MCMC MTSFB TC TXXX:2021

TECHNICAL CODE

DEPLOYMENT OF STATIONARY FUEL CELL AS A BACKUP POWER SOLUTION FOR THE TELECOMMUNICATION SITES

Developed by

Malaysian Technical Standards Forum Bhd

Registered by

MCMC

Registered date:

MCMC MTSFB TC TXXX:2021

Development of technical codes

The Communications and Multimedia Act 1998 ('the Act') provides for Technical Standards Forum designated under section 184 of the Act or the Malaysian Communications and Multimedia Commission ('the Commission') to prepare a technical code. The technical code prepared pursuant to section 185 of the Act shall consist of, at least, the requirement for network interoperability and the promotion of safety of network facilities.

Section 96 of the Act also provides for the Commission to determine a technical code in accordance with section 55 of the Act if the technical code is not developed under an applicable provision of the Act and it is unlikely to be developed by the Technical Standards Forum within a reasonable time.

In exercise of the power conferred by section 184 of the Act, the Commission has designated the Malaysian Technical Standards Forum Bhd ('MTSFB') as a Technical Standards Forum which is obligated, among others, to prepare the technical code under section 185 of the Act.

A technical code prepared in accordance with section 185 shall not be effective until it is registered by the Commission pursuant to section 95 of the Act.

For further information on the technical code, please contact:

Malaysian Communications and Multimedia Commission (MCMC)
MCMC Tower 1
Jalan Impact
Cyber 6
63000 Cyberjaya
Selangor Darul Ehsan
MALAYSIA

Tel: +60 3 8688 8000
Fax: +60 3 8688 1000
http://www.mcmc.gov.my

OR

Malaysian Technical Standards Forum Bhd (MTSFB)
MCMC Centre of Excellence (CoE)
Off Persiaran Multimedia
Jalan Impact
Cyber 6
63000 Cyberjaya
Selangor Darul Ehsan
MALAYSIA

Tel: +60 3 8320 0300
Fax: +60 3 8322 0115
http://www.mtsfb.org.my

CONTENTS

Page

Committee representation iii
Foreword iv

0. Introduction 1
1. Scope 1
2. Normative references 1
3. Abbreviations 2
4. Terms and definitions 2
   4.1 Authorised person 2
   4.2 Buoyancy 3
   4.3 Building owner 3
   4.4 Combustible materials 3
   4.5 Combustion 3
   4.6 Competent person 3
   4.7 Component 3
   4.8 Control devices 3
   4.9 Danger zones 3
   4.10 Electrical equipment 3
   4.11 Emergency 3
   4.12 Explosion 3
   4.13 Explosive atmosphere 3
   4.14 External temperature 4
   4.15 Facility 4
   4.16 Fire 4
   4.17 Fire barriers 4
   4.18 Flame 4
   4.19 Flammable gases 4
   4.20 Flammability 4
   4.21 Flue gas venting 4
   4.22 Fuel cell 4
   4.23 Fuel cell system 4
   4.24 Hazard 4
   4.25 Ignite 4
   4.26 Indoor installations 5
   4.27 Local authorities 5
   4.28 Lower flammability limits 5
   4.29 Machinery 5
   4.30 Manufacturer 5
   4.31 Operator 5
   4.32 Outdoor installation 5
   4.33 Pipeline 5
   4.34 Purge 6

4.35 Refilling mode 6
4.36 Replacement mode 6
4.37 Risk 6
5. General configuration of the stationary fuel cell system..6
5.1 Basic schematic diagram of the stationary fuel cell system for telecommunication site 6
6. Installation and site considerations 7
6.1 General requirement 7
6.2 Installation of fuel cell system 10
6.3 Site considerations..13
7. Operational/Maintenance Considerations 16
7.1 Equipment maintenance 17
7.2 Access to operating positions and servicing points 17
7.3 Isolation of energy sources 17
7.4 Operator intervention 17
7.5 Emergency planning 17
8. Marking, labelling and packaging..18
9. Permitting Route..19
9.1 General permitting checklist..19
9.2 Permitting processes..20

Annex A Comparison of Fuel Attributes..22
Annex B Steps of Risk Assessment 25
Annex C Codes and standards for hydrogen..27
Bibliography 31

Committee representation

The technical code was developed by Hydrogen Sub Working Group supervised by Green ICT, Environment and Climate Change Working Group under the Malaysian Technical Standards Forum Bhd (MTSFB), constituted by representatives from the following organisations:

Celcom Axiata Berhad

Duriane Professionals Sdn Bhd

edotco Malaysia Sdn Bhd

Shan Poornam Metals Sdn Bhd

Sustainable Energy Development Authority (SEDA)

UCSI University

Universiti Kebangsaan Malaysia

Universiti Teknologi MARA

Universiti Teknologi PETRONAS

Universiti Tun Hussein Onn Malaysia

Telekom Malaysia Bhd

Foreword

This technical code for Deployment of Stationary Fuel Cell as a Backup Power Solution for the Telecommunication Sites ('this Technical Code') was developed pursuant to section 185 of the Act 588 by the Malaysian Technical Standards Forum Bhd ('MTSFB') via its Green ICT, Environment and Climate Change Working Group.

This Technical Code shall continue to be valid and effective from the date of its registration until it is replaced or revoked.

DEPLOYMENT OF STATIONARY FUEL CELL AS A BACKUP POWER SOLUTION FOR THE TELECOMMUNICATION SITES

0. Introduction

The telecommunications sector continues to grow rapidly in Malaysia with the increased demand of network coverage and highspeed internet in parallel with the number of cell phone users. In order to support the demands, this industry requires an increase in the number of telecommunication sites including the cell phone towers and site facilities.

To maintain the service reliability, the stakeholders rely on the backup power to prevent power outages and to ensure a constant power supply to the towers and related facilities. General regulation for the telecommunication sites worldwide required a minimum 8 hours power backup and a longer duration for disaster prone areas up to 72 hours. Besides the commonly used battery and diesel generator, fuel cell technology is also worth to be considered as a backup power device because it last longer and is more predictable.

This Technical Code is developed as a guide to facilitate the telecommunications industries who install the fuel cells onsite as a power backup unit as well as carry out decarbonisation exercises for their infrastructure system through the utilisation of hydrogen/renewable hydrocarbon fuel. The targeted users including manufacturers, engineers, installers, regulators, and maintenance workers.

1. Scope

This Technical Code describes guidance on the deployment of stationary fuel cell system as a backup power solution for the telecommunication sites.

This technical code will only cover the stationary fuel system in the aspects of:

a) general configuration;

b) installation and site considerations;

c) safety requirements;

d) maintenance; and

e) permitting route.

For the installation and site considerations, the input fuel used in the stationary fuel cell system is hydrogen, methanol, natural gas, and propane. It is based on the usage in the telecommunication applications worldwide.

The requirements for portable, propulsion and micro fuel cell system are not covered in this Technical Code.

2. Normative references

The following normative references are indispensable for the application of this Technical Code. For dated reference, only the edition cited applies. For undated references, the latest edition of the normative reference (including any amendments) applies.

IEC 62282-3-100, *Fuel cell technologies: Stationary fuel cell power systems – Safety*

MCMC MTSFB G023, *Hydrogen Storage and Safety with Fuel Cell as Power Generator for Information, Communications and Technology Infrastructure*

National Fire Protection Agency, NFPA 853: *Standard for the Installation of Stationary Fuel Cell Power Systems*
P.U. (A) 39/1996, Occupational Safety and Health Act 1994, Occupational Safety and Health (Control of Industrial Major Accident Hazards) Regulations 1996

P.U. (A) 310., Occupational Safety and Health Act 1994, Occupational Safety and Health (Classification, Labelling and Safety Data Sheet of Hazardous Chemicals) Regulations 2013

RR715 Research Report, Health and Safety Executive, Installation permitting guidance for hydrogen and fuel cell stationary applications: UK version

Telecommunications Industry Association USA Reference Guide – Regulations, Codes, and Standards for The Deployment of Stationary Fuel Cells

3. Abbreviations

For the purposes of this Technical Code, the following abbreviations apply.

ANSI	American National Standards Institute
AIAA	American Institute of Aeronautics and Astronautics
BS	British Standard
DOSH	Department of Occupational Safety and Health
IEC	International Electrotechnical Commission
IFC	International Fire Code
ISO	International Organisation for Standardisation
HSE	Health and Safety Executive
LOC	Limiting Oxygen Concentration
LPG	Liquefied Petroleum Gas
MS	Malaysian Standard
NIOSH	The National Institute for Occupational Safety and Health
NFPA	National Fire Protection Association
SDS	Safety Data Sheets

4. Terms and definitions

For the purposes of this Technical Code, the following terms and definitions apply.

4.1 Authorised person

A person who has been given permission or mandate for approval to undertake any task on behalf of the manufacturer.

4.2 Buoyancy

Vertical force exerted on a body of less dense gas by the surrounding heavier static gas, typically air.

4.3 Building owner

Individual, company, corporation, authority, government entity, or any entity that holds title to subject building.

4.4 Combustible materials

Item capable of combustion even though flame-proofed, fire-retardant treated, or plastered.

4.5 Combustion

Reaction process by which a flammable substance is oxidised, producing hot product gases, heat, radiation and possibly pressure waves.

4.6 Competent person

A person who has been certified by the authority body to be competent to supervise the operation of a fuel cell system.

4.7 Component

Any part of a complete item or system.

4.8 Control devices

Devices that can be worked with sensor existence.

4.9 Danger zones

An area that is high risk to cause harm or injuries.

4.10 Electrical equipment

General term including material, fittings, devices appliances, fixtures, apparatus and the like used as part of, or in connection with and electrical installation.

4.11 Emergency

Unintended circumstance, bearing clear and present danger to personnel or property, which requires an immediate response.

4.12 Explosion

Sudden outburst that causes injuries and damages to the overall system.

4.13 Explosive atmosphere

Having a dangerous mixture of substance(s) in the form of gases, vapour, mist or dust within the air under atmospheric conditions. During the occurrence of ignition, the combustion spreads to the entire unburned mixture and caused explosion.

4.14 External temperature

Temperature of outdoor of the building or fuel cell system.

4.15 Facility

Group of buildings or equipment used for specific operations at one geographic location.

4.16 Fire

Sustained burning of a fuel jet as manifested by any or all of the following such as light, flame, heat and smoke.

4.17 Fire barriers

Barrier in terms of door(s), interior floor, interior ceiling or interior wall(s) that extend and concealed spaces from outside or another area(s) or space(s) in which are designed to divide portions and impede fire over a designed period of time.

4.18 Flame

Zone of combustion of a gas or vapour from which light and heat are emitted.

4.19 Flammable gases

Flammable gas means a gas or gas mixture having a flammable range with air at 20 °C and a standard pressure of 101.3 kPa.

4.20 Flammability

Degree to which a material is ignitable in an oxidising atmosphere.

4.21 Flue gas venting

Any equipment(s) or tool(s) in such duct, pipe, or opening for conveying exhaust gases from indoor to the outdoor.

4.22 Fuel cell

Degree to which a material is ignitable in an oxidising atmosphere.

4.23 Fuel cell system

Generator system that uses a fuel cell module(s) to generate electric power and heat.

4.24 Hazard

A source or a situation with a potential for harm in terms of human injury or ill health, damage to property, damage to the environment or a combination of these.

4.25 Ignite

To cause to burn or to catch fire.

4.26 Indoor installations

The location where a fuel cell system is sited, whether as a unit or built as an assembly, which is completely surrounded and enclosed by walls, a roof and a floor.

4.27 Local authorities

Rural and town board and local, city, municipal, district and town councils, or other similar local authority established by any written law and includes an authority in charge of a federal territory established by any written law.

4.28 Lower flammability limits

The lowest percentage concentration at which a flash or flame can develop and propagate from the source of ignition when in contact with a source of ignition in a combustible material.

4.29 Machinery

Includes steam boilers, unfired pressure vessels, fired pressure vessels, pipelines, prime movers, gas cylinders, gas holders, hoisting machines and tackle, transmission machinery, driven machinery, materials handling equipment, amusement device or any other similar machinery and any equipment for the casting, cutting, welding or electro-deposition of materials and for the spraying by means of compressed gas or air of materials or other materials, but does not include:

a) any machinery used for the propulsion of vehicles other than steam boilers or steam engines;

b) any machinery driven by manual power other than hoisting machines;

c) any machinery used solely for private and domestic purposes; or

d) office machines.

4.30 Manufacturer

A person who designs, manufactures, imports or supplies any plant for use at work, or formulates, manufactures, imports or supplies any substance for use at work.

4.31 Operator

Any person employed on any service involving the management or operation of, or attendance on, any machinery.

4.32 Outdoor installation

The location where a fuel cell and fuels system are sited, whether as a unit or built as an assembly, which is not located inside a building or that has only partial weather protection (maximum coverage of a roof and up to 25 % enclosing walls).

4.33 Pipeline

The physical facilities or any part of the physical facilities through which dangerous substances which may cause fire, explosion or adverse health effects to any person (other than petroleum or petroleum products) in the form of liquid or vapour or any combination of liquid or vapour are transported and includes pipes, pumps, compressors, meters, regulators and fabricated assemblies.

4.34 Purge

Process using an inert gas (i.e. nitrogen) to prevent the existence of a hydrogen/air mixture.

4.35 Refilling mode

A condition(s) in which the gases that should be supplied are in low level and required refilling procedure before it is empty.

4.36 Replacement mode

A condition(s) in which the equipment(s) or tool(s) are not in their peak performance and required replacement procedure before it break.

4.37 Risk

A combination of the likelihood of an occurrence of a hazardous event with specified period or in specified circumstances and the severity of injury or damage to the health of people, property, environment or any combination of these caused by the event.

5. General configuration of the stationary fuel cell system

5.1 Basic schematic diagram of the stationary fuel cell system for telecommunication site

The stationary fuel cell backup power system consists of the following components as shows in Figure 1.

a) rectifier;

b) battery;

c) fuel; and

d) fuel cell;

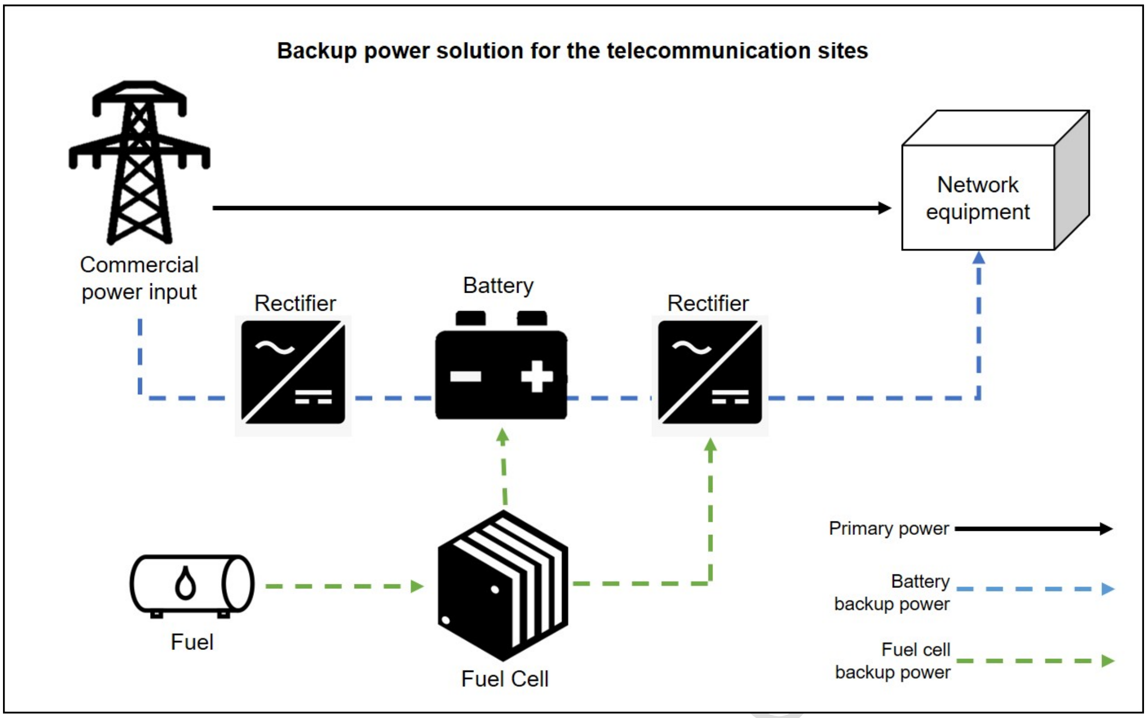

Figure 1. Basic schematic diagram of stationary fuel cell system for the telecommunication site

6. Installation and site considerations

6.1 General requirement

6.1.1 Risk analysis identification

The malfunction of the fuel cell system's components whose may result in a dangerous situation should be identified and updated regularly.

The manufacturer of a fuel cell and its components, or their authorised person, shall ensure that a risk assessment is carried out in order to determine the health and safety requirements that apply to the equipment. The equipment shall then be designed and constructed taking into account the results of the risk assessment.

This section is reproduced from HSE document with permission of the Health and Safety Executive under the terms of the Open Government Licence.

6.1.2 Protection against mechanical hazards

It is essential that the installation of mechanical components of the fuel cell system requires the following aspects to be considered:

a) Risks of loss of stability;

b) Risks of break-up during operation;

c) Risks due to falling or ejected objects;

d) Risks due to surfaces, edges or angles;

e) Risks related to combined equipment;

f) Risks related to variations in operating conditions;

g) Risks related to moving parts;

h) Choices of protection against risks arising from moving parts; and

i) Risks of uncontrolled movements.

6.1.3 Protection against electrical hazards

The electrical equipment, together with its component parts, should be made in such a way as to ensure that it can be safely and properly assembled and connected. The following should be addressed:

a) Protection against hazards arising from the electrical equipment;

b) Protection against hazards which may be caused by external influences on the electrical equipment;

c) Electricity supply;

d) Static electricity; and

e) Electromagnetic compatibility.

6.1.4 Protection from flammable gas appliance hazards

The protection from flammable gas appliance hazards in accordance with the Gas Supply Act 1993 and Gas Supply (Amendment) Regulations 2017.

6.1.5 Protection against fire and explosion hazards

The manufacturer should safeguard against risk of fire and explosion in accordance with the Occupational Safety and Health (Control of Industrial Major Accident Hazards) Regulations 1996 and Fire Services Act 1988.

Although the documents do not specifically specify the protection for the stationary fuel cell system, the key requirement of the Regulations is that risks from dangerous substances, e.g. flammable gases, are assessed and controlled.

6.1.6 Protection against pressure related hazards

The protection against pressure related hazard require the following aspects to be addressed:

a) Strength of equipment;

b) Provisions to ensure safe handling and operation;

c) Means of examination;

d) Means of draining and venting;

e) Materials for pressure vessels;

f) Wear;

g) Assemblies;

h) Provisions for filling and discharge;

i) Protection against exceeding the allowable limits of pressure equipment;

j) Safety accessories;

k) Manufacturing procedures;

l) Marking and labelling; and

m) Operating instructions

At elevated temperatures and pressures, hydrogen attacks mild steels severely, causing decarburisation and embrittlement. This is a serious concern in any situation involving storage or transfer of hydrogen gas under pressure. Proper material selection, e.g. special alloy steels, and technology are required to prevent embrittlement.

6.1.7 General health and safety requirements

General health and safety requirements should be addressed with respect to:

a) Materials and products;

b) External temperatures;

c) Errors of fitting;

d) Extreme temperatures;

e) Noise;

f) Vibrations;

g) External radiation;

h) Emissions of hazardous materials and substances;

i) Risk of being trapped in a machine;

j) Risk of slipping, tripping or falling; and

k) Lightning.

6.18 Control system requirements

For an appliance equipped with safety and controlling devices, the functioning of the safety devices shall not be overruled by the controlling devices.

All parts of appliances that are set or adjusted at the stage of manufacture and which should not be manipulated by the user or the installer should be appropriately protected.

Levers and other controlling and setting devices shall be clearly marked and give appropriate instructions to prevent any error in handling. Their design shall preclude accidental manipulation.

The surface temperature of knobs and levers of appliances shall not present a danger to the user.

Other areas that need to be addressed in the design of the control system are:

a) Safety and reliability of control systems;

b) Control devices;

c) Starting;

d) Stopping;

e) Selection of control or operating modes; and

f) Failure of the power supply.

6.2 Installation of fuel cell system

The fuel cell system shall be correctly installed and regularly serviced in accordance with the manufacturer's instructions to ensure that it can be safely and properly operated.

This section is reproduced from HSE document with permission of the Health and Safety Executive under the terms of the Open Government Licence.

6.2.1 Location

Where practical, particularly for industrial applications, the fuel cell should be located outdoors. For indoor installations, the fuel cell should be located in a well-ventilated area in which combustible materials are minimised.

In designing the installation consideration should be given as to whether it is necessary to separate the rooms or spaces that enclose the fuel cell installation from other building areas by fire barriers.

Use of appropriate protective devices for openings (i.e. doors, shutters, windows, service entries, etc) should also be considered. Voids or openings between the room in which the fuel cell is enclosed and adjacent rooms into which combustion products could pass should be avoided. The shared walls should be gas tight. Checking should be made that any automatic fire suppression system installed has been correctly specified for the room or space in which the fuel cell and associated components are located. All installations including any type of burner should comply with building and fire regulations.

For outdoor installations weather protection may be required. Hydrogen storage cylinders and vessels located outdoors need to be protected from extreme temperatures (below -20 °C and above 50 °C). Permanently installed hydrogen vessels should be provided with substantial supports, constructed of non-combustible material securely anchored to firm foundations of non-combustible material and protected from accidental impact, e.g. from a vehicle. Transportable compressed gas cylinders and vessels shall be secured against accidental dislodgement and protected from accidental impact. The area around hydrogen installations should be kept free of dry vegetation and combustible matter. If weed killers are used, chemicals such as sodium chlorate, which are a potential source of fire hazard, should not be selected for this purpose.

6.2.2 System purging

Purging of system with suitable medium should be conducted prior to start-up or after shutdown, in accordance to the product application manual specified by the manufacturer.

Systems should be suitably purged using an inert gas (i.e. nitrogen) to prevent the existence of a hydrogen/air mixture. Purging can be by sweep purging, evacuation or repeated pressurisation and venting cycles, using appropriately engineering and sited vent and purge connections. Also, consideration should be given to the asphyxiation hazards of using inert gases.

6.2.3 Ventilation

Suitable means shall be provided for the ventilation system as suggested in MTSFB2101R0 Requirements and Safety Aspect for the Fuel Cell System under section 7.3.1.

Natural or forced (mechanical) ventilation can be used to prevent the formation of potentially explosive mixtures. Natural ventilation is the preferred method due to its intrinsic reliability. If forced ventilation is used, then the reliability of the system has to be considered.

Appliances which are not fitted with devices such as flues to avoid a dangerous accumulation of unburned gas or combustion products in indoor spaces and rooms should be used only in areas where there is sufficient ventilation to avoid accumulation to dangerous levels.

6.2.4 Pressure systems

Suitable means should be provided for testing and venting pressure equipment. The risk assessment for the installation should cover the pressurising and venting operations. Adequate means should also be provided to permit cleaning, inspection and maintenance in a safe manner of all pressure systems.

6.2.5 Materials selection for installation

Materials used for the installation of hydrogen and fuel cell equipment should be suitable for such application during the scheduled lifetime unless replacement is foreseen.

In the construction and installation of a fuel cell system, asbestos or asbestos-containing material(s) shall not be used.

Where necessary, adequate allowance or protection against corrosion or other chemical attack should be provided, taking due account of the intended and reasonably foreseeable use within the scheduled lifetime of the equipment. Hydrogen gas dissolved in liquids will permeate into adjoining vessel materials; including piping systems and flue gas venting. At elevated temperatures and pressures, hydrogen attacks mild steels severely, causing decarburisation and embrittlement.

It is, therefore, vital that if hydrogen is stored or handled under pressure compatible materials, e.g. special alloy steels, are used for pipe work, vessels, etc.

6.2.6 Piping systems

All fuel handling equipment and piping shall be identified and appropriately labelled. It is essential that the piping and its associated joints and fittings should comply with requirement specified in the ISO 15649.

Piping system for non-fuel usage, are not included in the scope of ISO 15649. Such pipes, and their related joints and fittings, shall be designed and constructed with adequate strength for functionality and leakage resistance to prevent unintended releases.

Pipe routing should reflect consideration of factors such as risk from impact damage, formation of flammable mixtures in poorly ventilated areas, heat sources etc. Consequently, where pipe work passes through enclosed ducts, cavity walls etc, there should be no mechanical joints.

Piping should preferably be routed above ground; if underground pipe work is unavoidable, it should be adequately protected against corrosion. The position and route of underground piping should be recorded in the technical documentation to facilitate safe maintenance, inspection or repair. Underground hydrogen pipelines should not be located beneath electrical power lines.

Pipe work should be cleaned before being place into service using a suitable procedure for the type of containment, which provides a level of cleanliness required by the application.

6.2.7 Mechanical and thermal hazards

Equipment should be designed and constructed to minimise the risk of injuries from moving parts and hot surfaces. If there are moving parts, appropriate guarding should be provided to prevent accidental contact or ejection of failed components. Hot components need to be insulated or a means provided of preventing accidental contact. The maximum temperatures of the equipment should not exceed their temperature rating.

6.2.8 Slipping, tripping or falling hazards

Access to the equipment should be such that there are no slipping, tripping or falling hazards for personnel delivering supplies, e.g. gas cylinders, undertaking maintenance or carrying out repairs to the installation.

Rooms or enclosures containing equipment should be fitted with measures to prevent a person from being accidentally trapped within it or, if that is impossible, with a means of summoning help.

6.2.9 Chemical hazards

Adequate measures should be taken with the use of suitable protection on the parts that have the potential to be exposed to erosion, abrasion, corrosion or any other forms of chemical hazards. Frequent inspection and replacement should be in place for continued safe use.

6.2.10 Electrical safety

The fuel cell system should be designed in accordance to the power requirement at the dedicated site following the electrical product application manual specified by the manufacturer or other relevant standard.

The electric system design and construction, as well as the electric and electronic equipment should meet the requirements of the relevant electrical product application standards such as MS IEC 60950-1 (telecommunication), IEC 62040-1 (uninterruptible power supply).

The general requirements for the construction, testing and marking of electrical apparatus and components intended for use in hazardous areas where explosive gas/air mixtures exist under normal atmospheric conditions as specified in IEC 60079.

6.2.11 Electromagnetic compatibility (EMC)

For commercially available equipment, or combinations of equipment made into a single unit, intended for an end user and liable to generate electromagnetic disturbance, or the performance of which is liable to be affected by such disturbance should comply with requirement specified in IEC 61000 and MS 1760.

6.2.12 Lightning protection

Outdoor installations may also need protection against lightning strikes. This can be achieved by fitting a system for conducting the resultant electrical charge to earth and also ensuring all equipment is electrically bonded and earthed.

6.2.13 Gas venting

The gas venting system shall be provided in the fuel cell system to transfer products of combustion from fuel utilisation equipment to the outside atmosphere.

The manufacturer shall provide either a complete venting system, or product's technical document to allow selection of an appropriate venting system. The venting system shall comply with requirement as specified in IEC 62282-3-100.

6.2.14 Manual handling

Equipment, or each component part thereof, should:

a) be capable of being handled and transported safely; and

b) be packaged or designed so that it can be stored safely and without damage.

During the transportation of the equipment and/or its component parts, there shall be no possibility of sudden movements or of hazards due to instability as long as the equipment and/or its component parts are handled in accordance with the instructions.

Where the weight, size or shape of equipment or its various component parts prevents them from being moved by hand, the equipment or each component part shall:

a) either be fitted with attachments for lifting gear; or

b) be designed so that it can be fitted with such attachments; or

c) be shaped in such a way that standard lifting gear can easily be attached.

Where equipment or one of its component parts is to be moved by hand, it should:

a) either be easily moveable, or

b) be equipped for picking up and moving safely.

Special arrangements shall be made for the handling of tools and/or machinery parts which, even if lightweight, could be hazardous. The manufacturer shall specify special means for handling if required.

6.3 Site considerations

The fuel cell and associated equipment shall be suitably located to allow service, maintenance and fire department/emergency access and shall be supported, anchored and protected so that they will not be adversely affected by weather conditions (rain, seismic events and lightning) or physical damage. Furthermore, the placing of any components of the fuel cell system should not adversely affect required building exits, under normal operations or in emergencies.

Besides the general installation procedures for the stationary fuel cell system, the site considerations should depend on the fuel used.

This section is reproduced under written permission from Telecommunications Industry Association USA.

6.3.1 Hydrogen

For ground-based sites, replacement and refilling modes are both viable options for refuelling gaseous hydrogen. The refilling mode is desirable as it avoids moving heavy storage containers; however, site accessibility can limit its use. Although a slower and more labour-intensive mode of refuelling, cylinders can be moved safely by handcart through spaces that cannot be navigated by a vehicle.

For rooftop sites, replacement and refilling modes are both viable options, but more challenging than for ground-based sites. It is assumed in both cases that the hydrogen storage is on the roof with the fuel cell, as there often is no suitable space available around the building at ground level or inside the building. For the fill-in-place mode, if allowed by the building owner, hydrogen piping can be installed from the storage tanks down the outside of the building to ground level where the delivery truck can connect a refilling hose. For the replacement mode, cylinders (steel or carbon composite) can be taken up an elevator, after which there may be some stairs to roof level. During a power outage or other times when elevators are not operational, cylinders can be carried with a cylinder hand-truck up the stairwell if the building is not too tall.

For both ground-based and rooftop sites, compressed gas fuel such as hydrogen is almost always stored separately from the fuel cell cabinet, so compressed gas fuel cell systems tend to have a larger physical footprint compared to liquid-fuelled systems, where fuel can be stored in the base of the fuel cell enclosure. Storing hydrogen in higher pressure carbon composite tanks can help to reduce the footprint required for fuel.

Taking appropriate setback distances into account for hydrogen storage, the effective footprint (i.e., the physical occupied footprint plus the clearance area required for regulatory compliance) of the hydrogen solution tends to be the largest of available options.

Hydrogen is a very safe fuel for use on a rooftop, as it is the most buoyant of all gases (relative density of 0.0693 relative to air), and disperses quickly (diffusion coefficient of 0.61 x 10^{-4} m^2/s, compared to gasoline diffusion coefficient range of 0.006 – 0.02 x 10^{-4} m^2/s). In the unlikely event of a leak, hydrogen rises straight up into the open air and rapidly dilutes to non-combustible concentrations. The lower flammability limit (LFL) of hydrogen is 4 %, which is higher than the LFL of gasoline at 1.2 %.

6.3.2 Methanol

For ground-level sites, methanol fuel can be delivered and dispensed easily from containers such as drums or pails or directly from a fixed-tank fuel truck if the truck can get close enough to the site that it can be reached by hose.

For rooftop sites, liquid methanol/water fuel can be transported by elevator in drums, pails, or jugs to the top floor, after which there may be stairs to the roof level. During a power outage or at other times when elevators are not operational, fuel can be carried up the stairwell in pails or jugs, whichever is more manageable for the service personnel.

As a liquid fuel, methanol/water has a higher energy density than a gaseous fuel, and thus occupies less volume and can be integrated into the fuel cell cabinet, reducing the physical footprint. For quantities less than 60 gallons (~227 l), there are no setback requirements, so the effective footprint can be very small, which is particularly advantageous for rooftops where available area is scarce and expensive.

The LFL of methanol is higher (6.7 % by volume) than the LFL of all the other fuels considered here (see Annex A), meaning that more of it needs to accumulate before it can ignite. Methanol vapor density is slightly heavier than air (1.11), but it disperses (with a diffusion coefficient of 0.15 x 10^{-4} m^2/s, compared to the gasoline diffusion coefficient range of 0.006-0.02 x 10^{-4} m^2/s) 50 % faster than propane and similar to natural gas. The volatility of methanol is relatively low (32 kPa Reid vapor pressure (RVP) versus 48–62 kPa RVP for gasoline).

Methanol's relatively neutral buoyancy in air, low volatility, and higher dispersion relative to propane and gasoline, and its flammability only at high concentrations, are properties that contribute to its safety in general, and particularly for use on rooftops. Also, consideration should be given to the toxicity level of using methanol gas and shall comply the following regulation(s):

a) Department of Occupational Safety and Health, *Guidelines on the Monitoring of Airborne Contaminant for Chemicals Hazardous to Health 2002*;

b) Department of Occupational Safety and Health, *A manual of Recommended Practice on Assessment of The Health Risks Arising from The Use of Chemicals Hazardous to Health at The Workplace 2018*; and

c) The National Institute for Occupational Safety and Health, *Emergency Response Safety and Health Database – Methanol: Systemic Agents 2011*

6.3.3 Natural gas

As no fuel needs to be transported, there are no special transportation considerations for rooftop sites relative to ground-level sites.

Piped natural gas can be used both at ground-based sites and rooftop sites, as long as the infrastructure is available, and the building owner and local authorities allow it; however, natural gas infrastructure is often present only in residential and commercial buildings, so natural gas is a good option for rooftops, but simply may not be available at standalone ground-based telecom sites. If natural gas service is available, consultation with the gas company and landlord is advised to ensure that:

a) the gas service meets the pressure/flow-rate requirements of the fuel cell, and

b) the landlord/other tenants agree to share the gas supply.

Natural gas is lighter than air (0.55 methane/air relative density), and its dispersion rate (diffusion coefficient of 0.16 x 10^{-4} m^2/s, compared to gasoline diffusion coefficient of 0.006–0.02 x 10^{-4} m^2/s) is comparable to that of methanol vapor. Natural gas leaks tend to rise in air and disperse 8 to 27 times faster than gasoline.

The LFL of methane (the principal constituent of natural gas) is slightly lower (5 % by volume) compared to that of methanol and higher than the LFL of gasoline and propane. The high buoyancy of natural gas coupled with its relatively high LFL and good dispersion properties are factors that contribute to its safety.

6.3.4 Propane

For ground-level sites, propane tanks can be swapped, or the fuel can be dispensed directly from a propane bobtail truck if the truck can get close enough to the site that it can be reached by hose.

For rooftop sites, propane can be transported by elevator in smaller tanks, after which there may be some stairs to the roof level. During a power outage or at other times when elevators are not operational, fuel can be carried up the stairwell in tanks sized to be manageable for the service personnel.

As propane exists as a liquid under pressure, propane has a higher energy density than a gaseous fuel, and thus occupies less volume. The fuel tank is often external to the system, adding to the physical footprint; however, the high energy content and volumetric density of propane enable long run times in a relatively small fuel storage space. No setback requirements apply to tanks smaller than 125 gallons; however, in prime power applications, larger tanks are desirable to reduce the frequency of refueling visits.

Propane vapor is heavier than air (1.56 relative density), so propane vapor tends to pool and to not disperse well (diffusion coefficient of 0.10 x 10^{-4} m^2/s, compared to gasoline diffusion coefficient range of 0.006–0.02 x 10^{-4} m^2/s). The LFL of propane is comparable (2.1 % by volume) to the LFL of gasoline. Leaks are in gaseous form, as propane cannot exist in liquid form at atmospheric pressure.

In practice, propane systems can be difficult to site on rooftops for the same reason gasoline combustion-engine generators are not permitted on rooftops: the safety concerns of heavier-than-air vapors, low LFL,and high volatility are similar. Propane is common for residential and commercial use, and siting propane systems is straightforward for ground-based installations.

6.3.5 Fuel Comparison

Some properties of hydrogen, methanol/water, propane, and natural gas for fuel cells are compared in the table A.1 (see Annex A). The data reflect information at time of publication of the referred document from Telecommunications Industry Association USA.

Footprint vs. operating time with a 5 kW load is shown below for six different potential fuel options:

a) Hydrogen fuel cell, 8 cylinders, 300 series steel, 2,400 psi, swappable

b) Hydrogen fuel cell, 16 cylinders, large steel, 3,000 psi, fill-in-place cabinet

c) Hydrogen fuel cell, 8 cylinders, 90 L carbon composite, 5,000 psi, fill-in-place cabinet

d) Hydrogen fuel cell with methanol/water reformer, 59 gallon internal tank (located within fuel cell enclosure under fuel cell equipment – no incremental footprint for fuel)

e) Hydrogen fuel cell with methanol/water reformer, 275 gallon Intermediate Bulk Container external tank

f) Propane fuel cell with propane reformer, 125 gallon propane tank

Figure 2 below outlined the comparison between footprint and operating time with 5-kW load for six different fuel cell systems.

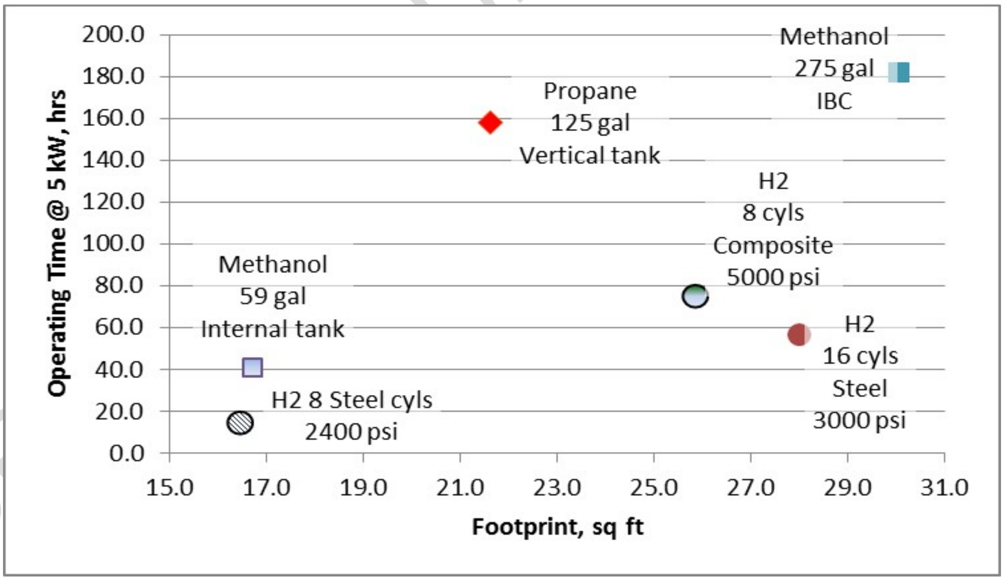

Figure 2. Comparison of footprint vs. operating time with 5-kW load for six different fuel cell systems

7. Operational/Maintenance Considerations

Maintenance works shall be performed regularly at suitable intervals.

This section is reproduced from HSE document with permission of the Health and Safety Executive under the terms of the Open Government Licence.

7.1 Equipment maintenance

Adjustment and maintenance points shall be located outside danger zones. It shall be possible to carry out adjustment, maintenance, repair, cleaning and servicing operations while equipment is at a standstill. If one or more of the above conditions cannot be satisfied for technical reasons, measures shall be taken to ensure that these operations can be carried out safely. In the case of automated equipment and, where necessary, other equipment, a connecting device for mounting diagnostic fault-finding equipment shall be provided.

Automated equipment components that have to be changed frequently should be capable of being removed and replaced easily and safely. Access to the components should enable these tasks to be carried out with the necessary technical means in accordance with a specified operating method.

Particular attention should be given to the design and location joints in the system that may require regular maintenance, or where mechanical joints will be frequently disturbed or made/broken as the likelihood of leaks in these areas is increased.

7.2 Access to operating positions and servicing points

Equipment should be designed and constructed in such a way as to allow access in safety to all areas where intervention is necessary during operation, adjustment and maintenance of the equipment.

7.3 Isolation of energy sources

Equipment should be fitted with means to isolate it from all energy sources. Such isolators should be clearly identified. They shall be capable of being locked if reconnection could endanger people. Isolators shall also be capable of being locked where an operator is unable, from any of the points to which he has access, to check that the energy is still cut off. In the case of equipment capable of being plugged into an electricity supply, removal of the plug is sufficient, provided that the operator can check from any of the points to which he has access that the plug remains removed.

After the energy is cut off, it shall be possible to dissipate normally any energy remaining or stored in the circuits of the equipment without risk to people. As an exception to the requirement laid down in the previous paragraphs, certain circuits may remain connected to their energy sources in order, for example, to hold parts, to protect information, to light interiors, etc. In this case, special steps shall be taken to ensure operator safety.

7.4 Operator intervention

Equipment should be so designed, constructed and equipped that the need for operator intervention is limited. If operator intervention cannot be avoided, it should be possible to carry it out easily and safely. If needed, operator intervention only carried out by authorised person.

7.5 Emergency planning

It is recommended that an emergency plan should be in place wherever compressed gaseous or cryogenic fluids are produced, handled or stored in accordance with NFPA 55. This emergency plan should include the following:

a) The type of emergency equipment available and its location;

b) A brief description of any testing or maintenance programs for the available emergency equipment;

c) An indication that hazard identification labelling is provided for each storage area;

d) The location of posted emergency procedures;

e) A list, including quantities, of compressed gases and cryogenic liquids and their materials safety data sheets (SDS) or equivalent;

f) A facility site plan including the following information:

   i) Storage and use areas;

   ii) Maximum amount of each material stored or used in each area;

   iii) Range of container sizes;

   iv) The location of gas and liquid conveying pipes;

   v) Locations of emergency isolation and mitigation valves and devices;

   vi) On and off positions of valves for those that are not self-indicating; and

   vii) A storage and distribution plan that is legible and drawn approximately to scale showing the intended storage arrangement, including the location and dimensions of walkways.

g) A list of personnel who are designated and trained to act as a liaison with the emergency services and who are responsible for the following:

   i) Aiding the emergency services in pre-emergency planning;

   ii) Identifying the location of compressed gases and cryogenic fluids stored or used;

   iii) Accessing SDS; and

   iv) Knowing the site emergency procedures.

8. Marking, labelling and packaging

For marking, labelling and packaging requirements of the fuel cell system, the manufacturer shall comply with the applicable laws and shall refer to the following:

a) ISO 3864-2;

b) ANSI/CSA America FC 1-2004; and

c) IEC 62282-3-100.

For marking, labelling and packaging requirements of the fuel system, the manufacturer shall comply with the applicable laws and shall refer to the following:

a) IFC 5303.4;

b) NFPA 55; and

c) MCMC MTSFB TC G023:2020

9. Permitting Route

Currently there is no formalised route for the approval of a hydrogen and fuel cell stationary installation. Guidance on installation can be found in IEC 62282-3-300.

9.1 General permitting checklist

The permitting route required for a particular installation should be proportionate to the scale and complexity of the installation.

The approval checklist below is intended to apply to both new-build and retro-fitted commercial/industrial installations.

This section is reproduced from HSE document with permission of the Health and Safety Executive under the terms of the Open Government Licence.

9.1.1 Step 1 – Risk assessment

Undertake a risk assessment to identify the hazards and the measures to be implemented to eliminate or mitigate their effects. The principal hazards will be fire and explosion ones, but other hazards, e.g. electrical, pressure and weather (for outdoor installations) related, also need to be considered. The hazards arising throughout the lifetime of the installation have to be covered by the assessment. This would include those hazards associated with the installation of the equipment, start up and shutdown of the equipment, delivery of consumables (e.g. gas cylinders) and the maintenance and repair of the equipment. Guidance on how to undertake a risk assessment can be found in Annex B.

9.1.2 Step 2 – Legislation directives

The equipment used in the installation shall comply with the essential health and safety requirements of all applicable directives List of the related regulations and standards can be found in Annex C.

The processes are in place to protect public safety, public health, and the environment. An example of the permits, agencies, and purposes for these multiple permitting processes is shown in Table 1.

Table 1. Fuel Cell Permitting/Potential Permits Required

Permit	Permit/Permit Scope
Construction	Permit to Construct General/Address safety construction issues
Drainage	Permit to Construct Drainage/Modification to sewer drainage
Site grading	Permit to Construct Grading/Modification to site elevation
Electrical Building/Electrical	Permit/Modification to electrical service
Demolition Building	Permit/Demolish structures required for dispenser construction
Air emission impacts	Air Quality Permit or No impact declaration
Fire safety	Permit/General fire code compliance

9.1.3 Step 3 – Installation issues

The equipment is to be installed, and maintained, by a competent person. At present there is no national scheme in place for training and assessing the competency of persons to install fuel cell systems, although some manufacturers do have schemes for training installers and service engineers.

9.1.4 Step 4 – Emergency responders

The local fire brigade is to be informed of the location and type of installation and given the opportunity to visit the installation. Of particular interest would be the location and quantity of any hydrogen stored at the site.

9.2 Permitting processes

This section is reproduced under written permission from Telecommunications Industry Association USA.

The permitting processes can be broken down into seven stages that help define the overall process and the timeline for completing all the required components.

a) Preliminary project scoping

b) Facility design

c) Approval process

d) Facility construction

e) Facility start-up

f) Facility operation

g) Facility maintenance

The required permits address all these phases, but the permitting structure does not correlate on a one to-one basis with the chronological steps required to build and operate a fuel cell.

The administrative process for reviewing and approving projects may vary by jurisdiction, but there are common elements. These basic elements are as follows:

a) Pre-submittal review and feedback.

b) Review and feedback to applicant.

c) Formal submission of application.

d) Public meeting (on an as-needed basis determined by both administrative law and the jurisdiction's determination as to whether public input should be solicited).

e) Make adjustments in the permit application (as needed) based on public input.

f) Review of modified application and feedback to application.

g) Resubmittal of modified application.

h) Issuance of permit.

i) Project construction.

j) Site inspection to determine that project built as shown in final design plans.

k) Periodic inspections to determine ongoing compliance.

The pre-submittal review, although not typically required, is a critical step in this process. It is at this time that significant problems could be identified and potentially averted. Examples of problems that could be averted are:

a) Identification of problems at the proposed site that the applicant is not aware of.

b) Identification of requirements the project should meet that the applicant had not evaluated in the draft application.

c) Any history of issues with similar projects in the jurisdiction.

Annex A
(Informative)

Comparison of Fuel Attributes

Table A.1 below list the comparison of fuel attributes which the table is reproduced under written permission from Telecommunications Industry Association USA

Table A1. Comparison of Fuel Attributes

Type	Hydrogen	Methanol/Water	Propane	Natural Gas
Small fuel cell status[1]	Commercial	Commercial	Early commercial	Early commercial
Fuel cell module size[2]	0.2-10 kW	0.3-7.5 kW	0.25-5 kW	0.25-5kW
Small fuel cell vendors	Many	Few	Few	Few
Typical usage	Backup power	Backup power	Prime power	Prime power
Fuel state	Compressed gas	Stable liquid	Liquid under pressure	Compressed gas
Density relative to air[3]	0.0693	1.11	1.56	0.55
Lower flammability limit[4]	4 %	6.7 %	2.1 %	5 %
Reid vapor pressure[5]	n/a (gas)	32 kPa	n/a (gas)	n/a (gas)

[1] "Commercial" means products that are available for sale in meaningful numbers, are supported with service and spare parts, and have evidence of deployment in significant numbers. "Early Commercial" means products that are available for sale, but no evidence exists yet of deployment in significant numbers.

[2] Modules can be cascaded for higher site power requirements.

[3] For reference, typical gasoline density is 3-4 relative to air: http://tsocorp.com/wp-content/uploads/2012/12/Gasoline-Unleaded-Regular.pdf

[4] For reference, compare to typical gasoline LFL of 1.2 %: https://www.mathesongas.com/pdfs/products/Lower-(LEL)-&-Upper-(UEL)Explosive-Limits-.pdf

[5] For reference, compare to typical gasoline RVP of 48-62 kPa: http://www.epa.gov/otaq/fuels/gasolinefuels/volatility/standards.htm

Type	Hydrogen	Methanol/Water	Propane	Natural Gas
Diffusion relative to gasoline[6]	30x-102x faster	7.5x-25x faster	5x-17x faster	8x-27x faster
Mode of transport	Steel or composite cylinders	Plastic or metal totes, drums, pails, jugs	Portable tanks or bobtail truck	Piped infrastructure
Mode of storage	Steel or composite cylinders	Integrated tank or external metal tank	Integrated tank or external pressurized tank	n/a
Mode of refuelling	Cylinder swap or fill-in-place	Pour or pump liquid	Swap tanks or refill with propane-specific nozzles/valves	No refuelling – direct feed from piped infrastructure
Common sources of fuel (who to call)	Industrial gas companies	Methanol/water blenders	See local directory for propane distributors	Determine supplier of gas to a specific site
Minimum quality	99.95 % industrial-grade hydrogen	Methanol: IMPCA specifications; Water: ASTM 1125, ASTM D5907, IMPCA 004-08, ASTM D4517; 61 %-63 % methanol by weight	HD5 HD5 spec propane consists of: Minimum of 90 % propane, Maximum of 5 % propylene - propylene is used in the manufacture of plastics, and Other gases constitute the remainder (iso-butane, butane, methane, etc.	Contact gas company/landlord to assure adequate pressure and flow rate for application
Ground-based site considerations	Suitable given sufficient space for fuel storage respecting setback limits	Integrated tank less than 60 gallons allows deployment in tight spaces	Suitable given sufficient space for fuel storage	May not find natural gas service at all ground sites

[6] For reference, diffusion coefficient of gasoline ranges from 0.006-0.02x10-4 m^2/s: http://www.jocet.org/papers/012-J30011.pdf

Type	Hydrogen	Methanol/Water	Propane	Natural Gas
Rooftop-based site considerations	Safe given hydrogen properties; fuel logistics challenging, especially when elevator not available	Safe given methanol properties; liquid fuel simplifies fuel logistics – delivering to site and carrying up to roof	May be challenges due to properties of propane; small tank delivery enables service to roof when elevator not available	If natural gas service available, no site visits required for fuel delivery; current architectures more suitable for prime power than backup power

Annex B
(Informative)

Steps of Risk Assessment

An example of the steps necessary to complete a risk assessment is given below. This is not the only way to perform a risk assessment but this method helps to assess health and safety risks in a straightforward manner. The law does not expect all risks to be eliminated, but protection of people as far as 'reasonably practicable' is required. This guidance on how to undertake a risk assessment is reproduced from HSE document with permission of the Health and Safety Executive under the terms of the Open Government Licence.

Step 1 - Identify the hazards.
The types of hazards identified and the methods used will vary according to the complexity of the installation.

Areas to be considered when identifying the hazards may/will include;
Site location, site evaluation, hydrogen storage location, security, choice of materials, access, deliberate attack and vandalism, impact, ventilation, fire protection, location of safety sensors, connection to grid.

A suitable emergency plan should be drawn up in the event of a leak or fire.

Step 2 - Decide who may be harmed and how.
For each hazard identified in Step 1 assess who might be harmed and how.

Step 3 - Evaluate the risks and decide what to do about them
Consideration should be given to removing the hazard and if that is not practical, how the hazard can be reduced or controlled.

Step 4 - Record and implement the findings
The risk assessment should show that all significant hazards have been recorded and addressed and how the hazards will be eliminated or if they cannot be eliminated how their effects will be minimised. Employees should be informed about the outcome of the risk assessment. The precautions taken should be reasonable and if there is a residual risk it should be low.

Step 5 - Review the Risk Assessment and update if and when necessary
Records of the installation, maintenance checks and servicing should be kept.

Any changes to the installation, work activities, process or incidents should be recorded and the risk assessment reviewed and if necessary additional safety measures implemented.

A risk assessment can be considered as "suitable and sufficient" if it has:

a) correctly identified all the hazards

b) disregarded inconsequential risks and those trivial risks associated with life in general

c) determined the likelihood of injury or harm arising

d) identified those who may be at particular risk, such as pregnant, elderly or disabled persons

e) taken into account any existing control measures

f) identified any specific legal duty or requirement relating to the hazard

g) provided sufficient information to decide upon appropriate control measures, taking into account

h) the latest scientific developments and advances

i) enabled the remedial measures to be prioritised

j) will remain valid for a reasonable period of time

Annex C
(Informative)

Codes and standards for hydrogen

Table C.1 lists useful codes and standards. Codes and standards are under continuous update and review. For the latest status of the hydrogen and fuel cell codes and standards the user is referred to: http://www.fuelcellstandards.com. This table is reproduced from HSE document with permission of the Health and Safety Executive under the terms of the Open Government Licence.

Table C.1 List of codes and standards.

Application/topic	Applicable codes and standards
Hydrogen system specifications	BS EN 62282-3-1: 2007. Fuel cell technologies – Part 3.1:Stationary Fuel Cell Power Systems – Safety.
	BS ISO 16110-1:2007. Hydrogen generators using fuel processing technologies. Safety.
	Supply of Machinery (Safety) Regulations.
	The Gas Appliances (Safety) Regulations 1995
	EN 50465: 2008. Gas appliances-Fuel cell gas heating appliance nominal heat input up to 70kW.
	BS EN 13611: 2007. Safety and control devices for gas burners and gas-burning appliances - general requirements.
	BS EN 161:2002. Automatic shut-off valves for gas burners and gas appliances.
	BS EN 298:2003. Automatic gas burner control systems for gas burners and gas burning appliances with or without fans.
	BS EN 437:2003. Test gases. Test pressures. Appliance categories.
	BS EN 483:1999. Gas-fired central heating boilers. Type C boilers of nominal heat input not exceeding 70 kW.
	BS EN 677:1998. Gas-fired central heating boilers. Specific requirements for condensing boilers with a nominal heat input not exceeding 70 kW.
	BS EN ISO 12100-1:2003. Safety of machinery. Basic concepts, general principles for design. Basic terminology, methodology.
	BS EN ISO 12100-2:2003. Safety of machinery. Basic concepts, general principles for design. Technical principles.
	BS EN 50165:1997. Electrical equipment of non-electric appliances for household and similar purposes. Safety requirements.
	BS EN 60079-14:2008. Explosive atmospheres. Electrical installations design, selection and erection.
	BS EN 60079-17:2007. Explosive atmospheres. Electrical installations inspection and maintenance.
	BS EN 60079-19:2007. Explosive atmospheres. Equipment repair, overhaul and reclamation.
	BS EN 60204-1:2006. Safety of machinery. Electrical equipment of machines. General requirements
Hydrogen system specifications	BS EN 60335-1:2002. Specification for safety of household and similar electrical appliances. General requirements.

Application/topic	Applicable codes and standards
	BS EN 60529:1992. Specification for degrees of protection provided by enclosures (IP code).
	BS EN 60730 series. Automatic electrical controls for household and similar use.
	BS EN 60950-1:2006. Information technology equipment. Safety. General requirements.
	BS EN 61000-6-2:2005. Electromagnetic compatibility (EMC). Generic Standards. Immunity for industrial environments.
	BS EN 61000-6-4:2001. Electromagnetic compatibility (EMC). Generic standards. Emission standard for industrial environments.
	ANSI/AIAA G-095-2004. Guide to Safety of Hydrogen and Hydrogen System. American National Standards Institute/American Institute of Aeronautics and Astronautics.
Fire safety	Regulatory Reform (Fire Safety) Order 2005.
	Fire (Scotland) Act 2005.
	PD 6686:2006. Guidance on directives, regulations and standards related to prevention of fire and explosion in the process industries.
Hydrogen systems installation	BS EN 61779 series (Parts 1 to 5). Electrical Apparatus for the Detection and Measurement of Flammable Gases.
	BS EN 60079-29-1:2007. Explosive atmospheres. Gas detectors. Performance requirements of detectors for flammable gases.
	BS EN 60079-29-2:2007. Explosive atmospheres. Gas detectors. Selection, installation, use and maintenance of detectors for flammable gases and oxygen.
	BS EN 62282-3-3: 2008. Fuel cell technologies – Part Stationary fuel cell power systems – Installation.
	EN 60079-10:2003. Electrical apparatus for explosive gas atmosphere. Classification of hazardous areas.
	HSG243. Fuel cells – Understand the hazards, control the risks. HSE Books.
	An Installation Guide for Hydrogen Fuel Cells and Associated Equipment (Draft). UK Hydrogen Association.
	CGA G-5.4. Standard for Hydrogen Piping Systems at Consumer Sites. Compressed Gas Association.
	CGA G-5.5. Hydrogen Vent Systems. Compressed Gas Association.
	NFPA 853: 2007. Standard for the Installation of Stationary Fuel Cell Power Plants. National Fire Protection Association.
	ASME B31. Hydrogen Piping and Pipeline Project Team. American Society of Mechanical Engineers.
Hydrogen storage	BS EN ISO 11114-1:1998. Transportable gas cylinders. Compatibility of cylinder and cylinder valve with gas contents. Metallic materials.
	BS EN ISO 11114-4:2005.Transportable gas cylinders . Compatibility of cylinder and cylinder valve with gas contents. Test methods for selecting metallic materials resistant to hydrogen.
	NFPA 55. Standard for the Storage, Use and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, cylinders, Equipment and Tanks. National Fire Protection Association.

Application/topic	Applicable codes and standards
	CGA C-10. Recommended procedures for changes of gas service of compressed gas cylinder. Compressed Gas Association.
	IGC Doc 100/03/E. Hydrogen cylinders and transport vessels. European Industrial Gases Association.
	CGA PS-20 CGA. Position Statement on the Direct Burial of Gaseous Hydrogen Storage Tanks. Compressed Gas Association.
	CGA PS-21. Position Statement on Adjacent Storage of Compressed Hydrogen And Other Flammable Gases. Compressed Gas Association.
	CGA Doc 02-50. Hydrogen Storage in Metal Hydrides. Compressed Gas Association.
General hydrogen safety	Biennial Report on Hydrogen Safety. HYSAFE Network of Excellence.
	Guidance for using hydrogen in confined spaces. InsHYde project (internal project of the HYSAFE Network of Excellence).
	ISO TR 15916:2004. Basic Considerations for the Safety of Hydrogen Systems.
	Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002.
	ANSI/AIAA G-095-2004. Guide to Safety of Hydrogen and Hydrogen System. American National Standards Institute/American Institute of Aeronautics and Astronautics.
	CGA P-6. Standard Density Data, Atmospheric Gases and Hydrogen. Compressed Gas Association.
	NFPA 50A. Standard for gaseous hydrogen system at consumer sites. National Fire Protection Association.
	The Fire Protection Research Foundation Technical Report. Siting Requirements for Hydrogen Supplies Serving Fuel cells in Non-combustible Enclosures.
Safety distances	IGC Doc 15/06/E. Gaseous Hydrogen Stations. European Industrial Gases Association.
	IGC Doc 75/01/rev. Determination of Safety Distances. European Industrial Gases Association.
	ISO TR 15916:2004. Basic Considerations for the Safety of Hydrogen Systems.
	NFPA 50A, 50B, 52 and 55. National Fire Protection Association.
Fuel cells - general	BS EN62282-3-1:2007. Fuel cell technologies – Part 3-1: Stationary fuel cell power systems – Safety.
	BS EN 62282-3-2:2006. Fuel cell technologies – Part 3-2: Stationary fuel cell power plants - Performance test methods.
	BS EN 62282-3-3:2008. Fuel cell technologies – Part 3-3: Stationary fuel cell power systems – Installation.
Hydrogen fuel	ISO 14687:1999. Hydrogen fuel. Product specification.
	ISO/TS 14687-2:2008. Hydrogen fuel. Product specification. Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles.
Hydrogen sensors	BS EN 61779, Parts 1 to 5. Electrical apparatus for the detection and measurement of flammable gases.

Application/topic	Applicable codes and standards
	BS EN 60079-29-1:2007. Explosive atmospheres. Gas detectors. Performance requirements of detectors for flammable gases.
	BS EN 60079-29-2:2007. Explosive atmospheres. Gas detectors. Selection, installation, use and maintenance of detectors for flammable gases and oxygen.
	ISO / DIS 26142. Hydrogen Detection.
	EN 50073:1999. Guide for selection, installation, use and maintenance of apparatus for the detection and measurement of combustible gases or oxygen.
	BS EN 62282-3-3:2008. Fuel cell technologies – Part 3-3: Stationary fuel cell power systems – Installation.
	ISO TR 15916:2004. Basic Considerations for the Safety of Hydrogen Systems.
	ANSI/AiAA G-095-2004. Guide to Safety of Hydrogen and Hydrogen System. American National Standards Institute/American Institute of Aeronautics and Astranautics.
Explosion venting	EN 14994:2007. Gas Explosion Venting Protective Systems.
	NFPA 68. Standard on explosion protection by deflagration venting (2007 edition). National Fire Protection Association.
Electrolysers	BS ISO 22734-1:2008. Hydrogen generators using water electrolysis process. Industrial and commercial applications.
	ISO/CD 22734-2 Hydrogen generators using water electrolysis process -- Part 2: Residential applications.
Reformers	BS ISO 16110-1:2007. Hydrogen generators using fuel processing technologies. Safety.
	ISO/DIS 16110-1:2007. Hydrogen generators using fuel processing technologies – Part 2: Procedures to determine efficiency.

Bibliography

[1] ANSI/AIAA G-095-2004, *Guide to Safety of Hydrogen and Hydrogen Systems*

[2] ANSI/CSA America FC 1-2004, *Stationary Fuel Cell Power Systems*

[3] BS 5925, *Code of practice for ventilation principles and designing for natural ventilation*

[4] Department of Occupational Safety and Health, *Guidelines on the Monitoring of Airborne Contaminant for Chemicals Hazardous to Health 2002*

[5] Department of Occupational Safety and Health, *A manual of Recommended Practice on Assessment of The Health Risks Arising from The Use of Chemicals Hazardous to Health at The Workplace 2018*

[6] Fire Services Act 1988

[7] Gas Supply Act 1993

[8] Gas Supply (Amendment) Regulations 2017

[9] *http://cafr1.com/Hydrogen_vs_Propane.pdf*

[10] *http://www.engineeringtoolbox.com/explosive-concentration-limits-d_423.html*

[11] *http://www.engineeringtoolbox.com/gas-density-d_158.html*

[12] *http://www.epa.gov/chemfact/s_methan.txt*

[13] *http://www.epa.gov/otaq/fuels/gasolinefuels/volatility/standards.htm*

[14] *http://www.gsi-net.com/en/publications/gsi-chemical-database/single/343.html*

[15] *http://www.hysafe.org/download/997*

[16] *http://www.hysafe.org/download/997*

[17] *https://www.mathesongas.com/pdfs/products/Lower-(LEL)-&-Upper-(UEL)-Explosive-Limits-.pdf*

[18] IEC 60079, *Explosive atmospheres*

[19] IEC 61000, *Electromagnetic compatibility (EMC)*

[20] IEC 62040-1, *Uninterruptible power systems (UPS) - Part 1: Safety requirements*

[21] IFC 5303.4, *General Requirement – Marking*

[22] ISO 15649:2001, *Petroleum and natural gas industries — Piping*

[23] ISO 3864-2, *Graphical symbols — Safety colours and safety signs — Part 2: Design principles for product safety labels*

[24] MS IEC 60950-1, *Information technology equipment – Safety – Part 1: General requirements*

[25] MS 1760:2004, *Guide on voltage dips and short interruptions on Public Power Supply System*

[26] NFPA 55, *Compressed Gases And Cryogenic Fluids Code*

[27] PD CEN/TR 15281:2006, *Guidance on inerting for the prevention of explosions*

[28] NFPA 30, Chapter 21, *Storage of Ignitible (Flammable or Combustible) Liquids in Tanks — Requirements for All Storage Tanks*

[29] The National Institute for Occupational Safety and Health, *Emergency Response Safety and Health Database – Methanol: Systemic Agents 2011*

Acknowledgements

Members of the Hydrogen Sub-Working Group

Dr Nurul Akidah Baharuddin (Chairman & Draft Lead)	Universiti Kebangsaan Malaysia
Dr Wong Wai Yin (Vice Chairman)	
Mr Mohamad Norzamir Mat Taib (Secretariat)	Malaysian Technical Standards Forum Bhd
Ms Norkhadhra Nawawi (Secretariat)	
Mr Mohd Fauzi Termizi	Celcom Axiata Berhad
Ir Yau Chau Fong	Duriane Professionals Sdn Bhd
Mr Muhammad Suhaimi Ithnin	edotco Malaysia Sdn Bhd
Mr P T Pawar	
Mr Alex Kuek	Shan Poornam Metals (Selangor) Sdn Bhd
Mr Khairul Izzuddin Sulaiman	Sustainable Energy Development Authority (SEDA)
Mr Mohd Shah Hambali Arifin	
Mr Frederick Wong Tsun Kiong	
Mr Mohd Adzha Bin. Husin	
Dr Teng Kah Hou	UCSI University
Prof Dato' Ir Dr Wan Ramli Wan Daud	Universiti Kebangsaan Malaysia
Prof Ir Dr Siti Kartom Kamarudin	
Prof Dr Mohammad Kassim	
Assoc Prof Dr Mohd Shahbudin Mastar @ Masdar	
Assoc Prof Dr Edy Herianto Majlan	
Assoc Prof Dr Mahendra Rao Somalu	
Dr Nabilah Afiqah Mohd Radzuan	
Dr Norazuwana Shaari	
Dr T. Husaini	
Dr Umi Azmah Hasran	
Ts Dr Lim Kean Long	
Dr Nafisah Mohd Isa @ Osman	Universiti Teknologi Mara
Assoc Prof Ts Dr Hamimah Abd.Rahman	Universiti Tun Hussein Onn Malaysia
Mr Najib Fadil Mohd Bisri @ Bisri	Telekom Malaysia Bhd

By invitation:

Assoc Prof Dr Suriati Sufian	Universiti Teknologi PETRONAS