truck transport of gas and liquid hydrogen
4. Ammonia as a carrier of hydrogen

Underground Storage of Hydrogen

Currently hydrogen is safely stored as a compressed gas or cryogenic liquid in tanks at production and end-user sites. As demand for hydrogen grows, there will be a need to increase storage capacity. Underground salt caverns and depleted hydrocarbon reservoirs are emerging as feasible, large-scale solutions for storing compressed hydrogen.

At a high level, the process involved in building and operating underground salt cavern for storage of hydrogen includes:

- Assessing the economic, technical, environmental and social viability of the site
- If deemed feasible, the salt cavern is developed by pumping water down a borehole into the salt. The salt is dissolved leaving a void and the water, now saline, is pumped back to the surface. The process continues until the cavern has been washed to the desired size.
  - The drilling and completion process for a salt cavern is similar to drilling a vertical conventional oil or gas well
    - Main difference is the hole size is much larger to accommodate multiple tubular strings for both the cavern leaching process as well as storage operations
- Ongoing operations and maintenance of underground hydrogen storage will be very similar to that for underground storage of natural gas

Underground Storage of Hydrogen *cont'd*

- Canada's geology has proven capacity for underground storage of gas
  - Alberta, British Columbia (B.C.), Ontario, Quebec, and Saskatchewan have underground natural gas storage facilities
  - Depleted oil and gas reservoirs are located across the Western Canadian Sedimentary Basin and may serve ideal locations for hydrogen storage
  - Geological characteristics of most depleted oil and gas reservoirs are well known and documented
- Underground storage also offers the opportunity to store surplus energy generated from renewable sources by first electrolyzing it into hydrogen and then storing it in caverns or reservoirs for power, industrial and transport applications as demand dictates

Underground Storage of Hydrogen: Core Occupations

Underground Storage of Hydrogen Workforce Requirements	
ENGINEERS • Drilling & completion engineer • Cavern engineer **FIELD OPERATORS** • Drilling crew • Heavy duty mechanic • Reservoir technologist • Service rig crew • Well completions operator • Well completions supervisor	**GEOSCIENCE PROFESSIONALS:** Geologist, Geophysicist, Geotechnical specialist **SURFACE FACILITY OPERATIONS & MAINTENANCE** • Control centre operator • Compression specialist • Maintenance trades: Electrical & Instrumentation, Mechanical • Measurement specialist

Underground Storage of Hydrogen: Core Occupations done

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
ENGINEERS & GEOSCIENCE PROFESSIONALS FOR UNDERGROUND STORAGE				
Drilling & completion engineer	Bachelor's Degree: Chemical, Mechanical or Petroleum Engineering	• Responsible for the design and execution of drilling and completions plans for hydrogen injection wells in accordance to company standards and regulatory requirements • Take an integrated approach to well design, drilling, completions, and well construction • Conduct digital field planning and optimization	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of properties and characteristics of hydrogen in a gaseous state • Well design and material choices based on understanding of regulatory environment, hydrogen injection stream properties, changes in hydrogen pressure over time and potential corrosive elements	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry

Underground Storage of Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Cavern engineer	Bachelor's Degree: Chemical, Geological, Mechanical or Petroleum Engineering	• Conduct detail modelling to evaluation and characterization of the cavern • Conduct the evaluation, appraisal, development and optimization of safe and reliable storage based on understanding of hydrogen characteristics and cavern, provide technical input into well design and spacing, and injection testing and analysis • Provide input into the project development lifecycle, including integrating surface and subsurface activities, ensuring regulatory compliance • Design cavern monitoring and surveillance program • Help to write programs, procure and oversee wireline, coil tubing or rig work, and assisting in program writing for cavern well workovers and mechanical integrity tests	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of properties and characteristics of hydrogen in a liquid and gaseous state • Understanding of cavern engineering fundamentals for hydrogen injection and well testing, pressure and rate transient analysis, fluid characterization • Pressure, voltage, temperature (PVT) characterization and thermal/flow modeling specific to sequestered gas and/or liquid composition • Migration modeling, zone selection and storage design. • Modeling hydrogen-water-mineral interactions	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry • Reservoir engineering fundamentals are similar to caverns • Understanding of subsurface chemistry, regional distress profiles, and pre-existing faults and fractures of value • Data and tools used for modelling, evaluating, visualizing and contextualizing subsurface opportunities

Underground Storage of Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
GEOSCIENCE PROFESSIONALS				
Geologist Geophysicist Geotechnical specialist	Bachelor's of Science Degree: Geology or Geophysics	• Apply seismic and geoscience databases to identify and assess cavern for suitability for hydrogen storage • Assess subsurface risk to inform reservoir and completion engineering • Conduct storage evaluation to determine capacity, containment and injectivity estimations to optimize operations during injection • Conduct geomechanical testing and analysis of cavern • Run various Excel-based simulations, including but not limited to: hydraulic simulations, test pressures, nitrogen equivalent volumes, leak rate calculations • Support mechanical integrity testing (MIT) to inform workovers of storage and injection wells • Assist in design of long-term monitoring system and procedures to ensure safety and to satisfy regulatory requirements	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of properties and characteristics of hydrogen in a gaseous state	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry • 2D, 3D & 4D stratigraphy-focused seismic data interpretation • Competent with different types of seismic data and interpretation software • Data and tools used for mapping, modelling, evaluating, visualizing and contextualizing subsurface opportunities

Underground Storage of Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
FIELD OPERATIONS				
Drilling crew	Leasehand is the entry level position on a drilling crew. Requirements include: • Legally eligible to work in Canada • At least 18 years of age • Possess a valid driver's license • Physically fit • Ability to work safely and plan ahead • Mechanical aptitude • Oilfied safety certifications Must pass pre-employment drug and alcohol test With experience, Leasehands can progress through to: Floorhand, Motorhand, Derrickhand, Driller and Rig Manager positions.	• Operate the machine and equipment used to drill hydrogen injection wells and monitoring wells into deep-isolated rock formations.	No unique requirements.	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry Currently a very tight labour market for drilling workforce

Underground Storage of Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Heavy duty mechanic	Certificate of Qualification in Heavy Duty or Industrial Mechanic (Millwright) • Registered apprentice Unrestricted Class 5 driver's license with satisfactory driver's abstract	• Daily repairs and preventative maintenance of drilling and well servicing equipment and service rigs • Trouble-shooting and diagnosing mechanical, hydraulic and/or electrical issues across a variety of equipment including transport tractors and trailers, injectors, diesel engineers, powertrain, pressure pumping equipment, tractors, trailers, and cranes • Maybe shop based or required in the field	No unique requirements.	Skills/knowledge and industry transferability opportunity with the oil & gas industry, agriculture, forestry, mining and transportation. Current shortage of Heavy duty mechanics/technicians.
Reservoir technologist	Technologist Diploma: Chemical, Petroleum Engineering	• Gather, process and integrate many different types of data and information including from satellite, gravity and electromagnetic measurements, 3D/4D seismic imaging, reservoir models and well data to inform CCS project planning and development and ensure corporate and regulatory, safety and environmental compliance • Assist in the interpretation of sub-surface data to evaluate storage potential • Construct sub-surface maps to help monitor wellsite operations	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of properties and characteristics of hydrogen in a gaseous state • Understanding of reservoir data as it relates to hydrogen injection and storage • Stay up to date on technology and options for hydrogen storage and monitoring	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry • Data and tools used for modelling, evaluating, visualizing and contextualizing subsurface opportunities

Underground Storage of Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Service rig crew	Leasehand is the entry level position on a service rig crew. Requirements include: • Legally eligible to work in Canada • At least 18 years of age • Possess a valid driver's license • Physically fit • Ability to work safely and plan ahead • Mechanical aptitude • Oilfield safety certifications Must pass pre-employment drug and alcohol test With experience, Leasehands can progress through to: Floorhand, Derrickhand, Driller and Operator positions.	• Perform maintenance, known as workovers, on hydrogen wells • Perform remedial treatments to ensure well integrity is maintained for the life of the well • Well decommissioning at the end of the well's life	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of properties and characteristics of hydrogen in a gaseous state • Understanding of appropriate well completion solutions for hydrogen	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry Currently a very tight labour market for service rig workforce

Underground Storage of Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Well completions operators	Valid Class 1 or Class 3 Driver's licence and clean driver's abstract • Legally eligible to work in Canada • Physically fit • Ability to work safely and plan ahead • Mechanical aptitude • Oilfield safety certifications Comfortable driving off-highway/off-road	• Safely drive equipment to site and engage in activities required to complete the hydrogen injection wells including casing (surface and injection) and cementing the wells. • Perform pre-trip and post-trip inspections by accurately completing corresponding driver log forms while remaining in accordance inspection procedures • Keep paper work up to date including all permits, government regulatory paperwork, iron inspections, and maintenance documentation • Rig-up treating iron, manifolds and recording equipment • Rig-out of all equipment for travel and conduct movement to following site • Perform maintenance on equipment	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of properties and characteristics of hydrogen in a gaseous state • Understanding of appropriate well completion solutions for hydrogen	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry Current shortage of well service operators. In part due to the shortage of Class 1 Drivers

Underground Storage of Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Well completions supervisor	Experienced well completions operator Valid Class 1 or Class 3 Driver's licence and clean driver's abstract	• Oversee well completions operations • Coach, mentor and train operators	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of properties and characteristics of hydrogen in a gaseous state • Understanding of appropriate well completion solutions for hydrogen	Skills/knowledge and industry transferability opportunity with the upstream oil & gas industry Current shortage of well service supervisors. In part due to the shortage of Class 1 Drivers

Underground Storage of Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
SURFACE FACILITY OPERATIONS & MAINTENANCE				
Control centre operator	Technology certification in Chemical Engineering, Power Engineering, or Petrochemical Engineering Technology	• Control, monitor and operate underground hydrogen storage system • Troubleshoot equipment issues and potential root causes using instrument indications • Support preparation of equipment and systems for maintenance and commissioning • Perform emergency corrective action	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of properties and characteristics of hydrogen in a gaseous state	Skills/knowledge and industry transferability opportunity with natural gas and liquid hydrocarbon pipelines and underground natural gas storage: • Monitoring and control through distributed control system (DCS) and programmable logic controller (PLC)
Compression specialist	*Multiple pathways to this career:* • Bachelor's Degree: Aerospace, Chemical or Mechanical Engineering • Technologist Diploma: Aerospace Engineering, Mechanical Engineering	• Provide design, engineering and other technical support for hydrogen compression and processing equipment • Model and simulation of complex thermomechanical systems (air flow, compression, heating, cooling, electro-mechanical actuation etc.) • Monitor compressor equipment performance and ancillary equipment such as air compressors, boilers, pumps and electrical equipment; trouble-shoot issues and identify solutions	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen compression processes • Appropriate selection, design and maintenance of hydrogen compression, turbine systems and equipment	• Skills/knowledge and industry transferability opportunity with natural gas and petroleum liquids pipelines, natural gas underground storage and aerospace.

Underground Storage of Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Maintenance trade – Electrical & Instrumentation	*Multiple pathways to this career:* • Certificate of Qualification in Instrumentation technician or Industrial Electrician • Registered apprentice • Technologist diploma in Instrumentation engineering or Electrical engineering A valid driver's license + clean abstract	• Ensure that electrical and instrumentation equipment and systems are maintained in compliance with regulations and procedure requirements • Trouble-shoot, test, calibrate electrical systems associated with compression, pumps, motors, valves, switchgear, flow meters, logic controls, motor control centers, compressors, power supplies, etc. • Program and trouble-shoot instrumentation systems including PLC's, RTAP, Flow Computer, and SCADA systems	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection and maintenance of electrical equipment and instrumentation systems required for hydrogen	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Underground natural gas storage closest match
Maintenance trade - Mechanical	*Multiple pathways to this career:* • Certificate of Qualification: Industrial Mechanic (Millwright) • Registered apprentice • Technologist diploma: Mechanical Engineering A valid driver's license + clean abstract	• Ensure that all mechanical equipment and systems are maintained in compliance with regulations and procedure requirements • Inspect, repair, troubleshooting, modify, install and commission mechanical equipment to such as reciprocating, centrifugal and screw compressors, cryogenic pumps, gear drives, turbines, fans and blowers, vessels, heat exchangers, reciprocating and centrifugal expanders, and piping systems • Lead equipment isolation, lock out/tag out activities	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Maintenance of mechanical equipment to withstand hydrogen pressure and temperatures • Knowledge of appropriate materials, seals, coatings	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Underground natural gas storage closest match

Underground Storage of Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Measurement specialist	*Multiple pathways to this career:* • Bachelor's Degree: Chemical, Electrical & Instrumentation, Mechanical Engineering • Technologist Diploma: Chemical, Electrical & Instrumentation, Mechanical, Petroleum Engineering	• Provide measurement and measurement systems expertise: flow meters, process analysers, flow measurement calculations • Conduct measurement uncertainty analysis and solve issues associated gas measurement including hydrogen,	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of measurement equipment and instrumentation associated with hydrogen transmission • Knowledge of hydrogen value-chains	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Underground natural gas storage closest match • Data validation and reconciliation

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Or continue on to Hydrogen Pipeline Core Occupations

Hydrogen Pipelines

Canada has several hundred kilometers of hydrogen pipelines including:

- Process pipelines that transport hydrogen inside industrial facilities that are mainly built on pipe racks above ground
- Transmission pipelines connecting hydrogen production facilities to customers in industrial hubs in Alberta and Ontario

As demand for hydrogen grows, there will be a need for safe, low-cost delivery of large volumes of hydrogen across long distances. Expanding the hydrogen pipeline network is a solution, however, there currently are no large high-pressure pipelines in Canada that deliver pure hydrogen to demand markets. Technical and economic challenges exist.

In the near-term blending hydrogen with natural gas in natural gas pipelines is a feasible strategy for providing a lower carbon gas product to consumers and establishing demand.

- Hydrogen can be transported in natural gas pipelines and used by existing household appliances with blends of up to 20%

Hydrogen Pipelines *cont'd*

Blending provides time to address technical and economic challenges.

- Researching resilient pipeline materials, hydrogen compression technology, controls for potential leaks and inspections, maintenance, risk management, and the potential to convert legacy natural gas pipelines to pure hydrogen.
- Ongoing testing of technologies such as liners, coatings, and integrity testing/monitoring for repurposing of existing pipelines.
- Establishing a regulatory environment, to ensure responsible linear project development and to promote safe construction, operation and abandonment.
- Revising Canadian pipeline standards as needed to address requirements for hydrogen in transmission and distribution networks.

Hydrogen Pipeline: Core Occupations

Hydrogen Pipeline Workforce Requirements	
ENGINEERS • Automation and control technician • Compression specialist • Corrosion specialist • Electrical & instrumentation engineer • Measurement specialist • Pipeline engineer • Pipeline integrity specialist • Process safety engineer	**OPERATIONS & MAINTENANCE** • Control centre operator • Pipeline scheduler • Pipeline technicians: Electrical & instrumentation, Mechanical • Station operators: Compression

Hydrogen Pipeline: Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
ENGINEERS				
Automation & controls specialist	*Multiple pathways to this career:* • Bachelor's Degree: Automation, Instrumentation & Controls or Electrical Engineering • Certificate of Qualification in Instrument technician • Technology Diploma: Instrumentation Engineering	• Support automation and controls functions including supervisory control and data acquisition (SCADA), programmable logic controller (PLC), remote terminal unit (RTU), distributed control system (DCS), human-machine interfaces (HMI), communications hardware, protocol and programming languages and related technologies • Configure systems, troubleshooting and support equipment related to process control including leak detection technology	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen compression processes	Skills/knowledge and industry transferability opportunity with gaseous pipelines: • Relevant codes and standards • Automated process systems and controls systems
Compression specialist	*Multiple pathways to this career:* • Bachelor's Degree: Aerospace, Chemical or Mechanical Engineering • Technologist Diploma: Aerospace Engineering, Mechanical Engineering	• Provide design, engineering and other technical support for hydrogen compression and processing equipment • Model and simulation of complex thermomechanical systems (air flow, compression, heating, cooling, electro-mechanical actuation etc.) • Monitor compressor equipment performance and ancillary equipment such as air compressors, boilers, pumps and electrical equipment; trouble-shoot issues and identify solutions	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen compression processes • Appropriate selection, design and maintenance of hydrogen compression, turbine systems and equipment	Skills/knowledge and industry transferability opportunity with with gaseous pipelines and aerospace.

Hydrogen Pipeline: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Corrosion specialist	*Multiple pathways to this career:* • Bachelor's Degree: Materials or Mechanical Engineering • Technologist Diploma: Materials Engineering, Mechanical Engineering A valid driver's license + clean abstract National Association of Corrosion Engineers (NACE) certification	• Apply knowledge of basic engineering principles and corrosion theory to hydrogen projects • Inspect, maintain and trouble-shoot pipeline facilities • Provide input into methodology, and pipeline integrity procedures, practices and technologies including cathodic protection equipment and systems and corrosion control systems • Apply corrosion prediction models that are used to assess corrosion rates	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge and selection of type of materials, coatings and inhibitors to use to protect from hydrogen corrosion	Skills/knowledge and industry transferability opportunity with gaseous hydrocarbon pipelines
Electrical & instrumentation engineer	Bachelor's Degree: Electrical & Instrumentation Engineering	• Design for new or modification of instrumentation, control systems, and electrical projects including Programmable Logic Controllers (PLC) and safety PLCs (SIS), Distributed Control Systems (DCS), fire and gas (F&G) systems • Size and select equipment • Supervise installation and commissioning • Provide technical expertise to resolve issues associated with instrumentation, electrical, and control/safety systems.	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of key instrumentation and electrical equipment and systems associated with hydrogen pipeline transmission including compression	Skills/knowledge and industry transferability opportunity with with gaseous hydrocarbon pipelines

Hydrogen Pipeline: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Measurement specialist	*Multiple pathways to this career:* • Bachelor's Degree: Chemical, Electrical & Instrumentation, Mechanical Engineering • Technologist Diploma: Chemical, Electrical & Instrumentation, Mechanical, Petroleum Engineering	• Provide measurement and measurement systems expertise: flow meters, process analysers, flow measurement calculations • Conduct measurement uncertainty analysis and solve issues associated gas measurement including hydrogen,	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of measurement equipment and instrumentation associated with hydrogen transmission • Knowledge of hydrogen value-chains	Skills/knowledge and industry transferability opportunity with gaseous hydrocarbon pipelines: • Data validation and reconciliation

Hydrogen Pipeline: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Pipeline engineer	Bachelor's Degree: Chemical, Civil or Mechanical Engineering	• Lead all aspects for expansion and maintenance capital projects for pipelines and related facilities • Approve and certify design and operations procedures with an engineering stamp ensuring conformation to laws and regulations, company policies and procedures, accepted engineering practice, and upholds public safety • Provide project support including the planning, design, approval and procurement of materials, tendering, constructing, testing and commissioning of the pipelines or related facilities • Prepare Technical Assessments, Material Specifications and/or updates to pipeline construction and maintenance manuals	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of properties and characteristics of hydrogen in a gaseous state • Understanding materials behaviour in high pressure hydrogen • Knowledge and selection of type of materials, coatings and inhibitors to use to protect from hydrogen corrosion and embrittlement • Appropriate selection and design of vessels, compressors, piping systems and fitting, valves and seals to withstand high hydrogen pressure	Skills/knowledge and industry transferability opportunity with gaseous hydrocarbon pipelines: • Understanding of pipeline design, pipelines systems codes and standards, construction practices and field operations. • Canadian regulations and standards related to pipelines including ASME and CSA 7662

Hydrogen Pipeline: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Pipeline integrity specialist	Bachelor's Degree: Chemical, Materials, Metallurgical or Mechanical Engineering National Association of Corrosion Engineers (NACE) certification	• Provide technical expertise in the design, implementation and updating of pipeline asset integrity management programs (IMP's) ensuring compliance to technical, regulatory, and legal requirements • Stay current and compliant with standards, pipeline regulations, industry standards, integrity assessment, monitoring, mitigation and repair methods • Oversee all aspects of pipe integrity, integrity management systems, fracture mechanics, mechanics of materials, risk analysis, pipeline construction, in-line inspection and cathodic protection • Analyze information to assess and manage potential pipeline integrity threats and damage prevention issues	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of properties and characteristics of hydrogen in a gaseous state • Understanding materials behaviour in high pressure hydrogen • Knowledge and selection of type of materials, coatings and inhibitors to use to protect from hydrogen corrosion and embrittlement • Appropriate selection and design of vessels, compressors, piping systems and fitting, valves and seals to withstand high hydrogen pressure	Skills/knowledge and industry transferability opportunity with gaseous hydrocarbon pipelines: • Understanding of pipeline design, pipelines systems codes and standards, construction practices and field operations. • Canadian regulations and standards related to pipeline integrity and damage prevention including ASME and CSA 7662

Hydrogen Pipeline: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Process safety engineer	Bachelor's Degree: Chemical or Process Engineering Significant experience in process equipment, engineering, safety and operational risk management • Process Hazard Analysis techniques (HAZOP, FMEA) • What-If studies, quantitative and semi-quantitative risk assessments (LOPA and FTA/ETA) • Reliability/Survival analysis • Knowledge of OSHA 1910.119, CSA Z767, CSA Z260, ISO 31000, API 1173 and related codes and standards.	• Lead the continual improvement of process safety and risk management processes and methodologies • Analyze and evaluate a wide range of operational risks affecting financial, safety, operational reliability, environmental and reputational receptors • Oversee application of codes, standards, and regulations relevant to process systems and process safety for carbon pipeline transmission • Oversee application of acceptable deviations from the approved standards, project specifications and processes • Facilitate the hazard identification and inventory (barrier management) process	• Process engineering and controls skills specific to hydrogen including hazard risk analysis and reviews, mechanical integrity and instrumented system analysis, and operation readiness inspection • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Skills/knowledge and industry transferability opportunity with gaseous hydrocarbon pipelines Specialized role with small talent pool like to make it difficult to fill positions.

Hydrogen Pipeline: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
OPERATIONS & MAINTENANCE				
Control centre operator	Technology certification in Chemical Engineering, Power Engineering, or Petrochemical Engineering Technology	• Remotely control and monitor pipeline system and operations • Monitor, resolve, and escalate operational and safety issues • Optimize operations by maximizing throughput while minimizing operating costs • Perform emergency corrective action as required • Maintain accurate logs and reports • Provide courteous and precise communications with external and internal customers	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of properties and characteristics of hydrogen in a gaseous state	Skills/knowledge and industry transferability opportunity with gaseous hydrocarbon pipelines: • Understanding of SCADA • Monitoring and control through distributed control system (DCS) and programmable logic controller (PLC)
Pipeline scheduler	Post-secondary training in business, commerce or or related discipline	• Manage scheduling of CO2 receipt locations and coordination deliveries to downstream connections • Manage daily nominations on pipeline • Communicate any maintenance or other shutdown intel with control room operations and external and internal customers • Gather, analyze and compile data for reporting	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of properties and characteristics of hydrogen in a gaseous state • Knowledge of hydrogen gas value-chains	Skills/knowledge and industry transferability opportunity with gaseous hydrocarbon pipelines: • Pipeline logistics • Pipeline compression

Hydrogen Pipeline Transmission: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Pipeline technician-Electrical & instrumentation	*Multiple pathways to this career:* • Certificate of Qualification in Instrumentation technician or Industrial Electrician • Registered apprentice • Technologist diploma in Instrumentation engineering or Electrical engineering A valid driver's license + clean abstract	• Ensure that electrical and instrumentation equipment and systems are maintained in compliance with regulations and procedure requirements • Trouble-shoot, test, calibrate electrical systems associated with pumps, motors, valves, switchgear, flow meters, logic controls, motor control centers, compressors, power supplies, etc. • Program and trouble-shoot instrumentation systems including PLC's, RTAP, Flow Computer, and SCADA systems • Communicate with contractors, public, landowners, and government agencies as required	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection and maintenance of electrical equipment and instrumentation systems required for pipeline transmission of gaseous hydrogen	Skills/knowledge and industry transferability opportunity with gaseous hydrocarbon pipelines

Hydrogen Pipeline Transmission: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Pipeline technician - Mechanical	*Multiple pathways to this career:* • Certificate of Qualification: Industrial Mechanic (Millwright) • Registered apprentice • Technologist diploma: Mechanical Engineering A valid driver's license + clean abstract	• Ensure that all stationary and rotating mechanical equipment and systems are maintained in compliance with regulations and procedure requirements • Perform inspections, troubleshoot and repair mechanical equipment: pumps, valves, actuators, tank mixers, mechanical seals, motors, fans, compressors, turbines, etc. • Lead pipeline isolation, lock out/tag out activities including blowing down, purging, and pressuring pipelines and the installation and operation of air movers/expellers • Communicate with contractors, public, landowners, and government agencies as required	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection and maintenance of stationary and rotating equipment and systems required for pipeline transmission of gaseous hydrogen	Skills/knowledge and industry transferability opportunity with gaseous hydrocarbon pipelines

Hydrogen Pipeline Transmission: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Station operator - Compression	*Multiple pathways to this career:* • Certificate of Qualification: Industrial Electrician or Industrial Mechanic (Millwright) • Registered apprentice • Technologist diploma: Electrical Engineering, Mechanical Engineering A valid driver's license + clean abstract	• Operate and maintain all facility equipment • Monitor, troubleshoot, and repair dehydration equipment, injection pumps, plunger lifts, compression, etc. • Responsible for isolation and permitting activities as required • Communicate with contractors, public, landowners, and government agencies as required	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen compression processes • Appropriate selection and maintenance of compression and turbine systems and equipment to withstand hydrogen pressure	Skills/knowledge and industry transferability opportunity with gaseous hydrocarbon pipelines: • Working with programmable logic controllers, pneumatic and automated operations systems

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Or continue on to Hydrogen Distribution by Truck Core Occupations

Hydrogen Distribution by Truck

Currently, truck transport of hydrogen is most common:

- Gaseous hydrogen in compressed tube trailers
- Liquid hydrogen in super-insulated, cryogenic liquid tankers

In absence of hydrogen transmission pipelines, trucking liquid hydrogen is more economical than trucking gaseous hydrogen.

- Liquid tanker truck can hold a much larger mass of hydrogen than a gaseous tube trailer can
- Truck transportation may be cost-prohibitive for applications that require larger volumes of steady supply such as heating

As the transportation sector adopts hydrogen as a fuel source, it is anticipated trucks transporting hydrogen will also operate on hydrogen.

- See Transportation as Demand section for workforce implications

Hydrogen Distribution by Truck: Core Occupations

Truck Transport (compressed & liquid H2) Workforce Requirements
• Cylinder technician • Heavy duty mechanic • Logistics coordinator • Tank inspector • Truck drivers (classes 1 & 3) – hydrogen delivery

Hydrogen Distribution by Truck: Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Cylinder technician	*Multiple pathways to this career:* • Certificate of Qualification: Refrigeration and Air Conditioning, Heavy Duty or Instrumentation • Registered apprentice • Technology Diploma in Instrumentation engineering Valid driver's license + clean abstract	Conducts maintenance including installation and repair of cryogenic vessels, high pressure systems and related equipment and components Performs brazing and welding on pressure system to repair/prevent leaks Ensures the appropriate preventive measures are in place	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen compression processes • Appropriate selection and maintenance of materials and equipment to withstand hydrogen pressure and temperatures	Skills/knowledge and industry transferability opportunity with the natural gas industry, aerospace, HVAC/refrigeration systems.
Heavy duty mechanic	Certificate of Qualification in Heavy Duty • Registered apprentice Valid driver's license + clean abstract	• Daily repairs and preventative maintenance of drilling and well servicing equipment and service rigs • Trouble-shooting and diagnosing mechanical, hydraulic and/or electrical issues across a variety of equipment including transport tractors and trailers, injectors, diesel engineers, powertrain, pressure pumping equipment, tractors, trailers, and cranes • Maybe shop based or required in the field	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen	Skills/knowledge and industry transferability opportunity with the oil & gas industry, agriculture, forestry, mining and transportation. Current shortage of Heavy duty mechanics/technicians.

Hydrogen Distribution by Truck: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Logistics coordinator	Bachelor's Degree or Diploma in Business Supply chain or logistics designation	• Ensure continuous customer supply by planning, analyzing, optimizing and coordinating and optimizing the distribution while respecting transportation of dangerous goods and other relevant regulations • Plan the utilization of trucks according to their maximal capacity and assign routes to drivers • Coordinate, in collaboration with the maintenance team, the management of the truck and trailer maintenance • Review driver's log books, any regulatory systems required and adherence to • equipment maintenance protocols or policies	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen	Skills and transferability opportunity with other industry with similar logistics requirements and operating under similar regulations. Transferability from military.
Tank tester/inspector	Certification from a training organization registered by Transport Canada to train tank testers and tank inspectors according to the requirements set out in the CSA B620 standard.	• Conduct inspection and tests on highway and trailer tanks • Sign off on CVIP inspections • Log all inspections and tests including the type of inspection/test, the highway/portable tank specification and the date of the inspection/test	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen compression processes • Appropriate selection and maintenance of materials and equipment to withstand hydrogen pressure and temperatures	CSA B620 standard, covering certification requirements for highway and portable tank testers and tank inspectors is transferable across industries

Hydrogen Distribution by Truck: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Truck driver – Hydrogen delivery	• Class 3 license as a minimum; Class AZ drivers license (ON) • Clean drivers abstract • Comfortable driving dangerous goods • Computer & smartphone skills	• Safely drive and operate truck to deliver hydrogen fuel • Perform fuel transfers from truck to customer • Plan daily route and prepare and complete of Transport Canada and Transportation of Dangerous Goods paperwork • Perform pre-trip, en-route, and post-trip inspections of vehicle systems, provide equipment report, and document any faults to ensure appropriate repair • Basic maintenance on assigned truck • Basic troubleshooting/maintenance at fueling stations on delivery route	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen	Currently a Canada-wide shortage of truck drivers

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Or continue on to Ammonia as a Chemical Carrier of Hydrogen Core Occupations

Ammonia as a Chemical Carrier of Hydrogen

Ammonia is produced using a process know as the Haber-Bosch process that fixes atmospheric nitrogen with hydrogen to produce ammonia (NH_3)

Ammonia is an effective chemical carrier for hydrogen because:

- It can be produced using low-carbon methods
- Has high hydrogen storage density
- Can be liquefied for transport by rail or ship
- The main hazard associated with ammonia is its toxicity; it is harmful to personnel at concentrations well below 15% in air

How it works …. rather than using ammonia for feedstock for fertilizer or other chemical manufacturing, it is transported in is compound form and processed to separate the hydrogen molecules at its destination. The process by which hydrogen is removed from an organic compound, such as ammonia, is called dehydrogenation.

The hydrogen can then be used for as a low-carbon energy source for transportation, heating and power, etc.

Ammonia as a Chemical Carrier of Hydrogen *cont'd*

Canada is already a major ammonia producer thanks to our well-established hydrogen production capabilities and available infrastructure.

- Hydrogen is typically produced on-site at ammonia plants using SMR of natural gas and would need to be combined with CCS to be considered low carbon.
    - The process uses extremely high pressure to force the chemical reaction. Plant operators require Power engineering or Stationary engineering certificate of qualification.

Green ammonia production is where the process uses hydrogen from water electrolysis and nitrogen separated from the air

- Currently, this electrochemical production of ammonia is significantly under-developed compared to the Haber–Bosch process

The ability to produce and transport low-cost, low-carbon hydrogen as liquid ammonia offers Canada an opportunity to export supply to jurisdictions that do not have the same capacity.

Ammonia: Core Occupations

Ammonia Workforce Requirements	
ENGINEERS	**PLANT OPERATIONS & MAINTENANCE**
• Automation and control specialist • Electrical & instrumentation engineer • Facility engineer • Measurement specialist • Mechanical engineers: Equipment & piping, Reliability • Process control engineer • Process engineer • Process safety engineer • Production engineer	• Control room operator • Lab technician • Maintenance planner • Maintenance trades: Electrical, Instrumentation & control, Mechanical • Plant manager • Plant operator

Ammonia Production: Core Occupations

As identified in the previous slides, ammonia production uses hydrogen that is manufactured onsite using SMR production technology. Therefore, the “Unique Requirements for Hydrogen” for the ammonia workforce are the same as those outlined in SMR/ATR Production.

Ammonia Production: Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
ENGINEERS				
Automation & controls specialist	*Multiple pathways to this career:* • Bachelor's Degree: Automation, Instrumentation & Controls or Electrical Engineering • Certificate of Qualification in Instrument technician • Instrumentation Engineering Technology diploma	• Support automation and controls functions including supervisory control and data acquisition (SCADA), programmable logic controller (PLC), remote terminal unit (RTU), distributed control system (DCS), human-machine interfaces (HMI), communications hardware, protocol and programming languages and related technologies. • Configure systems, troubleshooting and support equipment related to process control including leak detection technology	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR • Knowledge of automated process systems and controls systems for SMR/ATR	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Relevant codes and standards • Automated process systems and controls systems
Electrical & instrumentation engineer	Bachelor's Degree: Electrical & Instrumentation Engineering	• Design for new or modification of instrumentation, control systems, and electrical projects including Programmable Logic Controllers (PLC) and safety PLCs (SIS), Distributed Control Systems (DCS), fire and gas (F&G) systems • Size and select equipment • Supervise installation and commissioning • Provide technical expertise to resolve issues associated with instrumentation, electrical, and control/safety systems.	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of key instrumentation and electrical equipment and systems associated SMR and/or ATR production plants	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match

Ammonia Production: Core Occupations
cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Facility engineer	Bachelor's Degree: Chemical, Process or Mechanical Engineering .	• Provide technical support during routine operations, expansion and optimization, and during planned and unplanned outages. • Assist operations and integrity groups with compliance measures and best practices for process controls such as: MOC, HAZOP, design and repair, reporting and regulatory compliance. • Design and implement large scale facility capital projects	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match Experience in design, construction, operation and optimization of production facilities
Measurement specialist	Bachelor's Degree: Chemical, Electrical & Instrumentation, Mechanical Engineering	• Provide measurement and measurement systems expertise: flow meters, process analysers, flow measurement calculations • Conduct measurement uncertainty analysis and solve issues associated liquid and gas measurement including hydrogen and ammonia	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR • Knowledge of hydrogen gas value-chains	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Modelling experience using process simulators • Data validation and reconciliation

Ammonia Production: Core Occupations
cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Mechanical engineer - Equipment & piping	Bachelor's Degree: Mechanical Engineering	• Design pressure and stationary equipment associated with hydrogen and ammonia production including air separation units, vessels, piping and related auxillary systems • Design rotating equipment associated with ammonia and hydrogen production including turbines, compressors, pumps and related auxillary systems • Provide technical expertise on the maintenance and repairs of pressure equipment and systems, and rotating equipment to ensure accordance with all applicable codes and standards • Develop expertise in existing and emerging technologies associated ammonia and hydrogen production and related processes and equipment • Participate in Root Cause and Failure Analysis (RCFA)	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection, design and maintenance of air separation units, vessels, piping systems and fitting, valves and seals to withstand hydrogen pressure (high/low) and temperatures (hot/cold) • Appropriate selection, design and maintenance of combustion, compression, pumping and turbine systems and equipment to withstand hydrogen pressure (high/low) and temperatures (hot/cold)	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • High pressure gas system • Cryogenic/refrigeration system • Piping and pressure vessels • Air separation units • Flammable gas • Compressors • Regulatory inspection requirements and inspection/test procedures for high pressure process manufacturing including ASME / API Pressure Vessel, NBIC

Ammonia Production: Core Occupations
cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Mechanical engineer - Reliability	Bachelor's Degree: Mechanical Engineering	• Lead plant reliability program development and implementation in accordance with all applicable codes and standards • Oversee inspection, maintenance and repair of pressure and stationary equipment associated with ammonia and hydrogen production including electrolyzers, vessels, piping and related auxillary systems • Oversee inspection, maintenance and repair of rotating equipment associated with ammonia and hydrogen production including turbines, compressors, pumps and related auxillary systems • Develop expertise in existing and emerging technologies associated with the inspection and maintenance • Participate in Root Cause and Failure Analysis (RCFA)	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection, design and maintenance vessels, compressors, piping systems and fitting, valves and seals to withstand hydrogen pressure (high/low) and temperatures (hot/cold) • Appropriate selection, design and maintenance of combustion, compression, pumping and turbine systems and equipment to withstand hydrogen pressure (high/low) and temperatures (hot/cold)	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • High pressure gas system • Cryogenic/refrigeration system • Piping and pressure vessels • Flammable gas • Compressors • Regulatory inspection requirements and inspection/test procedures for high pressure process manufacturing including ASME / API Pressure Vessel, NBIC

Ammonia Production: Core Occupations
cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Process control engineer	Bachelor's Degree: Chemical or Electrical & Instrumentation Engineering	• Building, implementing, and maintaining the advanced control applications used to perform facility operations optimization using a combination of regulatory and model predictive control techniques. • Build and deploy advanced process control applications • Develop and test control applications • Process modelling and simulation using software	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Steam generation • Plant control systems and advanced control systems for process optimisation. • A strong knowledge of plant and equipment design. • Software to build, test and deploy Advanced Control applications

Ammonia Production: Core Occupations
cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Process engineer	Bachelor's Degree: Chemical or Process Engineering	• Ensure safe, reliable and efficient operation of the process equipment by applying knowledge of thermodynamics, electrochemistry, fluid mechanics, and materials science • Troubleshoot production and process issues • Assist in the resolution of longer-term reliability and maintenance issues involving unusual corrosion, steam quality concerns, fouling of heat transfer surfaces, pre-mature catalyst degradation, breakdown of insulation, and other chronic equipment and performance problems • Oversee plant modifications and upgrades to processes and related equipment ensure comply with regulatory standards • Participate in Root Cause and Failure Analysis	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • High pressure gas system • Cryogenic/refrigeration system • Piping and pressure vessels • Flammable gas • Compressors • Steam generation • Regulatory inspection requirements and inspection/test procedures for high pressure process manufacturing including ASME / API Pressure Vessel, NBIC

Ammonia Production: Core Occupations
cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Process safety engineer	Bachelor's Degree: Chemical or Process Engineering Significant experience in process equipment, engineering, safety and operational risk management • Process Hazard Analysis techniques (HAZOP, FMEA) • What-If studies, quantitative and semi-quantitative risk assessments (LOPA and FTA/ETA) • Reliability/Survival analysis • Knowledge of OSHA 1910.119, CSA Z767, CSA Z260, ISO 31000, API 1173 and related codes and standards.	• Lead the continual improvement of process safety and risk management processes and methodologies • Analyze and evaluate a wide range of operational risks affecting financial, safety, operational reliability, environmental and reputational receptors • Oversee application of codes, standards, and regulations relevant to process systems and process safety for hydrogen. • Oversee application of acceptable deviations from the approved standards, project specifications and processes • Facilitate the hazard identification and inventory (barrier management) process	• Process engineering and controls skills specific to hydrogen including hazard risk analysis and reviews, mechanical integrity and instrumented system analysis, and operation readiness inspection • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Steam generation Specialized role with small talent pool like to make it difficult to fill positions

Ammonia Production: Core Occupations
cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Production engineer	Bachelor's Degree: Chemical or Mechanical Engineering	• Support of all aspects of day-to-day operations, including troubleshooting plant process problems and lead/execute plant projects • Data analysis and tracking, systems integration, and ammonia and hydrogen production equipment and systems troubleshooting and monitoring • Participate in Root Cause Analysis (RCA) investigations to identify and eliminate sources of undesired performance	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match

Ammonia Production: Core Occupations
cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
PLANT OPERATIONS & MAINTENANCE				
Control room operator	Typically an experienced plant operator. Power Engineer or Stationary Engineer Certificate of Qualification	• Oversee day-to-day operations from centralized control room • Assist Plant operators diagnose operational deficiencies using instrument indications • Troubleshoot equipment issues and potential root causes using instrument indications • Support preparation of equipment and systems for maintenance and commissioning • Perform safety responsibilities such as hazard identification, equipment lock-out, emergency response, etc. • Issue work permits to maintenance personnel and ensure that they are aware of the risks associated with the work to be performed	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Steam generation • Working with programmable logic controllers, pneumatic and automated operations systems

Ammonia Production: Core Occupations
cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Lab technician	Post-secondary diploma: • Chemical, Process or Petroleum technology • Laboratory technician	• Conduct quality control testing on process samples and finished products • Properly apply standards, procedures • Document and communicate findings and results • Organize and store all chemicals substances, fluids and compressed gases according to safety instructions • Understand the operation and maintenance of specified lab instruments	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR	Skills/knowledge and industry transferability opportunities: oil & gas, chemical, petrochemicals, pulp & paper, etc. • Steam generation
Maintenance planner	*Multiple pathways to this career:* • Certificate of Qualification in Industrial electrician, Industrial mechanic/Millwright or Instrumentation technician • Bachelor's Degree: Electrical or Mechanical Engineering	• Develop preventive and predictive maintenance plans for the lifecycle of key electrical and mechanical equipment associated with ammonia and hydrogen production systems and facilities • Contribute achievement of key performance indicators by continuous improvement of maintenance function • Track best practices in preventive and predictive maintenance including leveraging of technology	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection, design and maintenance of vessels, compressors, piping systems and fitting, valves and seals to withstand hydrogen pressure and temperatures • Appropriate selection, design and maintenance of combustion, compression, pumping and turbine systems and equipment to withstand hydrogen pressure and temperatures	Skills/knowledge and industry transferability opportunities: oil & gas, chemical, petrochemicals, pulp & paper, etc. Experience working with computerized maintenance management systems (CMMS)

Ammonia Production: Core Occupations
cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Maintenance trade - Electrical	Certificate of Qualification in Industrial Electrician • Registered apprentice	• Inspect, repair, install, troubleshoot and modify electrical and electronic equipment and components, AC/DC motors and drives, low and high voltage motors/breakers programmable logic controls (PLC'), control circuits, switchgears, transformers, motors, starters, relays and hydraulic and pneumatic electrical controls • Install or replace electrical wiring, receptacles, switch boxes, conduits, feeders, fibre-optic and coaxial cable assemblies, lighting fixtures and other electrical components • Install, replace or repair generators, alternators and industrial storage batteries • Interpret drawings, blueprints, schematics and electrical code specifications	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection and maintenance of key electrical and electronic equipment and systems associated with a SMR and/or ATR hydrogen production plant	Skills/knowledge and industry transferability opportunities: oil & gas, chemical, petrochemicals, pulp & paper, etc.

Ammonia Production: Core Occupations
cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Maintenance trade – Instrumentation technician	Certificate of Qualification in Instrumentation technician • Registered apprentice	• Inspect, repair, install, troubleshoot and modify process controls, control valves, safety devices, analyzers, programmable logic controls (PLC), instrumentation (pressure, level and flow), process monitoring equipment, nd control circuits and distributed control systems (DCS) • Perform preventive and corrective maintenance on instrumentation and electrical equipment • Troubleshooting, repair, and calibration of plant instrumentation and controls. • Improve equipment performance and/or system reliability/capacity	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection and maintenance of key instrumentation equipment and systems associated with a SMR and/or ATR hydrogen production plant	Skills/knowledge and industry transferability opportunities: oil & gas, chemical, petrochemicals, pulp & paper, etc. Supports digitization across multiple industries; in high demand • Existing skill shortage

Ammonia Production: Core Occupations
cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Maintenance trade - Mechanical	Certificate of Qualification in Industrial Mechanic or Millwright • Registered apprentice In Ontario: Hydrogen Technician (TSSAH2) certification • Obtained by working under our TSSA-H2 technicians	• Inspection, repair, troubleshooting, modification, installation and commissioning of mechanical equipment to such as reciprocating, centrifugal and screw compressors, cryogenic pumps, gear drives, steam turbines, air separation units, fans and blowers, vessels, heat exchangers, reciprocating and centrifugal expanders. • Continuously improve machinery condition and reliability.	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Maintenance of vessels, compressors, piping systems and fitting, valves and seals, coatings and insulation to withstand hydrogen pressure and temperatures	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match
Plant manager	Likely to be an experienced worker with engineering, maintenance and/or operations experience.	• Manage the day-to-day operations including organizational tasks, assignment of work and meeting production targets and delivery dates • Ensure all plant employees work within occupational health and safety regulations, polices and procedures • Continuously look for ways to improve production process techniques and equipment • Assist with troubleshooting operational and maintenance issues • Coach, mentor, train and develop employees in their job performance; participate in succession planning and hiring activities	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of SMR and/or ATR processes and hydrogen production • Maintenance of equipment and systems involved in SMR and/or ATR hydrogen production	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Steam generation

Ammonia Production: Core Occupations
cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Plant operator	Power Engineer or Stationary Engineer Certificate of Qualification	• Responsible for ensuring safe plant operation and the production of ammonia and hydrogen Observe and analyze plant activity to identify potential operational problems, causes and propose appropriate corrective actions • Prepares equipment and systems for maintenance and commissioning • Track daily production and performance data to optimize production and inform equipment maintenance, safety and environmental indicators	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen production process using SMR and/or ATR	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including oil & gas, chemicals, petrochemicals, pulp & paper. • Natural gas processing closest match • Steam generation • Working with programmable logic controllers, pneumatic and automated operations systems

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Or continue on to Expanding Markets for
Low-carbon Hydrogen Core Occupations

Expanding Markets for Low-carbon Hydrogen

Hydrogen producers will not invest in increasing low-carbon supply if demand is not established. Expanding existing and creating new markets for low-carbon hydrogen is a pre-requisite to attracting investment in supply infrastructure.

The *Hydrogen Workforce Assessment Tool* focuses on the four end-use hydrogen technologies currently deployed or being piloted in Canada:

1. Transportation using hydrogen
    - Heavy and medium transport and freight, and return-to-base vehicles such as those used for municipal services and courier services that typically require drivers with Class 1 or 3 license
    - Rail
2. Hydrogen fueling stations
3. Heating
4. Power generation

Transportation Using Hydrogen

Hydrogen fuel cell electric vehicle (FCEV) is a promising technology for meaningfully reducing greenhouse gas (GHG) emissions.

- Near-term applications in Canada include heavy and medium truck transportation and freight sectors, rail, courier services, and municipal fleets.
- Hydrogen to fuel air and industrial applications such as mining are also being explored

The main difference between a FCEV and an internal combustion engine (ICE) is the FCEV propulsion system that consists of:

- Fuel cell stack where hydrogen and oxygen combine in a chemical reaction to create electricity that powers the electric motor that powers the vehicle
- Hydrogen supply system that pumps hydrogen that is safely stored is specially designed tank to the fuel cell stack
- Air supply system comprised of an air filter, air compressor and humidifiers and provides oxygen to the stack
- Water and heat management systems with separate water and coolant loops and eliminates waste heat and water
  - Heat from fuel cell can also be used to heat the vehicle cabin
- Power Control Unit (PCU) that controls when to use stored energy from the battery or draw directly from the fuel cell stack
- Battery – energy, recaptured during braking, is used to recharge the battery and assist when high power is required such as during acceleration

Transportation Using Hydrogen

Aside from the propulsion system, the components of an ICE vehicle and FCEV are essentially identical:

- Transmission, steering, brake and running systems.
- Electronic control system, safety system and entertainment/communications
- Advanced Driver Assist System (“ADAS”) & sensors
- Main body, seats and interior

There are three typical pathways for transitioning to hydrogen for transportation:

1. Investment in a new FCEV vehicle
2. Retrofitting an existing vehicle by replacing the internal combustion engine with a fuel cell system
3. Installing a co-combustion conversion kit that allows a vehicle to run on diesel and hydrogen
    - Hydrogen storage system
    - Hydrogen injection manifold in-line with the air intake to blend hydrogen and air before entering the engine
    - Hydrogen system controller and wiring harness

Transportation Using Hydrogen

Rail locomotives already operate with electric powertrains. The transition to hydrogen involves converting the locomotive's diesel-fuelled electric powertrains to hydrogen-electric powertrains.

Adoption of hydrogen for transportation will require heavy-duty technicians and locomotive mechanics with the appropriate technical know-how to install and maintain the hydrogen-fuelled propulsion systems.

- Many of the other mechanical and electronic aspects will remain the same and the maintenance and repair skills and knowledge of the existing heavy duty mechanic talent pool continues to be relevant

The overall driving experience is reported to be the same, if not better, than with an ICE.

- Cleaner, smoother ride
- Refueling time is about the same

Transportation Using Hydrogen: Core Occupations

Transportation (end-user) Workforce Requirements
• Dual fuel heavy duty mechanic • Fleet manager • Fuel cell electric vehicle (FCEV) technician • Locomotive engineer • Locomotive mechanic • Transportation solutions advisor • Transit operator • Truck drivers (classes 1 & 3)

Transportation Using Hydrogen: Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Dual fuel heavy duty mechanic	Certificate of Qualification in Heavy duty mechanic • Registered apprentice Additional certifications are assets: • Truck & Transport certification • Commercial Vehicle Inspection Program (CVIP) license Training on retrofitting diesel vehicles with hydrogen dual fuel kits and ongoing maintenance • Gasfitter may be required to converting vehicles to hydrogen dual fuel system	• Execute all planned maintenance inspections and repairs on all types of medium and heavy duty trucks, buses, shuttles, etc. • Inspect, maintain and repair systems, equipment and components associated with conventional diesel and hydrogen fuel sources including power and drive trains, fuel tanks, electrical and computerized controls, hydraulic, transmission, coolant and lubricant systems, transmissions and air-conditioning systems • Conduct mechanical and electrical troubleshooting • Troubleshooting and maintenance of high-pressure hydrogen storage and fueling systems • Test repaired equipment for proper performance and to ensure work meets manufacturers' specifications. • Perform Safety and Commercial Vehicle Inspections (CVIP) • Complete and sign fleet logs, work orders and service records.	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection, design and maintenance of hydrogen fuel tanks, piping systems and fitting, valves and seals to withstand hydrogen pressure (high/low) and temperatures (hot/cold)	Emerging occupation required by the hydrogen economy Publicly available training course or program needs to be established This occupations likely to come from existing pool of heavy-duty mechanics. Transferability of mechanics that work on other types of dual fuel engines (diesel/compressed natural gas) • Current shortage of Heavy duty mechanics

Transportation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Fleet manager	*Multiple pathways to this career:* • Certificate of Qualification in Heavy duty mechanic • Service manager with experience in overseeing a preventative and repair program • Experience with asset management • Supply chain or logistics designation Valid driver's license, + clean abstract Experience in transportation or logistics	• Develop and execute fleet management strategy including the incorporation of FCEV's and, establish and review fleet management policies and procedures • Ensure the fleet is always capable of fulfilling dispatch requirements • On-going review and continuous improvement of fleet management to optimize safety, utilization, and cost savings • Manage request-for-proposals and negotiation of contracts with key vendors to enable a cost-effective, safe and reliable fleet and develop and execute fleet replacement strategy and replacement policies • Oversee maintenance and operations of onsite and mobile hydrogen refueling systems • Ensures all fleet vehicle information is tracked and maintained. • Update vehicle registrations and inspections, logs, and maintenance of records and fuel cards.	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of hydrogen production, distribution, and dispensing technology • Management, maintenance and continuous improvement of FCEV fleet to optimize safety, utilization, and cost savings • Management, maintenance and continuous improvement of hydrogen fueling station and mobile systems	Emerging occupation required by the hydrogen economy that will require upskilling for FCEV fleets Publicly available training course or program needs to be established Skills/knowledge transferability opportunity across industries with fleets of trucks including transportation and freight, oil & gas, mining, forestry, construction, etc.

Transportation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Fuel cell electric vehicle (FCEV) technician	Certificate of Qualification in Heavy duty mechanic augmented with training on: • Fuel Cell Stack • Electric Traction Motor • DC/DC Converter • Hydrogen Fuel tank • Thermal system cooling • Battery Electrical Technician training is an asset Experience with Codes, Standards and compliance issues of electrical systems in road vehicles Experience with ISO6469-3, LV123 or other electric road vehicle safety standards	• Install and maintain fuel cell systems and equipment • Analyze interactions of fuel cell electrical and mechanical systems to diagnose issues and repair as required • Analyze power generation system operation and integration (switch gear, power system controls, uninterruptable power supply, etc.) to diagnose issues and repair as required • Perform specialized service procedures including field retrofits and software and hardware upgrades to existing fuel cells • Troubleshooting and maintenance of high-pressure hydrogen storage and fueling systems • Perform specialized service procedures, including but not limited to field retrofits, software and hardware upgrades to existing fuel cells and hydrogen system • Adhere to manufacturer's warranty policies and procedures	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of fuel cell technology • EMC/EMI compliance and standards • Experience with Codes, Standards and compliance issues of electrical systems in road vehicles • Appropriate selection, design and maintenance of hydrogen fuel tanks, piping systems and fitting, valves and seals to withstand hydrogen pressure	Emerging occupation required by the hydrogen economy No established publicly available training courses or program • FCEV maintenance and/or training currently done by OEM This occupations likely to come from existing pool of heavy-duty mechanics • Current shortage of Heavy duty mechanics

Transportation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Locomotive engineer	Locomotive engineers are typically promoted from the Conductor ranks. Conductor training offered by select group of institutions across Canada or internal company training	• Operate hydrogen-electric locomotives, railcars and passenger control-cars • Check the train's electro-mechanical condition and be on the lookout for possible problems • Monitor instruments that measure speed, amperage, battery charge and air pressure • Be constantly aware of what is going on with the train and how different elements affect its operation (i.e. cargo weight, grade, acceleration)	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of fuel cell technology, ability inspect vehicle and conduct basic maintenance • Eco-driving techniques: a method of driving a vehicle using less fuel and having less of an impact on the environment	Upskilling of existing talent pool of Locomotive engineers

Transportation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Locomotive mechanic (shop and field)	Certificate of Qualification: Heavy Duty Mechanic, Electrician, Automotive Technician • Registered apprentice Mix of mechanical and electrical experience is an asset	Shop: • Inspect locomotive, diagnose issues and repair/recondition as needed • Perform preventative maintenance and repairs on locomotive electrical and mechanical systems • Troubleshoot systems such as hydraulics, electrical, electronic and drive-train components, and hydrogen-electric powertrains • Work to blueprints, schematic drawings, service manual and other like information. Adapts to new methods, processes, material and equipment • Perform non-structural welding, (i.e. Tacking); - Adjust and calibrate mechanical components • Modify and construct mechanical assemblies; • Prepare inspection, maintenance, and work reports, and record details on prescribed forms in accordance with established procedures. • Maintain proper records (preventative maintenance sheets, invoices, shipping documents, expense reports) Field: • Service equipment while working on the track	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of fuel cell technology and hydro-electric power trains • Experience with Codes, Standards and compliance issues of electrical systems in road vehicles • Appropriate selection, design and maintenance of hydrogen fuel tanks, piping systems and fitting, valves and seals to withstand hydrogen pressure	Upskilling of existing talent pool of Locomotive engineers

Transportation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Transportation solutions advisor	Bachelor's Degree: Chemical, Mechanical Engineering	• Help fleet managers from transportation and freight sectors, airports, railways, courier services, industrial sectors such as mining, and municipalities etc. better understand the opportunities and implications of integrating hydrogen systems into their operations • Take ownership of projects from concept to design, construction and ongoing operations • Ongoing research into hydrogen technologies, markets and competitive forces	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of hydrogen fuel cell technology, how it works and value proposition re: emissions targets and cost effectiveness • Knowledge of hydrogen production, distribution, and dispensing technology to meet the needs of different fleets • Understanding of relevant hydrogen regulations, codes and standards • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Specialized role with small talent pool Experience in oil and gas industry maybe considered an asset and/or transferability opportunity

Transportation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Transit operator	• Class 2 or 4 Driver's license • Class C or F (ON) • Valid air brake endorsement • Clean abstract	• Safely operate transit vehicles in a variety of conditions, and in accordance with policies and procedures • Perform pre-trip, en-route, and post-trip inspections of vehicle systems, provide equipment report, and document any faults to ensure appropriate repair • Transport customers and courteously respond to their needs • Interpret and apply information from city route maps and schedules and locate all major city locations.	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of fuel cell technology, ability inspect vehicle and conduct basic maintenance • Hydrogen refueling • Eco-driving techniques: a method of driving a vehicle using less fuel and having less impact on the environment	Driving does not change Quieter, cleaner ride/drive
Truck drivers – Class 1 & 3 Transport, freight, delivery/courier	• Class 1 or 3 Driver's licence • Class AZ drivers license (ON) • Valid air brake endorsement • Clean abstract • Computer & smartphone skills	• Perform pre-trip, en-route, and post-trip inspections of vehicle systems, provide equipment report, and document any faults to ensure appropriate repair • Basic maintenance on assigned truck • Basic troubleshooting/maintenance at fueling stations on delivery route	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of fuel cell technology, ability inspect vehicle and conduct basic maintenance • Hydrogen refueling • Eco-driving techniques: a method of driving a vehicle using less fuel and having less impact on the environment	Driving does not change Quieter, cleaner ride/drive Currently a Canada-wide shortage of truck drivers

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Or continue on to Hydrogen Fueling Station Core Occupations

Hydrogen Fueling Stations

Hydrogen fuel cell electric vehicles (FCEV) convert compressed hydrogen into electricity to power the vehicle's motor and drivetrain. A network of fueling stations is required to enable increased use of hydrogen fuel cell vehicles.

- Permanent fueling stations are a system that include pressure vessels, vaporizers, flow, level and pressure control instrumentation, dispensers, pumps, PLC, and compressors
- Hydrogen fuel may be delivered as a gas or a liquid
  - If delivered as a gas, hydrogen is stored in a high-pressured tank system
  - Liquid hydrogen systems are lower pressured system that stores hydrogen in a cryogenic storage tank. A heat exchanger or cryogenic pump and evaporator system is required to gasify the hydrogen prior to dispensing
- Stations may also incorporate on-site hydrogen production using electrolyzers
- Mobile fueling systems include an integrated storage, compression and dispensing unit that brings fuel to FCEV's

Hydrogen Fueling Stations

- Numerous safety systems are incorporated into station design.
  - Dispensers monitor the fueling process in real time and shut off automatically if a leak or other anomaly is detected
  - Flame and hydrogen detectors are deployed at the station to monitor for fires and hydrogen leaks and are designed to shut off the supply of hydrogen in the event of an alarm.
- Customers will have a similar experience refueling their hydrogen fuel cell vehicle, in terms of duration, but the nozzle and hose are different.
  - Because the fuel is gaseous, the nozzle will form an airtight connection with the on-board fuel tank and it will feel cool to the touch

Hydrogen Fueling Stations: Core Occupations

Fueling Station Workforce Requirements	
ENGINEERS • Automation & control specialist • Electrical & instrumentation engineer • Mechanical engineers: Compression, Equipment & piping system, Reliability • Process controls engineer • Process engineer • Process safety engineer • Product engineer • Quality engineer	OPERATIONS & MAINTENANCE • Fueling station technician • Logistics coordinator • Maintenance technician: Compression, Electrical & mechanical • Truck driver (class 1 & 3) – hydrogen fuel delivery

Fueling Stations: Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
ENGINEERS				
Automation & controls specialist	*Multiple pathways to this career:* • Bachelor's Degree: Automation, Instrumentation & Controls or Electrical Engineering. • Journeyman Instrument Technician • Instrumentation Engineering Technology diploma	• Support automation and controls functions including supervisory control and data acquisition (SCADA), programmable logic controller (PLC), remote terminal unit (RTU), distributed control system (DCS), human-machine interfaces (HMI), communications hardware, protocol and programming languages and related technologies • Configure systems, troubleshooting and support and other equipment related to process control, cybersecurity and safety • Leak, flame and hydrogen detection and automatic shut-off technology deployment	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen	Skills/knowledge and industry transferability opportunity with other industrial sectors including oil & gas and chemical due to similarities of: • Relevant codes and standards • Automated process systems and controls systems
Electrical & instrumentation engineer	Bachelor's Degree: Electrical & instrumentation Engineering	• Lead and execute electrical and instrumentation design of hydrogen fueling equipment • Contribute towards the design of communication networks, systems for data collection and monitoring, cyber security • Provide technical input and directions to technicians and trades involved in installation and maintenance of refueling equipment	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of electrical equipment and instrumentation systems required for hydrogen fueling systems	Skills/knowledge and industry transferability opportunity with other industrial processing sectors including oil & gas and chemical with similar electrical, instrumentation and process control systems.

Fueling Stations: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Mechanical engineer - Compression	Bachelor's degree in Mechanical Engineering	• Design of hydrogen compression and thermal management systems including instrumentation and monitoring systems • Generate specification and select compression and thermal management equipment • Properly depicted mechanical systems on P&ID's • Develop functional test and quality check procedures	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen compression processes • Design and selection of compression systems for hydrogen pressure and temperatures associated with hydrogen fueling system	Skills/knowledge and industry transferability opportunity with other industrial sectors including oil & gas, chemical, Engineering, Procurement, Construction (EPC) that design for: • High pressure gas system • Cryogenic/refrigeration system • Piping and pressure vessels • Flammable gas • Compressors
Mechanical engineer - Equipment & piping	Bachelor's degree in Mechanical Engineering	• Design of piping and auxillary systems for hydrogen refueling station (filters, pressure vessels, closed loop cooling systems, etc.) • Generate specification and select piping and equipment: inline components, valve, static equipment, insultation, paint & coatings • Properly depicted mechanical systems on P&ID's • Develop functional test and quality check procedures	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Design and selection of pressure vessels, piping systems and fitting, valves and seals, coatings and insulation to withstand hydrogen pressure and temperatures associated with hydrogen fueling system	Skills/knowledge and industry transferability opportunity with other industrial sectors including oil & gas, chemical, Engineering, Procurement, Construction (EPC) that design for: • High pressure gas system • Cryogenic/refrigeration system • Piping and pressure vessels • Flammable gas • Compressors

Fueling Stations: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Mechanical engineer - Reliability	Bachelor's degree in Mechanical Engineering	• Lead refueling station network reliability program development and implementation in accordance with all applicable codes and standards • Oversee inspection, maintenance and repair of piping and auxillary systems for hydrogen refueling station • Participate in systems failure investigations	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection and maintenance of pressure vessels, piping systems and fitting, valves and seals, coatings and insulation associated with hydrogen fueling system	Skills/knowledge and industry transferability opportunity with other industrial sectors including oil & gas, chemical, etc. that maintain: • High pressure gas system • Cryogenic/refrigeration system • Piping and pressure vessels • Flammable gas • Compressors
Process control engineer	Bachelor's Degree: Chemical or Electrical & Instrumentation Engineering	• Build, deploy and maintain the advanced control applications used for hydrogen refueling dispensers, storage and compression systems • Develop and test control applications • Process modelling and simulation using software • Provide advanced troubleshooting and operations support	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of cryogenic and gaseous hydrogen storage and delivery systems	Skills/knowledge and industry transferability opportunities: • Industrial process manufacturing including chemical, oil & gas • Software to develop and test deploy Advanced Control applications

Fueling Stations: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Process engineer	Bachelor's degree: Chemical or Mechanical Engineering	• Design hydrogen fuel station processes and installations with the aim of continuously optimising integrating new solutions • Calculate capacity, pressure, temperature, and flow and develop process specifications for equipment packages • Develop equipment, control valve, and relief system process specification • Test and verify compliance with requirements and specifications • Plan and participate in commissioning and start-up activities including Operational Readiness Inspections	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of properties and characteristics of hydrogen in a liquid and gaseous state • Understanding of cryogenic and gaseous hydrogen storage and delivery systems	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including chemical, petrochemical and oil & gas. • Thermodynamics and fluid mechanics involving flow, pressure, temperature, and cooling parameters • Familiar with Safety studies • Safety relief and pressure drop calculations

Fueling Stations: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Process safety engineer	Bachelor's degree in Chemical Engineering Significant experience in process equipment, engineering, safety and operational risk management • Process Hazard Analysis techniques (HAZOP, FMEA) • What-If studies, quantitative and semi-quantitative risk assessments (LOPA and FTA/ETA) • Reliability/Survival analysis • Knowledge of OSHA 1910.119, CSA Z767, CSA Z260, ISO 31000, API 1173 and related codes and standards.	• Lead the continual improvement of process safety and risk management processes and methodologies • Analyze and evaluate a wide range of operational risks affecting financial, safety, reliability, environmental and reputational receptors • Oversee application of codes, standards, and regulations relevant to process systems and process safety for hydrogen. • Oversee application of acceptable deviations from the approved standards, project specifications and processes • Support commissioning and startup activities	• Process engineering and controls skills specific to hydrogen including hazard risk analysis and reviews, mechanical integrity and instrumented system analysis, and operation readiness inspection • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including chemical, petrochemical and oil & gas. Specialized role with small talent pool likey to make it difficult to fill positions.

Fueling Stations: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Product engineer	Bachelor's degree in Chemical, Electrical, or Mechanical Engineering	• Involved in full lifecycle of product development: product strategy development and planning, conceptual design and commercialization. • Design and integrate hydrogen fueling mechanical and control systems • Involved in commissioning, maintaining, monitoring, and troubleshooting all major hydrogen station components. • Analysis of data to inform product updates and improvements	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Experience and knowledge of hydrogen fueling equipment, technology and systems including on-site generation, compression, cooling systems, storage and dispensing • Knowledge of fueling standards for third-party certification of hydrogen product lines	Experienced position requiring significant knowledge and experience with hydrogen fueling systems and equipment required Specialized role with small talent pool Experience in oil and gas industry maybe considered an asset and/or transferability opportunity

Fueling Stations: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Quality engineer	*Multiple pathways to this career:* • Bachelor's degree in Mechanical or Industrial Engineering • Engineer technology diploma in Mechanical, Industrial or Chemical + experience QA/QC Certifications	• Develop and execute quality management systems for hydrogen fueling station • Develop and implement quality standards, procedures and control systems for selection and validation of material and equipment, installation and assemblies, process requirements and operational procedures • Inspect and test equipment, processes, and installations to ensure quality specifications • Validate procedures for engineered hydrogen assemblies and infrastructure installations. • Develop corrective actions, solutions, and improvements for quality issues	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Experience and knowledge of hydrogen fueling equipment, technology and systems including on-site generation, compression, cooling systems, storage and dispensing • Knowledge of codes, and industry standard processes as relates to hydrogen fueling station equipment	Skills/knowledge and industry transferability opportunity with other industrial process manufacturing including chemical, petrochemical and oil & gas. • Knowledge of applicable ISO, CSA, ASME and other Technical Standards and Codes

Fueling Stations: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
OPERATIONS & MAINTENANCE				
Fueling station technician	Post-secondary training as a Mechanical or Compression technician	• Oversees operation of fueling stations and sales of fuel to the public • Inspects, maintains, repairs and calibrates fueling station process equipment, compression and dispensing equipment • Monitors parts inventories and initiates reorders to ensure availability and supply of components necessary to complete routine maintenance requirements and activities. • Gathers, analyzed and interprets relevant systems and operations data; prepare status reports to ensure system conformance with systems design and standards • Applies knowledge of federal, provincial and municipal codes and regulations	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Troubleshooting and routine maintenance of hydrogen fuel compression and dispensing equipment	Transferable experience with maintenance and operation of a computerized fuel control system including petroleum fuel and compressed natural gas (CNG)

Fueling Stations: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Logistics coordinator	Bachelor's Degree or Diploma in Business Supply chain or logistics designation	• Ensure continuous customer supply by planning, analyzing, optimizing and coordinating and optimizing the distribution while respecting transportation of dangerous goods and other relevant regulations • Plan the utilization of trucks according to their maximal capacity and assign routes to drivers • Coordinate, in collaboration with the maintenance team, the management of the truck and trailer maintenance • Review driver's log books, any regulatory systems required and adherence to • equipment maintenance protocols or policies	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen	Skills and transferability opportunity with other industry with similar logistics requirements and operating under similar regulations Transferability from military

Fueling Stations: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Maintenance technician - Compression	*Multiple pathways to this career:* • Journey certification: Electrical, Industrial Mechanic (Millwright) or Instrumentation Technician • Registered apprentice • Technologist Diploma: Aerospace, Instrumentation or Mechanical Engineering Technologist Valid driver's licence + clean abstract	• Install, inspect and service hydrogen fueling station compression system and related instrumentation and controls equipment and systems • Commissioning and start-up of new equipment • Troubleshoot and diagnose issues	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection and maintenance of pressure vessels, compression systems and related instrumentation and controls equipment and systems associated with hydrogen fueling system	Skills/knowledge and industry transferability opportunity with other industrial sectors including oil & gas, chemical, etc. that maintain: • High pressure gas system • Cryogenic/refrigeration system • Piping and pressure vessels • Flammable gas • Compressors • PLC logic as it applies to compressor packages

Fueling Stations: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Maintenance technician – Electrical & mechanical	*Multiple pathways to this career:* • Journey certification: Aircraft Mechanic, Electrical, Gasfitter (Class A or B), Industrial Mechanic (Millwright) or Instrumentation Technician • Registered apprentice • Technologist Diploma: Aerospace, Instrumentation or Mechanical Engineering Technologist Experience with welding and brazing an asset Valid driver's licence + clean abstract	• Install, inspect and service hydrogen fueling station mechanical, electrical and instrumentation and controls equipment and systems • Read engineering drawings, flow sheets, equipment layout, piping drawings and electrical controls schematics • Commissioning and start-up of new equipment • Troubleshoot and diagnose issues	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of appropriate maintenance of hydrogen fueling systems include pressure vessels, vaporizers, flow, level and pressure control instrumentation, dispensers, pumps, PLC, and compressors, Human Machine Interface (HMI) and controls software	Skills/knowledge and industry transferability opportunity with other industrial sectors including oil & gas, chemical, etc. that maintain: • High pressure gas system • Cryogenic/refrigeration system • Piping and pressure vessels • Flammable gas • Compressors and pressure control instrumentation • Human Machine Interface (HMI) and controls software

Fueling Stations: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Truck Driver – Hydrogen fuel delivery	• Class 3 license as a minimum; Class AZ drivers license (ON) • Clean drivers abstract • Comfortable driving dangerous goods • Computer & smartphone skills	• Safely drive and operate truck to deliver hydrogen fuel • Perform fuel transfers from truck to station • Plan daily route and prepare and complete of Transport Canada and Transportation of Dangerous Goods paperwork • Perform pre-trip, en-route, and post-trip inspections of vehicle systems, provide equipment report, and document any faults to ensure appropriate repair • Basic maintenance on assigned truck • Basic troubleshooting/maintenance at fueling stations on delivery route	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Eco-driving techniques: a method of driving a vehicle with the goal of using less fuel and having less of an impact on the environment for fleet sustainability, better fuel consumption and lower costs • As use of FCEV for delivering hydrogen fuel increases, drivers will also need to have knowledge of fuel cell technology, ability inspect vehicle and conduct basic maintenance and hydrogen refueling	Transferability of skills and knowledge with other sectors that transport dangerous goods such as ammonia, liquid petroleum/ruel, Currently a Canada-wide shortage of truck drivers

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Or continue on to Heating & Power Using Hydrogen Core Occupations

Heating & Power Generation Using Hydrogen

Hydrogen can play a role in decarbonizing heating and power generation.

The focus of the *Hydrogen Workforce Assessment Tool* is on early deployment of heating and power generation technology that involves blending hydrogen with natural gas.

Blending hydrogen with natural gas offers the opportunity to:

- Build demand while the technologies and equipment required for using pure hydrogen continue to be tested and proven, and regulatory frameworks are established
- Reduce the GHG intensity of existing heating and power generation, and creating a lower carbon energy for Canadians
- Leverage natural gas resources, existing infrastructure, and energy expertise – key considerations for cost-effectiveand therefore, affordable energy transition
- Build publics awareness and confidence in hydrogen

Other hydrogen economy value chains are required to realize the use of hydrogen for heating and power applications:

- Connection to supply of low carbon hydrogen: Electrolysis or SMR/ATR and potentially Storage, Upgrading or Transporting technology

Heating With Hydrogen

Canada has two projects demonstrating the ability to blend hydrogen and natural gas for heating: Enbridge's initiative at its Markham Power-to-Gas facility and ATCO's Fort Saskatchewan Hydrogen Blending Project.

The concentration of hydrogen used in these two projects are below the 20% threshold that has been proven safe for use with existing natural pipelines and appliances:

- ATCO will initially use a 5% hydrogen blend; Enbridge's project includes up-to 2% hydrogen
- Hydrogen for heating includes appliances such as furnaces, boilers, water heaters, gas fireplaces, stoves, and laundry dryers

Activities associated with these projects and ongoing operations include:

- Inspection of existing distribution system and upgrade if needed
- Customer site inspections
- Connection to low carbon hydrogen source and blending facility installation
  - Both pilot projects are connected to hydrogen produced with electrolyzers but SMR/ATR with CCS can also be used
- Ongoing monitoring and maintenance as required

It is anticipated that the existing natural gas distribution workforce will be trained to have an increased awareness of hydrogen, its unique properties, safe handling and understanding the compatibility of materials, coatings, equipment and components.

Heating With Hydrogen: Core Occupations

Heating With Hydrogen Workforce Requirements	
• Asset performance manager • Hydrogen integration specialist • Gas fuser • Gasfitter • HVAC technician	• Utility inspector • Utility operator • Utility service planner • Utility service technician • Welding engineer

Heating With Hydrogen: Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Asset performance manager	Bachelor's degree in Mechanical Engineering	• Develop and lead the strategic operating procedures and processes in the planning, scheduling, execution and optimization of asset maintenance. Adjust accordingly for natural gas-hydrogen blending • Develop and recommend maintenance and replacement strategies aligned with use of natural-gas hydrogen blending • Foster changes and improvements required to ensure operations are cost-effective and delivering on business goals and customer service including emissions reduction by blending hydrogen with natural gas • Ensure full compliance with regulatory requirements • Provide oversight of all operations and contract portfolios to ensure a high level of customer service is maintained • Report and conduct evaluations on system outages and asset failures including Root Cause Analysis as needed.	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of technical factors associated with using hydrogen blending for heating • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Existing workforce to be trained to accommodate transition to heating using natural gas-hydrogen blending

Heating With Hydrogen: Core Occupations

cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Hydrogen integration specialist	Bachelor's degree in Chemical, Electrical, or Mechanical Engineering Strong knowledge of trending low carbon transition technologies and initiatives with special attention to hydrogen	• Lead a multi-discipline team to conduct detailed techno-economic assessment for hydrogen blending project and ongoing operations • Deliver detailed engineering design for hydrogen blending assets • Supporting asset construction, commissioning, and delivering associated operating procedures • Develop and support the execution of the Change Management and Communication Plan • Ensure techno-economic solutions for hydrogen blending are effectively deployed	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Strong industry knowledge and experience with hydrogen technologies, processes and equipment and components to use to withstand hydrogen pressure and temperatures • Appropriate selection of materials, coatings, odorants, inhibitors, etc. for hydrogen blending • Appropriate selection, design, modification to ventilation, leak detection, flame detection, corrosion prevention equipment and systems for hydrogen blending • Comprehensive understanding of aspects of installation and testing procedures that are different due to the nature of hydrogen • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Experienced hire with advanced knowledge about hydrogen Small talent pool with mix of technical, business, regulatory and policy expertise

Heating With Hydrogen: Core Occupations

cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Gas fuser	• Valid driver's license + clean abstract • Valid gas fusing ticket or willing to obtain it • Ground Disturbance Level 2 • Construction Safety Training System training	• Safely and accurately install, repair, test and perform tasks related to construction and maintenance of natural gas distribution systems • Fuse and install gas pipe in underground subdivisions • Assist in digging ditches and trenches • Operate equipment and tools as needed. • Some companies may look for workers that can operate heavy duty equipment such as excavators, back hoes, skid steers and underground trenching equipment	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Materials, coatings and inhibitors to use and correct application to protect from hydrogen corrosion • Welding procedures and techniques appropriate for hydrogen • Knowledge of hydrogen related regulations, standards and codes	Existing workforce to be trained to accommodate transition to heating using natural gas-hydrogen blending Competes with other industries hiring labourers: • Construction • Drilling & well services Current labour shortage

Heating With Hydrogen: Core Occupations

cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Gasfitter Also known as: • Gas technician • Customer service technician • Gas Servicer	Certification of Qualification: Gasfitter • Registered apprentice There are two types : • Gasfitter 1st Class: works on all equipment • Gasfitter 2nd Class: works on equipment with less than 400,000 BTUs (British thermal units) Valid driver's license + clean abstract Welding experience/credentials are considered an asset	• Install, inspect, repair and maintain gas lines and gas equipment such as meters, regulators, heating units and appliances in residential, commercial and industrial establishments • Test and certify installations, metering and gas pressure regulating equipment according to standards and codes • Test and upgrade lines and/or equipment as required to support hydrogen blending • Perform emergency response activities including line-breaks, leak and odour investigations, liaise with fire and police officials, Inspectors and others as require • Advise customers on safety features and maintenance of gas units	• Knowledge of hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Comprehensive understanding of aspects of installation and testing procedures that are different due to the nature of hydrogen • Knowledge of materials, equipment and components to use to withstand hydrogen pressure and temperatures • Welding procedures and techniques appropriate for hydrogen • Practices, technologies, equipment and systems to control hydrogen corrosion/embrittlement • Procedures to trace, locate and repair hydrogen leaks • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Existing workforce to be trained to accommodate transition to heating using natural gas-hydrogen blending

Heating With Hydrogen: Core Occupations

cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
HVAC technician Also known as: • Refrigeration and Air Conditioning Mechanic • HVAC-R technician	Certification of Qualification: Refrigeration and Air Conditioning Mechanic • Registered apprentice Valid driver's license + clean abstract	• Install, maintain and service residential, commercial, industrial and institutional heating, ventilation, air conditioning and refrigeration (HVAC-R) units and systems • Test and upgrade equipment and/or systems as required to support hydrogen blending • Commission and start-up, test, charge, adjust, calibrate, balance, measure, verify, maintain and document HVAC-R systems • Lay out reference points for installation of components, wiring to connect to power supply and calibrate related controls • Measure, cut, bend, thread and connect pipe to functional components and utilities • Inspect and test components, braze and solder parts to repair defective joints, adjusting and replacing worn or defective components and reassembling repaired components and systems	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Comprehensive understanding of aspects of installation and testing procedures that are different due to the nature of hydrogen • Knowledge of materials, equipment and components to use to withstand hydrogen pressure and temperatures • Welding procedures and techniques appropriate for hydrogen • Procedures to trace, locate and repair hydrogen leaks • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Existing workforce to be trained to accommodate transition to heating using natural gas-hydrogen blending

Heating With Hydrogen: Core Occupations

cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Utility inspector	*Multiple pathways to this career:* • Bachelor's Degree: Civil, Mechanical Engineering • Engineering Technology Diploma: Civil, Mechanical Related tickets/certifications considered an asset: • Damage Prevention • Gas Pipeline Inspection Valid driver's license + clean abstract	• Provide oversight for the planning, installation and maintenance of utility-related infrastructure including upgrades and modification required for hydrogen blending • Execute the Leak Survey Program; perform pressure and leakage tests, Issue permits and field/work orders to ensure compliance and facilitate quality and process improvement • Prepare inspection and installation reports, and certify construction completion and final acceptance • Develop and maintain expert knowledge on policies, procedures, codes, standards and legislation	• Knowledge of hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Comprehensive understanding of aspects of installation and testing procedures that are different due to the nature of hydrogen • Knowledge of materials, equipment and components to use to withstand hydrogen pressure and temperatures • Practices, technologies, equipment and systems to control hydrogen corrosion/embrittlement • Welding procedures and techniques appropriate for hydrogen • Procedures to trace, locate and repair hydrogen leaks • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Existing workforce to be trained to accommodate transition to heating using natural gas-hydrogen blending

Heating With Hydrogen: Core Occupations

cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Utility operator	Grade 12 Diploma or G.E.D. Valid driver's licence + clean abstract Natural gas utility operator certification or some Canadian utility companies will hire labourers and move them into trainee operator positions with their in-house training and progression program	• Entry-level roles provide labour support for construction, maintenance and repair of the natural gas distribution system • Hand digging, shoveling and backfilling • Landscaping and site cleanup and other general labour duties • More experienced roles perform leak surveys utilizing sensitive detection equipment to check for potential underground and above ground leaks	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of odorants used to assist with leak detection of hydrogen • Procedures to trace, locate and repair hydrogen leaks • Knowledge of hydrogen related regulations, standards and codes	Existing workforce to be trained to accommodate transition to heating using natural gas-hydrogen blending Competes with other industries hiring labourers: • Construction • Drilling & well services Current labour shortage

Heating With Hydrogen: Core Occupations

cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Utility services planner	*Multiple pathways to this career:* • Bachelor's Degree: Civil, Mechanical Engineering • Engineering Technology Diploma: Civil, Mechanical Related tickets/certifications considered an asset: • Damage Prevention • Gas Pipeline Inspection Valid driver's license + clean abstract	• Coordinate utility service construction and maintenance including the availability of required equipment • Prepare and distribute construction and maintenance work packages and job planning envelopes including those required to implement hydrogen blending project • Coordinate and work with external and internal customers • Ensure job packages are fully completed, all safety notes are updated and/or actioned and stakeholders notified	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Materials, coatings and inhibitors to use and correct application to protect from hydrogen corrosion • Knowledge of odorants used to assist with leak detection of hydrogen • Practices, technologies, equipment and systems to control hydrogen corrosion/embrittlement • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Existing workforce to be trained to accommodate transition to heating using natural gas-hydrogen blending

Heating With Hydrogen: Core Occupations

cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Utility services technician	*Multiple pathways to this career:* • Bachelor's Degree: Civil, Mechanical Engineering • Engineering Technology Diploma: Civil, Mechanical Related tickets/certifications considered an asset: • Damage Prevention • Gas Pipeline Inspection Valid driver's license + clean abstract	• Conduct odorant tests, cathodic reads and regulator station inspections • Repair and perform alterations of distribution systems including above and below grade piping and equipment • Repair and install natural gas meters, regulators and service lines • Inspect all new and replacement gas appliances • Repair and adjust furnaces, boilers, water heaters and natural gas cooking appliances • Respond to emergencies such as damaged gas lines, gas odour calls, fire calls and carbon monoxide calls	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Materials, coatings and inhibitors to use and correct application to protect from hydrogen corrosion • Knowledge of odorants used to assist with leak detection of hydrogen • Comprehensive understanding of aspects of installation and testing procedures that are different due to the nature of hydrogen • Procedures to trace, locate and repair hydrogen leaks • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Existing workforce to be trained to accommodate transition to heating using natural gas-hydrogen blending

Heating With Hydrogen: Core Occupations

cont'd

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Welding engineer	Bachelor's Degree: Materials, Mechanical Engineering Specialist training in Welding Engineering Related qualifications and certifications from the following agencies may be of benefit: • American Petroleum Institute (API) • American Society of Mechanical Engineers (ASME) • American Society for Nondestructive Testing (ASNT) • CSA/Standards Council of Canada (SCC) • International Organization of Standardization (ISO) • National NDT Certification Body (NDTCB) • Quality management programs	• Perform materials engineering duties • Be a subject matter expert for welding, materials, and hot tapping for Transmission and Distribution, including welding, materials fabrication, hot tapping and isolation on gas distribution lines and associated codes, standards, regulations, recommended practices and industry practices • Ensure quality of welds according to specifications • Conduct CSA Welder Testing • Provide technical support and project engineer level training to all other engineering groups on welding, NDE, materials, and quality related matters	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of material rules and welding processes and procedures compatible with hydrogen and hydrogen blending properties • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Existing workforce to be trained to accommodate transition to heating using natural gas-hydrogen blending

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Or continue on to Power Generation Using Hydrogen Core Occupations

Power Generation Using Hydrogen

Hydrogen does not currently play a large role in Canada's power generations sector – especially at the commercial scale. However, there are a number of potential applications that could be deployed in the longer-term:

- Hydrogen fuel cells use an electrochemical process to convert the hydrogen energy into electricity – just like how they work in FCEV's. Stationary and portable fuel cells are well suited for:
  - Back-up power
  - Electricity for large residential, commercial and institutional complexes such as hospitals, hotels, office buildings and universities where there is a relatively high coincident demand for electricity and thermal energy
    - Stationary fuel cells can also be configured for combined heat and power (CHP)
  - Replacement for diesel-generated power for remote locations
- Grid-connected electrolysers

Power Generation Using Hydrogen

- Hydrogen also has energy storage capability.
  - As the renewable power generation market grows, surplus renewable energy can be converted to hydrogen for energy storage to address challenges with renewable energy variability and uncertainty.
  - The workforce associated with underground storage of hydrogen energy is outlined in the Storage, Upgrading and Transporting section of this Tool
- Modern gas turbines used in natural-gas-fueled power plants are capable of operating using hydrogen-natural gas blends offering the opportunity for base load electricity grids that rely on fossil fuels to reduce emissions.
  - Besides turbines, using hydrogen-natural gas blends for the plant's compressor and combustion system are a consideration
  - The workforce for this type of power generation using hydrogen is the focus of this Tool
  - The existing natural gas power generation workforce will be trained to have an increased awareness of hydrogen, its unique properties, safe handling and understanding the compatibility of materials, coatings, equipment and components

Power Generation Using Hydrogen: Core Occupations

Power Generation Using Hydrogen Workforce Requirements	
ENGINEERS • Automation and control specialist • Compression specialist • Electrical engineer • Electrical & instrumentation engineer • Facility engineer • Hydrogen integration specialist • Mechanical engineers: Equipment & piping, Reliability • Process control engineer • Process engineer • Process safety engineer	**PLANT OPERATIONS & MAINTENANCE** • Control room operator • Maintenance planner • Maintenance trades: Electrical, Instrumentation & control, Mechanical • Plant manager • Plant operator • Power scheduler

Power Generation Using Hydrogen: Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
ENGINEERS				
Automation & controls specialist	*Multiple pathways to this career:* • Bachelor's Degree: Automation, Instrumentation & Controls or Electrical Engineering • Certificate of Qualification in Instrument technician • Instrumentation Engineering Technology diploma	• Support automation and controls functions including supervisory control and data acquisition (SCADA), programmable logic controller (PLC), remote terminal unit (RTU), distributed control system (DCS), human-machine interfaces (HMI), communications hardware, protocol and programming languages and related technologies. • Configure systems, troubleshooting and support equipment related to process control including leak detection technology	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of automated process systems and controls systems associated with power generation using hydrogen blending	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending
Compression specialist	*Multiple pathways to this career:* • Bachelor's Degree: Aerospace, Chemical or Mechanical Engineering • Technologist Diploma: Aerospace Engineering, Mechanical Engineering	• Provide design, engineering and other technical support for natural gas-hydrogen compression system and related equipment and systems including combustion and turbine • Model and simulation of complex thermomechanical systems (air flow, compression, heating, cooling, electro-mechanical actuation etc.) • Monitor compressor equipment performance and ancillary equipment; trouble-shoot issues and identify solutions	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen compression processes • Appropriate selection, design and maintenance of compression, turbine systems and equipment for hydrogen blending	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending

Power Generation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Electrical engineer	Bachelor's Degree: Electrical Engineering	• Provide expertise and leadership in the equipment specification and selection as it relates to high power rectification, harmonic filtering, high voltage and medium voltage power distribution equipment • Evaluate design and/or the impact of changes to existing plant electrical distribution systems. • Oversee electrical equipment installation and provide commissioning support of electrical equipment, such as switchgear, transformers and motors. • Provide technical guidance on application of codes, standards and project design criteria • Participate in Root Cause and Failure Analysis (RCFA)	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of high power electrical equipment associated with power generation using hydrogen blending	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending

Power Generation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Electrical & instrumentation engineer	Bachelor's Degree: Electrical & Instrumentation Engineering	• Design for new or modification of instrumentation, control systems, and electrical projects including Programmable Logic Controllers (PLC) and safety PLCs (SIS), Distributed Control Systems (DCS), fire and gas (F&G) systems • Size and select equipment • Supervise installation and commissioning • Provide technical expertise to resolve issues associated with instrumentation, electrical, and control/safety systems.	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of key instrumentation and electrical equipment and systems associated with ventilation, leak detection, flame detection, corrosion prevention system controls for hydrogen blending	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending

Power Generation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Facility engineer	Bachelor's Degree: Chemical, Process or Mechanical Engineering .	• Plan, direct and coordinate activities concerned with design, construction, modification, optimization and maintenance of power plant equipment and systems including turbines, compressors, combustion system, • Oversee changes in procedures, equipment, or materials as necessary to maintain and improve natural gas-hydrogen turbine performance • Assist operations and integrity groups with compliance measures and best practices for process controls such as: MOC, HAZOP, design and repair, reporting and regulatory compliance.	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of combined-cycle power generation using hydrogen blending • Knowledge of equipment and components including compression, turbines and combustion, etc. for hydrogen blending. • Appropriate selection of materials, coatings, odorants, inhibitors, etc. for hydrogen blending. • Maintenance of ventilation, leak detection, flame detection, corrosion prevention equipment and systems for hydrogen blending • Knowledge of hydrogen related regulations, standards and codes	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending

Power Generation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Hydrogen integration specialist	Bachelor's degree in Chemical, Electrical, or Mechanical Engineering Strong knowledge of trending low carbon transition technologies and initiatives with special attention to hydrogen .	• Lead a multi-discipline team to conduct detailed techno-economic assessment for hydrogen blending project and ongoing operations • Evaluate potential for existing gas turbine assets to be converted to operate on a hydrogen-natural gas blend • Deliver detailed engineering design for hydrogen blending assets • Oversee changes in procedures, equipment, or materials as necessary to maintain and improve natural gas-hydrogen blending project performance • Develop and support the execution of the Change Management and Communication Plan • Ensure techno-economic solutions for hydrogen blending are effectively deployed	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Strong industry knowledge and experience with hydrogen technologies, processes and equipment and components to use to withstand hydrogen pressure and temperatures • Appropriate selection, design and maintenance of power generation equipment including compression, turbines and combustion, etc. for hydrogen blending. • Appropriate selection of materials, coatings, odorants, inhibitors, etc. for hydrogen blending. • Appropriate selection, design, modification to ventilation, leak detection, flame detection, corrosion prevention equipment and systems for hydrogen blending • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Experienced hire with advanced knowledge of hydrogen Small talent pool with mix of technical, business, regulatory and policy expertise

Power Generation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Mechanical engineer - Equipment & piping	Bachelor's Degree: Mechanical Engineering	• Provide technical expertise on the design, maintenance and repairs of pressure equipment and systems, and rotating equipment in accordance with all applicable codes and standards • Lead mechanical engineering matters as it relates to power generation plant turbines, boilers, pressure vessels, fittings, valves, compressors, pumps, motors, piping systems, etc. • Troubleshoot and correct mechanical problems for combustion turbines, steam turbines, pumps, compressors, values, pressure vessels, boilers, piping systems, etc. • Conduct equipment assessment, troubleshoot operational issues and continually improve and optimize operation of mechanical equipment • Participate in Root Cause and Failure Analysis (RCFA)	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of combined-cycle power generation using hydrogen blending • Appropriate selection, design and maintenance of power generation equipment including compression, turbines and combustion, valves, fittings, piping systems etc. for hydrogen blending • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending

Power Generation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Mechanical engineer – Reliability	Bachelor's Degree: Mechanical Engineering	• Lead plant reliability program development and implementation in accordance with all applicable codes and standards • Oversee inspection, maintenance and repair of pressure, rotating and stationary equipment associated with power generation including combustion turbines, steam turbines, pumps, compressors, values, pressure vessels, boilers, piping systems, etc. • Develop expertise in existing and emerging technologies associated with the inspection and maintenance • Participate in Root Cause and Failure Analysis (RCFA)	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of combined-cycle power generation using hydrogen blending • Appropriate selection, design and maintenance of including steam and combustion turbines, compressors, pressure vessels, valves, steam generators, boilers, pumps, piping systems and other Balance of Plant (BOP) equipment to withstand hydrogen pressure and temperatures • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending

Power Generation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Process control engineer	Bachelor's Degree: Chemical or Electrical & Instrumentation Engineering	• Building, implementing, and maintaining the advanced control applications to perform facility operations optimization using a combination of regulatory and model predictive control techniques • Build and deploy advanced process control applications • Develop and test control applications • Process modelling and simulation using software	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of combined-cycle power generation using hydrogen blending • Knowledge of control systems and advanced control systems for combined-cycle power generation using hydrogen blending • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending

Power Generation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Process engineer	Bachelor's Degree: Chemical, Electrical, Mechanical or Process Engineering	• Ensure safe, reliable and efficient operation of the process equipment by applying knowledge of thermodynamics, fluid mechanics, and materials science • Troubleshoot production and process issues • Assist in the resolution of longer-term reliability and maintenance issues involving unusual corrosion, steam quality concerns, fouling of heat transfer surfaces, pre-mature catalyst degradation, breakdown of insulation, and other chronic equipment and performance problems • Oversee plant modifications and upgrades to processes and related equipment ensure comply with regulatory standards • Participate in Root Cause and Failure Analysis	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of combined-cycle power generation using hydrogen blending • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending

Power Generation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Process safety engineer	Bachelor's Degree: Chemical or Process Engineering Significant experience in process equipment, engineering, safety and operational risk management • Process Hazard Analysis techniques (HAZOP, FMEA) • What-If studies, quantitative and semi-quantitative risk assessments (LOPA and FTA/ETA) • Reliability/Survival analysis • Knowledge of OSHA 1910.119, CSA Z767, CSA Z260, ISO 31000, API 1173 and related codes and standards.	• Lead the continual improvement of process safety and risk management processes and methodologies • Analyze and evaluate a wide range of operational risks affecting financial, safety, operational reliability, environmental and reputational receptors • Oversee application of codes, standards, and regulations relevant to process systems and process safety for power generation • Oversee application of acceptable deviations from the approved standards, project specifications and processes • Facilitate the hazard identification and inventory (barrier management) process	• Process engineering and controls skills specific to hydrogen including hazard risk analysis and reviews, mechanical integrity and instrumented system analysis, and operation readiness inspection • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending

Power Generation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
PLANT OPERATIONS & MAINTENANCE				
Control room operator	Typically an experienced plant operator. Power Engineer or Stationary Engineer Certificate of Qualification	• Oversee day-to-day operations and status of all plant systems from centralized control room • Start up and shut down plant equipment from the control room as required • Assist Plant operators diagnose operational deficiencies using instrument indications • Troubleshoot equipment issues and potential root causes using instrument indications • Support preparation of equipment and systems for maintenance and commissioning • Perform safety responsibilities such as hazard identification, equipment lock-out, emergency response, etc. • Issue work permits to maintenance personnel and ensure that they are aware of the risks associated with the work to be performed	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of combined-cycle power generation using hydrogen blending	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending

Power Generation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Maintenance planner	*Multiple pathways to this career:* • Certificate of Qualification in Industrial electrician, Industrial mechanic/Millwright or Instrumentation technician • Bachelor's Degree: Electrical or Mechanical Engineering	• Develop preventive and predictive maintenance plans for the lifecycle of key electrical and mechanical equipment associated with combined-cycle power generation including steam and combustion turbines, compressors, pressure vessels, valves, steam generators, boilers, pumps, piping systems and other Balance of Plant (BOP) equipment • Contribute to achievement of key performance indicators by continuous improvement of maintenance function • Track best practices in preventive and predictive maintenance including leveraging of technology	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of combined-cycle power generation using hydrogen blending • Appropriate selection, design and maintenance of including steam and combustion turbines, compressors, pressure vessels, valves, steam generators, boilers, pumps, piping systems and other Balance of Plant (BOP) equipment to withstand hydrogen pressure and temperatures • Knowledge of hydrogen related regulations, standards and codes	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending

Power Generation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Maintenance trade - Electrical	Certificate of Qualification in Industrial Electrician • Registered apprentice	• Inspect, repair, install, troubleshoot and modify electrical and electronic equipment and components, AC/DC motors and drives, low and high voltage motors/breakers, programmable logic controls (PLC'), control circuits, switchgears, transformers, motors, starters, relays and hydraulic and pneumatic electrical controls • Install or replace electrical wiring, receptacles, switch boxes, conduits, feeders, fibre-optic and coaxial cable assemblies, lighting fixtures and other electrical components • Install, replace or repair generators, alternators and industrial storage batteries • Perform preventive maintenance inspections and testing of various electrical systems • Quickly repair electrical failure and replace parts where incorrect applications could cause danger and hazardous conditions • Interpret drawings, blueprints, schematics and electrical code specifications	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Appropriate selection and maintenance of key electrical and electronic equipment and systems associated with with power generation using hydrogen blending	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending

Power Generation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Maintenance trade – Instrumentation & controls	Certificate of Qualification in Instrumentation technician • Registered apprentice	• Inspect, repair, install, troubleshoot and modify process controls, control valves, safety devices, analyzers, programmable logic controls (PLC), instrumentation (pressure, level and flow), process monitoring equipment, and control circuits and distributed control systems (DCS) • Maintain gas turbine continuous emissions monitoring system • Perform preventive and corrective maintenance on instrumentation and electrical equipment • Troubleshooting, repair, and calibration of plant instrumentation and controls. • Improve equipment performance and/or system reliability/capacity -	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Selection, calibration and maintenance of key instrumentation equipment and systems associated with power generation using hydrogen blending	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending Supports digitization across multiple industries; in high demand • Existing skill shortage

Power Generation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Maintenance trade – Mechanical	Certificate of Qualification in Industrial Mechanic or Millwright • Registered apprentice In Ontario: Hydrogen Technician (TSSAH2) certification • Obtained by working under our TSSA-H2 technicians	• Inspection, repair, troubleshooting, modification, installation and commissioning of mechanical equipment to such as steam and combustion turbines, steam generators and related auxiliary equipment to include piping systems, heat exchangers, pumps, mechanical seals, and valves. • Continuously improve machinery condition and reliability	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Maintenance of vessels, compressors, turbines, piping systems and fitting, valves etc. to withstand hydrogen pressure and temperatures • Knowledge of appropriate materials, seals, coatings to use with hydrogen blending	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending
Plant manager	Likely to be an experienced worker with engineering, maintenance and/or operations experience.	• Manage the day-to-day operations including organizational tasks, assignment of work and meeting power generation targets • Ensure all plant employees work within occupational health and safety regulations, polices and procedures • Continuously look for ways to improve plant operations • Assist with troubleshooting operational and maintenance issues • Coach, mentor, train and develop employees in their job performance; participate in succession planning and hiring activities	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of combined-cycle power generation using hydrogen blending • Maintenance of equipment and systems involved in combined-cycle power generation using hydrogen blending	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending

Power Generation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Plant operator	Power Engineer or Stationary Engineer Certificate of Qualification Many plants require a minimum 3rd Class certificate	• Responsible for ensuring safe plant operation and the generation of electricity in a highly automated plant • Control and monitor equipment and processes including include combustion turbines, heat recovery steam generators, steam turbines, zero-discharge water treatment plant, water treatment plant, gas pipeline equipment, water pipeline equipment and balance-of-plant equipment to meet power requirements • Observe and analyze plant activity and equipment, take reading of temperature, pressures and flows to identify potential operational problems, causes and propose appropriate corrective actions • Prepare equipment and systems for maintenance and commissioning • Track daily performance data to optimize production and inform equipment maintenance, safety and environmental indicators	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of combined-cycle power generation using hydrogen-blending	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending

Power Generation Using Hydrogen: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Power scheduler	Bachelor's degree: Commerce, Economics, Engineering	• Analyze market conditions and making strategic decisions to optimize generation portfolio and merchant exposure • Ensure operational and market rules compliance through the dispatch and monitoring of generation assets • Collaborate with plant operators, front office managers and gas marketers to meet dispatches and contract obligations • Support identification of opportunities to develop the business and maximize profit • Develop daily same-day price forecast and financial and operational data for asset optimization • Maintain a strong understanding of control area rules and operations, commercial structures and potential constraints	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of combined-cycle power generation using hydrogen-blending	Existing workforce to be trained to accommodate transition to power generation using natural gas-hydrogen blending

Back to Value Chains Menu

Or continue on to Manufacturing for the Hydrogen Economy Core Occupations

Manufacturing for the Hydrogen Economy

Canada's manufacturing sector is key for ensuring the availability of hydrogen appropriate equipment and technology, and to derisk the potential for supply chain bottlenecks that could impede accelerating a hydrogen economy. Three strategies are expected:

1. Existing manufacturers diversifying their product lines so that they are suitable for use within the hydrogen economy:
   - Aerospace
   - Automotive and autoparts
   - Appliances
   - Heavy-duty and medium-duty vehicle (drivetrains, glider kits)
   - Oil & gas and power generation: piping and pressure vessels, compressors, valves, turbines and other equipment

2. Expanded use of modular fabrication and assembly facilities established to maximize efficiency, quality and cost effectiveness for construction of industrial process operations to include hydrogen and CCS infrastructure

3. Companies focused on hydrogen-related R&D companies expanding into manufacturing
   - Fuel cells and stacks, electrolyzers, etc.

Manufacturing for the Hydrogen Economy

cont'd

The composition of the manufacturing workforce required for hydrogen is very similar to that in place for other manufacturing in Canada. The manufacturing workforce can be divided into two categories:

1. Workers involved in delivering the product:
    - Engineering & design
    - Fabrication and assembly
    - Testing and quality control
2. Workers involved in facility operations and maintenance including deployment of advance manufacturing technology and mechatronics:
    - Integration of mechanics, electronics, computing and integrated control systems needed to automated manufacturing

Advancing the hydrogen economy will likely have to contend with existing shortages of manufacturing occupations.

Manufacturing for Hydrogen Economy

cont'd

Specialized knowledge that may be required by some occupations involved in the engineering, design, assembly and quality control of products manufactured for the hydrogen economy including:

- Hydrogen properties, behaviour and potential hazards created and safety when working with or around hydrogen
- Electrochemical reactions and systems such as electrolysers, fuel cells, and batteries
- Material compatibility and design considerations for hydrogen systems
- Coatings and inhibitors to use to protect from hydrogen corrosion
- Design and selection of vessels, compressors, piping systems, turbines, tanks, pumps, and other equipment to withstand hydrogen pressure (high/low) and temperatures (hot/cold)
- Knowledge and selection of type of fittings, threaded steel joints, valves, seals and sealants to use with hydrogen
- Instrumentation and electrical equipment and systems associated with hydrogen value chains and embedded controls for electro-mechanical systems.
- Hydrogen-related regulations, codes and standards

Manufacturing for the Hydrogen Economy: Core Occupations

The following is a generic set of occupations that may require specialized skills and knowledge for some hydrogen-related manufacturing.

MANUFACTURING WORKFORCE REQUIREMENTS	
PRODUCT DESIGN, ASSEMBLY, QUALITY CONTROL	FACILITY OPERATIONS & MAINTENANCE
• Applications engineer • Assembly technician • Compliance specialist • CNC fabrication technician • Design engineers: Electrical & instrumentation, Mechanical, Mechatronics • Manufacturing engineer • Materials specialist • Pipefitters/Steamfitters • Production scheduler • Production supervisor • Quality control specialist • Service technician • Sourcing specialist • Test technician • Test validation engineer • Welder	• Facility maintenance planner • Maintenance trades: Electrical, Electromechanical, Instrumentation & control, Mechanical • Mechatronics engineer: Facility

Manufacturing for Hydrogen Economy: Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
PRODUCT DESIGN, ASSEMBLY & QUALITY CONTROL				
Applications engineer	*Multiple pathways to this career:* • Bachelor's Degree: Automation, Instrumentation & Controls or Electrical Engineering • Engineering Technology Diploma: Automation, Instrumentation or Electrical Engineering	• Design and specify components for complex tooling and processes associated with automated manufacturing machinery and systems including assembly, inspection and material handling. • Design verification, validation and testing procedures	Nothing that impacts this occupation's ability to apply expertise to manufacturing for hydrogen supply chains	Skills/knowledge and transferability with advanced manufacturing for other sectors, automation and robotics.
Assembly technician Also known as: • Production worker	Mechanical and/or electrical aptitude • Able to multitask and prioritize • Able to perform manual tasks requiring dexterity and coordination	• Assemble mechanical, electrical and other product components while meeting quality standards and specifications, and production deadlines • Operate automated equipment in the performance of manufacturing duties, and monitor its performance. • Monitor the functioning of all tools equipment and report any problems • Perform final checks and adjustments for any defects to ensure high quality products • Use test and validation equipment and tooling to assess pass/fail criteria for product	Nothing that impacts this occupation's ability to apply expertise to manufacturing for the hydrogen industry	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment and components including automotive, oil & gas, agriculture, mining, aerospace

Manufacturing for Hydrogen Economy: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Compliance specialist Also known as: • Controls specialist	*Multiple pathways to this career:* • Bachelor's Degree: Automation, Industrial, Instrumentation & Controls, Mechanical or Robotics Engineering • Engineering Technology Diploma: Automation, Instrumentation, Mechanical or Robotics Engineering	• Support in the development of production tooling and equipment standards to ensure delivery of highest quality products • Evaluate, debug, and implement solutions to manufacturing and technical issues including revising equipment, processes, line balancing, standardized work, and procedures to maintain and improve the manufacturing floor and production capability	Depending on the hydrogen-related product manufactured, may require hydrogen specific skills/knowledge as listed here	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment and components including automotive, oil & gas, agriculture, mining, aerospace • Six Sigma • Quality management tools • Lean manufacturing techniques
CNC fabrication technician Also known as: • CNC operator • CNC programmer • Manufacturing technician	Certificate of Qualification: Machinist • Apprentice	• Program and operate computer numerically controlled (CNC) and mechanically-operated machines used to create molds and to manufacture parts and products from engineered drawings • Verify dimensions of parts machined using micrometers, calipers and other precision measuring instruments • Problem solve and trouble shoot machine errors, program errors and inconsistencies	Nothing that impacts this occupation's ability to apply expertise to manufacturing for the hydrogen industry	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment and components including automotive, oil & gas, agriculture, mining, aerospace

Manufacturing for Hydrogen Economy: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Design engineer - Electrical & instrumentation	Bachelor's Degree: Electrical or Instrumentation Engineering	• Detailed design of electrical, electronic and instrumentation components and systems required in full compliance with regulations, codes, standards and guidelines • Select, source and inspect electrical, electronic and instrumentation components • Support the assembly of electrical, electronic and instrumentation components and test stations	Depending on the hydrogen-related product manufactured, may require hydrogen specific skills/knowledge as listed here	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment and components including automotive, oil & gas, agriculture, mining, aerospace: • Electrical, instrumentation and process control systems • Testing facility, building prototypes, validating, and testing designs
Design engineer- Mechanical	Bachelor's Degree: Mechanical Engineering	• Detailed design of mechanical components, systems and structures for new and existing products in full compliance with regulations, codes, standards and guidelines • Support the design, build, assembly and testing of prototypes • Conduct tolerance analysis, structural calculations and other analysis • Select, source and inspect mechanical components • Support the mechanical assembly of mechanical components and test stations	Depending on the hydrogen-related product manufactured, may require hydrogen specific skills/knowledge as listed here	Skills/knowledge and transferability with manufacturing for sectors requiring similar mechanical equipment and components including automotive, oil & gas, agriculture, mining, aerospace: • High temperature, high-pressure systems and component design • Testing facility, building prototypes, validating, and testing designs

Manufacturing for Hydrogen Economy: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Design - Mechatronics	Bachelor's Degree in Electrical, Mechanical or Mechatronics Engineering	• Design and draw interfaces of computer, mechanical and electrical/instrumentation assemblies and components required for manufactured product • Design hardware and software interfaces as it relates to embedded controls for electro-mechanical systems • Compile data, compute quantities, determine materials needed, and prepare cost estimates • Participate in the development and assembly of prototype systems • Evaluate performance, production quality, diagnose and address production and process issues	Depending on the hydrogen-related product manufactured, may require hydrogen specific skills/knowledge as listed here	Skills/knowledge and transferability with manufacturing for sectors requiring similar electromechanical systems interface including automotive, oil & gas, agriculture, mining, aerospace. • Relevant codes and standards • Automated process systems and controls systems

Manufacturing for Hydrogen Economy: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Manufacturing engineer Also known as: • Manufacturing design engineer • Manufacturing process engineer • Tooling engineer	Bachelor's Degree in Electrical, Industrial, Instrumentation or Mechanical Engineering	• Optimize utilization of the production facilities, manufacturing processes, material handling processes, equipment and systems • Manage issues and drive root cause analysis to identify and control manufacturing process defects, reduce customer complaints, and product return rate • Analyze the impact of mechanical stresses and material properties on the performance of the production line and product quality • Develop and implement quality procedures, quality plans, quality performance trends, statistical plans, and continuous improvement initiatives • Design, document, and implement new manufacturing processes for new products	Depending on the hydrogen-related product manufactured, may require hydrogen specific skills/knowledge as listed here	Skills/knowledge and transferability with manufacturing for sectors requiring similar mechanical equipment and components including automotive, oil & gas, agriculture, mining, aerospace: • Manufacturing Execution System (MES)

Manufacturing for Hydrogen Economy: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Materials specialist	*Multiple pathways to this career:* • Engineering Technology Diploma: Electrical, Instrumentation or Mechanical Engineering • Certification of Qualification: Electrician, Industrial Mechanic (Millwright) Certification in supply chain an asset	• Participate in sales and product forecasting Convert forecast for products into material requirement demand plans and into physical orders. • Understands business trends, opportunities and how they impact the demand forecast. • Ensure that all material, parts or equipment received are inspected • Release all incoming goods to the appropriate department after they have undergone inspections, write-ups and tagging • Material management analysis: material consumption, aged inventory, aged purchase orders, in-transit material analysis, etc.	Depending on the hydrogen-related product manufactured, may require hydrogen specific skills/knowledge as listed here	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment and components including automotive, oil & gas, agriculture, mining, aerospace • Knowledge of codes and standards
Pipefitters/Steamfitters	Certificate of Qualification: Pipefitter • Registered Apprentice	• Read and interpret drawings, blueprints and specifications to ensure quality work performed • Layout and install various major equipment and prefabricated component of piping system (spools), while meeting various codes and specifications • Conduct pneumatic testing of spools	Depending on the hydrogen-related product manufactured, may require hydrogen specific skills/knowledge as listed here	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment and components including automotive, oil & gas, agriculture, mining, aerospace • Knowledge of codes and standards

Manufacturing for Hydrogen Economy: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Production scheduler	*Multiple pathways to this career*: • Post-secondary Diploma in Business • Training and/or certification in Supply Chain and/or Inventory Management	• Develop and maintain the master production schedule to ensure that actual production meets scheduled requirements • Monitor line productivity and job schedule throughout the day; adjust production schedule and notify of any deviations • Work with designers to ensure the new product builds are on track to meet significant milestones. • Perform production order expediting and inventory reconciliations. • Communicate schedule, changes to schedule to all stakeholders including customers • Support production improvement initiatives through data gathering, implementation and generating ideas	Depending on the hydrogen-related product manufactured, may require hydrogen specific skills/knowledge as listed here	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment and components including automotive, oil & gas, agriculture, mining, aerospace • Manufacturing Material Requirement Planning (MRP) systems
Production supervisor	Bachelor's Degree: Mechanical Engineering	• Oversee the day-to-day operations at manufacturing plants to ensure that production stays on schedule • Troubleshoot production issues • Hire and provide performance management coaching to production workers	Depending on the hydrogen-related product manufactured, may require hydrogen specific skills/knowledge as listed here	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment, components and systems including automotive, oil & gas, agriculture, mining, aerospace

Manufacturing for Hydrogen Economy: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Quality control specialist	Bachelor's Degree in Engineering Quality assurance and control certifications	• Develop and implement Quality Management System to identify improvements and design/process enhancements to meet internal goals and satisfy external customers • Assist manufacturing operations to resolve quality issues quickly and permanently • Examine materials and products for any hazards, defects, or deviations. • Lead preventive and corrective actions using effective engineering judgment and appropriate root cause analysis tool	Depending on the hydrogen-related product manufactured, may require hydrogen specific skills/knowledge as listed here	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment, components and systems including automotive, oil & gas, agriculture, mining, aerospace • Material Review Board (MRB) processes • Advanced Product Quality Planning (APQP) • Failure Mode and Effects Analysis (FMEA)

Manufacturing for Hydrogen Economy: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Service technician	*Multiple pathways to this career:* • Bachelor's Degree: Electrical, Electrochemical, Mechanical Engineer • Certificate of Qualification: Electrician, Instrumentation, Industrial Mechanic • Technology diploma: Electrical, Instrumentation or Mechanical Engineering TSSA-H2 Certified Technician for hydrogen-specific components and equipment (ON) Valid driver's license + clean abstract	• Support product deployment through field installation, commissioning and on-going service • Deliver and install, test performance • Troubleshoot and repair product, component and system as required	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen Depending on the hydrogen-related product manufactured, may require hydrogen specific skills/knowledge as listed here	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment and components including automotive, oil & gas, agriculture, mining, aerospace

Manufacturing for Hydrogen Economy: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Sourcing specialist	Degree in Mechanical, Electrical or Electro-Mechanical Engineering	• Act as point of contact for suppliers engaged in product • Find, establish and support qualification of strategic suppliers and components • Conduct market assessment and identification of new suppliers and component technologies required to support new product design and existing products undergoing design changes • Create, issue and analyze RFI/RFP/RFQ and supplier cost break down documents	Depending on the hydrogen-related product manufactured, may require hydrogen specific skills/knowledge as listed here	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment, components and systems including automotive, oil & gas, agriculture, mining, aerospace
Test technician	*Multiple pathways to this career:* • Technology Diploma: Aerospace, Electrical, Mechanical Engineering • Bachelor's Degree: Aerospace, Electrical, Mechanical Engineering	• Perform product systems validation plans from a variety of inputs to identify potential failure modes, while managing product risk • Mitigate potential product failure modes, by testing interfaces, functions, functional • requirements, interactions, control factors, noise factors, etc. efficiently improve the reliability of products.	Depending on the hydrogen-related product manufactured, may require hydrogen specific skills/knowledge as listed here	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment and components including automotive, oil & gas, agriculture, mining, aerospace: • Experience operating, monitoring and maintaining test equipment

Manufacturing for Hydrogen Economy: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Test validation engineer	*Multiple pathways to this career:* • Bachelor's Degree: Mechanical Engineering • Technology Diploma: Mechanical Engineering	• Responsible for Design Verification Planning and Reporting (DVP&R) activities • Develop plans and protocols to test product/component performance, durability, accelerated stress testing for new materials and technology • Identify failure mechanisms, documentation and analysis of failures using root cause analysis, and develop mitigation strategies. • Provide guidance to test operators for test execution and improving testing practices	Depending on the hydrogen-related product manufactured, may require hydrogen specific skills/knowledge as listed here	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment, components and systems including automotive, oil & gas, agriculture, mining, aerospace
Welder	Certificate of Qualification: Welder • Registered Apprentice B or C Pressure Welding Ticket maybe required for some manufacturing (i.e.: pressure vessels, piping systems, etc.) Brazing knowledge an asset	• Analyze product drawings and specifications to plan, layout, assembly and welding of materials • Measure, cut and prepare raw material. • Install, assemble and test components and systems as identified in the project scope of work and fabrication drawings	Depending on the hydrogen-related product manufactured, may require hydrogen specific skills/knowledge as listed here	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment and components including oil & gas, agriculture, mining, aerospace: • Welding processes • Codes and standards

Manufacturing for Hydrogen Economy: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
FACILITY OPERATIONS & MAINTENANCE				
Facility maintenance planner	*Multiple pathways to this career:* • Certificate of Qualification in Industrial electrician, Industrial mechanic/Millwright or Instrumentation technician • Bachelor's Degree: Electrical or Mechanical Engineering	• Plan and oversee execution of the preventive, predictive, and condition-based maintenance of production equipment	Nothing that impacts this occupation's ability to apply expertise to manufacturing for the hydrogen supply chains	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment and components including automotive, oil & gas, agriculture, mining, aerospace
Maintenance trades - Electrical	Certificate of Qualification in Industrial electrician • Registered apprentice	• Build, install, commission, test, troubleshoot and maintain electrical systems in the manufacturing facility • Ensure that all work is performed in full compliance with codes, regulations and established safety standards • Recommend changes to designs, drawings and modifications of equipment or parts	Nothing that impacts this occupation's ability to apply expertise to manufacturing for the hydrogen industry	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment and components including automotive, oil & gas, agriculture, mining, aerospace

Manufacturing for Hydrogen Economy: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Maintenance trade - Electromechanical	Certificate of Qualification in Industrial electrician, Industrial mechanic or Millwright • Registered apprentice Electrical and mechanical certification an asset	• Build, install, commission, test, troubleshoot and maintain electromechanical equipment and systems in the manufacturing facility • Ensure that all work is performed in full compliance with codes, regulations and established safety standards • Recommend changes to designs, drawings and modifications of equipment or parts	Nothing that impacts this occupation's ability to apply expertise to manufacturing for the hydrogen supply chains	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment and components including automotive, oil & gas, agriculture, mining, aerospace
Maintenance trade - Instrumentation & controls Also known as: • Automation technician	Certificate of Qualification in Instrumentation technician • Registered apprentice	• Build, install, commission, test, troubleshoot and maintain robotic equipment and automated production systems in the manufacturing facility • Ensure that all work is performed in full compliance with codes, regulations and established safety standards	Nothing that impacts this occupation's ability to apply expertise to manufacturing for the hydrogen supply chains	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment and components including automotive, oil & gas, agriculture, mining, aerospace
Maintenance trade - Mechanical	Certificate of Qualification in Industrial mechanic or Millwright • Registered apprentice	• Build, install, commission, test, troubleshoot and maintain mechanical systems in the manufacturing facility • Ensure that all work is performed in full compliance with codes, regulations and established safety standards • Recommend changes to designs, drawings and modifications of equipment or parts	Nothing that impacts this occupation's ability to apply expertise to manufacturing for the hydrogen supply chains	Skills/knowledge and transferability with manufacturing for sectors requiring similar equipment and components including automotive, oil & gas, agriculture, mining, aerospace

Manufacturing for Hydrogen Economy: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Mechatronics engineer - Facility	Bachelor's Degree in Electrical, Mechanical or Mechatronics Engineering	• Custom-design computer, software, electrical and instrumentation systems and mechanical machines to work together for automated manufacturing processes and production lines as per advanced manufacturing concepts • Design computer-controlled electromechanical systems that packages components considering their mechanical, thermal, and • electrical connections • Research, design, develop, or test automation, intelligent systems, smart devices, or industrial systems control • Evaluate performance, production quality, diagnose and address process issues	Nothing that impacts this occupation's ability to apply expertise to manufacturing for hydrogen supply chains	Skills/knowledge and transferability with advanced manufacturing facilities for other sectors • Automation and robotics.

Back to Value Chains Menu

Or continue on to Core Occupations Required Across the Hydrogen Value Chains

Roles Common Across the Hydrogen Value Chains

There are core occupations employed across all value chains that are focused on creating the ecosystem required to achieve the desired pace of development of the hydrogen economy.

- Roles that support the expansion of the hydrogen economy using specialized skills and knowledge:
  - Sustainability, regulatory compliance, safety, public engagement and relationship building
  - While not necessarily required in great numbers, shortages of qualified talent could cause bottlenecks and impede progress
  - Some occupations are technical in nature and need hydrogen-specific expertise

Depending on the size of the company, these the activities and accountability associated with these roles may be divided across a number of positions.

Roles Common Across the Hydrogen Value Chains *cont'd*

- **Business and commercial development occupations** crucial for building market pull to drive the hydrogen economy.
- **Digital occupations** as the value chains associated with the hydrogen economy will be highly digitized.
  - Digital and automated operations are not only cost effective, but they also can enable reduction of environmental impacts and improve workforce and public safety
- **Sustainability & ESG roles** focus on supporting energy transition, improving sustainability and ESG-related performance to meet values-driven goals and attract investment and employees.
  - It is not enough for low-carbon hydrogen producers and end-user companies to say they are advancing ESG and sustainability, they need to provide data-driven evidence and demonstrate commitment through their decisions and activities.
  - Public confidence and support for the hydrogen economy are critical to its success
  - Relationships with Indigenous communities are distinct from other stakeholder relationships due to Indigenous rights to their land and traditions, and federal laws regulating environmental assessment and consultation processes

Roles Common Across the Hydrogen Value Chains *cont'd*

- **Inspection** as the emerging nature of some hydrogen technologies likely to drive the need for more regular inspections.
  - Additional inspections of new and in-service equipment, piping and facilities may be required due to hydrogen's unique characteristics, the complexity of its processes, and its robust safety regulations
  - Traditional and advanced inspection and testing including non-destructive evaluation (NDE), non-destructive testing (NDT), failure analysis, materials and coating engineering, and monitoring reliability of equipment and systems exposed to pressured and cryogenic hydrogen environments.
  - Inspections driven by federal and provincial codes or regulations to ensure workforce, public and environmental safety
  - Agencies involved in certifying inspectors may need to upgrade existing certifications and/or develop new ones for hydrogen

Roles Common Across the Hydrogen Value Chains: Core Occupations

Core Occupational Groupings		

• **Business & commercial development specialist**
• **Digital occupations:**
  ○ Cybersecurity specialist
  ○ Data analyst
  ○ Data engineer
  ○ Data scientist
  ○ Software developer
  ○ Systems integration specialist
	• **Environmental, Social and Governance (ESG) roles** such as:
	  ○ Environmental specialist
	  ○ Environment, Social, Governance: Analyst, Leader
	  ○ Government relations specialist
	  ○ Health & safety advisor
	  ○ Indigenous relations professional
	  ○ Regulatory analyst and compliance specialist
	  ○ Stakeholder engagement and communications specialist
	  ○ Sustainability specialist
		• **Inspectors**
		  ○ Cathodic protection technician
		  ○ Coating inspector
		  ○ Construction inspector
		  ○ Corrosion specialist
		  ○ In-service pressure equipment inspectors
		  ○ Non-destructive (NDE) inspector and technician
		  ○ Safety codes inspector
		  ○ Welding inspector

Roles Common Across the Hydrogen Value Chains: Core Occupations

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity

Business & commercial development specialist	Bachelors Degree in Chemical or Mechanical Engineering
	
	Likely supplemented with Master of Business Administration (MBA), or equivalent business development training and experience
		• Monitor and analyze market development
		• Evaluate potential opportunities with functional experts against commercial, technical and non-technical criteria
		• Prepare and present preliminary project feasibility studies
		• Assist in conducting due diligence for investment, acquisition and partnership opportunities
		• Write contracts and lead negotiations with customer through to closing
			• Hydrogen properties, behaviour and potential hazards created
			• Safety when working with or around hydrogen
			• Understanding of hydrogen technologies, costs, and carbon advantages and disadvantages in order to evaluate project opportunities and feasibility against commercial, technical and non-technical requirements
			  • Produce techno-economic analysis reports
			  • Develop and present business case for hydrogen
				Small talent pool of with mix of business development skills and technical hydrogen expertise
				
				Skills, knowledge and transferability opportunities likely greatest with natural gas industry

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
DIGITAL OCCUPATIONS				
Cybersecurity specialist	*Multiple pathways to this career:* • Bachelor's Degree: Computer Engineering, Computer Science, Information Technology, Software Engineering, • Technology Diploma: Computer Engineering, Information Technology Engineering, Software Development Cybersecurity certification an asset	• Develop and implement applicable policy, standards, guidelines, and procedures to formally address the purpose, scope, roles, and responsibilities for a cybersecurity program. • Oversee compliance requirements • Establish risk-based controls to manage, prevent, detect, and deter threats • Make recommendations concerning the issuance of security clearance eligibility	Nothing that specifically impacts this occupation's ability to apply expertise to the hydrogen industry	Transferability of technical expertise: • User activity monitoring tools Data loss prevention tools • Case management systems Current talent shortage of experienced IT/digital talent
Data analyst	*Multiple pathways to this career:* • Bachelor's Degree: Computer Engineering, Computer Science, Information Technology or Software Engineering • Technology Diploma: Computer Engineering, Information Technology Engineering, Software Development • Data analytics bootcamps	• Identify and collect data to analyze • Clean the data in preparation for analysis • Analyze the data and interpret the results of the analysis to solve problems and make data-driven decisions by answering "what happened?" "why did it happen?" and "what should we do about it?" • Conduct predictive analytics to form projections about the future.	Domain knowledge of the hydrogen value chain involved is an asset	Transferability of technical expertise: • Programming languages: SQL, R and Python • Data modelling • Extract Transform Load (ETL) • Data Warehousing • Visualization programs: Power BI, Tableau Current talent shortage of experienced IT/digital talent

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Data engineer	*Multiple pathways to this career:* • Bachelor's Degree: Computer Engineering, Computer Science, Information Technology, Software Engineering, Statistics • Technology Diploma: Computer Engineering, Information Technology Engineering, Software Development	• Design, develop, optimize, and maintain data pipelines to extract data from a variety of sources, including unstructured, semi-structured, and fully structured data • Design, develop, and implement Data Warehouse solutions • Integrate and organize data that underpin the company's critical applications and reporting • Maintain and optimize systems	Nothing that impacts this occupation's ability to apply expertise for the hydrogen industry	Transferability of technical expertise: • Designing, building and maintaining complex data pipelines and warehousing • Building distributed systems to process batch and streaming data • Programming languages Python and SQL Current talent shortage of experienced IT/digital talent
Data scientist	Bachelor's Degree: Computer Engineering, Computer Science, Information Technology, Software Engineering, Statistics	• Analyze and synthesize data collected by the company and other sources to predict trends, glean business insights, and answer questions that are relevant to the organization	Domain knowledge of the hydrogen value chain involved is an asset	Transferability of technical expertise: • Programming languages Python, R and SQL • Machine Learning and Artificial Intelligence (AI) • Data analysis, statistics and algorithms Current talent shortage of experienced IT/digital talent

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Software developer	*Multiple pathways to this career:* • Bachelor's Degree: Computer Engineer, Computer Science, Information Technology or Software Engineer • Technology Diploma: Computer Engineering, Information Technology Engineering, Software Development • Software developer bootcamps	• Combination of software development, coupled with top-tier software as a service (SaaS) systems. • Hands-on coding of services, applications, and system-to-system integrations • Ongoing support of applications in response to changing business and system requirements • Build scripts to create data pipelines	Nothing that impacts this occupation's ability to apply expertise for the hydrogen industry	Transferability of technical expertise: • Programming languages Python, R and SQL • Machine Learning and Artificial Intelligence (AI) Current talent shortage of experienced IT/digital talent
Systems integration specialist	*Multiple pathways to this career:* • Bachelor's Degree: Computer Engineer, Computer Science, Information Technology or Software Engineer • Technology Diploma: Computer Engineering, Information Technology Engineering, Software Development	• Apply engineering principles to ensure complex software systems and hardware are effectively integrated and work together • Quality control testing on software, hardware, network configurations and overall integration	Domain knowledge of the hydrogen value chain involved is an asset	Transferability of technical expertise: • Programming languages Python, R and SQL • SQL Server Management • Network communications • PLC programming and development • HMI programming and development Current talent shortage of experienced IT/digital talent

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
SUSTAINABILITY AND ENVIRONMENTAL, SOCIAL & GOVERNANCE (ESG) ROLES				
Environmental specialist	Bachelor's Degree: Environmental Sciences, Geography, Resource Management, Public Policy	• Plan and execute environmental impact assessments, federal, provincial and local permitting, and environmental compliance activities • Provide technical environmental advice to inform risk identification and mitigation strategies and contingency planning • Collaborates with key internal groups responsible for land, community relations, Indigenous relations, regulatory, legal, and safety to identify and resolve issues, execute project execution plans and schedules, and support the integration of environment considerations into project and operations planning	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of environmental laws, regulations and practices pertaining to hydrogen and related infrastructure and operations	Skills/knowledge and industry transferability opportunity with other industrial sectors including oil & gas, chemicals, petrochemicals, pulp & paper. • Knowledge/understanding of federal and provincial regulations

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Environment, Social, Governance (ESG) analyst	*Multiple pathways to this career:* • Bachelor's Degree: Business, Accounting, Environmental & Science disciplines, Policy • Technology Diploma: Business, Accounting, Environmental & Science disciplines	• Compile and review ESG metrics provided by business groups across the company • Assist in the development of processes and controls around the gathering, and reporting, of ESG data • Prepare responses to ESG rating agencies • Assist with the preparation of the Company's external sustainability reports • Assist in the evaluation of projects • Assist with ESG materially assessments	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of hydrogen technologies and value proposition as it relates to ESG factors and how to measure them	Emerging occupation across a number of industries Small talent pool with mix of technical, business, regulatory and policy expertise
Environment, Social, Governance (ESG) leader	Bachelor's Degree: Business, Accounting, Engineering, Environmental & Science disciplines, Policy	• Provide strategic leadership and oversight for company's sustainability plan and Environmental, Social, Governance (ESG) performance and integration of material ESG topics across corporate functions and business units • Oversee ESG reporting and disclosure • Ensure appropriate positioning and communication of ESG commitments within sustainability framework • Monitor internal and external sustainability information and assess future implications • Provide leadership and information exchange with government agencies and legislators	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of hydrogen technologies and value proposition as it relates to ESG factors • Expert knowledge of sustainability and ESG, expectations, climate issues climate science and targets	Experienced hire with advanced knowledge Emerging occupation across a number of industries Small talent pool with mix of technical, business, regulatory and policy expertise

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Government relations specialist	Bachelor's Degree: in Business, Engineering, Environmental science, Law, Policy Strong business acumen and experience	• Direct and manage the Government Relations Program including identification of issues, policy and legislation with direct business implications • Effectively interact with federal, provincial, and local officials, provincial legislators, and regulatory agencies • Provide expertise and recommendations that inform leadership to effectively address critical and complex regulatory and policy issues • Lead international, national, and provincial policy advocacy for company's interests • Assess impacts of new, emerging and existing laws, regulations and policies including those related to climate impact reduction • Create an environment with governments that are supportive of business priorities, ongoing operations and new projects • Engage and manage outside consultants and lobbyists as required • Participate in key industry trade associations and user group activities	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of hydrogen technologies and value proposition re: environment, climate change, etc. • Understanding of current and evolving environmental, energy and climate change policy and regulatory frameworks in Canada, USA and Internationally as they pertain to hydrogen	Experienced hire with advanced knowledge Small talent pool with mix of technical, business, regulatory and policy expertise as it related to hydrogen Skills/knowledge and industry transferability opportunity with other industrial sectors including oil & gas, chemicals, petrochemicals, pulp & paper. • Knowledge/understanding of federal and provincial regulations, policies and programs

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Health & safety advisor	Post-secondary training in occupational health & safety Additional certifications that may be beneficial: • Canadian Registered Safety Professional (CRSP) • National Construction Safety Officer (NCSO) • Qualified Health & Safety Officer (QHSO) • Joint Health & Safety Committee (JHSC) training	• Develop, implement, monitor, and revise programs and procedures associated with environment, health, and safety systems throughout the organization • Monitor and ensure compliance with applicable safety legislation • Define an incident investigation process and oversee implementation as required • Keep current with best practices • Conduct company safety audits • Develop emergency response procedures for hydrogen related safety incidents • Liaise with governing bodies as required • Keep up-to-date with changes in technology, regulations, codes and standards	• Advanced knowledge of hydrogen properties, behaviour and potential hazards created • Advanced knowledge of safety when working with or around hydrogen • Advanced knowledge of regulatory systems, standards and policy related to hydrogen	Skills/knowledge and industry transferability opportunity with other industrial sectors including oil & gas, petrochemicals, chemical manufacturing, mining, Engineering, Procurement, Construction (EPC) • Safety Management Systems • Regulations

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Indigenous relations specialist	*Multiple pathways to this career:* • Bachelor's Degree in First Nations and Indigenous Studies, Political Science, Business Administration, Public Administration, Law, Natural Resources Management, or other related field • A combination of related education and Indigenous relations experience Cultural competency including an understanding of colonization, decolonization, land and governance issues	• Establish and lead development of strategic Indigenous engagement • Develop and maintain constructive, authentic, and collaborative relationships with Indigenous communities and businesses • Advise leadership to ensure Indigenous relations principles, stakeholder engagement strategies, and negotiated commitments are integrated across the company including approach to major projects • Identify mitigation or avoidance strategies for social risks related to Indigenous peoples • Support company interactions with Indigenous communities in relation to major project development, regulatory processes, environmental management, archaeological resource management, etc. • Advise on Indigenous local content and procurement strategies • Drive company culture around Indigenous Peoples understanding and inclusion; support creation and delivery of Indigenous cultural awareness training	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of hydrogen technologies, and economic and social advantages and disadvantages	Skills/knowledge and industry transferability opportunity with other industrial sectors including oil & gas, petrochemicals, chemical manufacturing, mining, Engineering, Procurement, Construction (EPC) Working for a First Nation, Federal, Provincial, or local government or an Indigenous organization or agency.

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Regulatory analyst and compliance specialist	*Multiple pathways to this career:* *Multiple pathways to this career:* • Bachelor's Degree: Business, Accounting, Engineering, Environmental & Science disciplines, Policy • Technology Diploma: Business, Accounting, Environmental & Science disciplines	• Analyze federal, provincial and international regulatory programs to inform pathways for company response • Define and implement company compliance strategy including Greenhouse Gas (GHG) and alternate approaches including carbon tax, carbon offsets, cap & trade, etc. • Coordinate compliance submissions to regulators • Monitor and identify all new and amended laws, rules and regulations affecting current and future company pathways • Engage legal, compliance and other internal stakeholders to ensure consistency and alignment in regulatory applications and reporting accountabilities • Represent company and industry positions to regulatory agencies, government ministries and industry associations	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Advanced knowledge of current and evolving regulatory systems, standards and policy related to hydrogen	Skills/knowledge and industry transferability opportunity with other industrial sectors including oil & gas, biofuels, petrochemicals, chemical manufacturing, mining, etc. Emerging skill and knowledge requirements related to compliance strategy including Greenhouse Gas (GHG) and alternate approaches such as carbon tax, carbon offsets, cap & trade, etc. • Likely to be a talent shortage

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Stakeholder engagement and communications specialist	Bachelor's degree: Business, Communication, Environmental Management, Policy, Political Science, Social Sciences	• Ensuring robust stakeholder consultation strategies are in place and executed according to project and operations timelines • Coordinate and support key engagements in the community and with key stakeholders including provincial and federal regulators and Indigenous groups • Support ongoing issue identification and management, and dispute resolution as required • Create positive relationships that fosters trust and credibility • Continuously improve stakeholder engagement as it relates to the consultation and regulatory process	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of hydrogen technologies and value proposition and benefits re: socio-economic, environment, climate change, etc.	Skills/knowledge and industry transferability opportunity with other industrial sectors involved in large-scale development including oil & gas, pipelines, biofuels, petrochemicals, chemical manufacturing, mining, Engineering Procurement & Construction (EPC) etc.

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Sustainability specialist	Bachelor's Degree in Engineering Environmental science, Law Familiarity with: • Internationally recognized sustainability reporting standards and frameworks • Climate regulatory policy experience across Canada Understanding of carbon lifecycle analysis models/tools (carbon intensity). • Knowledge of relevant federal, provincial and local government climate activities in Canada	• Play a lead role in sustainability and environmental, social and governance (ESG) initiatives • Monitor external environment for research and policy activities, trends, and issues related to energy and climate policy and identify potential disruptive market and technology trends • Assess business impacts of new, emerging and existing climate related reduction laws, regulations and policies • Develop models and scenario analysis around climate change and assess any potential impact to long-term business strategy and development plan • Develop and implement climate-related regulatory strategies • Apply technical knowledge of GHG emissions and ESG/Sustainability reporting • Work with business to extract the data necessary to calculate and report emissions –related data for regulatory compliance • Lead corporate interactions with governmental agencies, industry associations and ENGOs (Environment non-governmental Organization)	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Knowledge of hydrogen technologies and value proposition and benefits re: socio-economic, environment, climate change, etc. • Advanced knowledge of current and evolving regulatory systems, standards and policy related to hydrogen	Experienced hire with advanced knowledge Emerging occupation across a number of industries Small talent pool with mix of technical, business, regulatory and policy expertise

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
INSPECTORS				
Cathodic protection technician	Combination of education, experience and certification *Multiple pathways to this career:* • Technologist Diploma: Electrical, Materials Engineering, Mechanical Engineering • Bachelor's Degree: Materials or Mechanical Engineering Cathodic protection technician is a designated occupation in Alberta offering training and certification through Valid driver's license + clean abstract National Association of Corrosion Engineers (NACE) certification • Cathodic Protection Tester	• Install, commission, energize, monitor, evaluate, maintain, repair and decommission cathodic protection systems used to stop or slow corrosion • Install test equipment and perform advanced field tests to assess effectiveness of the cathodic protection system • Adjust cathodic protection systems as required to optimize cathodic protection effectiveness • Keep up-to-date with changes in technology, regulations, codes and standards	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of cathodic protection equipment and techniques effective to protect against hydrogen corrosion/embrittlement	Existing workforce trained to conduct inspections taking hydrogen properties and characteristics into account Certifying body(ies) may need to upgrade existing certifications and/or develop new ones for hydrogen

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Coating inspector	Combination of education, experience and certification Certification of Qualification: Painter National Association of Corrosion Engineers (NACE) certification • Coating Inspector Society for Protective Coatings (SSPC) certification • Protective Coatings Inspector (NACE & SSPC have recently amalgamated under Association for Materials Protection and Performance (AMPP))	• Inspection, Measurement, and Monitoring (IMM) of coating activities to ensure in-process applications are followed accurately • Ensure that environmental conditions are suitable for coating application • Verify substrate cleanliness and surface profile preparation • Ensure consistent verification of coating product batch number, temperature, and mixing practices • Verify coating application technique and wet film thickness • Verify dry film thickness, coating cure, and coating hardness • Verify holiday detection equipment and activities • Perform visual coating inspection, and oversee coating quality control practice • Keep up-to-date with changes in technology, regulations, codes and standards	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of coatings effective for protecting equipment, piping, pipelines, etc. used for hydrogen against corrosion/embrittlement and their correct application	Existing workforce trained to conduct inspections taking hydrogen properties and characteristics into account Certifying body(ies) may need to upgrade existing certifications and/or develop new ones for hydrogen

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Construction inspector	*Multiple pathways to this career:* • Bachelor's Degree: Civil or Mechanical Engineering • Engineering Technologist Diploma: Civil or Mechanical Valid driver's license + clean abstract	• Conduct inspections and ongoing monitoring throughout construction of new infrastructure to ensure conformance with plans, specifications, codes and regulations • Witness acceptance testing, compliance testing and material testing	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Understanding of acceptance, compliance and materials testing required for hydrogen infrastructure • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Existing workforce trained to conduct inspections taking hydrogen properties and characteristics into account
Corrosion specialist	Combination of education, experience and certification *Multiple pathways to this career:* • Bachelor's Degree: Materials or Mechanical Engineering • Engineering Technologist Diploma: Materials/Metallurgical, Mechanical National Association of Corrosion Engineers (NACE) certification Valid driver's license + clean abstract	• Apply knowledge of engineering principles and corrosion theory to hydrogen projects • Inspect, maintain and trouble-shoot equipment, facilities and pipelines • Provide input into methodology, and integrity procedures, practices and technologies including cathodic protection equipment and systems and corrosion control systems • Apply corrosion prediction models to assess corrosion/embrittlement rates	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Materials, coatings and inhibitors to use and correct application to protect from hydrogen corrosion • Practices, technologies, equipment and systems to control hydrogen corrosion/embrittlement • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Existing workforce trained to conduct inspections taking hydrogen properties and characteristics into account Certifying body(ies) may need to upgrade existing certifications and/or develop new ones for hydrogen

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
In-service pressure equipment inspector	Combination of education, experience and certification • Provincially regulated occupation *Multiple pathways to this career:* • Bachelor's Degree: Materials, Mechanical, Metallurgical, Welding Engineering • Certificate of Qualification: Power Engineer or Stationary Engineer • Engineering Technologist Diploma: Materials/Metallurgical, Mechanical or Welding Additional relevant certifications from: • American Petroleum Institute (API) • American Society of Mechanical Engineers (ASME) • American Society for Nondestructive Testing (ASNT) • National NDT Certification Body (NDTCB) Valid driver's license + clean abstract	• Conduct integrity assessments of in-service pressure equipment that contain expansible fluid under pressure including boilers, pressure coil, thermal liquid heating systems, pressure vessels and tanks, pressure piping systems and fittings • Inspect and certify in-service pressure equipment and any repairs done as required by codes and standards • Conduct incident investigations that are caused by or affect in-service pressure equipment • Keep up-to-date with changes in technology, regulations, codes and standards	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Assess integrity of vessels, tanks, piping systems and fitting, valves and seals to withstand hydrogen pressure and temperatures • Assess strength and integrity of welds to withstand hydrogen pressure and temperatures • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Existing workforce trained to conduct inspections taking hydrogen properties and characteristics into account Certifying body(ies) may need to upgrade existing certifications and/or develop new ones for hydrogen

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Non-destructive (NDE) inspector and technician	Combination of education, experience and certification *Multiple pathways to this career:* • Bachelor's Degree: Materials or Mechanical Engineering • Engineering Technologist Diploma: Materials/Metallurgical, Mechanical Additional relevant certifications from: • American Petroleum Institute (API) • American Society of Mechanical Engineers (ASME) • American Society for Nondestructive Testing (ASNT) • Association for Materials Protection and Performance (AMPP)/National Association of Corrosion Engineers (NACE) • National NDT Certification Body (NDTCB) Valid driver's license + clean abstract	• Conduct tests that provide information about the condition of materials and components without destroying them • Set up and calibrate testing equipment • Apply testing techniques such as: Magnetic particle inspection (MPI), Liquid penetrant inspection (LPI), Radiography testing (RT), Ultrasonic testing (UT), Eddy current testing (ET), acoustic emission, vibration analysis, infrared thermography and laser shearography • Devise ways to examine objects that could include use of advanced computer systems, drone, and robotic systems to capture and analyze data in difficult areas, etc.	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Assess integrity of vessels, tanks, piping systems and fitting, valves and seals to withstand hydrogen pressure and temperatures • Assess strength and integrity of welds to withstand hydrogen pressure and temperatures • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Existing workforce trained to conduct inspections taking hydrogen properties and characteristics into account Certifying body(ies) may need to upgrade existing certifications and/or develop new ones for hydrogen

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Safety codes inspector Also known as: • Safety codes officer	Combination of education, technical experience and certification • Provincially regulated occupation *Multiple pathways to this career:* • Bachelor's Degree in Engineering • Engineering Technologist Diploma • Certificate of Qualification: Trades • Certificate of Qualification: Power Engineer or Stationary Engineer Subject to certification requirements established through provincial regulatory agency Valid driver's license + clean abstract	• Enforce safety codes and regulations by • examining plans, specifications and related technical documents and conducting inspections to ensure conformance • Conduct field inspections, investigate complaints, liaise with contractors and regarding permit status and infractions/deficiencies • interpret technical reports • Prepare and submit detailed inspection reports on all site inspections • Interpret and enforce regulations impartially and tactfully communicate with stakeholders	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Advanced knowledge of legislation relating to hydrogen safety codes and standards • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes and assess impact to safety requirements	Existing workforce trained to conduct safety code inspections taking hydrogen properties, behaviour, potential hazards, regulations, codes and standards into account Certifying body(ies) may need to upgrade existing certifications and/or develop new ones for hydrogen

Roles Common Across the Hydrogen Value Chains: Core Occupations *cont'd*

Core Occupation	Typical Qualifications (min)	Key Activities	Unique Requirements for Hydrogen	Potential Talent Risk/Opportunity
Welding inspector	Combination of education, experience and certification *Multiple pathways to this career:* • Certification of Qualification: Welder • Bachelor's Degree: Materials or Mechanical Engineering • Technologist Diploma: Materials Engineering, Mechanical Engineering Canadian Welding Bureau (CWB) certification for Welding Inspectors Valid driver's license + clean abstract	• Review welding procedures against related standards, codes, and drawings • Monitor and examine work performed by tackers, welding operators or welders • Verify that the specified base metal and welding materials are used properly and maintained in good condition • Verify that joint preparation and fit-up meet requirements • Examine and evaluate welds • Keep up-to-date with changes in technology, regulations, codes and standards	• Hydrogen properties, behaviour and potential hazards created • Safety when working with or around hydrogen • Welding procedures and techniques appropriate for hydrogen • Assess strength and integrity of welds to withstand hydrogen pressure and temperatures • Knowledge of hydrogen related regulations, standards and codes • Keep up-to-date with changes to hydrogen technology, regulations, standards and codes	Existing workforce trained to conduct safety code inspections taking hydrogen properties, behaviour, potential hazards, regulations, codes and standards into account Certifying body(ies) may need to upgrade existing certifications and/or develop new ones for hydrogen

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