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1 Introduction

This deliverable will aim to compile a 'Glossary of Terms' to clearly define terminology often used in educational institutions and FCH technologies relevant to the project. Also, this document will help to establish important terms associated with FCH technologies in countries where this subject is relatively new and an emerging field.

2 Glossary of education terms

Academia: a term that refers to the scientific and cultural community involved in novel research and higher education.

Academic degree: a qualification awarded after successfully completing a programme of study/course at a higher education institution such as a university.

Academic institution: a higher education institute that also engages in novel research and awards academic degrees.

Active learning: a learning process whereby the students actively engage in activities such as reading, writing, classroom discussion, problem solving, etc.

Aims and objectives: the aims outline the purpose of a programme of study/course and objectives states the knowledge or skills the students are expected to attain upon successful completion of a module or course.

Assessment: a tool used to measure the knowledge and/or skills learnt by a student after completing a module or course.

Asynchronous learning: a method for delivering teaching material using online computer technology whereby the student covers the course content at a time convenient to them.

Autodidactism: the process of self-education driven by the students' self-motivation and initiative to learn independently.

Blended learning: a process that involves a combination of delivery methods ranging from classroom-based teaching to distance learning online.

Computer based learning: a method for delivering teaching material using computer-based technology.

Course: a programme of study on a specific subject that leads to a degree or diploma upon successful completion.

Critical pedagogy: a teaching method that encourages students to question and challenge various subject matters, ideologies and practices.

Critical thinking: the process of evaluating information and knowledge by scrutinising their accuracy, clarity, precision, bias and reliability.

Curriculum: a selection of courses and their contents offered by an institution such as a university.

Distance learning: a learning concept focusing on the use of pedagogy and technology for the delivery of course material to students that are not physically present in the classroom.

Education: a social science that involves the teaching and learning of certain knowledge and skills.

E-learning: a delivery and learning approach via computer and online technology using electronic devices such as PCs, laptops and mobile phones. Furthermore, communication technology can enable learning through the internet, email, discussion forums, video-sharing websites, etc.

Higher education: education delivered by universities that award academic degrees.

Knowledge: information acquired by an individual and also a high level of understanding of a subject.

Learning: the acquisition of knowledge, skills and beliefs through study, experience and/or teaching.

Learning management system: a software application designed for the administration, documentation, monitoring, reporting and delivery of educational courses.

Learning outcome: a set of knowledge and skills acquired by a student upon successful completion of a module/course.

Lecture: a teaching method commonly adopted by higher education institutions for conveying knowledge to students in the form of an oral presentation. In this context, students experience passive learning.

Module: is a distinct section of a course. A series of modules can form a course similar to chapters in a book.

Passive learning: a process of learning whereby the students receive information and knowledge from a teacher often in the form of a lecture.

Pedagogy: the theory and practice of teaching.

Postgraduate education: is the fourth level of education and is achieved upon the successful completion of a postgraduate course, typically a master's course.

Problem-based learning: a learning process whereby students collaborate in small groups to solve a problem with the aim of developing communication, teamworking and critical thinking skills.

Professional certification: a qualification awarded by a professional body to an individual to certify that they possess the knowledge and skills necessary to perform a job.

Quiz: a form of assessment whereby students are presented with a series of short-answer questions to complete.

Research: a systematic process of inquiry and investigation for the purpose of achieving new knowledge as well as interpretation of new information and revision of facts.

Rote learning: a learning process that focuses more on memorising teaching material and less on deep comprehension of a subject.

School: a place designed specifically for learning.

STEM: science, technology, engineering and mathematics.

Student: an individual who attends a school, college, university or any other learning institute for the purpose of acquiring an education.

Syllabus: documentation that describes and summaries topics covered in a course.

Teacher: an individual who imparts knowledge and skills onto students.

Tertiary education: education offered at an institution such as a college or university following secondary education. Tertiary education can also include vocational education and training.

Technician: an individual working in a technological field who is highly competent and skilled in their profession.

Textbook: is a book considered the standard and authority for certain subjects and often contains the latest information.

Tuition: teaching, instruction or fees charged for receiving an education at an institute.

Virtual learning environment: is a software designed to enable teachers to administrate and manage courses online and is often used in conjunction with distance learning and classroom-based teaching.

Vocational education: is a type of education designed to prepare individuals for careers in a trade, craft or technical profession as a technician.

Workshop: a short intensive course, seminar or meeting designed for the purpose of transferring knowledge.

3 Glossary of FCH technology terms

Acceptance criteria (for risk or harm): acceptable level of risk or harm, locally defined as a tolerable risk value, a specified harm level, or requirements in a prescriptive document.

Accident: is an unforeseen and unplanned event or circumstance causing loss or injury.

Activation losses: energy losses due to slow reaction kinetics occurring at the fuel cell electrode surface.

Adsorption: is the process whereby a gas or liquid solute physically adheres to the surface of an adsorbent (solid or liquid) typically via Van der Waals interaction.

Alkali anion exchange membrane: is a semipermeable membrane composed of ionomers capable of conducting anions whilst being impermeable to hydrogen and oxygen gas.

Alkaline fuel cell (AFC): a type of fuel cell that uses an electrolyte based on a strong alkali such as sodium or potassium hydroxide. In this type of fuel cell, H_2 and hydroxide ions (OH^-) from the electrolyte react to form H_2O and in the process release electrons into the external circuit. At the cathode, O_2 and H_2O combine with electrons from the external circuit to produce the OH^- ions.

Alloy: a solid solution of two or more elements whereby at least one of the constituents is a metal.

Alternating current (AC): electric current that periodically reverses its direction of flow.

Ambient air: surrounding air in a closed system.

Ambient temperature: surrounding temperature in a closed system.

Anion: a negatively charged ion.

Anode: is an electrode whereby the flow of electrical current is directed towards an electrical load or device.

Atmospheric pressure: is the pressure of the atmosphere at a given altitude.

Auto-ignition temperature: is the minimum temperature required to initiate a combustion reaction of a fuel-oxidant mixture in the absence of an external source of ignition.

Autothermal reforming (ATR): a hydrogen production process involving the reaction of O_2 and CO_2 or H_2O with CH_4 to produce synthesis gas.

Auxiliary power unit (APU): a device that generates power onboard a vehicle for purposes other than propulsion.

Back pressure: is the pressure exerted on a fluid by obstructions in a conduit that opposes the direction of flow.

Balance of plant (BOP): all equipment and devices, not including the fuel cell, that make up the infrastructure and are essential for operation.

Biofuel: is a fuel sourced from recently deceased biological matter and is distinct from a fossil fuel which is derived from biological matter that died long ago.

Biogas: is a gas produced from the decomposition of biological matter in the absence of O_2.

Bioreactor: is a device or system that facilitates biological reactions and processes.

Bipolar plate: is a component of a fuel cell stack that is an electrically conductive plate which serves as an anode in one cell and a cathode in the neighbouring cell.

Boiling point: is the temperature at which a fuel must be cooled in order to store and use it as a liquid. The *normal boiling point* (NBP) of a liquid is when the vapour pressure of the liquid equals the defined atmospheric pressure at sea level (1 atmosphere or 101,325 Pa). The *standard boiling point* (SBP) is defined as the temperature at which boiling occurs under a pressure of 1 bar (100,000 Pa).

Capital cost: a one-time fixed cost incurred for the purchase of land, buildings, various equipment as well as cost of construction necessary to enable the production of goods or provision of services.

Carbon black: is a substance produced as a result of the incomplete combustion of various tars.

Catalysis: is the process of increasing the rate of reaction for a process through the use of a catalyst.

Catalyst: is a substance used to increase the rate of a reaction without undergoing a chemical change itself.

Catalyst layer: a layer of catalyst on the fuel cell electrodes responsible for the electrochemical reactions.

Catalyst poisoning: is the deactivation of a catalyst preventing it from increasing the rate of a reaction.

Catalytic partial oxidation (CPOX): is the use of a catalyst during partial oxidation in order to reduce the reaction temperature.

Cathode: is an electrode whereby the flow of electrical current is received from an electrical load or device.

Cation: is a positively charged ion.

Ceramic: is a solid, inorganic, non-metallic material containing metal, non-metal or metalloid atoms.

Cermet: is a composite material comprised of both ceramic and metal.

Chemical thermodynamics: the mathematical study of the relationship between heat and work with chemical processes as well as physical changes in states of matter within a closed system.

Circuit: is a closed system made up of various conductors and electronic components through which electrical current can flow.

Cogeneration: also known as combined heat and power (CHP), is the use of process heat generated from the production of electrical energy.

Combustion: an exothermic chemical reaction involving a fuel, oxidant and heat.

Combustion chamber: is the region inside an engine where fuel combustion takes place.

Compressed hydrogen: hydrogen gas compressed to high pressures of around 35 to 70 MPa.

Compressed natural gas: natural gas compressed to high pressures of around 20 to 25 MPa.

Concentration: the number of moles of a solute dissolved in a certain volume of solvent.

Cryogenic liquefaction: a process that involves converting a gas, such as H_2, to the liquid state under pressure and extremely low temperatures.

Current collector: is fuel cell stack component that collects electrons on the anode side and releases them on the cathode side and is located between the fuel cell electrodes and bipolar plates.

Current density: is the quantity of electrical current passing through a material per unit cross-sectional area.

DC to DC converter: is a circuit that converts a supply of direct current from one voltage to another.

Deflagration: the combustion of a substance producing a reaction wave which propagates at a velocity that is less than the speed of sound.

Density: is the mass per unit volume of a substance.

Detonation: the combustion of a substance producing a reaction wave which propagates at a velocity that is greater than the speed of sound.

Diffusion: the movement of atoms/molecules from a region of high concentration to low concentration. The driving force for this phenomenon is the concentration gradient of the diffusing specie.

Direct borohydride fuel cell (DBFC): a type of alkaline fuel cell that is directly fuelled with either sodium borohydride or potassium borohydride.

Direct carbon fuel cell (DCFC): a type of fuel cell that uses either biomass or coal as fuel.

Direct current: is the flow of electrical current in one direction.

Direct ethanol fuel cell (DEFC): a type of polymer electrolyte fuel cell that is directly fuelled with ethanol.

Direct methanol fuel cell (DMFC): a type of polymer electrolyte fuel cell that is directly fuelled with methanol.

Distributed generation: the concept of generating power from many small-scale power generators.

Electrical conductivity: is the measure of the ability of a material to conduct an electrical current.

Electrical efficiency: is the ratio of power output to power consumption for an electrical device expressed as a percentage.

Electrical insulator: is a material with extremely poor electrical conductivity that resists the flow of an electrical current.

Electrical resistance: is the measure of the ability of a material to resist the flow of an electrical current.

Electrical current: is the flow of electrons through an electrically conductive material.

Electricity generation: the conversion of non-electrical energy into electrical energy.

Electrochemistry: a branch of chemistry concerning chemical reactions and electron transfer occurring at the interface between an electrode (electron conductor) and electrolyte (ionic conductor).

Electrochemical cell: a device that converts chemical energy into electrical energy.

Electrode: is an electrical conductor that is typically in contact with non-metallic components in a circuit.

Electrolysis: a technique that uses an electrical current to decompose a chemically bonded compound.

Electrolyte: is a substance that contains freely moving ions which can move under a potential difference.

Electron: is considered a fundamental subatomic particle that is negatively charged.

Endothermic: a process or reaction that requires heat energy in order to proceed.

Energy: the ability of a system to do work.

Energy carrier: a substance containing energy that can be converted to other forms such as heat, mechanical, etc.

Engine: a device that converts heat energy into mechanical energy.

Energy density: energy present within a substance or system per unit volume or mass.

Enthalpy: is a measure of heat content of a system under constant pressure and entropy.

Enthalpy of vaporisation: is the heat necessary to convert a given amount of a substance in the liquid phase into the gas phase.

Ethanol: a volatile, flammable and colourless alcohol.

Evaporation: the process whereby a liquid is converted to a gas.

Equivalence ratio: is the ratio of the fuel-to-oxidant ratio to the stoichiometric fuel-to-oxidant ratio.

Exhaust gas: product gases from a process or reaction such as combustion of fossil fuels which is released into the atmosphere.

Exothermic: a process or reaction that releases energy into the surrounding system.

Fire-resistance rating: is a measure of time for which a passive fire protection system can withstand a standard fire resistance test.

Flammability: the measure of a substance's ability to ignite resulting in combustion.

Flammability limit: comprises the lower flammability limit (LFL) and upper flammability limit (UFL) between which a combustible gas mixture is flammable.

Flammability range: is the range of concentrations between the lower and the upper flammability limits. The LFL is the lowest concentration of a combustible substance in a gaseous oxidant that will propagate a flame. The UFL is the highest concentration of a combustible substance in a gaseous oxidant that will propagate a flame.

Flash point: is the minimum temperature over which a flammable substance can be ignited in air.

Flue: is a duct or pipe that conveys flue gas from a process to the outside atmosphere.

Flue gas: is exhaust gas escaping to the atmosphere via a flue.

Fluid dynamics: a sub-discipline of fluid mechanics that involves flow of fluids such as liquids and gases.

Fluid mechanics: is the study of fluid motion under the influence of forces.

Flux: is the quantity of atoms flowing through a unit of area per unit of time.

Formic acid: is a carboxylic acid with the chemical formula, CH_2O_2.

Formic acid fuel cell: is a type of polymer electrolyte fuel cell that is directly fuelled with formic acid.

Fossil fuel: is a hydrocarbon formed over millions of years from dead organic matter that has been exposed to extreme heat and pressure in the earth's crust.

Fuel: is a substance that can be combusted or chemically changed to release energy.

Fuel cell: an electrochemical device that requires an external fuel supply to convert chemical energy into electrical energy.

Fuel cell electric vehicle (FCEV): a vehicle that uses a rechargeable battery that supplies electrical energy for propulsion. The battery can be recharged with an on-board fuel cell.

Fuel processor: a device that produces hydrogen from other fuels like propane and ethanol for use in fuel cells.

Gadolinium doped ceria (GDC): an electrolyte material used in SOFCs

Gas compressor: a mechanical device that can increase the pressure of a gas by decreasing its volume.

Gas diffusion: the movement of gas atoms/molecules from a region of high concentration to a region of low concentration.

Gas diffusion electrode (GDE): is a fuel cell component that facilitates the electrochemical reactions and is located at the interface between the solid, liquid and gas phase as well as the catalyst layer.

Gas diffusion layer (GDL): is a porous material composed of dense carbon fibres which provides electrical contact between the bipolar plates and electrodes as well as facilitate contact between the gases and catalyst layer.

Gasification: is a process that involves a reaction between a carbonaceous material, such as biomass, with O_2 and/or steam to produce CO and H_2.

Gravimetric energy density: is the energy content of a fuel per unit mass.

Gibbs free energy: is a thermodynamic term that describes the amount of energy in a system to do work.

Graphite: is an allotrope of carbon like diamond and fullerene.

Greenhouse effect: the effect of greenhouse gases trapping and reflecting solar radiation back to the earth's surface.

Greenhouse gases: gases such as CH_4, CO_2 and H_2O, that trap and reflect solar radiation back to the earth's surface.

Half-reaction: describes either the oxidation or reduction process in a redox reaction.

Harm: is physical injury or damage to the health of people, damage to property or the environment.

Hazard: potential source of harm.

Hazard distance: is a distance from the (source of) hazard to a determined (by physical or numerical modelling, or by a regulation) physical effect value (normally, thermal or pressure) that may lead to a harm condition (ranging from "no harm" to "maximum harm") to people, equipment or environment.

Hazardous area (on account of explosive gas atmospheres): an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment.

Heat exchanger: a device that transfers heat from one medium to another.

Heat transfer: the transfer of heat from a hot body to a cold body.

Heating value: is the heat generated upon the combustion of a substance with oxygen.

Heat of combustion: see 'Heating value'.

High temperature shift (HTS): the portion of the water gas shift reaction occurring at 350 °C in the presence of a nickel catalyst.

Higher heating value: is the amount of heat produced upon combustion of a given quantity of fuel (originally at 25 °C) and includes the latent heat of vaporisation.

Hybrid electric vehicle (HEV): is a vehicle that utilises conventional propulsion with a rechargeable energy storage system.

Hydride: is a hydrogen ion with a negative charge, H^-.

Hydrocarbon: is an organic compound made up primarily of hydrogen and carbon atoms.

Hydrogen: is the lightest chemical element on the periodic table with an atomic mass of 1 and chemical symbol, H.

Hydrogen safety engineering (HSE): is application of scientific and engineering principles to the protection of life, property and environment from adverse effects of incidents/accidents involving hydrogen.

Incident: is something that occurs in connection with something else.

Indirect methanol fuel cell (IMFC): a type of polymer electrolyte fuel cell where the methanol feed is reformed prior to being fed to the anode.

Internal combustion engine: is a device where combustion of a fuel and an oxidant occur to convert the stored chemical energy within the fuel into mechanical energy.

Inverter: a device that converts DC into AC.

Ion: a positively or negatively charged atom or molecule.

Kilowatt: a unit of electrical power.

Kilowatt-hour: a unit of energy.

Laminar burning velocity: is the rate of flame propagation relative to the velocity of the unburned gas that is ahead of it under stated conditions of composition, temperature, and pressure of the unburned gas.

Limiting oxygen index: is the minimum concentration of oxygen that will support flame propagation in a mixture of fuel, air and nitrogen.

Life cycle analysis (LCA): the analysis of the environmental impact of a product or service over its entire lifetime.

Liquified natural gas (LNG): is natural gas stored in the liquid phase.

Liquified petroleum gas (LPG): a mixture of hydrocarbons, such as propane and butane, stored in the liquid phase.

Liquefaction: the process of turning a substance into the liquid phase.

Lower flammability limit (LFL): is the minimum concentration of a flammable substance and air mixture capable of igniting at a specific temperature and pressure.

Lower heating value (LHV): is the amount of heat produced upon combustion of a given quantity of fuel (originally at 25 °C) not including the latent heat of vaporisation.

Low temperature shift (LTS): the portion of the water gas shift reaction occurring between 190 and 210 °C in the presence of a nickel catalyst.

Mach disk: is a strong shock normal to the under-expanded jet flow direction.

Maximum experimental safe gap (MESG): is the lowest value of the safe gap of flammable gases and vapours measured according to IEC 60079-1-1 (2002) by varying the mixture composition. The safe gap is the gap width (determined with a gap length of 25 mm) at which in the case of a given mixture composition, a flashback just fails to occur.

Membrane electrode assembly (MEA): is the heart of the PEFC consisting of the proton exchange membrane (PEM) which has the anode and gas diffusion layer (GDL) positioned on one side and the cathode and another GDL positioned on the other side.

Methanation: is the process of reacting CO or CO_2 with H_2 to produce CH_4.

Methane reformer: a device containing a catalyst for the purpose of converting CH_4 into H_2.

Microbial fuel cell: a type of fuel cell that utilises microorganisms to convert chemical energy into electrical energy.

Minimum ignition energy (MIE): for flammable gases and vapours is the minimum value of the electric energy, stored in the discharge circuit with as small a loss in the leads as possible, which (upon discharge across a spark gap) just ignites the quiescent mixture in the most ignitable composition. For a given mixture composition, the following parameters of the discharge circuit must be varied to achieve the optimum conditions: capacitance, inductivity, charging voltage, as well as shape and dimensions of the electrodes and the distance between electrodes.

Molten carbonate fuel cell (MCFC): is a type of high temperature fuel cell operating above 600 °C and utilises a molten carbonate electrolyte.

Nafion: is a proton conducting polymer used as an electrolyte material in a PEFC.

Natural gas: is a fossil fuel which is a gas mixture mostly composed of CH_4 and other hydrocarbons and gases.

Nernst equation: is used to determine the equilibrium reduction potential of a half-cell in an electrochemical cell.

Normal Temperature and Pressure (NTP): 293.15 K and 101.325 kPa.

Open circuit voltage (OCV): is the potential difference between two electrodes of an electrochemical cell when no current is drawn by an electrical load.

Overpotential: is the potential difference between the theoretically determined potential at which the half-reaction is expected to occur and the observed potential at which the electrochemical reaction actually occurs.

Oxidant: is a chemical compound that readily losses oxygen atoms or a substance that readily gains electrons during a redox reaction.

Partial oxidation (POX): is a substoichiometric combustion reaction occurring between a fuel and an oxidant.

Partial pressure: represents the individual pressure of a constituent gas of an ideal gas mixture occupying a given volume.

Parts per million (ppm): is a unit of concentration for a substance in a mixture.

Permeation: is the transport of a fluid through a dense or porous medium.

Phosphoric acid fuel cell (PAFC): is a type of fuel cell operating between 150 and 210 °C and utilises phosphoric acid as an electrolyte.

Polymer electrolyte membrane (PEM): is a polymeric proton conducting membrane used as an electrolyte material in a PEFC.

Polymer electrolyte fuel cell (PEFC): is a type of low temperature fuel cell operating below 100 °C and utilises a PEM electrolyte.

Pressure swing adsorption (PSA): is a technique for separating certain gas components from a gas mixture under pressure according to their molecular weight and affinity for an adsorbent material.

Proton: is a subatomic particle with a positive charge often denoted as, H^+.

Quenching distance: is the maximum distance between two parallel plates that will extinguish a flame passing between them.

Quenching gap: is the spark gap between two flat parallel-plate electrodes at which ignition of combustible fuel-air mixtures is suppressed. The quenching gap is the passage gap dimension requirement to prevent propagation of an open flame through a flammable fuel-air mixture that fills the passage.

Reactor: is a specially designed vessel where chemical reactions and processes take place.

Reagent: is a reactant such as a chemical compound that is consumed in a chemical reaction.

Rectifier: a device that converts AC into DC.

Redox: a chemical reaction where the oxidation number of the reactants change.

Reformate: is a hydrocarbon-based fuel that has been converted into H_2 and other products for use in a fuel cell.

Renewable energy: is a natural renewable source of energy such as sunlight, wind, tidal, etc.

Reversible fuel cell (RFC): is a fuel cell that can be run in reverse mode as an electrolyser.

Reynolds number: is the ratio of inertial forces to viscous forces for a fluid in motion.

Risk: is the combination of the probability of an event and its consequence.

Safety: freedom from unacceptable risk.

Safety distance: distance to acceptable risk level or minimum risk-informed distance between a hazard source and a target (human, equipment or environment), which will mitigate the effect of a likely foreseeable incident and prevent a minor incident escalating into a larger incident.

Scrubber: is a device used for removing certain gases or particles from an exhaust stream.

Short circuit: is an electrical circuit where the current flows through an unintended path with little to no electrical impedance.

Sodium borohydride: is a chemical compound with the chemical formula, $NaBH_4$.

Solid oxide electrolyser cell (SOEC): is a solid oxide fuel cell run in reserve mode to convert water back to H_2 and O_2 using a solid oxide ceramic electrolyte.

Solid oxide fuel cell (SOFC): is a high temperature fuel cell operating between 500 and 1,000 °C and utilises a solid oxide ceramic as an electrolyte.

Solubility: the ability of a solute to dissolve in a solvent.

Sorbent: is a material capable of adsorbing liquids and gases.

Sorption: is the process of absorption or adsorption.

Specific gravity: is the ratio of the density of a substance to the density of a reference substance, both at the same temperature and pressure.

Stack: is an array of cells connected either in series to produce a higher voltage or parallel to produce a higher current output.

Steady state: the behaviour of a system that is expected to be the same in the future.

Steam methane reforming (SMR): the conversion of CH_4 and H_2O into H_2 and CO between 700 and 1,100 °C in the presence of nickel.

Sublimation: is the change directly from solid to vapour or vice versa without going through the liquid phase.

Synthesis gas (syngas): a gas mixture mainly consisting of H_2 and CO.

Tafel equation: an equation that describes the relationship between the electrochemical reaction rate and overpotential.

Triple phase boundary (TPB): is a contact interface between a solid, liquid and gas.

Under-expanded jet: is a jet with a pressure at the nozzle exit which is above atmospheric pressure.

Uninterruptible power supply (UPS): is a device that provides continuous power that is separate from the grid supply.

Vapour pressure: is the pressure of a substance in the vapour phase that is in equilibrium with its non-vapour phase.

Volumetric energy density: is the energy content of a fuel per unit volume.

Water gas shift reaction (WGS): is a process where CO reacts with H_2O to produce CO_2 and H_2.

Yttria stabilised zirconia (YSZ): an oxide conducting ceramic often used as an electrolyte material in SOFCs.