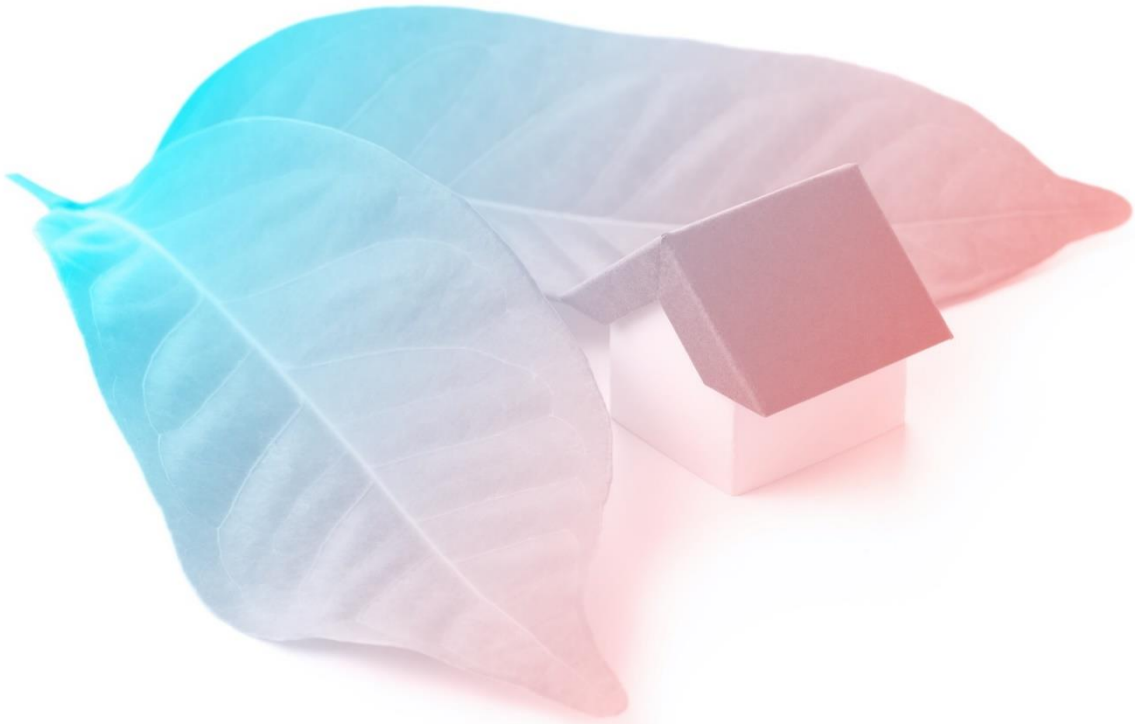
D2.3 Analysis of relevant legislation and standards for system operation



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D2.3 Analysis of relevant legislation and standards for system operation

Summary

This Deliverable identifies relevant standards and legislation applicable to system design and operation with two main objectives. The first one is to focus on standards necessary to obtain the "CE Marking", that will allow future commercialization of the product throughout all the European Union. Additionally, some recommendations are given related to the most suitable paths to achieve CE marking compliance. The second objective is to identify standards that can define system design and operation, which when improperly managed, can become a regulatory barrier for full application of the system.

The first part of the report focuses on explaining relevant European Directives and their applicable harmonized standards and national regulations. The second part of the report begins analyzing constraints placed by the directives and norms, such as EN-378, and how to best comply with them for successful thermal and electrical storage by the system. This part also analyses how the identified standards translate to practical application in terms of risk reduction and standard transposition to the context of a Member State (Hungary). The report also examines how integration of thermal and electrical storage takes part in the context of standardization, such as analysis of tightness restrictions to prevent leaks or the capacity to export electricity.

This first approach to hazards' reduction is based on a literature review of recommendations by relevant national bodies in Europe, the U.S. and Brasil (which belong to the Mission Innovation global initiative). They reveal that a safe thermal and electrical storage system using the proposed materials must be properly designed, mantained and operated following existing standards. It is also found that a gap exists in specific directives for thermal storage, therefore a series of applicable standards from different EU directives need to be considered.

The review of applicable standards also becomes relevant due to the expected increase in the use of natural refrigerants such as ammonia, due to their zero global warming and zero ozone layer depletion potential, as expressed in regulation (EU) No 517/2014.

Deliverable Number	Work Package
D2.3	WP 2
Lead Beneficiary	**Deliverable Author(S)**
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Type of deliverable	R	Report	X
	D	Draft	
Dissemination Level	CO	Confidential, only for members of the consortium (including the Commission)	
	PU	Public	X

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List of abbreviations

Abbreviation	Meaning
ANSI	American National Standards Institute
ATEX	Regulations for potentially explosive atmospheres
CE	Conformity marking of European health, safety, and environmental protection standards for products sold within the EEA
CEC	Citizen Energy Community
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
DoC	Declaration of Conformity
EEA	European Economic Area
EEE	electrical and electronic equipment
EMC	Electromagnetic Compatibility Directive
EN	European Norm
ETSI	European Telecommunications Standards Institute
EU	European Union
HFC	Hydrofluorocarbon gases
HVAC	Heating, ventilation and air conditioning
IEC	International Electrotechnical Commission
ISO	International Standards Organization
LFL	Lower flammability limit
PCM	Phase-change material
PVT	Photovoltaic thermal panels
RES	Renewable Energy Sources
RoHS	Restriction of Hazardous Substances
SET	Strategic Energy Technology Plan
TCM	Thermochemical material
TRL	Technology Readiness Level
TvMI	Fire Protection Technical Guideline Hungary

1 Introduction

This deliverable presents the results of a structured search for European Norms, Standards and Directives that are relevant for the design, manufacture, operation, maintenance and future commercialization of the MiniStor system for thermal and electrical energy storage.

The examination of standards was guided by the different components used. For the thermal energy storage part, many of the elements that have been specified in other deliverables (D3.1, D3.2, D4.1, D4.2, D4.3) are widely used in refrigeration equipment. Custom-made elements such as the thermochemical (TCM) reactor are examined through requirements to perform their described functions, for example tightness and pressure.

The usage of compounds not frequently present in domestic settings to produce the desired thermal energy storage (e.g. ammonia, salts, as well as hot and cold waxes), makes it necessary to review relevant safety and operation norms at both the EU and country level to help advance these technologies.

These materials are recommended as part of the next generation of refrigerants and energy management systems due to their zero global warming potential [1], with ammonia being a mentioned alternative that can help the European Commission's aims to reduce and eliminate hydrofluorocarbons (HFCs) as expressed through regulation (EU) No 517/2014 [2] through the so-called "natural refrigerants". The zero global warming potential and zero ozone layer depletion potential of ammonia can also contribute to the Strategic Energy Technology (SET) plan for the EU to develop more efficient cooling and heating solutions [3]. Thermal storage is an application that can put natural refrigerants to the forefront.

Components specified for the renewable energy (RES) collection, such as PVT panels, electrical storage part (D3.4), and the control system (WP5) are based on well-known technologies. However, their applicability in different Member States is dependent on local legislation and operator rules, such as the ability for a small local producer/consumer (prosumer) to sell electricity to the grid. An analysis has been done in D3.4 for the different scenarios for electrical energy storage.

Although the expected final TRL level of the project is 7 (Demonstration), this deliverable will contribute to future commercialization of the project results by considering the steps needed to obtain CE marking. It will also contribute to the market and environmental analysis of WP7, the formulation of circular economy models and guidelines related to safety assessments in relative to the TCM unit WP4 (ammonia risks considerations) and to the other components of the Ministor systems in WP2 (solar loop, PCM storages, Heat-pump, Li-ion batteries, etc.).

Any gaps and challenges in the standards have been identified from this analysis of relevant standards, and along with practical experience gained in the demonstration phase, will serve as a basis to approach relevant organizations, standardization bodies and related stakeholders for proposals for regulatory changes (T8.4).

Although this deliverable focuses primarily on European standards and legislation, this is complemented by a first approach to the reduction of hazards as found in the literature and recommended by relevant national bodies in Europe, the U.S. and Brasil (which belong to the Mission Innovation global initiative [4]).

The contents of this deliverable have been agreed by the Consortium based on the Consortium Agreement rules.

2 European directives applicable to MiniStor

The following sections list the different existing Directives, as they appear on the European Commission website and are analysed paying greater attention to those that are considered to:

a) Have a direct involvement with Ministor (using examination factors such as size, amounts of refrigerant or battery size, purpose of use) and can be a determining factor for the design of the system. A description of how the system works can be found in D3.1, "Initial dimensioning of the system according to general use typologies".
b) Can affect certain parts or components of the system, which must be taken into account when choosing these components.

All the information related to the CE marking provided below comes from the guides of the European Commission available from its own website [5] or from different sources that are indicated throughout the text.

2.1 CE Marking

As the European Commission inform us, the letters ´CE´ "signify that products sold in the EEA have been assessed to meet high safety, health, and environmental protection requirements". [6]
The responsibility for adding the CE mark belongs to manufacturers, who by affixing it to a product declare that the product meets all the legal requirements for CE marking and can be sold throughout the EEA.

It must be noted that not all the products need to be marked, and that certain products are simultaneously subject to several EU requirements, since the same product can present different risks that are dealt with in different directives. If a product is within the scope of one or more directives, it must comply with the set of essential requirements that apply to it before it is placed on the market.
A unique marking will be necessary to certify the conformity of the product with the directives that apply to it.

A manufacturer can only place a product on the EU market when it meets all the applicable requirements. The conformity assessment procedure is carried out before the product can be sold:

- The conformity of a product is assessed before it is placed on the market
- It needs to demonstrate that all legislative requirements are met
- It includes testing, inspection and certification
- The procedure for each product is specified in the applicable product legislation

The various existing conformity assessment procedures are harmonized in Council Decision 93/465 / EEC. The evaluation procedures are divided into modules. Only Module A (design and production stages that are part of the internal production control) and Module C (conformity to type based on internal production control) do not require the intervention of a Notified Body, which is an organization designated by an EU country to assess the conformity of certain products before being placed on the market [7]. The other modules require this notification to be done as they are close to the mass production stage. The modules are illustrated in the following figure:

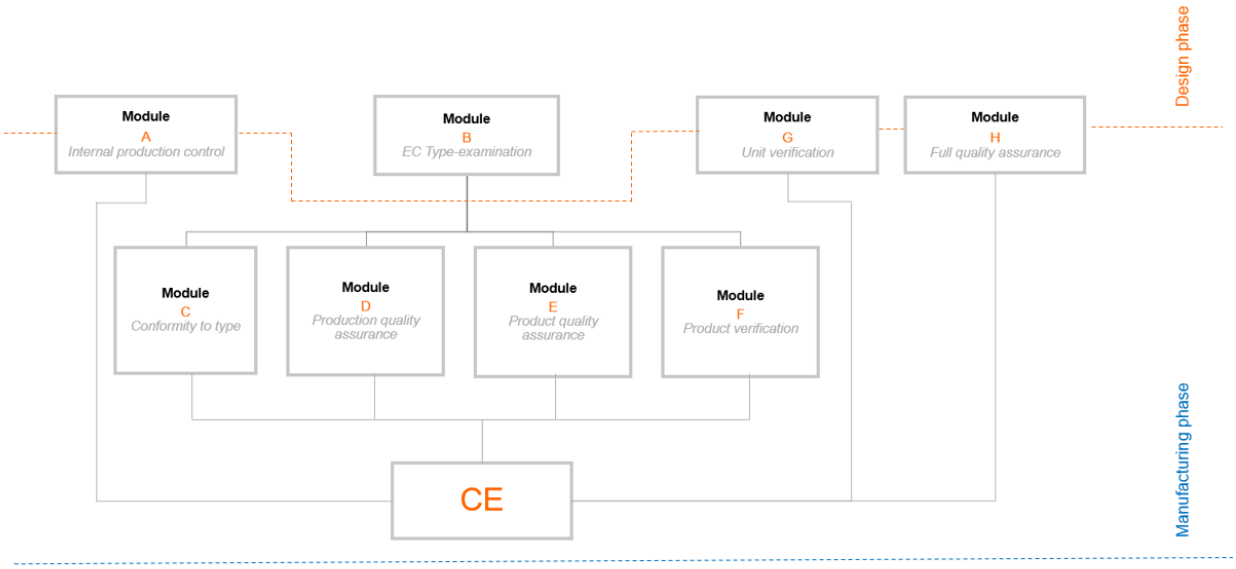


Figure 1. Conformity assessment modules

2.2 What are the European Directives?

The New Approach Directives are those that establish the CE marking. Those provisions revoke national provisions that contradict them. They are addressed to the Member States that have the obligation to transpose them into their national legislation. [8]

Directives do not include a list of products to which they apply, so it is needed to consult each directive to see if it applies in full or in part to the product to be commercialized. The complete list of directives by product groups from European Commission is the following, with those applying to MiniStor in bold:

a) Active implantable medical devices
b) Appliances burning gaseous fuels
c) Cableway installations designed to carry persons
d) Construction products
e) Ecodesign of energy related products
f) Electromagnetic compatibility
g) Equipment and protective systems intended for use in potentially explosive atmospheres
h) Explosives for civil uses
i) Hot-water boilers
j) In vitro diagnostic medical devices
k) Lifts
l) Low voltage
m) Machinery
n) Measuring Instruments
o) Medical devices
p) Noise emission in the environment
q) Non-automatic weighing instruments
r) Personal protective equipment
s) Pressure equipment
t) Pyrotechnics
u) Radio equipment
v) Recreational craft
w) Restriction of Hazardous Substances in Electrical and Electronic Equipment
x) Safety of toys

y) Simple pressure vessels

Multiple directives apply to the system, since it is a composite product for both thermal storage and electrical storage. The directives are detailed in full in Section 2.5.

2.3 Manufacturers' obligations

The manufacturer must firstly identify the applicable directive or directives and harmonised standards that apply to its product and verify the product specific requirements. Following that, the product must be tested and checked for its conformity.

It is important to keep in mind that certain products can need an independent conformity assessment by a notified body. The new approach notified and list of designated organisations can be find at the website of European Commission: https://ec.europa.eu/growth/tools-databases/nando/

The manufacturer must draw up and keep available the required technical documentation, affix the CE marking to the product, and draw up the EU Declaration of Conformity.

2.4 Harmonised standards

A harmonised standard is a European standard developed by a recognised European Standards Organisation: CEN, CENELEC, or ETSI. It is created following a request from the European Commission to one of these organisations. Manufacturers, other economic operators, or conformity assessment bodies can use harmonised standards to demonstrate that products, services, or processes comply with relevant EU legislation. The references of harmonised standards must be published in the Official Journal of the European Union.

The use of these standards remains voluntary and the manufacturers are free to choose another technical solution to demonstrate compliance with the mandatory legal requirements.

2.5 List of directives and possible application to the MiniStor system

The standards that can be considered applicable, due to the characteristics of the system, and that must be taken into account as conditioning factors in the development of the components, are those shown below:

1- Construction products - Regulation (EU) Nº 305/2011
2- Ecodesign of energy related products - Directive 2009/125/EC
3- Electromagnetic compatibility – Directive 2014/30/EU
4- Equipment and protective systems intended for use potentially explosive atmospheres – Directive 2014/34/EU
5- Low voltage – Directive 2014/35/EU
6- Machinery – Directive 2006/42/EC
7- Pressure equipment – Directive 2014/68/EU
8- Restriction of Hazardous Substances in Electrical and Electronic Equipment – Directive 2011/65/UE
9- Simple pressure vessels – Directive 2014/29/EU

2.6 Relevant directives analysis

In the following sections, the Directives considered to be of greater relevance are analysed in more detail. Products may be mentioned that are not used directly by MiniStor, but are listed to provide the context covered by the directives.

2.6.1 Construction products - Scope and harmonised standards

According to the Regulation (EU) Nº 305/2011 of the European Parliament and Council, a "construction product" means any product or kit which is produced and placed on the market for incorporation in a permanent manner in construction works or parts thereof and the performance of which has an effect on the performance of the construction works with respect to the basic requirements for construction works.

If the product falls into this classification and therefore needs to be evaluated for CE marking as a construction product, the following steps should be followed:

a) Verify if the product counts with an Harmonised European standard on construction products developed by technical experts from the European Standardisation Organisations (CEN/CENELEC) available in the following link: https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/construction-products_en
b) In case of the product is not within the scope of any Harmonised European standard it can be marked voluntarily with CE. But first the website of European Commission must be checked for the list of European Assessment Documents. The list is in the NANDO (New Approach Notified and Designated Organisations) area: https://ec.europa.eu/growth/tools-databases/nando/
c) In case the product and the intended use or uses are not in the scope of any of the European Assessment Documents, the manufacturer can request a Technical Assessment Body to develop a European Assessment Document.

In any case, a "CE marking step-by-step" reference guide is available in all EU languages and can be consulted at the following link:
https://ec.europa.eu/docsroom/documents?tags=ce-guide

2.6.2 2009/125/EC - Scope and most relevant harmonised standards

The Directive 2009/125/EC establishes a framework for the setting of ecodesign of energy related products. On the other hand, the Regulation (EU) 2017/1369 sets the framework for energy labelling.

To find out what type of products are covered by the Directive, the following sentences of the "scope" and "definition" articles shall be read:

"*This Directive establishes a framework for the setting of Community ecodesign requirements for energy-related products with the aim of ensuring the free movement of such products within the internal market*"

"'*Energy-related product', (a 'product'), means any good that has an impact on energy consumption during use which is placed on the market and/or put into service, and includes parts intended to be incorporated into energy-related products covered by this Directive which are placed on the market and/or put into service as individual parts for end-users and of which the environmental performance can be assessed independently*"

There are no references of harmonised standards which have been published in the Official Journal of the European Union under the ecodesign and energy labelling framework directives, but under the ecodesign and energy labelling implementing measures some references of harmonised standards have been published related to:

Circulators	Set-top boxes
Computers	Standby and off mode
Dishwashers	Television
Domestic ovens, hobs and range hoods	Transformers
Electric motors	Tumble driers
Fans	Vacuum cleaners
Heating and cooling appliances	Ventilation
Lamps (various types)	Washer-driers
Power supplies	Washing machines
Refrigerated storage cabinets	Water pumps
Refrigeration appliances	

In addition, the following items are included within the Heating and Cooling Appliances paragraph:

- Air conditioners and comfort fans
- Hot-water boilers
- Water heaters and hot water storage tanks
- Space heaters
- Local space heaters, Solid fuel local space heaters
- Solid fuel boilers
- Air heating products, cooling products, high temperature process chillers and fan coil units

The link to access the references from the European Commission website is:
https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/ecodesign_en

2.6.3 2014/30/EU - Scope and most relevant harmonised standards

Directive 2014/30/EU on Electromagnetic Compatibility (EMC) is intended to ensure that equipment liable to generate or to be affected by electromagnetic disturbance can be used in the electromagnetic environment for which it has been designed without causing disturbances to other equipment or being affected by them.

The essential requirements regarding electromagnetic compatibility for equipment are set out in Annex I of the directive.

The EMC Directive does not require the intervention of a notified body. However, the manufacturer or their authorised representative in the EU can present technical documentation to a notified body which will review it and assess whether the technical documentation properly demonstrates that the requirements of the directive have been met.

Afterwards, the manufacturer draws up the declaration of conformity (DoC) to declare on his sole responsibility conformity to the relevant directive.

The following table summarizes a list of standards that apply to different MiniStor components:

Reference number of the standard	Title of the standard
EN 619:2002+A1:2010	Continuous handling equipment and systems - Safety and EMC requirements for equipment for mechanical handling of unit loads
EN 13241-1:2003+A1:2011	Industrial, commercial and garage doors and gates - Product standard - Part 1: Products without fire resistance or smoke control characteristics
EN 14010:2003+A1:2009	Safety of machinery - Equipment for power driven parking of motor vehicles - Safety and EMC requirements for design, manufacturing, erection and commissioning stages
EN 50065-1:2011	Signalling on low-voltage electrical installations in the frequency range 3 kHz to 148,5 kHz - Part 1: General requirements, frequency bands and electromagnetic disturbances
EN 50065-2-2:2003, EN 50065-2-2:2003/A1:2005, EN 50065-2-2:2003/A1:2005/AC:2006, EN 50065-2-2:2003/AC:2003	Signalling on low-voltage electrical installations in the frequency range 3 kHz to 148,5 kHz - Part 2-2: Immunity requirements for mains communications equipment and systems operating in the range of frequencies 95 kHz to 148,5 kHz and intended for use in industrial environments
EN 50065-2-3:2003, EN 50065-2-3:2003/A1:2005, EN 50065-2-3:2003/AC:2003	Signalling on low-voltage electrical installations in the frequency range 3 kHz to 148,5 kHz - Part 2-3: Immunity requirements for mains communications equipment and systems operating in the range of frequencies 3 kHz to 95 kHz and intended for use by electricity suppliers and distributors
EN 50083-2:2012, EN 50083-2:2012/A1:2015	Cable networks for television signals, sound signals and interactive services - Part 2: Electromagnetic compatibility for equipment
EN 50130-4:2011	Alarm systems - Part 4: Electromagnetic compatibility - Product family standard: Immunity requirements for components of fire, intruder, hold up, CCTV, access control and social alarm systems
EN 50148:1995	Electronic taximeters
EN 50270:2015, EN 50270:2015/AC:2016-08	Electromagnetic compatibility - Electrical apparatus for the detection and measurement of combustible gases, toxic gases or oxygen
EN 50370-1:2005	Electromagnetic compatibility (EMC) - Product family standard for machine tools - Part 1: Emission
EN 50370-2:2003	Electromagnetic compatibility (EMC) - Product family standard for machine tools - Part 2: Immunity
EN 50412-2-1:2005, EN 50412-2-1:2005/AC:2009	Power line communication apparatus and systems used in low-voltage installations in the frequency range 1,6 MHz to 30 MHz - Part 2-1: Residential, commercial and industrial environment - Immunity requirements
EN 50428:2005, EN 50428:2005/A1:2007, EN 50428:2005/A2:2009	Switches for household and similar fixed electrical installations - Collateral standard - Switches and related accessories for use in home and building electronic systems (HBES)
EN 50470-1:2006	Electricity metering equipment (a.c.) - Part 1: General requirements, tests and test conditions - Metering equipment (class indexes A, B and C)
EN 50491-5-1:2010	General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS) - Part 5-1: EMC requirements, conditions and test set-up
EN 50491-5-2:2010	General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS) - Part 5-2: EMC requirements for HBES/BACS used in residential, commercial and light industry environment

Reference number of the standard	Title of the standard
EN 50491-5-3:2010	General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS) - Part 5-3: EMC requirements for HBES/BACS used in industry environment
EN 50498:2010	Electromagnetic compatibility (EMC) - Product family standard for aftermarket electronic equipment in vehicles
EN 50529-1:2010	EMC Network Standard - Part 1: Wire-line telecommunications networks using telephone wires
EN 50529-2:2010	EMC Network Standard - Part 2: Wire-line telecommunications networks using coaxial cables
EN 50550:2011, EN 50550:2011/AC:2012, EN 50550:2011/A1:2014	Power frequency overvoltage protective device for household and similar applications (POP)
EN 50561-1:2013, EN 50561-1:2013/AC:2015	Power line communication apparatus used in low-voltage installations - Radio disturbance characteristics - Limits and methods of measurement - Part 1: Apparatus for in-home use
EN 55011:2016, EN 55011:2016/A1:2017, EN 55011:2016/A11:2020	Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement
EN 55012:2007, EN 55012:2007/A1:2009	Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of off-board receivers
EN 55014-1:2017, EN 55014-1:2017/A11:2020	Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 1: Emission
EN 55014-2:1997, EN 55014-2:1997/A1:2001, EN 55014-2:1997/A2:2008, EN 55014-2:1997/AC:1997	Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 2: Immunity - Product family standard
EN 55032:2015, EN 55032:2015/A11:2020	Electromagnetic compatibility of multimedia equipment - Emission Requirements
EN 55035:2017, EN 55035:2017/A11:2020	Electromagnetic compatibility of multimedia equipment - Immunity requirements
EN 60034-1:2010, EN 60034-1:2010/AC:2010	Rotating electrical machines - Part 1: Rating and performance
EN 60204-31:2013	Safety of machinery - Electrical equipment of machines - Part 31: Particular safety and EMC requirements for sewing machines, units and systems
EN 60255-26:2013, EN 60255-26:2013/AC:2013	Measuring relays and protection equipment - Part 26: Electromagnetic compatibility requirements
EN 60669-2-1:2004, EN 60669-2-1:2004/A1:2009, EN 60669-2-1:2004/A12:2010, EN 60669-2-1:2004/AC:2007	Switches for household and similar fixed electrical installations - Part 2-1: Particular requirements - Electronic switches
EN 60730-1:2011	Automatic electrical controls for household and similar use - Part 1: General requirements
EN 60730-2-5:2002, EN 60730-2-5:2002/A11:2005, EN 60730-2-5:2002/A1:2004, EN 60730-2-5:2002/A2:2010	Automatic electrical controls for household and similar use - Part 2-5: Particular requirements for automatic electrical burner control systems
EN 60730-2-6:2008	Automatic electrical controls for household and similar use - Part 2-6: Particular requirements for automatic electrical pressure sensing controls including mechanical requirements

Reference number of the standard	Title of the standard
EN 60730-2-7:2010, EN 60730-2-7:2010/AC:2011	Automatic electrical controls for household and similar use - Part 2-7: Particular requirements for timers and time switches
EN 60730-2-8:2002, EN 60730-2-8:2002/A1:2003	Automatic electrical controls for household and similar use - Part 2-8: Particular requirements for electrically operated water valves, including mechanical requirements
EN 60730-2-9:2010	Automatic electrical controls for household and similar use - Part 2-9: Particular requirements for temperature sensing controls
EN 60730-2-14:1997, EN 60730-2-14:1997/A1:2001	Automatic electrical controls for household and similar use - Part 2-14: Particular requirements for electric actuators
EN 60730-2-15:2010	Automatic electrical controls for household and similar use - Part 2-15: Particular requirements for automatic electrical air flow, water flow and water level sensing controls
EN 60870-2-1:1996	Telecontrol equipment and systems - Part 2: Operating conditions - Section 1: Power supply and electromagnetic compatibility
EN 60945:2002	Maritime navigation and radiocommunication equipment and systems - General requirements - Methods of testing and required test results
EN 60947-1:2007, EN 60947-1:2007/A1:2011, EN 60947-1:2007/A2:2014	Low-voltage switchgear and controlgear - Part 1: General rules
EN 60947-2:2006, EN 60947-2:2006/A1:2009, EN 60947-2:2006/A2:2013	Low-voltage switchgear and controlgear - Part 2: Circuit-breakers
EN 60947-3:2009, EN 60947-3:2009/A1:2012	Low-voltage switchgear and controlgear - Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units
EN 60947-4-1:2010, EN 60947-4-1:2010/A1:2012	Low-voltage switchgear and controlgear - Part 4-1: Contactors and motor-starters - Electromechanical contactors and motor-starters
EN IEC 60947-4-1:2019	Low-voltage switchgear and controlgear - Part 4-1: Contactors and motor-starters - Electromechanical contactors and motor-starters
EN 60947-4-2:2012	Low-voltage switchgear and controlgear - Part 4-2: Contactors and motor-starters - AC semiconductor motor controllers and starters
EN 60947-4-3:2014	Low-voltage switchgear and controlgear - Part 4-3: Contactors and motor-starters - AC semiconductor controllers and contactors for non-motor loads
EN 60947-5-1:2004, EN 60947-5-1:2004/A1:2009, EN 60947-5-1:2004/AC:2004, EN 60947-5-1:2004/AC:2005	Low-voltage switchgear and controlgear - Part 5-1: Control circuit devices and switching elements - Electromechanical control circuit devices
EN IEC 60947-5-2:2020	Low-voltage switchgear and controlgear - Part 5-2: Control circuit devices and switching elements - Proximity switches
EN 60947-5-3:1999, EN 60947-5-3:1999/A1:2005	Low-voltage switchgear and controlgear - Part 5-3: Control circuit devices and switching elements - Requirements for proximity devices with defined behaviour under fault conditions (PDF)
EN 60947-5-6:2000	Low-voltage switchgear and controlgear - Part 5-6: Control circuit devices and switching elements - DC interface for proximity sensors and switching amplifiers (NAMUR)
EN 60947-5-7:2003	Low-voltage switchgear and controlgear - Part 5-7: Control circuit devices and switching elements - Requirements for proximity devices with analogue output
EN 60947-5-9:2007	Low-voltage switchgear and controlgear - Part 5-9: Control circuit devices and switching elements - Flow rate switches

Reference number of the standard	Title of the standard
EN 60947-6-1:2005, EN 60947-6-1:2005/A1:2014	Low-voltage switchgear and controlgear - Part 6-1: Multiple function equipment - Transfer switching equipment
EN 60947-6-2:2003, EN 60947-6-2:2003/A1:2007	Low-voltage switchgear and controlgear - Part 6-2: Multiple function equipment - Control and protective switching devices (or equipment) (CPS)
EN 60947-8:2003, EN 60947-8:2003/A1:2006, EN 60947-8:2003/A2:2012	Low-voltage switchgear and controlgear - Part 8: Control units for built-in thermal protection (PTC) for rotating electrical machines
EN IEC 60947-9-1:2019	Low-voltage switchgear and controlgear - Part 9-1: Active arc-fault mitigation systems - Arc quenching devices
EN 60974-10:2014	Arc welding equipment - Part 10: Electromagnetic compatibility (EMC) requirements
EN 61000-3-2:2014	Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)
EN 61000-3-3:2013	Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current <= 16 A per phase and not subject to conditional connection
EN 61000-3-11:2000	Electromagnetic compatibility (EMC) - Part 3-11: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems - Equipment with rated current <= 75 A and subject to conditional connection
EN 61000-3-12:2011	Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current > 16 A and <= 75 A per phase
EN 61000-6-2:2005, EN 61000-6-2:2005/AC:2005	Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity for industrial environments
EN 61000-6-4:2007, EN 61000-6-4:2007/A1:2011	Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments
EN 61000-6-5:2015, EN 61000-6-5:2015/AC:2018-01	Electromagnetic compatibility (EMC) - Part 6-5: Generic standards - Immunity for equipment used in power station and substation environment
EN 61008-1:2012, EN 61008-1:2012/A1:2014	Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) - Part 1: General rules
EN 61009-1:2012	Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs) - Part 1: General rules
EN IEC 61058-1:2018	Switches for appliances - Part 1: General requirements
EN 61131-2:2007	Programmable controllers - Part 2: Equipment requirements and tests
EN 61204-3:2000	Low voltage power supplies, DC output - Part 3: Electromagnetic compatibility (EMC)
EN 61326-1:2013	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 1: General requirements
EN 61326-2-1:2013	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 2-1: Particular requirements - Test configurations, operational conditions and performance criteria for sensitive test and measurement equipment for EMC unprotected applications

Reference number of the standard	Title of the standard
EN 61326-2-2:2013	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 2-2: Particular requirements - Test configurations, operational conditions and performance criteria for portable test, measuring and monitoring equipment used in low-voltage distribution systems
EN 61326-2-3:2013	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 2-3: Particular requirements - Test configuration, operational conditions and performance criteria for transducers with integrated or remote signal conditioning
EN 61326-2-4:2013	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 2-4: Particular requirements - Test configurations, operational conditions and performance criteria for insulation monitoring devices according to IEC 61557-8 and for equipment for insulation fault location according to IEC 61557-9
EN 61326-2-5:2013	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 2-5: Particular requirements - Test configurations, operational conditions and performance criteria for devices with field bus interfaces according to IEC 61784-1
EN 61439-1:2011	Low-voltage switchgear and controlgear assemblies - Part 1: General rules
EN 61439-2:2011	Low-voltage switchgear and controlgear assemblies - Part 2: Power switchgear and controlgear assemblies
EN 61439-3:2012, EN 61439-3:2012/AC:2019-04	Low-voltage switchgear and controlgear assemblies - Part 3: Distribution boards intended to be operated by ordinary persons (DBO)
EN 61439-4:2013	Low-voltage switchgear and controlgear assemblies - Part 4: Particular requirements for assemblies for construction sites (ACS)
EN 61439-5:2011	Low-voltage switchgear and controlgear assemblies - Part 5: Assemblies for power distribution in public networks
EN 61439-6:2012	Low-voltage switchgear and controlgear assemblies - Part 6: Busbar trunking systems (busways)
EN 61543:1995, EN 61543:1995/A11:2003, EN 61543:1995/A12:2005, EN 61543:1995/A2:2006, EN 61543:1995/A11:2003/AC:2004, EN 61543:1995/AC:1997	Residual current-operated protective devices (RCDs) for household and similar use - Electromagnetic compatibility
EN 61557-12:2008	Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V DC - Equipment for testing, measuring or monitoring of protective measures - Part 12: Performance measuring and monitoring devices (PMD)
EN 61800-3:2004, EN 61800-3:2004/A1:2012	Adjustable speed electrical power drive systems - Part 3: EMC requirements and specific test methods
EN 61812-1:2011	Time relays for industrial and residential use - Part 1: Requirements and tests
EN 62020:1998, EN 62020:1998/A1:2005	Electrical accessories - Residual current monitors for household and similar uses (RCMs)
EN 62026-1:2007	Low-voltage switchgear and controlgear - Controller-device interfaces (CDIs) - Part 1: General rules
EN 62026-2:2013, EN 62026-2:2013/A1:2019	Low-voltage switchgear and controlgear - Controller-device interfaces (CDIs) - Part 2: Actuator sensor interface (AS-i)

Reference number of the standard	Title of the standard
EN 62026-3:2009	Low-voltage switchgear and controlgear - Controller-device interfaces (CDIs) - Part 3: DeviceNet
EN 62026-7:2013	Low-voltage switchgear and controlgear - Controller-device interfaces (CDIs) - Part 7: CompoNet
EN 62040-2:2006, EN 62040-2:2006/AC:2006	Uninterruptible power systems (UPS) - Part 2: Electromagnetic compatibility (EMC) requirements
EN 62052-11:2003	Electricity metering equipment (AC) - General requirements, tests and test conditions - Part 11: Metering equipment
EN 62052-21:2004	Electricity metering equipment (AC.) - General requirements, tests and test conditions - Part 21: Tariff and load control equipment
EN 62053-11:2003	Electricity metering equipment (AC.) - Particular requirements - Part 11: Electromechanical meters for active energy (classes 0,5, 1 and 2)
EN 62053-21:2003	Electricity metering equipment (AC.) - Particular requirements - Part 21: Static meters for active energy (classes 1 and 2)
EN 62053-22:2003	Electricity metering equipment (AC.) - Particular requirements - Part 22: Static meters for active energy (classes 0,2 S and 0,5 S)
EN 62053-23:2003	Electricity metering equipment (AC.) - Particular requirements - Part 23: Static meters for reactive energy (classes 2 and 3)
EN 62054-11:2004	Electricity metering (AC) - Tariff and load control - Part 11: Particular requirements for electronic ripple control receivers
EN 62135-2:2008	Resistance welding equipment - Part 2: Electromagnetic compatibility (EMC) requirements
EN 62310-2:2007	Static transfer systems (STS) - Part 2: Electromagnetic compatibility (EMC) requirements
EN 62423:2012	Type F and type B residual current operated circuit-breakers with and without integral overcurrent protection for household and similar uses
EN 62586-1:2014	Power quality measurement in power supply systems - Part 1: Power quality instruments (PQI)
EN 62586-2:2014	Power quality measurement in power supply systems - Part 2: Functional tests and uncertainty requirements
EN 62606:2013	General requirements for arc fault detection devices
EN 63024:2018	Requirements for automatic reclosing devices (ARDs) for circuit-breakers, RCBOs and RCCBs for household and similar uses
EN 300 386 V1.6.1	Electromagnetic compatibility and Radio spectrum Matters (ERM); Telecommunication network equipment; ElectroMagnetic Compatibility (EMC) requirements
EN 301 489-1 V1.9.2	Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 1: Common technical requirements
EN 301 489-34 V1.4.1	Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 34: Specific conditions for External Power Supply (EPS) for mobile phones

Table 1. 2014/30/EU - Relevant harmonized standards

It should be noted that the cited standards are those considered relevant and have been included taking into account the information available at the time of issuing this report. Other standards may be relevant to development, commissioning, operation, and other phases in the life of the system.
The full list of regulations related to this Directive can be found at the following link: https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/electromagnetic-compatibility_en

2.6.4 2014/34/EU - Scope and most relevant harmonised standards

The ATEX Directive 2014/34 / EU on equipment and protective systems intended for use in potentially explosive atmospheres specifies in detail the essential requirements the product has to meet in order for the manufacturer to affix the CE marking.

According to Chapter 1, Article 1 of the ATEX Directive, it shall apply to the following, hereinafter referred to as ´products´.

a) equipment and protective systems intended for use in potentially explosive atmospheres;
b) safety devices, controlling devices and regulating devices intended for use outside potentially explosive atmospheres but required for or contributing to the safe functioning of equipment and protective systems with respect to the risks of explosion;
c) components intended to be incorporated into equipment and protective systems referred to in point (a).

The ATEX Directive shall not apply to:

a) medical devices intended for use in a medical environment;
b) equipment and protective systems where the explosion hazard results exclusively from the presence of explosive substances or unstable chemical substances;
c) equipment intended for use in domestic and non-commercial environments where potentially explosive atmospheres may only rarely be created, solely as a result of the accidental leakage of fuel gas;
d) personal protective equipment covered by Council Directive 89/686/EEC of 21 December 1989 on the approximation of the laws of the Member States relating to personal protective equipment (9);
e) seagoing vessels and mobile offshore units together with equipment on board such vessels or units;
f) means of transport, i.e. vehicles and their trailers intended solely for transporting passengers by air or by road, rail or water networks, as well as means of transport in so far as such means are designed for transporting goods by air, by public road or rail networks or by water. Vehicles intended for use in a potentially explosive atmosphere shall not be excluded from the scope of this Directive;
g) the equipment covered by point (b) of Article 346(1) of the Treaty on the Functioning of the European Union.

Annex I of the directive indicates the criteria determining the classification of equipment-groups into categories. In summary:

Equipment group 1 (M1 and M2):
Equipment in this category is intended for use in underground parts of mines as well as those parts of surface installations of such mines endangered by firedamp and/or combustible dust.

Equipment group 2:

a) Equipment category 1. Very high level of protection. Equipment in this category is intended for use in areas in which explosive atmospheres caused by mixtures of air and gases, vapours or mists or by air/dust mixtures are present continuously, for long periods or frequently.
b) Equipment category 2. High level of protection. Equipment in this category is intended for use in areas in which explosive atmospheres caused by gases, vapours, mists or air/dust mixtures are likely to occur occasionally.
c) Equipment category 3. Normal level of protection. Equipment in this category is intended for use in areas in which explosive atmospheres caused by gases, vapours, mists, or air/dust mixtures are unlikely to occur or, if they do occur, are likely to do so only infrequently and for a short period only.

The product classification of equipment group and its category determines the applicable requirements of Annex II (essential health and safety requirements relating to the design and construction of equipment and protective systems intended for use in potentially explosive atmospheres) that must be met.

The manufacturer must determine if they can assess their product by themselves or whether they have to involve a notified body.

The standards listed in the table below are those that are considered most relevant:

Reference number of the standard	Title of the standard
EN 1127-1:2019	Explosive atmospheres - Explosion prevention and protection - Part 1: Basic concepts and methodology
EN 13237:2012	Potentially explosive atmospheres - Terms and definitions for equipment and protective systems intended for use in potentially explosive atmospheres
EN 14373:2005	Explosion suppression systems
EN 14460:2018	Explosion resistant equipment
EN 14522:2005	Determination of the auto ignition temperature of gases and vapours
EN 14797:2006	Explosion venting devices
EN 14986:2017	Design of fans working in potentially explosive atmospheres
EN 14994:2007	Gas explosion venting protective systems
EN 15089:2009	Explosion isolation systems
EN 15198:2007	Methodology for the risk assessment of non-electrical equipment and components for intended use in potentially explosive atmospheres
EN 15233:2007	Methodology for functional safety assessment of protective systems for potentially explosive atmospheres
EN 15794:2009	Determination of explosion points of flammable liquids
EN 15967:2011	Determination of maximum explosion pressure and the maximum rate of pressure rise of gases and vapours
EN 16009:2011	Flameless explosion venting devices
EN 16020:2011	Explosion diverters
EN 16447:2014	Explosion isolation flap valves
EN 1839:2017	Determination of the explosion limits and the limiting oxygen concentration(LOC) for flammable gases and vapours
EN 50104:2010	Electrical apparatus for the detection and measurement of oxygen - Performance requirements and test methods
EN 50223:2015	Stationary electrostatic application equipment for ignitable flock material - Safety requirements
EN 50271:2018	Electrical apparatus for the detection and measurement of combustible gases, toxic gases or oxygen - Requirements and tests for apparatus using software and/or digital technologies
EN 50381:2004	Transportable ventilated rooms with or without an internal source of release
EN 50495:2010	Safety devices required for the safe functioning of equipment with respect to explosion risks
EN 60079-1:2014	Explosive atmospheres - Part 1: Equipment protection by flameproof enclosures "d"
EN 60079-11:2012	Explosive atmospheres - Part 11: Equipment protection by intrinsic safety "i"
EN 60079-15:2010	Explosive atmospheres - Part 15: Equipment protection by type of protection "n"
EN 60079-18:2015, EN 60079-18:2015/A1:2017	Explosive atmospheres - Part 18: Equipment protection by encapsulation "m"

Reference number of the standard	Title of the standard
EN 60079-2:2014	Explosive atmospheres - Part 2: Equipment protection by pressurized enclosure "p"
EN 60079-20-1:2010	Explosive atmospheres - Part 20-1: Material characteristics for gas and vapour classification - Test methods and data
EN 60079-25:2010	Explosive atmospheres - Part 25: Intrinsically safe electrical systems
EN 60079-26:2015	Explosive atmospheres - Part 26: Equipment with Equipment Protection Level (EPL) Ga
EN 60079-28:2015	Explosive atmospheres - Part 28: Protection of equipment and transmission systems using optical radiation
EN 60079-29-1:2016	Explosive atmospheres - Part 29-1: Gas detectors - Performance requirements of detectors for flammable gases
EN 60079-29-4:2010	Explosive atmospheres - Part 29-4: Gas detectors - Performance requirements of open path detectors for flammable gases
EN 60079-30-1:2017	Explosive atmospheres - Part 30-1: Electrical resistance trace heating - General and testing requirements
EN 60079-5:2015	Explosive atmospheres - Part 5: Equipment protection by powder filling "q"
EN 60079-6:2015	Explosive atmospheres - Part 6: Equipment protection by liquid immersion "o"
EN 60079-7:2015, EN IEC 60079-7:2015/A1:2018	Explosive atmospheres - Part 7: Equipment protection by increased safety "e"
EN IEC 60079-0:2018	Explosive atmospheres - Part 0: Equipment - General requirements
EN ISO 16852:2016	Flame arresters - Performance requirements, test methods and limits for use (ISO 16852:2016)
EN ISO 80079-36:2016	Explosive atmospheres - Part 36: Non-electrical equipment for explosive atmospheres - Basic method and requirements (ISO 80079-36:2016)
EN ISO 80079-37:2016	Explosive atmospheres - Part 37: Non-electrical equipment for explosive atmospheres - Non-electrical type of protection constructional safety ''c'', control of ignition sources ''b'', liquid immersion ''k'' (ISO 80079-37:2016)
EN ISO/IEC 80079-34:2011	Explosive atmospheres - Part 34: Application of quality systems for equipment manufacture (ISO/IEC 80079-34:2011)

Table 2. 2014/34/EU Relevant harmonized standards

It should be noted that the cited standards are those considered relevant and have been included taking into account the information available at the time of issuing this report. Other standards may be relevant to development, commissioning, operation, and other phases in the life of the system.
The full list of regulations related to this Directive can be found at the following link: https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/equipment-explosive-atmosphere_en

2.6.5 2014/35/EU - Scope and most relevant harmonised standards

This Directive, relating to the making available on the market of electrical equipment designed for use within certain voltage limits, shall apply to electrical equipment designed for use with a voltage rating of between 50 and 1 000 V for alternating current and between 75 and 1 500 V for direct current, other than the equipment and phenomena listed in Annex II.

The equipment and phenomena listed on Annex II and outside the scope of this Directive are:

- Electrical equipment for use in an explosive atmosphere
- Electrical equipment for radiology and medical purposes
- Electrical parts for goods and passenger lifts
- Electricity meters
- Plugs and socket outlets for domestic use
- Electric fence controllers
- Radio-electrical interference
- Specialised electrical equipment, for use on ships, aircraft or railways, which complies with the safety provisions drawn up by international bodies in which the Member States participate.
- Custom built evaluation kits destined for professionals to be used solely at research and development facilities for such purposes.

Conformity assessment from the products covered by the Low Voltage Directive takes the form of an internal production control procedure carried out by the manufacturer himself.
Directive 2014/35/EU does not require notified bodies to carry out the conformity assessment procedure.

Reference number of the standard (C)	Title of the standard (D)
EN 50491-3:2009	General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS) - Part 3: Electrical safety requirements
EN 50491-4-1:2012	General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS) - Part 4-1: General functional safety requirements for products intended to be integrated in Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS)
EN 50491-6-1:2014	General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS) - Part 6-1: HBES installations - Installation and planning
EN 60204-1:2006, EN 60204-1:2006/A1:2009, EN 60204-1:2006/AC:2010	Safety of machinery - Electrical equipment of machines - Part 1: General requirements
EN 60204-1:2018	Safety of machinery - Electrical equipment of machines - Part 1: General requirements
EN 60335-1:2012, EN 60335-1:2012/AC:2014, EN 60335-1:2012/A11:2014	Household and similar electrical appliances - Safety - Part 1: General requirements
EN 60335-1:2012, EN 60335-1:2012/AC:2014, EN 60335-1:2012/A11:2014, EN 60335-1:2012/A13:2017	Household and similar electrical appliances - Safety - Part 1: General requirements

Reference number of the standard (C)	Title of the standard (D)
EN 60335-1:2012, EN 60335-1:2012/AC:2014, EN 60335-1:2012/A11:2014, EN 60335-1:2012/A13:2017, EN 60335-1:2012/A1:2019, EN 60335-1:2012/A14:2019, EN 60335-1:2012/A2:2019	Household and similar electrical appliances - Safety - Part 1: General requirements
EN 60335-2-34:2013	Household and similar electrical appliances - Safety - Part 2-34: Particular requirements for motor-compressors
EN 60335-2-40:2003, EN 60335-2-40:2003 /A11:2004, EN 60335-2-40:2003 /A12:2005, EN 60335-2-40:2003 /A1:2006, EN 60335-2-40:2003 /A13:2012/AC:2013, EN 60335-2-40:2003 /A13:2012, EN 60335-2-40:2003/A2:2009, EN 60335-2-40:2003/AC:2006, EN 60335-2-40:2003/AC:2010	Household and similar electrical appliances - Safety - Part 2-40: Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers
EN 60335-2-41:2003, EN 60335-2-41:2003/A1:2004, EN 60335-2-41:2003/A2:2010	Household and similar electrical appliances - Safety - Part 2-41: Particular requirements for pumps
EN 60335-2-51:2003, EN 60335-2-51:2003/A1:2008, EN 60335-2-51:2003/A2:2012	Household and similar electrical appliances - Safety - Part 2-51: Particular requirements for stationary circulation pumps for heating and service water installations
EN 60335-2-88:2002	Household and similar electrical appliances - Safety - Part 2-88: Particular requirements for humidifiers intended for use with heating, ventilation, or air-conditioning systems
EN 60730-2-4:2007	Automatic electrical controls for household and similar use - Part 2-4: Particular requirements for thermal motor protectors for motor-compressors of hermetic and semi-hermetic type
EN 62253:2011	Photovoltaic pumping systems - Design qualification and performance measurements

Table 3. 2014/35/EU relevant harmonized standards

It should be noted that the cited standards are those considered relevant and have been included taking into account the information available at the time of issuing this report. Other standards may be relevant to development, commissioning, operation, and other phases in the life of the system.
The full list of regulations related to this Directive can be found at the following link: https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/low-voltage_en

2.6.6 2006/42/CE - Scope and most relevant harmonised standards

The Directive 2006/42/CE relating to machinery applies to the following products:

- Machinery
- Interchangeable equipment
- Safety components
- Lifting accessories
- Chains, ropes and webbing
- Removable mechanical transmission devices
- Partly completed machinery

For the purposes of this Directive, the "machinery" term relates to:

a) an assembly, fitted with or intended to be fitted with a drive system other than directly applied human or animal effort, consisting of linked parts or components, at least one of which moves, and which are joined together for a specific application,
b) an assembly referred to in the first indent, missing only the components to connect it on site or to sources of energy and motion,
c) an assembly referred to in the first and second indents, ready to be installed and able to function as it stands only if mounted on a means of transport, or installed in a building or a structure,
d) assemblies of machinery referred to in the first, second and third indents or partly completed machinery which, in order to achieve the same end, are arranged and controlled so that they function as an integral whole,
e) an assembly of linked parts or components, at least one of which moves and which are joined together, intended for lifting loads and whose only power source is directly applied human effort;

The manufacturer can assess the product by themselves except if the product to be assessed falls in one of the categories listed under Annex IV of the Directive. In that case, a Notified Body must be involved.
The complete list of products in the Annex IV are listed below:

- Circular saws (single- or multi-blade) for working with wood and material with similar physical characteristics or for working with meat and material with similar physical characteristics, of the following types:
    - sawing machinery with fixed blade(s) during cutting, having a fixed bed or support with manual feed of the workpiece or with a demountable power feed;
    - sawing machinery with fixed blade(s) during cutting, having a manually operated reciprocating saw-bench or carriage;
    - sawing machinery with fixed blade(s) during cutting, having a built-in mechanical feed device for the workpieces, with manual loading and/or unloading;
    - sawing machinery with movable blade(s) during cutting, having mechanical movement of the blade, with manual loading and/or unloading.
- Hand-fed surface planing machinery for woodworking.
- Thicknessers for one-side dressing having a built-in mechanical feed device, with manual loading and/or unloading for woodworking.
- Band-saws with manual loading and/or unloading for working with wood and material with similar physical characteristics or for working with meat and material with similar physical characteristics, of the following types:
    - sawing machinery with fixed blade(s) during cutting, having a fixed or reciprocating-movement bed or support for the workpiece;
    - sawing machinery with blade(s) assembled on a carriage with reciprocating motion.
- Combined machinery of the types referred to in points 1 to 4 and in point 7 for working with wood and material with similar physical characteristics.
- Hand-fed tenoning machinery with several tool holders for woodworking.
- Hand-fed vertical spindle moulding machinery for working with wood and material with similar physical characteristics.
- Portable chainsaws for woodworking.

- Presses, including press-brakes, for the cold working of metals, with manual loading and/or unloading, whose movable working parts may have a travel exceeding 6 mm and a speed exceeding 30 mm/s.
- Injection or compression plastics-moulding machinery with manual loading or unloading.
- Injection or compression rubber-moulding machinery with manual loading or unloading.
- Machinery for underground working of the following types:
    - locomotives and brake-vans;
    - hydraulic-powered roof supports.
- Manually loaded trucks for the collection of household refuse incorporating a compression mechanism.
- Removable mechanical transmission devices including their guards.
- Guards for removable mechanical transmission devices.
- Vehicle servicing lifts.
- Devices for the lifting of persons or of persons and goods involving a hazard of falling from a vertical height of more than three metres.
- Portable cartridge-operated fixing and other impact machinery.
- Protective devices designed to detect the presence of persons.
- Power-operated interlocking movable guards designed to be used as safeguards in machinery referred to in points 9, 10 and 11.
- Logic units to ensure safety functions.
- Roll-over protective structures (ROPS).
- Falling-object protective structures (FOPS).

Related uniformity check of conformity, for machinery that does not fall under one of the 23 categories listed in Annex IV to the Directive, the manufacturer themselves carry out internal checks on the conformity of the product.

HARMONISED STANDARDS

The first step a manufacturer should take to ensure that a machine will be compliant with the Directive is to carry out an assessment procedure, with regard to the essential requirements. This includes also to check which European Harmonised Standards are applicable, as a way to get presumption of conformity.

There are three types of machinery standards: A, B and C:

- A-type standards specify basic concepts, terminology and design principles applicable to all categories of machinery.
- B-type standards deal with specific aspects of machinery safety or specific types of safeguard that can be used across a wide range of categories of machinery.
- C-type standards provide specifications for a given category of machinery. The specifications of the C-type standard take precedence over the specifications of the A or B-type standard.

The A-type and C-type standards considered most relevant are listed below.
On the other hand, the application of B-type standards depends on the considered design of the machinery, its shelter and the machinery room because these standards deal with issues such as acoustics, safeguards, ladders, lighting, etc.

A- TYPE STANDARDS

Reference number of the standard	Title of the standard	Type
EN ISO 12100:2010	Safety of machinery - General principles for design - Risk assessment and risk reduction (ISO 12100:2010)	A

Table 4. 2006/42/CE Type A relevant harmonized standards

C-TYPE STANDARDS

Reference number of the standard	Title of the standard	Type
EN 378-2:2016	Refrigerating systems and heat pumps - Safety and environmental requirements - Part 2: Design, construction, testing, marking and documentation	C
EN 809:1998+A1:2009, EN 809:1998+A1:2009/AC:2010	Pumps and pump units for liquids - Common safety requirements	C
EN 1012-1:2010	Compressors and vacuum pumps - Safety requirements - Part 1: Air compressors	C
EN 1012-2:1996+A1:2009	Compressors and vacuum pumps - Safety requirements - Part 2: Vacuum pumps	C
EN 1012-3:2013	Compressors and vacuum pumps - Safety requirements - Part 3: Process compressors	C
EN 1028-1:2002+A1:2008	Fire-fighting pumps - Fire-fighting centrifugal pumps with primer - Part 1: Classification - General and safety requirements	C
EN 1028-2:2002+A1:2008	Fire-fighting pumps - Fire-fighting centrifugal pumps with primer - Part 2: Verification of general and safety requirements	C
EN ISO 2151:2008	Acoustics - Noise test code for compressors and vacuum pumps - Engineering method (Grade 2) (ISO 2151:2004)	C
EN 12162:2001+A1:2009	Liquid pumps - Safety requirements - Procedure for hydrostatic testing	C
EN 12547:2014	Centrifuges - Common safety requirements	C
EN 12693:2008	Refrigerating systems and heat pumps - Safety and environmental requirements - Positive displacement refrigerant compressors	C
EN 14070:2003+A1:2009, EN 14070:2003+A1:2009/AC:2010	Safety of machine tools - Transfer and special-purpose machines	C
EN ISO 20361:2015	Liquid pumps and pump units - Noise test code - Grades 2 and 3 of accuracy (ISO 20361:2015)	C
EN ISO 20361:2019, EN ISO 20361:2019/A11:2020	Liquid pumps and pumps units - Noise test code - Grades 2 and 3 of accuracy (ISO 20361:2019)	C
EN 50569:2013	Household and similar electrical appliances - Safety - Particular requirements for commercial electric spin extractors	C
EN 50569:2013, EN 50569:2013/A1:2018	Household and similar electrical appliances - Safety - Particular requirements for commercial electric spin extractors	C
EN 60335-1:2012, EN 60335-1:2012/AC:2014, EN 60335-1:2012/A11:2014, EN 60335-1:2012/A13:2017	Household and similar electrical appliances - Safety - Part 1: General requirements	C

Reference number of the standard	Title of the standard	Type
EN 60335-2-40:2003, EN 60335-2-40:2003/A11:2004, EN 60335-2-40:2003/A12:2005, EN 60335-2-40:2003/A1:2006, EN 60335-2-40:2003/A13:2012/AC:2013, EN 60335-2-40:2003/A13:2012, EN 60335-2-40:2003/A2:2009, EN 60335-2-40:2003/AC:2006, EN 60335-2-40:2003/AC:2010	Household and similar electrical appliances - Safety - Part 2-40: Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers	C
EN 60335-2-89:2010, EN 60335-2-89:2010/A1:2016, EN 60335-2-89:2010/A2:2017	Household and similar electrical appliances - Safety - Part 2-89: Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor	C
EN 60947-5-3:2013	Low-voltage switchgear and controlgear - Part 5-3: Control circuit devices and switching elements - Requirements for proximity devices with defined behaviour under fault conditions (PDDB)	C
EN 60947-5-5:1997, EN 60947-5-5:1997/A1:2005, EN 60947-5-5:1997/A11:2013, EN 60947-5-5:1997/A2:2017	Low-voltage switchgear and controlgear - Part 5-5: Control circuit devices and switching elements - Electrical emergency stop device with mechanical latching function	C

Table 5. 2006/42/CE Type C relevant harmonized standards

It should be noted that the cited standards are those considered relevant and have been included taking into account the information available at the time of issuing this report. Other standards may be relevant to development, commissioning, operation, and other phases in the life of the system.
The full list of regulations related to this Directive can be found at the following link:
https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/machinery_en

2.6.7 2014/68/EU - Scope and most relevant harmonised standards

According to its chapter 1, article 1 "Scope", the Directive 2014/68 / EU relates to pressure equipment applied to the design, manufacture and conformity assessment of pressure equipment and assemblies with a maximum allowable pressure (PS) greater than 0.5 bar. It also indicates in the same article a list of exclusions:

a) pipelines comprising piping or a system of piping designed for the conveyance of any fluid or substance to or from an installation (onshore or offshore) starting from and including the last isolation device located within the confines of the installation, including all the annexed equipment designed specifically for pipelines; this exclusion shall not apply to standard pressure equipment such as may be found in pressure reduction stations or compression stations;
b) networks for the supply, distribution and discharge of water and associated equipment and headraces such as penstocks, pressure tunnels, pressure shafts for hydroelectric installations and their related specific accessories;
c) simple pressure vessels covered by Directive 2014/29/EU;
d) aerosol dispensers covered by Council Directive 75/324/EEC;
e) equipment intended for the functioning of vehicles (defined by the legal acts that you can be found at the chapter 1, article 1 "Scope" of the Directive)
f) equipment classified as no higher than category I under Article 13 of this Directive and covered by one of the Directives (that can be found listed at the chapter 1, article 1 "Scope" of the Directive)
g) equipment covered by point (b) of Article 346(1) TFEU;
h) items specifically designed for nuclear use, failure of which may cause an emission of radioactivity;
i) well-control equipment used in the petroleum, gas or geothermal exploration and extraction industry and in underground storage which is intended to contain and/or control well pressure; this shall comprise the wellhead (Christmas tree), the blow out preventers (BOP), the piping manifolds and all their equipment upstream;
j) equipment comprising casings or machinery where the dimensioning, choice of material and manufacturing rules are based primarily on requirements for sufficient strength, rigidity and stability to meet the static and dynamic operational effects or other operational characteristics and for which pressure is not a significant design factor; such equipment may include:
    a. engines including turbines and internal combustion engines;
    b. steam engines, gas/steam turbines, turbo-generators, compressors, pumps and actuating devices;
k) blast furnaces including the furnace cooling system, hot-blast recuperators, dust extractors and blast-furnace exhaust-gas scrubbers and direct reducing cupolas, including the furnace cooling, gas converters and pans for melting, re-melting, de-gassing and casting of steel, iron and non-ferrous metals;
l) enclosures for high-voltage electrical equipment such as switchgear, control gear, transformers, and rotating machines;
m) pressurised pipes for the containment of transmission systems, e.g. for electrical power and telephone cables;
n) ships, rockets, aircraft and mobile off-shore units, as well as equipment specifically intended for installation on board or the propulsion thereof;
o) pressure equipment consisting of a flexible casing, e.g. tyres, air cushions, balls used for play, inflatable craft, and other similar pressure equipment;
p) exhaust and inlet silencers;
q) bottles or cans for carbonated drinks for final consumption;
r) vessels designed for the transport and distribution of drinks having a PS·V of not more than 500 bar·L and a maximum allowable pressure not exceeding 7 bar;
s) equipment covered by Directive 2008/68/EC and Directive 2010/35/EU and equipment covered by the International Maritime Dangerous Goods Code and the Convention on International Civil Aviation;
t) radiators and pipes in warm water heating systems;

u) vessels designed to contain liquids with a gas pressure above the liquid of not more than 0,5 bar.

The pressure equipment in the scope of the Directive is classified in different categories (ranging from I to IV), according to ascending level of hazard in accordance with Annex II of the Directive.

For checking conformity take account that only the equipment in category I will be subject to the manufacturer´s own internal production control. The modules for products in higher categories will require the involvement of Notified Bodies.

Reference number of the standard (C)	Title of the standard (D)
EN 12178:2016	Refrigerating systems and heat pumps - Liquid level indicating devices - Requirements, testing and marking
EN 13136:2013+A1:2018	Refrigerating systems and heat pumps - Pressure relief devices and their associated piping - Methods for calculation
EN 13445-1:2014, EN 13445-1:2014/A1:2014	Unfired pressure vessels - Part 1: General
EN 13445-2:2014, EN 13445-2:2014/A1:2016, EN 13445-2:2014/A2:2018, EN 13445-2:2014/A3:2018	Unfired pressure vessels - Part 2: Materials
EN 13445-3:2014, EN 13445-3:2014/A1:2015, EN 13445-3:2014/A2:2016, EN 13445-3:2014/A3:2017, EN 13445-3:2014/A4:2018, EN 13445-3:2014/A5:2018, EN 13445-3:2014/A6:2019, EN 13445-3:2014/A7:2019, EN 13445-3:2014/A8:2019	Unfired pressure vessels - Part 3: Design
EN 13445-4:2014	Unfired pressure vessels - Part 4: Fabrication
EN 13445-5:2014, EN 13445-5:2014/A1:2018	Unfired pressure vessels - Part 5: Inspection and testing
EN 13445-6:2014, EN 13445-6:2014/A2:2018	Unfired pressure vessels - Part 6: Requirements for the design and fabrication of pressure vessels and pressure parts constructed from spheroidal graphite cast iron
EN 13445-8:2014, EN 13445-8:2014/A1:2014	Unfired pressure vessels - Part 8: Additional requirements for pressure vessels of aluminium and aluminium alloys
EN 14276-1:2020	Pressure equipment for refrigerating systems and heat pumps - Part 1: Vessels - General requirements
EN 14276-2:2020	Pressure equipment for refrigerating systems and heat pumps - Part 2: Piping - General requirements

Table 6. 2014/68/EU relevant harmonized standards

It should be noted that the cited standards are those considered relevant and have been included taking into account the information available at the time of issuing this report. Other standards may be relevant to development, commissioning, operation, and other phases in the life of the system.
The full list of regulations related to this Directive can be found at the following link: https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/pressure-equipment_en

2.6.8 2011/65/EU (ROHS) - Scope and most relevant harmonised standards

This Directive (also known as RoHS 2) lays down rules on the restriction of the use of hazardous substances in electrical and electronic equipment (EEE) with a view to contributing to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE.

The RoHS Directive currently restricts the use of ten substances: lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE), bis(2-ethylhexyl) phthalate (DEHP), butyl benzyl phthalate (BBP), dibutyl phthalate (DBP) and diisobutyl phthalate (DIBP).
All products with an electrical and electronic component, unless specifically excluded, have to comply with these restrictions.

The first point of the second article "Scope" of the Directive 2011/65/UE on the restriction of the use of certain hazardous substances in electrical and electronic equipment, establishes that the Directive apply to the EEE falling within the categories set out in Annex I.

Within the Annex I, the mentioned categories of EEE covered by the Directive are:

1. Large household appliances.
2. Small household appliances.
3. IT and telecommunications equipment.
4. Consumer equipment.
5. Lighting equipment.
6. Electrical and electronic tools.
7. Toys, leisure and sports equipment.
8. Medical devices.
9. Monitoring and control instruments including industrial monitoring and control instruments.
10. Automatic dispensers.
11. Other EEE not covered by any of the categories above.

Article 7(b) of RoHS 2 requires the manufacturer to draw up the required technical documentation and carry out the internal production control procedure in line with module A of Annex II Decision No. 768/2008/EC (common framework for the marketing of products). It can also be carried out on the manufacturer's behalf.

RoHS 2 applies to the equipment and all its constituent parts, for example an electric power tool sold together with adjusting tools and case. However, RoHS 2 does not apply to any manuals, documentation, consumables etc. that do not have an equipment constituent as well as any packaging intended to be discarded soon after putting the equipment into service.

The European Commission has a "FAQ key guidance document – ROHS" available to download at: https://ec.europa.eu/environment/topics/waste-and-recycling/rohs-directive_en

Reference number of the standard	Title of the standard (D)
EN IEC 63000:2018	Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances

Table 7. 2011/65/EU relevant harmonized standards

It should be noted that the cited standards are those considered relevant and have been included taking into account the information available at the time of issuing this report. Other standards may be relevant to development, commissioning, operation, and other phases in the life of the system.
The full list of regulations related to this Directive can be found at the following link: https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/restriction-of-hazardous-substances_en

2.6.9 2014/29/EU - Scope and most relevant harmonised standards

The 2014/29/EU Directive applies to the simple pressure vessels manufactured in series with the following characteristics:

- the vessels are welded, intended to be subjected to an internal gauge pressure greater than 0,5 bar and to contain air or nitrogen, and are not intended to be fired;
- the parts and assemblies contributing to the strength of the vessel under pressure are made either of non-alloy quality steel or of non-alloy aluminium or non-age hardening aluminium alloys;
- the vessel is made of either of the following elements:
    - a cylindrical part of circular cross-section closed by outwardly dished and/or flat ends which revolve around the same axis as the cylindrical part;
    - two dished ends revolving around the same axis;
- the maximum working pressure of the vessel does not exceed 30 bar and the product of that pressure and the capacity of the vessel (PS × V) does not exceed 10 000 bar.L;
- the minimum working temperature is no lower than – 50 °C and the maximum working temperature is not higher than 300 °C for steel and 100 °C for aluminium or aluminium alloy vessels.

A Notified Body verifies the compliance of a product with the Directive by conducting a conformity assessment. Depending on the use or not of harmonised European standards and the potential pressure hazard determined by the total energetic content of the vessels - determined by the product of PS (pressure) and V (volume) - appropriate conformity assessment procedures are defined in the Directive.

The complete list of harmonised standards and amendments related to this Directive as it appears at the European Commission web, are listed below:

Reference number of the standard	Title of the standard (D)
EN ISO 9606-1:2017	Qualification testing of welders - Fusion welding - Part 1: Steels (ISO 9606-1:2012 including Cor 1:2012 and Cor 2:2013)
EN 10207:2017	Steels for simple pressure vessels - Technical delivery requirements for plates, strips and bars
EN ISO 15614-1:2004	Specification and qualification of welding procedures for metallic materials - Welding procedure test - Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys (ISO 15614-1:2004)
EN ISO 15614-1:2004 /A1:2008	
EN ISO 15614-1:2004 /A2:2012	
EN ISO 15614-2:2005	Specification and qualification of welding procedures for metallic materials - Welding procedure test - Part 2: Arc welding of aluminium and its alloys (ISO 15614-2:2005)
EN ISO 15614-2:2005 /AC:2009	

Table 8. 2014/29/EU relevant harmonized standards

https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/simple-pressure-vessels_en

3 Safety and operation standards and legislation related to use of ammonia in refrigeration systems

3.1 Ammonia constraints (EN 378 analysis)

3.1.1 Introduction

The use of ammoniated salts in the MiniStor system arises from solid/gas sorption processes on TCM materials that offer an advantage for heat and mass transfer against hydrates because of the higher pressure levels at which ammoniates/NH3 working pairs operate [9]. Specifically, ammoniated halide salts are the most attractive sorbents as they are cheap and offer a wide range of thermodynamic properties [10]. Partner CNRS-PROMES has gained a solid expertise on halide salts based thermochemical storage systems at pilot scale, mainly focusing on a BaCl2/NH3 (barium chloride/ammonia) cycle for cooling/refrigerant purposes [11]. The MiniStor system uses a thermochemical heat storage (TCM) technology based on a CaCl2/NH3 (calcium chloride/ammonia) cycle, utilizing reversible chemical reactions to generate both heat and cooling. As a distinguishing feature, it uses proprietary technology based on ammonia reactions to stabilize the TCM materials and provide long-term operation. The TCM technology is combined with other key components to develop an integrated system capable of providing sustainable heating, cooling and electricity storage, while utilizing renewable energy sources, specifically solar energy. Therefore, ammonia is used and circulated in an enclosed vessel to promote a reversible reaction that generates heat stored in the salts. The heat is later transferred through additional indirect systems to the dwelling.

Ammonia has been used as a refrigerant since the start of refrigeration systems in the early 20th century. In the 1930s, fluorinated gases became widespread in refrigeration systems, with ammonia being used mostly in industrial refrigeration plants (such as meat and fish storage). However, it also forms part of the so-called "natural refrigerants" together with carbon dioxide, propane and isobutene. This means that ammonia occurs in nature, and has no global warming potential or impact on the ozone layer [12]. These properties have made these natural refrigerants to be reconsidered for wider use as alternatives to fluorinated greenhouse gases, the use of which the EU intends to reduce or phase out as part of regulation (EU) No 517/2014.

Detailed functional descriptions of the system can be found in D3.1 and D3.2. The figure below illustrates the latest version of the system. The thermochemical reactor where ammonia is used is enclosed in the dotted green lines. The orange solid line represents the boundaries of components of the thermal system.

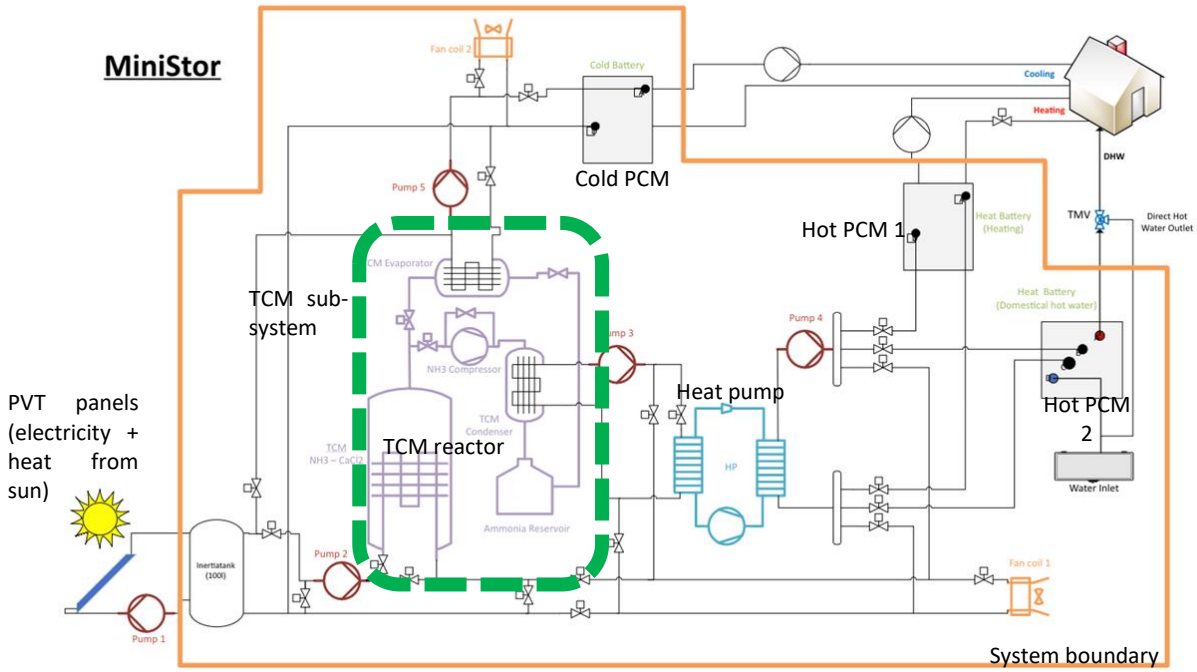


Figure 2 MiniStor system layout with main components. Green denotes the section using ammonia directly, orange the system boundary of thermal system components

After a research seeking for standards that cover constraints related to the ammonia-containing parts of the system, it was concluded that the most important one is the refrigeration standard **EN 378**. This standard specifies the requirements for the safety of people and property, provides guidance for the protection of the environment and establishes procedures for the operation, maintenance and repair of refrigerating systems and the recovery of refrigerants, including ammonia (also known as R717).

For the large majority of EU countries, either there is no standard of their own, or they have an adaptation of the international standard EN 378, which is identical. Therefore, it can be concluded that EN 378 gives an adequate guidance for the project objectives. In addition, French legislation (Article L. 512-11 of the French Environment Code) limits to 50kg the amount of ammonia to be used in *containers* not subject to mandatory French regional government periodic supervision, while an *installation* with a quantity of less than 150 kg does not require any authorization or administrative declaration. This is elaborated further at the end of section 3.1.4.

This section is developed specifically to provide a higher level of detail on the operative and safety measures needed due to the proposed use of ammonia in domestic environments.

3.1.2 Classification

This section provides the main forms of classification of refrigeration systems, according to their location, access, refrigerant used or how they work.

3.1.2.1 Access categories

3.1.2.1.1 General

Occupancies are categorised with respect to the safety of people, who may be directly affected in the event of abnormal operation of the refrigerating system. Considerations of safety in refrigerating systems take into account the site, number of people occupying the site and access categories.

In case of using a machinery room (where HVAC equipment is kept for operation), this shall not be considered occupied space except as defined in EN 378-3:2016, 5.1. Access categories are defined in Table 9.

Categories	General characteristics	Examples [a]
General access **a**	Rooms, parts of buildings, building where — sleeping facilities are provided — people are restricted in their movement — an uncontrolled number of people are present — any person has access without being personally acquainted with the necessary safety precautions	Hospitals, courts or prisons, theatres, supermarkets, schools, lecture halls, public transport termini, hotels, dwellings, restaurants
Supervised access **b**	Rooms, parts of buildings, buildings where only a limited number of people may be assembled, some being necessarily acquainted with the general safety precautions of the establishment	Business or professional offices, laboratories, places for general manufacturing and where people work
Authorized access **c**	Rooms, parts of buildings, buildings where only authorized persons have access, who are acquainted with general and special safety precautions of the establishment and where manufacturing, processing or storage of material or products take place	Manufacturing facilities, e.g. for chemicals, food, beverage, ice, ice-cream, refineries, cold stores, dairies, abattoirs, non-public areas in supermarkets
[a] The list of examples is not exhaustive.		

Table 9. Access categories according to EN 378

NOTE: Occupancies can be categorised by national requirements.

3.1.2.1.2 More than one access category

Where there is the possibility of more than one access category, the more stringent requirements apply. If occupied spaces are isolated, e.g. by sealed partitions, floors and ceilings, then the requirements of the individual access category applies.

3.1.2.2 Designation and classification of refrigerants

Refrigerants listed in Annex E of EN 378-1 use the designation and safety class specified in ISO 817. Practical limit values shall be those assigned in Annex E of the same standard.

The practical limit for a refrigerant represents the highest concentration level in an occupied space which will not result in any escape impairing (i.e. acute) effects or create a risk of ignition of the refrigerant. It is used to determine the maximum charge size for that refrigerant in a specific application.

3.1.2.3 Location classification of refrigerating systems

There are four classes of location for refrigerating systems. The appropriate location shall be selected in accordance with this European Standard EN 378 which takes account of possible hazards.

The four classes of location are:

a) Class IV - Ventilated enclosure

If all refrigerant-containing parts are located in a ventilated enclosure, then the requirements for a class IV location shall apply. The ventilated enclosure shall fulfil the requirements of EN 378-2 and EN 378-3.

b) Class III – Machinery room or open air

If all refrigerant-containing parts are located in a machinery room or open air, then the requirements for a class III location shall apply. The machinery room shall fulfil the requirements of EN 378-3.

c) Class II – Compressors in machinery room or open air

If all compressors and pressure vessels are either located in a machinery room or in the open air, then the requirements for a class II location shall apply unless the system complies with the requirements of class III. Coils and pipework including valves may be located in an occupied space.

d) Class I – Mechanical equipment located within the occupied space

If the refrigerating system or refrigerant-containing parts are located in the occupied space, then the system is considered to be of class I unless the system complies with the requirements of class
II.

Refrigerating systems or parts of systems shall not be installed in or on stairways, landings, entrances or exits used by the public, if free passage is thereby limited.

If a secondary system serving an occupied space employs a substance that is listed as a refrigerant under Annex E, the charge of that heat-transfer fluid shall be calculated by using the requirements for direct releasable systems according to the procedure detailed in Section 3.1.3.2 of EN 378.

3.1.2.4 Refrigerating system classification

Refrigerating systems are classified as described in this section, according to the method of extracting heat from cooling or adding heat to heating the atmosphere or substance to be treated. The systems are described in full in the section in order to understand the best category for the MiniStor system.

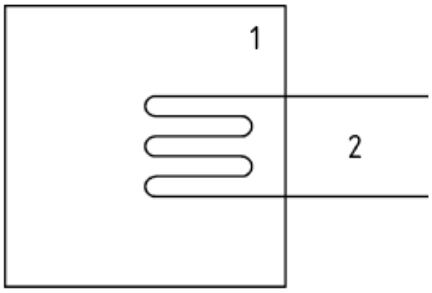
3.1.2.4.1 Direct releasable systems

The evaporator, condenser or gas cooler of the refrigerating system is in direct contact with the air or the substance to be cooled or heated. Systems in which a heat-transfer fluid is in direct contact with the air or the goods to be cooled or heated (spray or ducted systems) shall be treated as direct releasable systems.

3.1.2.4.1.1 Direct system

A direct system shall be classified as a direct releasable system if a single rupture of the refrigerant containing circuit results in refrigerant release in the occupied space, irrespectively of the location of the refrigerant circuit (see Figure 3).

Direct systems are considered to be located in location Class I or II.



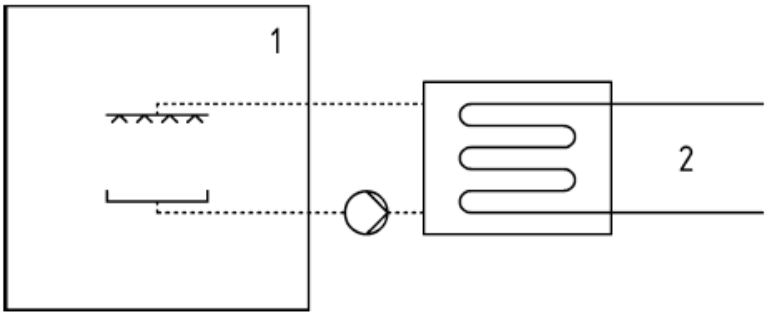
Key
1 occupied space
2 refrigerant-containing part(s)

Figure 3. Example of a direct releasable system

3.1.2.4.1.2 Open spray system

An open spray system shall be classified as a direct releasable system if the heat-transfer fluid is in direct contact with refrigerant-containing parts and the indirect circuit is open to an occupied space (see Figure 4).

Open spray systems are considered to be located in location Class I or II.



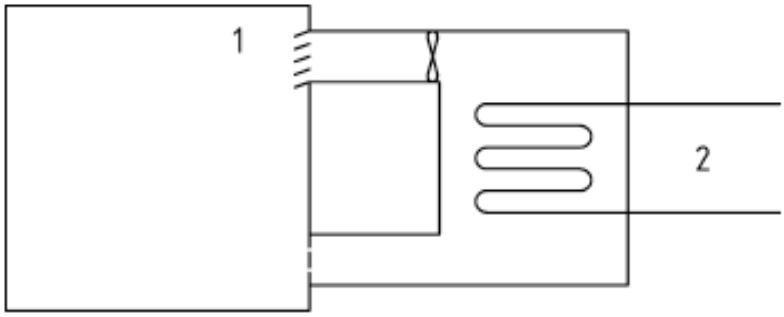
Key
1 occupied space
2 refrigerant-containing part(s)

Figure 4. Example of an open spray system

3.1.2.4.1.3 Direct ducted system

A ducted system is classified as a direct releasable system if the conditioned air is in direct contact with refrigerant-containing parts of the circuit and the conditioned air is supplied to an occupied space (see Figure 5).

Direct ducted systems are considered to be located in location Class I or II.



Key

1 occupied space

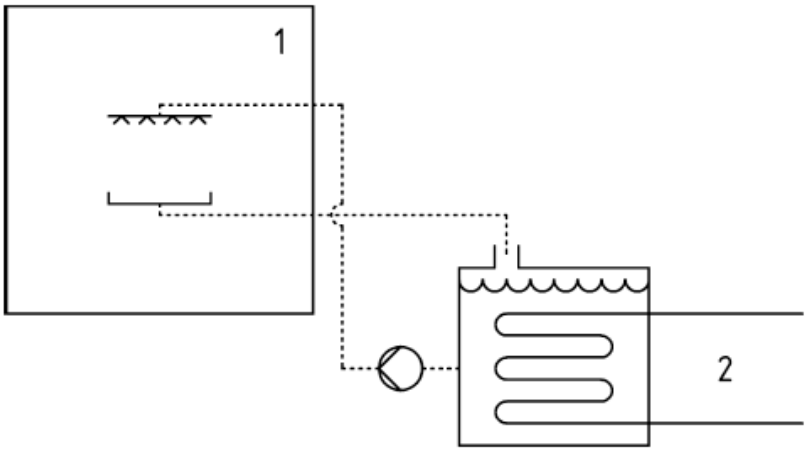
2 refrigerant-containing part(s)

Figure 5. Example of a direct ducted system

3.1.2.4.1.4 Open vented spray system

An open vented spray system is classified as a direct releasable system if the heat-transfer fluid is in direct contact with refrigerant-containing parts of the circuit and the indirect circuit is open to an occupied space. The heat-transfer fluid shall be vented to the atmosphere outside the occupied space, but the possibility remains that a single rupture of the refrigerant circuit could result in refrigerant release to the occupied space (see Figure 6).

Open vented spray systems are considered to be located in location Class I or II.



Key

1 occupied space

2 refrigerant-containing part(s)

Figure 6. Example of an open vented spray system

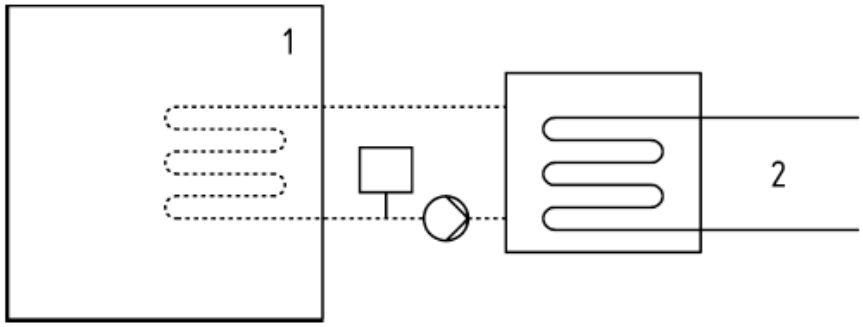
3.1.2.4.2 Indirect systems

The evaporator cools or the condenser or gas cooler heats the heat-transfer fluid which passes through a closed circuit containing heat exchangers that are in direct contact with the substance to be treated.

3.1.2.4.2.1 Indirect closed system

An indirect system shall be classified as an indirect closed system if the heat-transfer fluid is in direct communication with an occupied space and a refrigerant leak into the indirect circuit can enter into the occupied space if the indirect circuit also leaks or is purged (see Figure 7).

Indirect closed systems are considered to be located in location Class I or II.



Key

1 occupied space

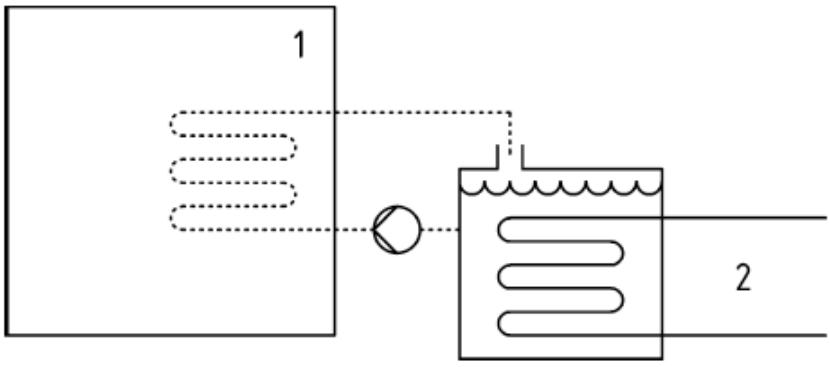
2 refrigerant-containing part(s)

Figure 7. Example of an indirect closed system

3.1.2.4.2.2 Indirect vented system

An indirect system shall be classified as an indirect vented system if the heat-transfer fluid is in direct communication with an occupied space and a refrigerant leak into the indirect circuit can vent to the atmosphere outside the occupied space (see Figure 8).

Indirect vented systems are considered to be located in location class III.



Key

1 occupied space

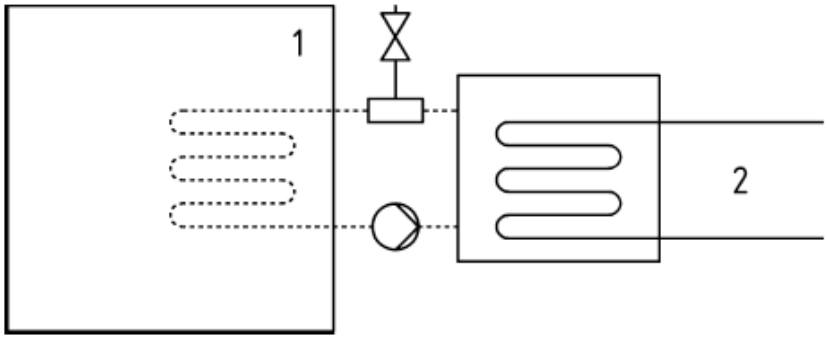
2 refrigerant-containing part(s)

Figure 8. Example of an indirect vented system

3.1.2.4.2.3 Indirect vented closed system

An indirect system shall be classified as an indirect vented closed system if the heat-transfer fluid is in direct communication with an occupied space and a refrigerant leak into the indirect circuit can vent to the atmosphere through a mechanical vent, outside the occupied space (see Figure 9).

Indirect vented systems are considered to be located in location class III.



Key

1 occupied space

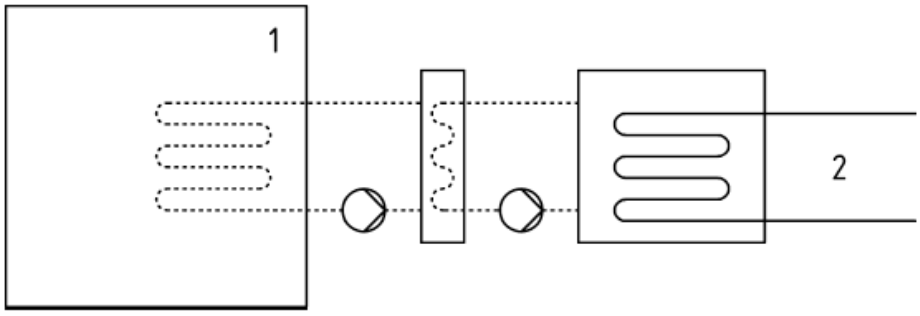
2 refrigerant-containing part(s)

Figure 9. Example of an indirect vented closed system

3.1.2.4.2.4 Double indirect system

An indirect system shall be classified as a double indirect system if the heat-transfer fluid is in direct communication with refrigerant-containing parts and the heat can be exchanged with a second indirect circuit that passes into an occupied space (see Figure 10). A refrigerant leak cannot enter the occupied space.

Double indirect systems are considered to be located in location class III.



Key

1 occupied space

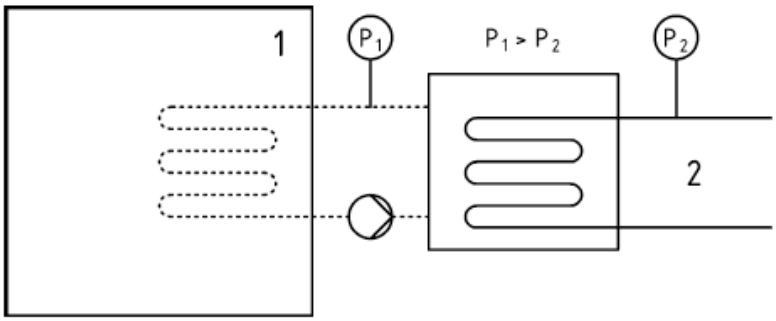
2 refrigerant-containing part(s)

Figure 10. Example of a double indirect system

3.1.2.4.2.5 High pressure indirect system

An indirect system shall be classified as a high pressure indirect system if the heat-transfer fluid is in direct communication with an occupied space and the indirect circuit is maintained at a higher pressure than the refrigerant circuit at all times so that a rupture of the refrigerant circuit cannot result in a refrigerant release to the occupied space (see Figure 11). The refrigerant cannot leak into the indirect circuit.

High pressure indirect systems are considered to be located in location class III.



Key

1 occupied space

2 refrigerant-containing part(s)

P_1 Pressure 1

P_2 Pressure 2

Figure 11. Example of a high-pressure indirect system

3.1.2.4.2.6 Classification of the MiniStor system

The previous list of systems can be compared to the thermal storage configuration presented in Figure 2. From this comparison, the MiniStor system can be classified **as a double indirect system** (see Figure 10). Heat produced from the thermochemical reaction is upgraded by the heat pump and then dispatched to the hot PCMs. The stored heat is then transferred via heat exchangers to the existing heating system in the dwelling.

3.1.3 Refrigerant charge limit requirements

3.1.3.1 Previous considerations

3.1.3.1.1 Quantity of refrigerant

The maximum refrigerant charge that can be permitted in a system is determined by the access categories of any space into which the refrigerant could leak, either directly or in some circumstances through a heat-transfer fluid.

The space which determines the charge limits might not be the space that is served by the refrigerating fluid or air-conditioning system.

The quantity of refrigerant that could enter into a space shall be determined as follows:

- the refrigerant quantity shall not exceed the amounts specified in Section 3.2 of EN 378;
- the refrigerant quantity is the quantity that can be released into the space where the refrigerant quantity shall be the largest charge of any single refrigerating system unless otherwise specified in this standard.

Where product standards exist for particular types of systems and where these product standards refer to refrigerant quantities limits, such quantities shall overrule the requirements of standard EN 378.

3.1.3.1.2 Space volume calculations

According to the standard, the space considered shall be any space which contains refrigerant-containing parts or into which refrigerant could be released.

The volume (V) of the smallest, enclosed, occupied space shall be used in the determination of the refrigerant quantity limits.

Multiple spaces that have appropriate openings (which cannot be closed) between the individual spaces or are connected with a common ventilation supply, return or exhaust system not containing the evaporator or the condenser shall be treated as a single space.

Where the evaporator or condenser is located in an air supply duct system serving multiple spaces, the volume of the smallest single space shall be used.

If the air flow to a space cannot be reduced to less than 10 % of the maximum air flow by the use of an air flow reducer, then that space shall be included in the volume of the smallest human occupied space.

For refrigerants of safety class A1 the total volume of all the rooms cooled or heated by air from one system is used as the volume for calculation, if the air supply to each room cannot be restricted below 25 % of its full supply. For refrigerants of safety class A1 the effect of the air changes may be considered in calculating the volume if the space has a mechanical ventilation system which will be operating during the occupation of the space.

Where the evaporator or condenser is located in an air supply duct system and the system serves an unpartitioned multi-storey building, the occupied volume of the smallest occupied storey of the building shall be used.

The space above a false ceiling or partition shall be included in the volume calculation unless the false

ceiling is airtight.

Where an indoor unit, or any related refrigerant-containing pipework, is located in a space such that the total charge exceeds the allowable charge, special provisions shall be made to ensure at least an equivalent level of safety. See 3.1.3.3.1.

3.1.3.2 Charge limits requirements for refrigerating systems

Refrigerant charge limits shall be calculated according to Table C.1 and Table C.2 of EN 378 depending on the toxicity and/or the flammability of the refrigerant.

Where more restrictive national or regional regulations exist, they take precedence over the charge limit requirements of this standard.

The following method shall be applied to determine the charge limit of a refrigerating system:

a) determine the appropriate access category a, b or c according to Table 9 and location I, II, III, or IV according to Section 2.3 of EN 378 for the system;

b) determine the toxicity class of the refrigerant used in the refrigerating system which will be A or B, being the first character in the safety class specified in Annex E. The toxicity limit equals ATEL/ODL values (see Annex E) or the practical limit (see Annex E) whichever is higher;

c) determine the charge limit for the refrigerating system based on toxicity as the greater of:

1) Charge limit from Table C.1;
2) 20 m^3 multiplied by the toxicity limit for sealed refrigerating systems;
3) 150 g for sealed refrigerating system using toxicity class A refrigerant;

d) determine the flammability class of the refrigerant used in the refrigerating system which will be 1, 2L, 2 or 3, being the characters following A or B in the safety class specified in Annex E. Determine the corresponding LFL (Lower Flammability Level) according to Annex E;

e) determine the charge limit for the refrigerating system based on flammability as the greater of:

1) Charge limit from Table C.2;
2) m_1 x 1,5 for sealed refrigerating systems using flammability class 2L;
3) m_1 for sealed refrigerating systems using flammability class 2 or 3;
4) 150 g for sealed refrigerating systems;

f) apply the lowest refrigerant charge obtained according to c) and e). For determination of charge limits for refrigerants of flammability class 1, e) is not applicable.

The charge limits in Table C.2 are capped to a limit based upon the LFL of the refrigerant. In case of flammability class 2 or 3 refrigerants, the basic cap factor is m_1, m_2 and m_3. For flammability class 2L refrigerants the basic cap factor is increased by a factor of 1,5 in recognition of the lower burning velocities of these refrigerants, which lead to a reduced probability and consequence of ignition.

The cap factors shown in Table C.2 are:
— m_1 = 4 m^3 × LFL
— m_2 = 26 m^3 × LFL
— m_3 = 130 m^3 × LFL
where LFL equals the lower flammable limit in kg/m3 according to Annex E.
The limits for the MiniStor system are discussed in detail in Section 3.1.4 of this document.

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Table C.1 — Charge limit requirements for refrigerating systems based on toxicity

Toxicity class	Access category		Location classification			
			I	II	III	IV
A	a		Toxicity limit × Room volume or see C.3		No charge restriction [a]	The charge requirements based on toxicity shall be assessed according to location I, II or III, depending on the location of the ventilated enclosure
	b	Upper floors without emergency exits or Below ground floor level	Toxicity limit × Room volume or see C.3	No charge restriction [a]		
		Other	No charge restriction [a]			
	c	Upper floors without emergency exits or Below ground floor level	Toxicity limit × Room volume or see C.3			
		Other	No charge restriction [a]			
B	a		For sealed sorption systems, toxicity limit × Room volume and not more than 2,5 kg, all other systems, toxicity limit × Room volume		No charge restriction[a]	
	b	Upper floors without emergency exits or Below ground floor level	Toxicity limit × Room volume	Charge not more than 25 kg[a]		
		Density of personnel <1 person per 10 m²	Charge not more than 10 kg[a]	No charge restriction[a]		
		Other		Charge not more than 25 kg[a]		
	c	Density of personnel <1 person per 10 m²	Charge not more than 50 kg[a] and emergency exits are available	No charge restriction[a]		
		Other	Charge not more than 10 kg[a]	Charge not more than 25 kg[a]		

[a] For open air, EN 378-3:2016, 4.2 applies and, for machinery rooms, EN 378-3:2016, 4.3 applies.

Table 10. Charge limit requirements for refrigerating systems based on toxicity EN 378

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869821

Table C.2 — Charge limit requirements for refrigerating systems based on flammability

Flammability class	Access category		Location classification			
			I	II	III	IV
2L	a	Human comfort	According to C.2 and not more than m_2 [a] × 1,5 or According to C.3 and not more than m_3 [b] × 1,5		No charge restriction [c]	Refrigerant charge not more than m_3 [b] × 1,5
		Other applications	20 % x LFL × Room volume and not more than m_2 [a] × 1,5 or According to C.3 and not more than m_3 [b] × 1,5			
	b	Human comfort	According to C.2 and not more than m_2 [a] × 1,5 or According to C.3 and not more than m_3 [b] × 1,5			
		Other applications	20 % × LFL × Room volume and not more than m_2 [a] × 1,5 or according to C.3 and not more than m_3 [b] × 1,5	20 % × LFL × Room volume and not more than 25 kg [c] or according to C.3 and not more than m_3 [b] × 1,5		
	c	Human comfort	According to C.2 and not more than m_2 [a] × 1,5 or According to C.3 and not more than m_3 [b] × 1,5			
		Other applications	20 % × LFL × Room volume and not more than m_2 [a] × 1,5 or according to C.3 and not more than m_3 [b] × 1,5	20 % × LFL × Room volume and not more than 25 kg [c] or according to C.3 and not more than m_3 [b] × 1,5		
		<1 person per 10 m^2	20 % × LFL × Room volume and not more than 50 kg [a] or according to C.3 and not more than m_3 [b] × 1,5	No charge restriction [c]		

[a] $m_2 = 26\ m^3 \times LFL$.

[b] $m_3 = 130\ m^3 \times LFL$.

[c] For open air, EN 378-3:2016, 4.2 applies and, for machinery rooms, EN 378-3:2016, 4.3 applies.

Table 11. Charge limit requirements for refrigerating systems based on flammability

3.1.3.3 Charge limitations due to flammability for air conditioning systems or heat pumps for human comfort

3.1.3.3.1 Refrigerant-containing parts in an occupied space

When the charge of refrigerants with flammability class 2L is greater than m1 x 1,5, the maximum charge in the room shall be in accordance with Formula (C.1).

$$m_{max} = 2{,}5 \cdot LFL^{5/4} \cdot h_0 \cdot A^{0.5} \quad (C.1)$$

Where

m_{max} is the allowable maximum charge in a room in kg;
A is the room area in m^2;
LFL is the Lower Flammable Limit in kg/m^3, as defined in Annex E;
h_0 is the height factor of the appliance:

- 0,6 for floor location;
- 1,8 for wall mounted;
- 1,0 for window mounted;
- 2,2 for ceiling mounted,

3.1.4 Ammonia constraints for MiniStor

Beyond the explanation of the main parts of the EN-378, in this section, ammonia constraints for the MiniStor system are going to be studied according to the restrictions previously explained.

As seen in the following figures, in the MiniStor system, ammonia is released due to the decomposition reaction (charging phase) in the TCM Tank at a pressure of 3 bar. Besides that, it is compressed to a pressure of 11 bar in order to condense it, where it releases heat to a water loop at 28ºC. Then, the ammonia is collected and stored in a tank at 11 bar. The synthesis reaction (discharging phase) takes place at 4 bar, so it is necessary to drop down the ammonia pressure. A chilled water loop is connected to the evaporator and can be utilized for air conditioning during the summer period.

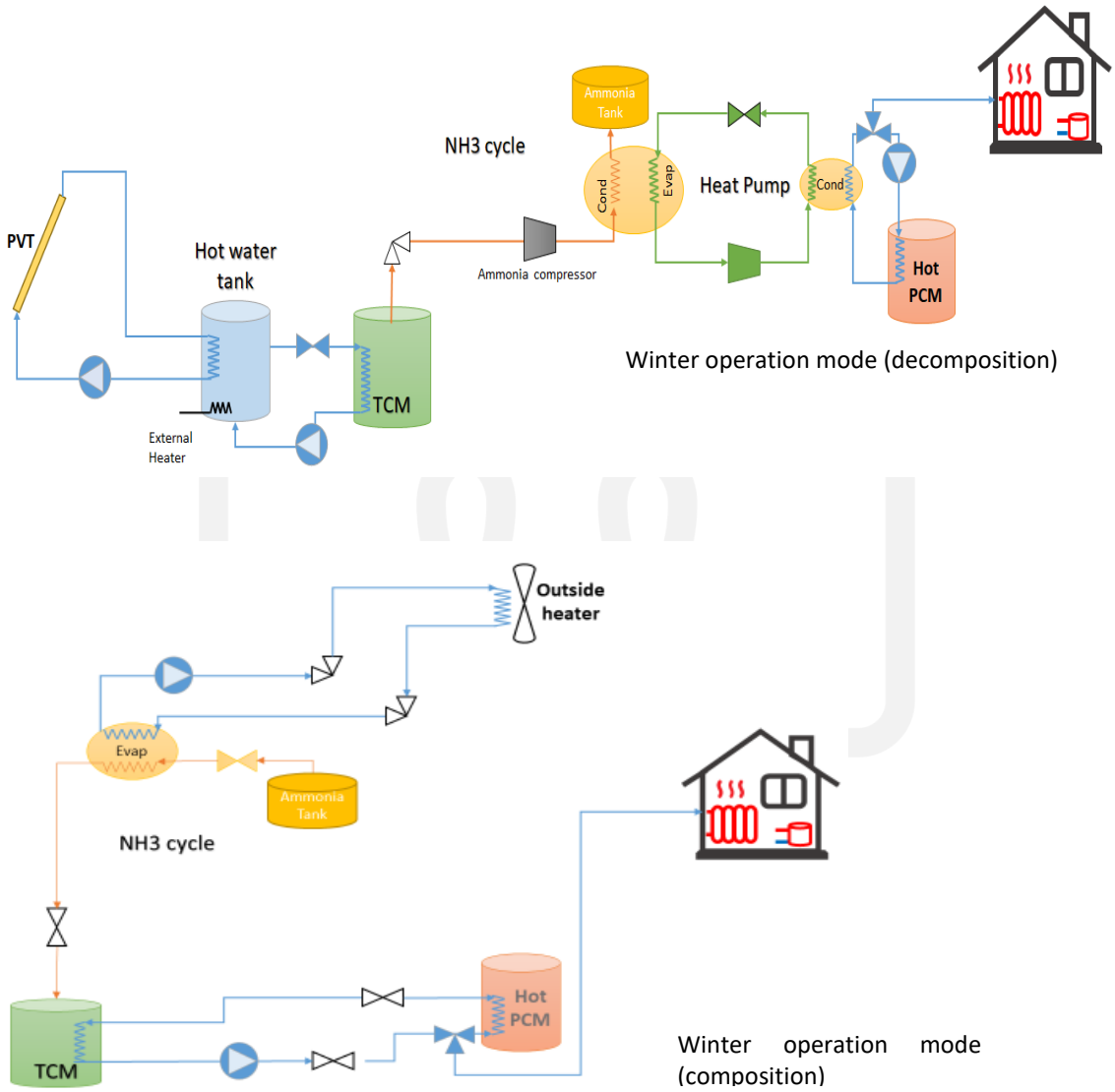

Figure 12. Winter (heating) operation modes of MiniStor (decomposition and composition)

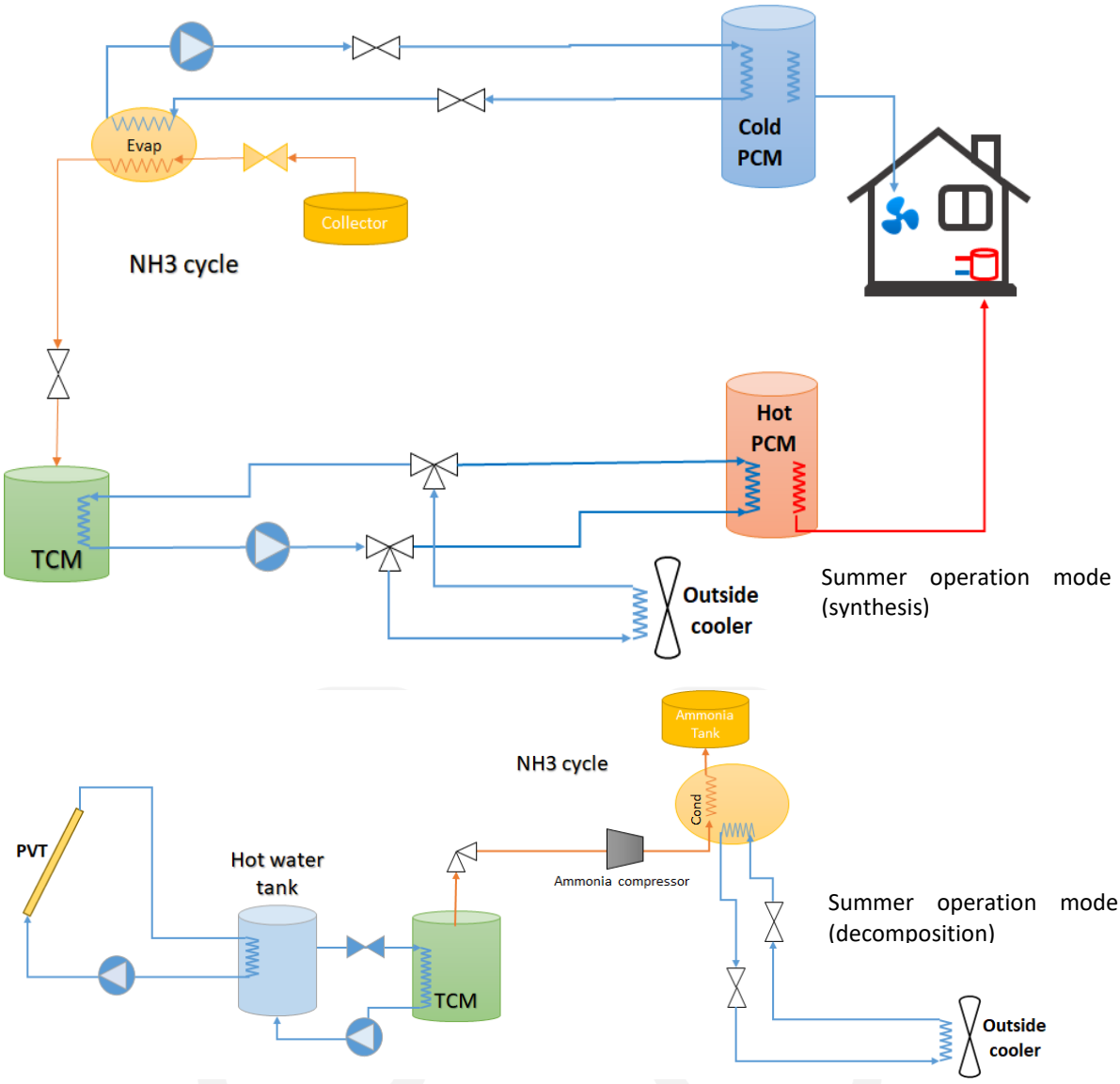

Figure 13 Summer (cooling) operation modes of the MiniStor system

Therefore, on the basis of this configuration and according to the refrigerating system classification in EN 378, the MiniStor system can be classified **as a double indirect system** (see Figure 10), which usually are considered to be in **Location Class III - machinery room or open air** (see Table 10 Location classification of refrigerating systems).

Location Class III defines no charging restrictions. However, in addition and once the system is classified, it is necessary to study the refrigerant properties. The following table contains the main information about ammonia, according to Annex E of the EN-378 Part 1.

Information from EN-378 Annex E: Ammonia	
Refrigerant Number	717
Chemical formula	NH_3
Pressure Equipment Directive 2014/68/EU Fluid Group	1
Safety Class	B2L
Practical limit (kg/m^3)	0.00035
ATEL/ODL (kg/m^3)	0.00022
LFL (kg/m^3)	0.116

Vapour density (kg/m³)	0.700
Normal boiling point (º C)	-33
Auto ignition temperature (º C)	630

Table 12. Ammonia properties (Source: Annex E of EN 378)

It is necessary to clarify some terms presented by the table:

- Practical limit. Concentration used for simplified calculation to determine the maximum acceptable amount of refrigerant **in an occupied space which will not result in any escape impairing (i.e. acute) effects**.

- ATEL/ODL. Concentration of a refrigerant or other gas that results in insufficient oxygen for normal breathing. ATEL stands for Acute-Toxicity Exposure Limit and ODL stands for Oxygen Deprivation Limit. It is a measure of the toxicity.

- LFL. It stands for Lower Flammability Level. It is the minimum concentration of refrigerant that is capable of propagating a flame within a homogeneous mixture of refrigerant and air.

- Safety Class. It is a classification depending on the toxicity and flammability of the refrigerant. There are two toxicity classes (A and B) and three flammability classes (1, 2L, 2, 3).

A very important matter to highlight is the fact that ammonia has the lowest practical limit for use in an occupied space within the refrigerant list in Annex E. This is to say, it has the highest volume restrictions due to its toxicity. For example, common refrigerants like R134a or R410a have practical limits of 0.25 kg/m3 and 0.44 kg/m3, however the practical limit of ammonia is 0.00035 kg/m3 (~ 1,000 times lower).

It is obvious that this matter will constrain placement of the whole system, since the maximum allowable ammonia volume **in an indoor occupied space** as defined in EN 378-3:2016, "5.1. Access categories", is extremely low.

Finally, it is also necessary to study the location where the system is going to be placed. The system is intended to be placed in dwellings, where Access Category must be A (see Access categories, Table 9). The only matter that remains to be defined is the Location Classification (see table 10 Location classification of refrigerating systems).

For example, if the most restrictive room with parts containing ammonia (the most restrictive is the smallest space) inside a domestic building is a 50 m2 room (on average rooms might be smaller), the ammonia limit is 38.5 gr, which is very small for the TCM storage unit. Please check the Annex "EN 378 Ammonia Calculations" delivered with this document.

After performing all the necessary calculations based on EN 378, the main conclusion is that the only feasible way to use ammonia as a refrigerant for use in Access Category A (dwellings) **is to keep all the *ammonia-containing parts* in a machinery room or in an outside open air shelter (Location Class III), in order to comply with restrictions due to its toxicity, while at the same time allow for amounts that can be used to produce thermochemical reactions generating heat that can be meaningful for use in a dwelling.**

In terms of maximum charge for outdoor equipment, it has been found that France is the only European Union member to impose specific limits on the use of ammonia in refrigeration [13]. These are regulated by Article L. 512-11 of the French Environment Code, which states that **ammonia-based system reservoirs with a charge less than 50 kg per refrigeration unit are exempt of mandatory reporting and periodic inspections by approved organisations in each prefecture**. Installations (whole systems) with a quantity of less than 150kg do not require any authorization or administrative declaration. Calculations for the MiniStor system carried out by CNRS have been done using the maximum limit of 50 kg. The chosen

storage capacity for the TCM unit of 16 kWh of heat / 10 kWh of cold leads to a maximum ammonia amount of **59.1 kg**.

3.1.5 EN-378 Part 3. Open air and machinery room requirements for use with ammonia refrigerant

In either case of open air or machinery room, it is necessary to point out that EN-378-Part 3 sets some mandatory conditions for the space that will contain the ammonia loop. These conditions must be taken into account in order to provide a safe and proper design.

This section contains a summary of the main requirements set in the EN-378-3 for refrigerating installations and particular requirements for installations that use ammonia as a refrigerant.

As it has been explained previously, the only feasible way to use the required amounts of ammonia to produce a reaction in the TCM material and supplement heat requirements in a dwelling, is to place all ammonia refrigerant-containing parts in the open air or in a machinery room. The requirements for each case are explained below.

3.1.5.1 Open air requirements

Refrigerating systems sited in the open air shall be positioned to avoid leaked refrigerant flowing into a building or otherwise endangering people and property. The refrigerant shall not be able to flow into any ventilation fresh air opening, doorway, trap door or similar opening in the event of a leak. Where a shelter is provided for refrigerating equipment sited in the open air, it shall have natural or forced ventilation.

An enclosed space where at least one of the longer walls is open to the outside air by means of louvres with 75 % free area and covering at least 80 % of the wall area (or the equivalent if more than one wall is facing outside), is considered as being in the open air.

For refrigeration systems installed outside in a location where a release of refrigerant can stagnate, e.g. below ground, then the installation shall comply with the requirements for gas detection and ventilation of machinery rooms. For refrigerants of class 2L, 2 and 3 requirements regarding ignition sources in EN 378-2:2016, 6.2.14 shall apply where appropriate.

3.1.5.2 Refrigerating equipment located in a machinery room

When a machinery room is chosen for the location of the refrigerating equipment it shall meet the requirements specified in this section.

A risk analysis based on the safety concept for the refrigerating system (as determined by the manufacturer and including the charge and safety classification of the refrigerant used) shall be conducted to determine whether it is necessary to place the refrigerating system in a separate refrigeration machinery room.

NOTE: National regulations may set specific additional requirements for the use of separate refrigeration machinery rooms.

3.1.5.2.1 Access to machinery rooms

Machinery rooms should not be used as occupied spaces (where other activities are performed or materials stored). The operator shall ensure that access is permitted only by instructed personnel doing the necessary maintenance to the machinery room or general plant. If machinery rooms are used for significant periods, e.g. as a building maintenance workspace, they shall be considered as occupied spaces under access category c, authorised access, given in EN 378-1.

A separate refrigeration machinery room shall not be used as an occupied space.

3.1.5.2.2 Venting from or through the machinery room

Refrigerant shall be prevented from entering neighbouring rooms, staircases, courts, gangways or building draining systems and the escaping gas shall be vented outdoors.

There shall be no airflow to an occupied space through a machinery room unless the air is ducted and sealed to prevent any refrigerant leakage from entering the air stream.

3.1.5.2.3 Combustion equipment and air compressors

Where combustion equipment or air compressors are located in a machinery room containing refrigerating equipment, the combustion air supply for combustion engines or boilers or the supply air for air compressors shall be ducted from outside in such a manner as to prevent any refrigerant from entering the air intake.

3.1.5.2.4 Open flame

Open (naked) flames shall not be permitted in machinery rooms, except for welding, brazing or similar activity and then only provided the refrigerant concentration is monitored and adequate ventilation is ensured. Such open flames shall not be left unattended.

3.1.5.2.5 Storage

Machinery rooms shall not be used for storage with the exception of tools, spare parts and compressor oil for the installed equipment. Any refrigerants, or flammable or toxic materials shall be stored as required by national regulations.

3.1.5.2.6 Remote emergency switch

A remote switch for stopping the refrigerating system shall be provided outside the room, near to the machinery room door. A similar acting switch shall be located at a suitable location inside the room. The switches shall meet the requirements for emergency switches in accordance with EN ISO 13850 and EN 60204-1.

For gas fired refrigeration systems specific measures may be required including local regulations.

3.1.5.2.7 Exterior openings of the machinery room

Exterior openings shall not be situated within **2 m** of building emergency exit staircases or other building openings, e.g. windows, doors, ventilation inlets.

3.1.5.2.8 Piping and ducting

All piping and ventilation ducting that passes through walls, ceiling and floors of machinery rooms, shall be sealed where it passes through the walls ceiling or floors. The seal shall have at least the same fire resistance as the walls, ceiling or floor.

3.1.5.2.9 Normal lighting

Fixed lighting shall be selected and positioned in spaces containing refrigerating equipment to provide adequate illumination for safe operation. The illumination level and location shall be as required by national regulations. Filament light bulbs shall be protected by "splash safe" covers (EN 60529 IPX 4) in machinery rooms containing ammonia refrigerating systems.

3.1.5.2.10 Emergency lighting

A fixed or portable emergency lighting system shall be provided, adequate to allow operation of controls and evacuation of personnel, when normal lighting fails. The illumination level and location shall be as required by national regulations.

3.1.5.2.11 Dimensions and accessibility

The dimensions of the machinery room shall allow easy installation and sufficient room for service, maintenance, operation, repair and disassembly of the refrigerating equipment, including sufficient space for persons wearing personal protection equipment.

If necessary, catwalks and fixed ladders shall be provided in order to avoid standing or walking on piping, fittings, their supports and supporting structures and on components during the operation, maintenance, inspection and repair of the refrigerating system.

There shall be clear headroom of at least 2,1 m below equipment situated over gangways and permanent work places. The requirements for work staging shall be according to EN ISO 14122-2.

3.1.5.2.12 Doors, walls and ducts

3.1.5.2.12.1 Doors and openings

Machinery rooms shall have doors opening outward and sufficient in number to ensure persons can escape in an emergency.

The doors shall be tight fitting and self-closing. They shall be so designed that they can be opened from inside (anti-panic system). The doors shall have at least a one-hour fire resistance construction, using materials and construction tested in accordance with EN 1634. There shall be no openings that permit unintended passage of escaping refrigerant, vapours, odours and all other gases to any occupied space.

3.1.5.2.12.2 Emergency

Provision shall be made to facilitate immediate exit from the machinery room in the event of an emergency.

At least one emergency exit shall open directly to the open air or it shall lead to an emergency exit passageway.

3.1.5.2.12.3 Service ducts

Service ducts shall conform to the requirements of EN 1366-1 and EN 1366-2, and they shall be sealed to minimize escaped refrigerant leakage into the service duct, and shall have at least the same fire resistance as walls and doors.

Service ducts, including walkways and crawl spaces, containing piping for refrigerants shall be vented to a safe place to prevent a dangerous accumulation of refrigerant in the event of a leak. Service ducts shall not be used for ventilation or conditioned air.

3.1.5.2.12.4 Ventilation ducts

Sheet metal for normal and emergency ventilation ducts shall be in accordance with EN 1507 and supported as required by EN 12236. After erection all duct seams and joints shall be sealed to minimize gas leakage from the duct. The ventilation duct shall have at least the same fire resistance as the doors and walls of the machinery room.

3.1.5.2.13 Ventilation

The ventilation of machinery rooms shall be sufficient both for normal operating conditions and emergencies.

Air from machinery rooms shall be vented outdoors using mechanical ventilation in case of a release of refrigerant due to leaks of components. This ventilation system shall be independent of any other ventilation system on the site.

Provision shall be made for a sufficient supply of outside replacement air and a good distribution of that air over the machinery room avoiding dead zones.

Openings for outside air shall be positioned to avoid re-circulation into the room.

3.1.5.2.13.1 Ventilation for normal operating conditions or when machinery room is occupied

Ventilation shall be in accordance with national regulations with a minimum of 4 air changes per hour when the machinery room is occupied (e.g. for inspections). In the event that the necessary ventilation rate cannot be achieved an audible and/or visual alarm shall be initiated and, where relevant, electrical supplies shall be terminated.

3.1.5.2.13.2 Emergency mechanical ventilation

If gas detection is required in the machinery room, the emergency mechanical ventilation system shall be activated by a detector(s), located in the machinery room. The detector(s) shall be as specified in other sections of this document.

Emergency mechanical ventilation shall be provided with two independent emergency controls one located outside the machinery room, and the other inside.

3.1.5.2.13.3 Required airflow for emergency mechanical ventilation

Airflow of the mechanical ventilation shall be at least the quantity obtained by the following formula:

$$\dot{V} = 0.014 \cdot m^{2/3}$$

Where:
V is the air flow rate in m^3/s;

m is the mass of refrigerant charge, in kg, in the refrigerating system with the largest charge, any part of which is located in the machinery room;

An emergency ventilation system with 15 air changes per hour is sufficient.

3.1.5.2.13.4 Mechanical ventilation openings

Mechanical ventilation openings shall be made in the position and of sizes to permit sufficient airflow considering the characteristics of the refrigerant, the choice of intake or exhaust and the performance of the ventilator. The intake and exhaust openings shall be arranged to evacuate the refrigerant under all conditions of leaking refrigerant.

3.1.5.2.14 Specific requirements for Ammonia

Machinery rooms with group A2L, A2, B2L, B2, A3, B3 refrigerants shall be assessed with regard to flammability and classified according to the requirements of EN 60079-10-1 for the hazardous zone.

3.1.5.2.14.1 Emergency exhaust ventilation

The emergency exhaust ventilation fan shall be either:

a) in the air flow with the motor outside the airflow, or

b) rated for hazardous areas as required in EN 378-2:2016, 6.2.14.

The fan shall be located to avoid pressurization of the exhaust ductwork in the machinery room.

The fan shall not cause sparks to occur if it contacts the duct material.

The outlet from the exhaust ventilation shall be in accordance with national regulations. The outlet shall not be restricted but have means of keeping rubbish, leaves and birds from entering. The bottom of any rising ductwork open to the outside shall have a drain with a trap for rainwater and with access for inspection.

For doors communicating to other areas inside a building and where the gas detector is not able to detect refrigerants when these doors are opened, emergency ventilation shall be initiated when a door is opened for more than 60 seconds.

3.1.5.2.14.2 Drainage

To prevent R-717 spill reaching surface waters, a catchment system shall be designed and installed in accordance with national regulations. The machinery room floor shall be designed in order to prevent liquid R-717 from spilling out from the room. The drain from the catchment system shall be normally closed.

3.1.5.2.14.3 Specific equipment for emergency washing

For R-717 easily accessible eye wash facilities (e.g. eye wash bottle) for all systems shall be provided. For systems with a refrigerant charge **over 1,000 kg** an emergency shower, providing at least 1 l/s flow at between 25 °C and 30 °C shall be located outside the emergency exit from the machinery room.

3.1.5.2.14.4 Fire sprinkler systems

Provided the machinery room is fully compliant with the requirements of this standard, fire suppression systems of the water sprinkler type shall not be installed in machinery rooms with R-717 refrigerating systems unless the following conditions are fulfilled:

- the sprinkler heads are individually actuated at 141 °C or higher (high temperature according to EN 12845);
- there is no manual override of the activation of the sprinkler system;
- the sprinkler installation conforms to the requirements of EN 12845.

NOTE:

The addition of water to a pool of liquid ammonia can cause the rapid evolution of large amounts of ammonia gas in the atmosphere resulting in increased risk of injury to persons in the vicinity.

A pre-action system where an actuated water valve in the sprinkler supply is controlled by a fire detection system can be used to reduce the probability of accidental discharge of any of the sprinkler heads.

The provision for a remote sump in the drainage system from the machinery room will reduce the risk of environmental pollution from the run-off water.

Note: In the extreme case of an ammonia leakage, the amount of ammonia to be used in the MiniStor system reduces the possibility of having such pool of ammonia, but instead will become vapour at atmospheric pressure.

3.1.5.2.14.5 Maximum surface temperature

Hot surfaces shall not exceed a temperature of 80 % of the auto-ignition temperature (in °C) or 100 K less than the auto-ignition temperature of the refrigerant, whichever is higher.

3.1.5.2.14.6 Doors and openings

Machinery rooms shall have a door that either opens directly to the outside air or through a dedicated vestibule equipped with self-closing, tight-fitting doors.

3.1.5.2.14.7 Electrical equipment

Electrical equipment shall be deemed to comply with the requirements if the electrical supply is isolated when the refrigerant concentration reaches 25 % of the lower flammable limit or less. Equipment which remains live in the event of the refrigerant concentration exceeding the main alarm level, for example alarms, gas detectors, ventilation fans and emergency lighting, shall be suitable for operation in a hazardous area.

This clause applies to all electrical equipment and power supplies in the room, not only the refrigerating system.

3.1.5.3 Safety alarms

If alarms are employed to warn of a leak in the machinery room or the occupied space the alarm shall warn of a refrigerant leak in accordance with Section 8.3 of the standard. The alarm shall be turned on by the signal from the detector in accordance with Clause 9. The alarm shall also alert an authorised person to take appropriate action.

3.1.5.3.1 Alarm system power

In cases where an alarm system is installed the power source of the alarm system shall be from a power source independent of the mechanical ventilation or other refrigerating systems which the alarm system is protecting.

3.1.5.3.2 Alarm system warning

The alarm system shall warn both audibly and visibly such as both a loud (15 dB(A) above the background level) buzzer and a flashing lamp.

For a machinery room the alarm system shall warn both inside and outside the machinery room. The alarm outside the machinery room may be installed in a supervised location.

For an occupied space the alarm system shall warn at least inside the occupied space.

For Access Category A (see Access categories) the alarm system shall also warn at a supervised location such as the night porter's location as well as the occupied space.

3.1.5.3.3 Additional alarm system requirements for ammonia systems with charges above **3 000 kg**

The refrigerating system user/owner shall ensure that a continuously attended station is provided as a central alarm station. Specialised personnel shall be present on site within 60 min of an alarm. The personnel may also be informed of the alarm by technical equipment, e.g. mobile telephone, pager, etc.

3.1.5.4 Detectors

When the concentration of the refrigerant can exceed the practical limit in accordance with EN 378-1:2016, Annex C, detectors shall at least actuate an alarm and in the case of the machinery room the emergency mechanical ventilation. In case of ammonia, this concentration is 0.00035 kg/m^3 (500ppm). They shall conform to the requirements given below.

3.1.5.4.1 Location of detectors

The location of detectors shall be chosen in relation to the refrigerant and they shall be located where the refrigerant will concentrate from a leak.

The positioning of the detector shall be done with due consideration of local airflow patterns, accounting for location sources of ventilation and louvers. Consideration shall also be given to the possibility of mechanical damage or contamination.

At least one detector shall be installed in each machinery room or the occupied space being considered and/or at the lowest underground room for refrigerants heavier than air and at the highest point for refrigerants lighter than air.

3.1.5.4.2 Type and performance of detectors

Any suitable detector may be used and shall give an electrical signal at the pre-set value of the refrigerant or oxygen concentration (the pre-set value) that activates the shut-off valves, the alarm system, the mechanical ventilation or other emergency controls.

Detectors shall be continuously monitored for functioning. In the case of a detector failure, the emergency sequence should be activated as if refrigerant had been detected.

The pre-set value for the refrigerant detector at 30 °C or 0 °C, whichever is more critical, shall be set to 25 % of the LFL or 50 % of the ATEL/ODL, whichever is the lower value, as given in EN 378-1:2016, Annex E. The pre-set value for the oxygen deprivation detector shall be 18 % or higher.

The sensitivity tolerance of the detector shall be considered to ensure that the output signal is triggered at or below the pre-set value. The tolerance of the detector shall take into account the ± 10 % of power line voltage tolerance.

An appropriate maintenance period shall be established for each type of detector used.

3.1.5.4.3 Special requirements for ammonia

In order to warn against the danger of explosion or fire in equipment in machinery rooms, and for control purposes **where the charge size is more than 50 kg**, an ammonia detector is required which shall function at a concentration not exceeding:

- 350 mg/m^3 (volume fraction of 500 × 10^{-6}; 500ppm) (pre-alarm);
- 21 200 mg/m^3 (volume fraction of 30 000 × 10^{-6}; 3%) (main alarm).

At the pre-alarm level, an alarm and the mechanical ventilation shall be activated.

At the main alarm level:

- the refrigerating system shall be stopped automatically;
- the power supply to the machinery rooms shall be isolated automatically;
- the mechanical ventilation shall be stopped if appropriate provisions are not made (see *Emergency exhaust ventilation*).

Where the machinery rooms only house the compressors or compressor units, at least one detector shall be placed over the compressors or units. The site of refrigerant pumps in either the machinery room or other areas shall also be monitored by a detector, mounted above and near the pumps.

Detectors shall be suitable for their use and calibrated by a competent organization.

Ammonia detectors shall be incorporated in the heat transfer circuit of indirect systems, for example water or glycol circuits, to detect the presence of refrigerant in the circuit, if the ammonia charge is greater than 500 kg (see also EN 378-2:2016, 6.2.6.8). These detectors shall initiate an alarm in the machinery room, and where practicable in the control system operator interface, but they shall not trigger beacons or klaxons, and they shall not initiate an evacuation.

3.1.5.5 Conclusions from machinery room requirements

The previous sections have shown that safety requirements have been drafted mainly for applicability in large ammonia installations for industrial usages, and beyond the 30kg limit to be used by MiniStor. Further research is needed to provide state-of-the-art safety systems that meet the same level of safety but with simplified systems at the dwelling level, such as predictive maintenance monitoring, use of localized fire prevention systems that can seal leaks, and remote monitoring for system performance. These measures also do not substitute proper training by users during the demonstration period in order to activate emergency measures such as local shutdown done remotely, call to emergency responders, etc.

The cost of these preventive measures must also be considered in future commercialization plans, either by bringing down cost or investigating new complementary technologies.

3.2 Thermochemical storage and phase-change material storages

The search for directives and regulations for system components did not reveal specific ones that apply to the use of specific thermal storage materials, either as thermochemical or phase change materials. Standards are related to the equipment that contain them, such as pressure vessels. Other applicable standards relate to compressors used to cycle the refrigerant, low voltage equipment regulations, etc.

a) Mechanical regulations

Relevant directives include the following

- Pressure Equipment Directive: PED 2014/68/EU
- The Pressure System Safety Regulations 2000 (PSSR)
- Provision and Use of Work Equipment Regulations 1998 (PUWER)
- EN378:2016 Refrigerating systems and heat pumps – Safety and environment requirements (Part 1-4)
- EN12693:2008 Refrigeration systems and heat pumps – Safety and environmental requirements –Positive displacement refrigerant compressors.

These are examined in detail in Section 3.3

b) Energy regulations

Relevant directives include the following:

- Energy Labelling Framework Regulation 2017/1369/EU

However, specific calculations must be followed in order to determine the exact class where the product can be placed. As a composite product, special procedures must be investigated for MiniStor and comparable energy storage products such as water heaters.

c) Electrical regulations

Relevant directives include the following:

- Low Voltage Directive 2014/35/EU

Which has been discussed in detail in Section 2.6.5.

3.3 Tightness requirements to prevent leaks

3.3.1 Introduction

In this section, relevant standards and legislation related to tightness requirements to prevent leaks are analysed. They are essential in order to prevent leaks from potential operations that could accidentally cause over or under pressure.

It must be noted that this topic is strongly related to Section 2.6.7., which contains the analysis of the Pressure Equipment Directive (PED) and its harmonised standards.

3.3.2 Standards to be considered

In a first approach, the analysis began with EN 378 – Part 2 standard. This standard, which is a Type C standard as stated in EN ISO 12100, is applicable to the design, construction and installation of

refrigerating systems including piping, components and materials. It also specifies requirements for testing, commissioning, marking and documentation.

In EN 378-2, relevant standards related to tightness are identified. The following table shows those standards for each subcomponent of the installation:

COMPONENT		Related standard AND requirements
Heat exchangers: — **pipe coil without air (tube in tube)** — **multi-tubular (shell and tubes)**		EN 14276–1 or EN 13445 if applicable combined with 5.2.2 of EN-378-2
Plate heat exchangers		EN 14276–1 or EN 13445 if applicable combined with 5.2.2 of EN-378-2
Headers, coils and grids with air as secondary fluid		EN 14276–2 or EN 14276–1 if applicable combined with 5.2.2.2 of EN-378-2
Receiver/accumulator/economizer		EN 14276–1 or EN 13445 if applicable combined with 5.2.2 of EN-378-2
Oil separator		EN 14276–1 or EN 13445 if applicable combined with 5.2.2 of EN-378-2
Drier		EN 14276–1 or EN 13445 if applicable combined with 5.2.2 of EN-378-2
Filter		EN 14276–1 or EN 13445 if applicable combined with 5.2.2 of EN-378-2
Muffler		EN 14276–1 or EN 13445 if applicable combined with 5.2.2 of EN-378-2
Hermetic positive displacement motor-compressor		EN 14276–1, EN 60335–2-34 or EN 12693
Semi-hermetic positive displacement motor-compressor		EN 60335–2-34 or EN 12693
Open positive displacement compressor		EN 12693
Non positive displacement compressor		EN 14276–1, EN 1012–3 or EN 13445 if applicable combined with EN 60204–1
Pump	general requirements	EN 809 combined with EN 60204–1, and combined with 5.2.2.2 and 5.2.2.4 of EN-378-2
	additional requirements for pumps in refrigerating systems and heat pumps with R-717	Annex A
Piping		EN 14276–2 or EN 13480
Piping joints: permanent joints		EN 14276–2
Piping joints: detachable joints		5.2.2.2 and 5.2.2.3 of EN-378-2
Flexible piping		EN 1736
Valves	general	EN 12284
	isolating valves	EN 12284

COMPONENT	Related standard AND requirements
hand operated valves	EN 12284
valves with seal cap	EN 12284
pressure relief valve	EN 13136 and EN ISO 4126-1 combined with 5.2.2 of EN-378-2
Safety switching devices for limiting the pressure	EN 12263 combined with 5.2.2.2 of EN-378-2
Bursting disc	EN ISO 4126-2 and EN 13136 combined with 5.2.2.2 of EN-378-2
Liquid level indicators	EN 12178 combined with 5.2.2.2 of EN-378-2
Gauges	EN 837–1, EN 837–2 and EN 837–3 combined with 5.2.2.2 of EN-378-2
Brazing and soldering materials	5.3.1.3 e), f) of EN-378-2
Welding materials	EN 14276–2

Table 13. Tightness-related standards in EN 378-2

In EN 378-2 Annex A, additional requirements for refrigerating systems containing R-717 are specified. Those requirements are related to the installation of certain types of valves (*remote controlled if charge is > 3,000 kg)* and pumps, which have to be centrifugal pumps with hermetic motor, or be equipped with a double seal system.

For MiniStor, the compressor model "Frigopol 7DLY", which is the smallest model manufactured by Frigopol is suitable for the MiniStor application. This compressor is a semi-hermetic type of compressor with a separating hood to reduce ammonia leakage risks. Its nominal swept volumetric flow rate is 7.22 m3/h @ 1450 rpm (50Hz) and can operate with a maximum compression ratio of 6.

3.4 Usage conditions

Part 4 of EN 378 sets out the modes of operation, maintenance, repair and recovery related to refrigerating systems and heat pumps. All these indications suppose the correct usage conditions of this machinery and will allow its proper functioning and keep the good condition of the equipment in safe conditions.

Some of the most relevant points from this standard are listed below.

Related to operating instructions:

- The person responsible for placing the system in operation shall ensure that the operating personnel are adequately instructed and competent, as well the personnel charged with the operation, supervision and maintenance.
- The logbook shall be kept into the machinery room (or a printout in case of it was stored digitally). The logbook shall be updated following any maintenance or repair.

Related to maintenance and repair:

- The operator of the refrigerating system shall ensure that the system is inspected, regularly supervised and maintained. Maintenance will be in accordance with the instruction manual.
- Repairs on refrigerant containing components shall be carried out by a competent person.

- Refrigerant leaks shall be identified and repaired without undue delay.
- In addition all other instructions from the EN 378-4 related to maintenance and repair must be considered too.

In the event of a change of the refrigerant type used in the refrigerating system, the EN 378-4 point 5.4 planning and execution activities shall be carried out and conformance to the relevant requirements of EN 378-1, EN 378-2 and EN 378-3 shall be implemented where applicable.

Disposal of refrigerating systems and parts shall be undertaken in accordance with national regulations. Recovery, reuse, recycle, reclaim and disposal shall only be undertaken by competent persons.
En 378-4 standard requirements for recovery, reuse and disposal must be considered (chapter 6).

The EN 378-4 standard includes some annexes where instructions and explanations are given for:

- Draining the oil from a refrigerating system
- Guide specification for recycled refrigerant
- Handling and storage of refrigerants.
  For using where no similar criteria exist in national regulations.
- In-service inspection.
  During the operational life of the system, inspection and testing are carried out according to national regulations. Information about in-service inspection given in this annex can be used where no similar criteria exist in national regulations.
- Guidelines for repairs of equipment using flammable refrigerants

3.5 Integration of thermal and electrical energy storages as a single unit

3.5.1 Introduction

In this section, relevant standards and legislation regarding the integration of thermal and electrical energy storages in a single unit is analysed.

Firstly, it is necessary to establish the interactions between thermal parts to the electrical parts. Currently, MiniStor design considers that the main thermal components (PVT panels, TCM tank and PCM storage tanks) are placed outside the building, either in a machinery room or controlled open air space. The cold/hot water produced by the thermal storage will be conducted to heat exchange coils placed inside the occupied spaces in order to interact with the existing HVAC system. PVT panels will be placed on the roof or a suitable solar energy catchment area.

Regarding the electrical parts, the most critical equipment are the lithium batteries, which will be placed inside the dwelling, separate from the thermal unit.

Therefore, the standards and legislation considered in this section is, on the one hand, those regarding TCM/PCM storage tanks, which has been analysed in Section 3.3. On the other hand, those regarding batteries and electrical parts safety are studied in Section 3.6.

3.5.2 Electrical parts

Apart from the harmonised standards identified from the Low Voltage Directive 2014/35/EU in previous sections of the report, that set the requirements for all relevant electrical devices, specific standards related to batteries have been analysed. The main standards are the following:

- IEC 62619 - Stationary Energy Storage Systems with Lithium Batteries in Industrial Applications
- IEC 61427-2: Secondary cells and batteries for renewable energy storage - General requirements and methods of test - Part 2: On-grid applications
- IEC 63056:2020 - Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries for use in electrical energy storage systems
- IEC 62485-5:2020 - Safety requirements for secondary batteries and battery installations - Part 5: Safe operation of stationary lithium ion batteries

This last standard is the most important one to consider, specially its section 9 "Accommodation, Housing", that contains requirements of how and where they have to be placed. This standard also defines different electric configurations allowed to connect the batteries to the building grid.

3.6 Integration of the system into an existing HVAC system

Since the aim of the thermal energy storage system is to supplement and support and existing heating or cooling installation, it is important to provide an adequate connection. However, due to the multiple water-based systems available, this section will only consider the standards related to tightness. The main one is EN 378-2: A tightness test shall be performed according to the type approval procedure as specified in EN 16084.

Unless otherwise agreed with the manufacturer of the assembly, components, not covered by the scope of EN 16084, shall be tested with detection equipment having a sensitivity equivalent to 3 g/year of refrigerant leakage or better, under a pressure of at least 0,25 × PS. The acceptance criterion is that no leak shall be detected.

6 Requirements for assemblies

6.1 General

The design, construction, testing, installing, documentation and marking of the refrigerating system assembly shall comply with this clause.

Refrigerating system assemblies using R-717 as refrigerant shall also comply with the additional requirements as specified in Annex A.

Determination of the category of the assembly shall be done in accordance with Annex B.

Refrigerating systems shall be charged with refrigerant at the manufacturing location or charged on site as recommended by the manufacturer (see 6.4.3.2).

Figure 14 Requirements for assemblies EN-378

3.7 Transposition of standards: Hungarian case

After the previous sections have shown relevant EU directives, this section focuses on how Member States transpose them. This analysis focuses on the Hungarian context in detail:

1- Construction products - Regulation (EU) № 305/2011

Not relevant as the equipment will not be produced in Hungary.

2- Ecodesign of energy related products - Directive 2009/125/EC

It is used as an obligatory guideline in Hungary. Either the EU regulation is applied directly or standards and regulations of certain disciplines are applied. It applies to all disciplines covered by Directive 2009/125 / EC. (For example, pumps, heating and cooling equipment, heat pumps, etc.)

3- Electromagnetic compatibility – Directive 2014/30/EU

Its Hungarian equivalent is "8/2016. (XII. 6.) NMHH (National Media and Communications Authority) Decree on Electromagnetic Compatibility", which calls in § 2 the following EU directives and regulations:
„12. harmonized standard: about European standardization, Council Directives 89/686 / EEC and 93/15 / EEC, 94/9 / EC, 94/25 / EC, 95/16 / EC, 97/23 / EC amending Directives 98/34 / EC, 2004/22 / EC, 2007/23 / EC, 2009/23 / EC and 2009/105 / EC of the European Parliament and of the Council and amending Council Directive 87/95 / EEC harmonized standard as defined in Article 2 (1) (c) of Regulation (EU) No 1025/2012 of the European Parliament and of the Council of 25 October 2012 repealing Decision No 1673/2006 / EC of the European Parliament and of the Council; "
Link: https://net.jogtar.hu/jogszabaly?docid=a1600008.nmh

4- Equipment and protective systems intended for use potentially explosive atmospheres – Directive 2014/34/EU

The scope of these products is defined in 35/2016. (IX. 27.) NGM Decree (hereinafter: NGM - Ministry of National Economy Decree). The NGM Decree transposes Directive 2014/34 /EU of the European Parliament and of the Council into Hungarian law.

The equipments in subject are called explosion-proof equipments. A potentially explosive atmosphere is one in which a mixture of flammable gases, vapors, mists or dusts with air may be formed. The directive 2014/34 / EU is also commonly referred to as the ATEX Directive. ATEX is an acronym derived from the French name for explosive atmospheres (atmosphères explosibles).

The responsibilities of the Authority include the equipment and protection systems belonging to the so-called "application group II" based on 3. § 26. of the NGM Decree. These are explosion-proof equipments that were not intended for use in mines. The Hungarian Mining and Geological Service deals with the market supervision of the equipment belonging to application group I.
In addition to the CE marking on explosion-proof equipment, an (Ex) marking enclosed in a hexagon is mandatory.
- The NGM Decree is linked to Decree 3/2003. (III. 11.) about minimum safety requirements for workplaces in potentially explosive atmospheres

Link.: https://mkeh.gov.hu/piacfelugyeleti_muszaki/Robbanasveszelyes

5- Low voltage – Directive 2014/35/EU

The scope and safety requirements of these products are set out in 23/2016. (VII. 7.) NGM decree. This Regulation transposes Directive 2014/35 / EU of the European Parliament and of the Council into Hungarian law.

The 23/2016. (VII. 7.) NGM covers electrical products with a nominal voltage between 50 and 1000 V AC and a voltage between 75 and 1500 V DC, with the exception of the following product ranges and phenomena:

• electrical products intended for use in potentially explosive atmospheres;

• electrical products for radiological and medical purposes;
• passenger and freight lifts and safety equipment designed for use in lifts;
• electricity meters;
• household plugs and sockets;
• power supply units for electric pens;
• radio electrical interference;
• special electrical products for use on ships, aircraft or railways complying with safety provisions drawn up by international bodies in which Member States participate;
• custom-made assessment equipment for professionals that can only be used in research and development facilities for research and development

• A harmonized standard - The MSZ EN 50525 series of standards describes the technical characteristics, production requirements and test methods for checking compliance with the requirements for low-voltage power lines. By applying the regulations, the cables according to the MSZ EN 50525 series of standards meet the essential health and safety requirements of the Low Voltage Directive (2006/95 / EC).
Link.: https://mkeh.gov.hu/piacfelugyeleti_muszaki/Kisfeszultsegi_villamossagi_termekek_LVD

6- Machinery – Directive 2006/42/EC

It is used as an obligatory guideline in Hungary. The directive 2006/42/EC covers e.g. machinery, lifting appliances, chains, ropes and slings, interchangeable equipment, mechanical transmission devices, safety components, etc. This Directive does not cover electrical and electronic products, including household appliances, audio and video equipment, IT equipment and general office machinery, which are covered by Directive 2006/95 / EC (on the safety of low voltage electrical equipment (LVD)).

Link.: http://www.mszt.hu/web/guest/frissult-a-gepek-iranyelvhez-harmonizalt-szabvanyok-listaja

7- Pressure equipment – Directive 2014/68/EU

Guideline about pressure vessels

PED: Directive 2014/68 / EU of the European Parliament and of the Council on the harmonization of the laws of the Member States relating to the distribution of pressure equipment.

SPVD: Directive 2014/29 / EU of the European Parliament and of the Council on the harmonization of the laws of the Member States relating to the distribution of simple pressure vessels.

Current transposing legislation: Decree 44/2016 (XI. 28.) NGM on the safety requirements and certification of conformity of pressure equipment and systems. Decree 44/2016 (XI. 28.) NGM on the safety requirements and certification of conformity of pressure equipment and systems introduces two directives into the domestic legal system, the Pressure Equipment Directive 2014/68 / EU (PED) and the simple Directive 2014/29 / EU on simple pressure vessels (SPVD).

Link.:
https://mkeh.gov.hu/piacfelugyeleti_muszaki/Nyomastarto_berendezesek_es_rendszerek_egyszeru_nyomastarto_edenyek_PED_es_SPVD

8- Restriction of Hazardous Substances in Electrical and Electronic Equipment – Directive 2011/65/UE

A directive transposed into law in the Hungarian legal system. The Restriction of Hazardous Substances in Electrical and Electronic Equipment (RoHS) has its Hungarian transposing legislation:
374/2012. (XII. 18.) Government Decree on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

Link.:
https://mkeh.gov.hu/piacfelugyeleti_muszaki/Elektromos_es_elektronikus_berendezesek_veszelyes_anyagainak_korlatozasa_RoHS

9- Simple pressure vessels – Directive 2014/29/EU

The directive has been transposed into a NGM decree:
44/2016. (XI. 28.) NGM Decree on the safety requirements and certification of conformity of pressure equipment and systems.
Link.: https://net.jogtar.hu/jogszabaly?docid=A1600044.NGM

3.8 Use of two-way electricity batteries in an electricity market

3.8.1 Introduction

In this section, relevant legislation and standards related to the use of two-way electricity batteries are studied. Regarding the MiniStor system, this analysis is translated to check if there is any restriction related to the capacity of the system to export electricity to the grid. For the market conditions of each demonstration site, please refer to D3.4 "Design and integration of improved PVT electrical generation system".

3.8.2 European legislation

In November 2016, the EU Clean Energy Package was proposed, comprising of a series of policy documents and legislative proposals that included provisions on prosumers. The most relevant legislative proposals for this study are the recast of the Renewable Energy Directive (Directive (EU) 2018/2001) or RED II, and the recast of the Electricity Directive (Directive (EU) 2019/944), or ED [14].

The recast Renewable Energy Directive 2018/2001/EU moves the legal framework to 2030 and sets a new binding renewable energy target for the EU for 2030 of at least 32%, with a clause for a possible upwards revision by 2023, and comprises measures for the different sectors to make it happen. This includes new provisions for enabling self-consumption of renewable energy, an increased 14 % target for the share of renewable fuels in transport by 2030 and strengthened criteria for ensuring bioenergy sustainability.

The RED II also defines 'Jointly Acting Renewable Self-consumers' as a "group of at least two jointly acting renewables self-consumers in accordance with point who are located in the same building or multi-apartment block" (Art. 2.15). This concept describes a form of collective self-consumption, possible only to households who share a specific geographic location [14]. This means that it is fully allowed the electricity exchange between different consumers.

The RED II sets the 30th of June 2021 as the deadline for all EU State Members to transpose it into national legislation.

Additionally, the Electricity Directive (Directive (EU) 2019/944) presents the definition of 'Citizen Energy Community' (CEC) (ED, Art. 2.11), which is similar to that of a Renewable Energy Community, but CECs also may engage in operating grid infrastructure, aggregation, storage, energy efficiency services or 'other' energy services [14].

Therefore, it can be concluded that EU legislation is totally aimed to the electricity exchange between consumers, encouraging those who can export a surplus to do it, by means of a national operator, creation of smart grids or creation of citizen energy communities.

3.8.3 EU Members

Besides the European framework provided by RED II, that has to be transposed to national legislation before July 2021, a research through the state members has been contacted.

It has not been found any legislation specifically forbidding against exporting the electricity surplus to the grid in any country, although the procedures for rewarding this energy are very different, and the minimal amounts to participate might discourage very small producers. It will be necessary to study specifically for each country which strategy is most beneficial, to optimize the level of exported or stored energy.

Through the website of the European Commission (http://www.res-legal.eu/home/) it can be analysed the different policies and frameworks in all EU Countries regarding renewables. Moreover, for some EU Member States, it has been possible to find the specific laws that define this framework. These are mentioned in the following table:

EU Country	Legislation
Spain	RD 15/2018 Royal Decree with urgent measures for the energy transition and the protection of consumers RD 244/2019 Royal Decree regulates the technical conditions of electric self-consumption
Belgium	Law of April 1999 - Organization of the electricity market
Croatia	2015 Law on renewable energy sources and high efficiency CHP
Italy	Energy authority resolution 578/2018/R/EEL
Netherlands	Electricity Act 1998 - Last amendment in 2018
Lithuania	Amendments to the Law on Energy from Renewable Sources
Latvia	Energy Development Guidelines 2016-2020 were released on 9 February 2016
UK	ROO 2015. The Renewables Obligation, Order 2015, No. 1947). EnA 2016. The Energy Act 2016, c 20. FTO 2018. The Feed-In Tariffs (Closure, etc.) Order 2018.
Portugal	DL 162/2019 Law of collective self-consumption
Germany	2017 - Renewable Energy sources act
France	2015-992 Energy transition law 2016-1019 Self consumption Ordinance that regulates individual and collective self-consumption

Table 14. EU Members and UK legislation found regarding exporting electricity to grid

4 Country-specific regulatory analysis focused on the countries of the demo sites (Spain, Greece, Ireland, Hungary)

In this section the specific regulations related to ammonia use on HVAC systems that apply to the countries of the demo sites will be analysed. These countries are Spain, France, Greece, Hungary and Ireland. We will see them below independently.

4.1 Spain

In order to identify the Spanish regulations that may pose possible technical or administrative limitations for the use of ammonia in the Ministor system, the following actions have been carried out:

Online search in Spanish legislation was done. A series of regulations related to the use of ammonia in HVAC systems was detected.

In addition to the **EN 378** standard, the content of which has already been dealt with in deliverable *T2.3 Highlights for designing of a machinery room in a container based on European Standard 378*, the most relevant Spanish standard within Spanish legislation due to its high impact on the project is the standard **RD 552/2019** by which the Safety Regulation for refrigeration facilities and its complementary technical instructions are approved (Real Decreto 552/2019, de 27 de septiembre, por el que se aprueban el Reglamento de seguridad para instalaciones frigoríficas y sus instrucciones técnicas complementarias).

Some of the most important details to take into account of this standard are detailed below. It should be noted that this is not an exhaustive list, so it will be necessary in any case to read and understand properly the law (Royal Decree 552/2019):

- The system must be installed by an authorized company, which must meet some requirements and have authorized installers. There is a database of the accredited companies.
- Depending of the complexity, the owner of the system could be required to have an insurance up to 500.000€
- It is necessary to have a facility management contract with an accredited company.
- There must be a design project carried out by an authorized professional.
- There is an ammonia storage limit for maintenance allowed inside a machine room, as well as some conditions for its storage.
- You may need a maintenance contract with an accredited company.
- The engine room that will house the system must comply with "Instruction IF-07", where the specific construction, ventilation, alarm installation and other requirements are detailed.

The importance of Royal Decree RD 178/2021, known as RITE (Regulation of Thermal Installations in Buildings / Reglamento de Instalaciones Térmicas en Edificios) is due that this is the rule that establishes the requirements of energy efficiency and safety that thermal installations in buildings must meet for the demand for well-being and hygiene of people, during its design and dimensioning, execution, maintenance and use, as well as determining the procedures that allow to prove its compliance.

For the purposes of the application of the RITE, fixed installations for air conditioning (heating, cooling and ventilation) and the production of domestic hot water, designed to meet the demand for thermal well-being and hygiene of people, will be considered as thermal installations.

The agents involved in the design and sizing, execution, maintenance and inspection of these facilities, as well as the entities and institutions involved in the visa, supervision or report of the projects or technical

reports and the owners and users of the same, as established in the regulations, are responsible for compliance with the RITE.

This standard also establishes a series of documentary and production conditions. Some of those that are considered important are mentioned below.
A project must be carried out when the nominal thermal power to be installed in heat or cold generation is greater than 70kW. The project must be drafted and signed by a competent qualified technician. It will be necessary to carry out an engine room of the characteristics (construction, ventilation, ...) indicated in the standard.

- A technical report must be written when the nominal thermal power to be installed in heat or cold generation is greater than or equal to 5 kW and less than or equal to 70 kW.
- The installations will be carried out by authorized installation companies and once the commissioning tests of the installation have been completed and carried out, the authorized installer and the director of the installation will sign the certificate of the installation.
- For the necessary commissioning the registration of the certificate of the installation in the competent body of the Autonomous Community where the installation is located.
- The competent body of the Autonomous Community may order an initial inspection of the thermal installations, in order to verify compliance with this RITE, once the thermal installations have been executed and the necessary documentation has been presented to it for its commissioning.

Of great importance is also the **R.D. 732/2019** or **CTE** "Technical Building Code / Código Técnico de la Edificación" that is applicable to new construction buildings or in major renovations of existing buildings. Its sections define the technical and construction conditions in areas such as energy efficiency, fire safety, health or the environment. Therefore, compliance with its requirements may imply limitations for the installation of the Ministor system in new buildings, but it would not affect the installation of demo sites, as they are existing constructions.

The contact and the information provided by the University of Santiago de Compostela corroborates and complements the available information. The conclusions provided by them are added below.

1. Object
This document briefly describes the conclusions of the findings from the analysis of the legislation found and the consultations made to people, services and organizations related to energy installations to know the viability of the installation of the MINISTOR system in the demonstration center of Santiago de Compostela .

2.-Methodology.
To collect data and information on the viability of the installation of the Ministor System, two strategies were developed:
a) Search for information on the Internet
b) Consultation with experts

The Search for information on the Internet was carried out using phrases in Spanish. The purpose of the Search was to obtain data and information on legislation in various fields that was related to ammonia from various approaches, as a refrigerant, as a gas, as part of a system, as a toxic compound, etc.
Several search expressions were used in Spanish and the texts of the legislation found were analyzed and saved for later reading and analysis.
The expert consultation was carried out by e-mail through an e-mail that described the use of ammonia in the Ministor System and its basic characteristics.
Emails were sent to:
a) an industrial engineer with experience in installations
b) an engineering company with extensive experience in facilities
c) The National Technological Center for Energy and Sustainability, whose acronym is ENERGYLAB.

3.-Results

The results of the search for legislation related to ammonia carried out on the Internet and of the contribution of the experts are shown in Table I.

Law/Standard	Acronym	Description	Impact
R.D. 732/2019	CTE	Technical Building Code	High
R.D. 178/2021	RITE	Regulation of Thermal Installations of Buildings	High
R.D. 552/2019	RSIF	Safety Regulations for Refrigeration Installations and their Complementary Technical Instructions (ITC) --ITC IF-05. Design, construction, materials and insulation used in refrigeration components --ITC IF-07. Specific engine room, design and constructionn --ITC IF-09. Pre-commissioning tests, tests and reviews --ITC IF-12. Electrical installations --ITC IF-16. Prevention and personal protection measures --ITC IF-17. Refrigerant handling and leakage reduction	Very High
R.D. 656/2017		Chemical Storage Regulations and their Complementary Technical Instructions (ITC) ---ITC MIE APQ 4 – storage of ammonia anhydrous.	High
R.D. 842/2002		Low Voltage Electrotechnical Regulation	Medium
R.D. 2060/2008		Regulation of pressure equipment and its Complementary Technical Instructions (ITC)	Low
UNE-EN 378-1:2017+A1:2021	UNE-EN 378	Cooling systems and heat pumps. Safety and environmental requirements. Part 1: Basic requirements, definitions, classification and selection criteria.	Very High
R.D. 39/2017		Improvement of air quality (modification of 102/2011)	None
R.D. 102/2011		Improving air quality --Article 12.-measurements of ammonia concentrations.	None
R.D. 31/1995		Occupational Risk Prevention	Medium
R.D. 485/1997		Minimum requirements for occupational safety and health signs.	Low

Table I. Spanish legislation & standards related with the use of ammonia as a refrigerant.

4.-Analysis.

From the analysis of the information found and the contribution of the experts, we have classified the legislation by its impact on the viability of the Ministor system in six (6) levels: null, very low, low, medium, high, very high. This classification has been included in Table I in the column titled observations.

In table I, it can be seen that the importance of the UNE-EN 378 and R.D. 552/2019, RSIF, the Safety Regulation of Refrigeration Installations and its Complementary Technical Instructions (ITC) that the MInistor system must comply with.
As part of a home heating and cooling system, the Ministor System is also subject to the basic building legislation and its regulation of thermal installations, that is, R.D. 732/2019, called the Technical Building Code (CTE), and R.D. 178/2021 called Regulation of Thermal Installations of Buildings.
The R.D. 178/2021 publishes the Regulations for the Storage of Chemical Products and its Complementary Technical Instructions (ITC) with an ITC dedicated to the storage of anhydrous ammonia. Depending on the amount of ammonia in the Ministor system, it could be affected by this law.
The R.D. 31/1995, relating to the Prevention of occupational hazards and all the legislation in the area of safety are very important in the viability of the implementation of the Ministor system, although from another approach.

5.-Involved authorities and role.
The entities that are involved in the authorization of the installation of the Sistama Ministor in the USC demonstration center are:
a) The autonomous government of Galicia in the legalization of the installation
b) The Municipality of Santiago de Compostela, with regard to emergency plans, fire defense and urban planning.
c) The USC through its infrastructure management services and occupational health and safety that will propose to the academic authorities the application or not of corresponding permits and other necessary actions

6.-Conclusions
In the absence of a more in-depth study, the conclusions drawn for the time of documentation are:
a) the use of a machine room outside the apartment facilitates installation by eliminating many restrictions
b) the reduction of the amount of ammonia load to 32 kg makes its authorization more viable, although in the legislation there are some assumptions of installation limited to 25 kg of load.
c) The interpretation of the regulations is confusing with several R.D. imposing restrictions with somewhat ambiguous scopes of application for not very expert people.
d) As an energy system loaded with more than 10 kg of NH3, the Ministor system must comply with ITC IF-12 of the R.D. 552/2019, RSIF.
e) The Ministor system must comply with the provisions of the following ITCs: ITC IF-05, ITC IF-07, ITC IF-09, ITC IF-16, ITC IF-017. (see Table I)
f) Gas ammonia sensors to detect leaks at various levels, electrical installations with automatic power switches and warning elements are mandatory.
g) It is necessary to protect access to the Ministor system, limit access to authorized personnel and signal it in accordance with the regulations.
h) Periodic maintenance must be contracted with an authorized company
i) We have to take out insurance for an amount of 500,000 euros.
j) A study of the risks to the health of the residents in the demonstration center and the building that contains it is necessary. This has to be done by the USC risk prevention service.

4.2 Greece

In this section, the results of the survey carried out by CERTH are presented. In order to identify possible limitations and required licencing for the usage of ammonia containing systems, such as Ministor system, the following steps have been subsequently taken:

- A first search in Greek Legislation was conducted through an online search engine (www.kodiko.gr) using the keyword "αμμωνία" (i.e. the Greek word for ammonia). **No law or regulation prohibiting or limiting the use of ammonia as refrigerant was identified**. However, two legislature acts were found that regard the safe use and disposal of ammonia in industrial facilities. The first one (Ministerial Decision 136860/1673/Φ15/2018) dictates that in case of usage of dangerous gases such as chlorine, hydrogen, ammonia etc., **the facility should be equipped with detectors that will be able to automatically stop the gas flow in case of a leakage**. Additionally, at least one protective uniform satisfying the safety requirements that correspond to the used substance should be available for use. This decision also describes the necessary fire safety measures in such industrial facilities, without making any further specific reference to ammonia. The second relevant legislature act (Ministerial Decision Δ16γ/381/5/44/Γ/2012) imposes **maximum limits of ammonia concentration in the liquid waste rejected in the sewage system** by industrial facilities located in the region of Attica (i.e. in a different region than Thessaloniki). Nevertheless, the mentioned limit of 60 mg/L denotes that any rejection of undiluted ammonia to the sewage system should be avoided.
- As a next step, the **Greek Cold Storage & Logistics Association (GCSLA) was contacted** (first contact was made on 15th July 2021). The association preserves an online library (http://www.cold.org.gr/listlibrary.aspx?lang=gr) for its members (mainly Greek industries that manufacture refrigerating systems), where useful information about the use of refrigerants can be found. Documents of interest we identified and after the finalization of the necessary procedures, CERTH was given access to them on 23rd August 2021. Additional relevant documents were found during the same period on the online library of "Cryologic" (http://www.cryologic.gr/shoplist.aspx?CatId=40) a Greek consultancy in the field of cold chain logistics. The titles of the reviewed documents (all of them were in Greek) are the following: "Ammonia handling" "Refrigerant substances and their future" "Refrigeration using ammonia", "Ammonia detectors", "Low charge ammonia systems" and "Refrigeration using natural gaseous substances and small amounts of ammonia". All of them highlight the need to find alternatives to fluorinated greenhouse gases in accordance with current EU regulations (i.e. Regulation No 517/2014) and render ammonia as an excellent alternative due to its zero ODP and GWP. Of course, the potential dangers of using ammonia are mentioned as well along with the corresponding regulations set by OSHA (Occupational Safety and Health Administration), ACGIH (American Conference of Governmental Industrial Hygienists), NIOSH (National Institute of Occupational Safety and Health), and recommendations of EPA (Environment Protection Agency) and IIAP (International Institute of Ammonia Refrigeration). However, **only EU Standard EN-378 is identified as a regulation that dictates the installation and operation of ammonia containing systems. No reference to additional Greek regulations or legislature acts is made in these documents**.
- Additionally, the Technical Services of CERTH have been asked about their possible knowledge of regulations that dictate the use of ammonia in Greece. However, they replied on 1st November 2021 that they could provide a definite answer, due to their unfamiliarity with this topic.
- Finally, "Psyctotherm" a Greek company with experience in the manufacture of HVAC systems for industrial and marine applications was asked accordingly on 22nd October 2021. In their reply, provided on 25th October 2021, they indicated that the installation and operation of ammonia containing systems along with the corresponding safety measures, **are defined by EN-378** standard. Moreover, in paragraph 5.12.2.1 of the aforementioned standard it is mentioned that the location of systems' installation should comply with local and national regulations. Regarding the latter, "Psyctotherm" indicated the existence of **Ministerial Decision 172058/2016 that imposes regulations and restrictions for limiting the impact of large-scale accidents in facilities**

containing dangerous substances. Anhydrous ammonia is identified as one of them in the Decision Annex (this is the reason for not identifying this legislature act during the initially conducted search, as Annexes are sometimes not taken into account by the utilized search engine). The facilities for which the provisions of this Decision apply are classified into two categories: low grade and high grade facilities. Additionally, such facilities should be located at a distance from residential areas, which is decided at each case by urban planning authorities. Regarding ammonia content, as high grade facilities are defined those containing amounts higher than 200 tonnes, whereas for **low grade facilities the limit is set to 50 tonnes**. So, the conclusion of their answer was that for systems with smaller ammonia charges, such as MiniStor, **there are no specific restrictions imposed by national regulations and only provisions of EU Standard EN-378 apply**.

Thus, the outcome of this research is that for the installation and operation of systems with low ammonia charge, the provisions of EU Standard EN-378 should be followed.

4.3 Ireland

This section summarizes a survey of different regulations and legislation, as well as a short interview with a member of the Health and Safety Authority of Ireland (HSA). Since there is no local legislation or regulation that addresses directly thermal storage systems for residences, the nearest equivalent systems were searched for regulations using the online search feature for Irish regulations (referred as Statutory Instrument, S.I.).

The use and safety operation of ammonia in compact refrigeration systems is codified for fishing vessels in S.I. No. 640/2007 - Merchant Shipping (Safety of Fishing Vessels) (15-24 Metres) Regulations 2007. It determines direct ventilation, explosion proof components, support for piping, separation from living quarters, waterproofing of the room and rigid piping.

The planning and development act, S.I. No. 600/2001 - Planning and Development Regulations, 2001-2021 determines that environmental studies are required if bulk storage of ammonia (above 50 tons) is kept on site and away from any establishment, and that the HSA needs to provide specific guidance. Storage below this amount is exempt. However, the Safety, Health and Welfare at Work Act 2005 would apply to the MiniStor project itself due to its research nature, classifying it as a "workplace". The Act specifies safety measures, signalling, personal protective equipment (PPE) to be worn, and type of personnel allowed entering the premises (the prototype).

Other applicable regulations concern compliance of the TCM reactor with the simple pressure vessels Directive 2014/29/EU, and the relevant HSA guidance for operation and maintenance for pressurized systems, Regulations 2012 (S.I. No. 445 of 2012).

Although specific regulations do not exist on system placement, the HSA recommends assessment by process safety consultants that can include risk assessment calculations for the spread of chemicals in case of explosions (which is standard procedure for the design and location of industrial facilities).

4.4 Hungary

In this section, the results of the survey carried out by WOODSPRING are presented. In order to identify possible limitations and required licencing for the usage of ammonia containing systems, such as Ministor system, the following steps have been subsequently taken:

Online search in Hungarian Legislation was done on the official codes, which contains also the laws and the regulations. The search was done to the word ammonia. There were 77 documents mentioned the word ammonia in the Hungarian Legislations.

- 219/2011 government decree (219/2011. (X. 20.) Korm. rendelet) is a regulation which give important information about using ammonia. In 1. § part 3 C point is determined the amount which over there is prescribed a safety plan. Under this amount it is not needed but risks must be minimized. In case of damage of the storage tank a free distance from households must be kept. The amount determined is 1000 kg in the regulation. In case of a storage greater than 1000 kg of ammonia the company/owner has to prepare a risk analysis and an activity plan to minimize the hazard in case of an ammonia leak.

- 90/2007 government decree (90/2007. (IV. 26.) Korm. rendelet) establishes the plan for minimizing the risk for the manufacturer of ammonia.

- 35/2014 NGM decree (35/2014 (XI. 19.) determines regulations for high pressure containers if the ammonia concentration is greater than 35%. This decree regulates how to check the container before filling, and the handling in its usage. The decree is limited to the container and contains general rules. No limitation is given to the amount of the filling substances.
- 28/2004 decree (28/2004 (XII.25.) KvVm rendelet) describes the limitation of the threshold of ammonia concentration in wastewater in 10 mg/l in a 2 hours average samples. For shorter time it can be accepted the 25 mg/l amount.

There was taken a contact with the expert of Fire Department of Sopron (Zsolt Csuka) on the 11th of November 2021. The question was: what are the restriction in regulation of usage of ammonia amount in residential thermal storage system. He answered that the regulation does not separate the residential and industrial utilization of hazardous materials. He referred in his answer the 219/2011 government decree and said if the amount is less than 1000 kg, only the normal caution is necessary, but there are not further regulations. In case the amount is less, as it happens in Sopron Demo Site, it is not prescribed any manual or activity plan. Especially, since the MiniStor block is in free space the risk is minimized.

Additionally, ÉMI, as an authorized organization concerning all of building materials (including thermal storage), has been contacted. They informed us that they do not know any law or decree which restricts the usage of ammonia for the purpose of energy storage in Hungary. However, it is used widely in refrigeration systems. Although they participate in the MiniStor project it was mentioned there was no case occurred till now anybody asked for permit in similar purpose than MiniStor.

The regulation determined the limit of ammonia in 1000 kg, but this limit is relevant just for the needed documentation and the preparation for handling hazardous material. According to the information from MiniStor project the TCM will contain as maximum 59.1 kg of ammonia and, for sure, in any case it will reach 1000 kg.

5 Associated risks and risk mitigation measures for materials used in the system

This section aims to illustrate the practical application of the standards related to different hazardous materials used in the project, and as a preparatory work to the full extent of measures that need to be taken for system manufacture. Further details will be provided in D4.5 and D4.6 concerning the specific safety measures implemented.

The MiniStor system comprises several types of heat storage that each use chemical materials for which it is important to assess their hazards and identify potential mitigation strategies in the event of accidental release.

5.1 Phase change material (PCM), calcium chloride and ammonia hazard assessment

These materials absorb heat on melting and release heat on cooling. The project makes use of two heat storage technologies based on PCMs – heat storage at above 58 °C and cold storage at 5 °C or 11 °C.

5.1.1 High-temperature PCM storage

The high-temperature store (SU58) is based on existing technologies developed and commercialised. The heat battery contains 100 litres of a PCM formulation comprising predominantly of sodium acetate trihydrate (CAS 6131-90-4) in contact with a copper heat exchanger.
The whole assembly surrounded by thermal insulation (vacuum insulation panels) and is enclosed in an aluminium case. The non-flammable insulation keeps heat away from the material in the event of a building fire, delaying and limiting heating as much as possible. Sodium acetate trihydrate is non-toxic, non-corrosive, and non-flammable – see Appendix 2 for Material Safety Data Sheet (MSDS). These heat batteries are approved for installation in domestic dwellings and have been granted CE marking. Any leakage of hot liquid from the heat battery results in solidification of the PCM through the leak to await repair by experts. However, any handling of spill over material must be done with specialized personal protective equipment, adequate ventilation and to avoid the formation of dust. Carbon oxides or sodium oxides can form from intense heat.

5.1.2 Low-temperature PCM storage

The low-temperature store (SU11) is also based on the same heat battery and has the same type of aluminium enclosure. The non-flammable insulation keeps the heat away from the material in the event of a building fire, delaying and limiting heating as much as possible. The storage will contain dimethyl adipate (CAS 627-93-0).

Dimethyl adipate is a di-ester of adipic acid and is regarded as non-toxic (oral LD50 > 5000 mg/kg), non-corrosive, and non-carcinogenic. Although it is very difficult to ignite (flash point 110 °C) it is classed as combustible when heated strongly and incomplete combustion produces carbon monoxide. It can also form explosive mixtures with air on intense heating. See Appendix 2 for Material Safety Data Sheet.

The associated risks are mitigated through containment within the store enclosure and protection from the intense heat associated with a domestic fire. At temperatures above 160 °C, the plastic and PCM will be molten and will be encased by the metal shell, and at this point may burn. The PCM will convert to the vapour phase and is likely to ignite in contact with a naked flame or sufficient heat source.

A protective aluminium case is expected to maintain integrity whilst containing the liquid PCM. Thermal insulation surrounding the battery can also be used to limit heating up the PCM. Any fires resulting from PCM materials must be extinguished using alcohol-resistant foam, dry chemical or carbon dioxide.

However, to fully mitigate the risk of combustion or their contribution to flammability in a fire, hot or cold PCM storage should be installed in accordance with fuel oil tank installation regulations and good practice with respect to flammability. In lieu of a more appropriate installation standard, **they should not be installed indoors**. Precautions are required to prevent any leakage of methyl laurate into drainage systems.

5.1.3 Calcium Chloride

The TCM material proposed is calcium chloride. When exposed to ammonia, these form solid ammoniates, e.g. CaCl2.4NH3. Calcium chloride (CAS 10043-52-4) is a non-flammable, non-toxic salt (oral LD50 500-1000 mg/kg) that presents relatively few hazards – see Appendix 2 for Material Safety Data Sheet. Under conditions of extreme heat and fire, hazardous decomposition products may be formed: hydrogen chloride gas, calcium oxide.

This non-volatile material is sealed within the TCM reactor in a double steel tank and therefore under normal operating conditions presents very little hazard.

5.1.4 Ammonia

Anhydrous ammonia is used as a refrigerant in mechanical compression systems, most frequently at a large number of industrial facilities. Many parts of a refrigeration system contain ammonia liquefied under pressure. The use of natural refrigerants in general comes with additional safety requirements in comparison to HFCs. Ammonia flammability, toxicity and pressures lead to various implications regarding system design, choice of components and placement of the units. However, with proper design and responsible maintenance, natural refrigerants are a sustainable alternative for most cooling applications [15].

It is important to recognize that ammonia is toxic under ambient conditions and can be a hazard to human health. It may be harmful if inhaled at high concentrations (beyond 300ppm). Releases of ammonia have the potential for harmful effects on workers and the public. If ammonia is under pressure, risk of exposure increases since larger quantities of the refrigerant have the potential for rapid release into the air. Also, some explosions have been attributed to releases of ammonia contaminated with lubricating oil [16]. However, ammonia is readily detectable by smell at concentrations substantially below levels that cause any lasting health consequences [17] . An important property of ammonia is its pungent odour. The threshold concentration at which ammonia is detectable varies from person to person; however, ammonia can be usually detected at concentrations in the range of 5 ppm to 50 ppm by people not used to it [18]. Concentrations above about 100 ppm are uncomfortable to most people; concentrations in the range of 300 to 500 ppm will cause people to leave the area immediately [16]. The following figures show the ranges according to different sources taking into account time and concentration [19] [20]:

Concentration/Time	% Ammonia/Time	Effect
20 ppm to 50 ppm	0.002 % to 0.005%	Mild discomfort, depending on whether an individual is accustomed to smelling ammonia
50 ppm to 80 ppm for 2 hr	0.005 % to 0.008% for 2 hr	Perceptible eye and throat irritation
100 ppm for 2 hr	0.01% for 2 hr	Nuisance eye and throat irritation
134 ppm for 5 min	0.0134% for 5 min	Tearing of the eyes, eye irritation, nasal irritation, throat irritation, chest irritation
140 ppm for 2 hr	0.0140% for 2 hr	Severe irritation, need to leave exposure area
300 ppm to 500 ppm for 30 min [9]	0.03% to 0.05% for 30 min	Upper respiratory tract irritation; tearing of the eyes (lacrimation), hyperventilation
700 ppm to 1700 ppm	0.07% to 0.17%	Incapacitation from tearing of the eyes and coughing
5000 ppm to 10 000 ppm	0.5% to 1.0%	Rapidly fatal
10 000 ppm	1.0%	Promptly lethal

Figure 15 Effects of ammonia on the human body from specific concentrations. Source: ANSI/CGA G-2.1-2014

Exposure		Signs and symptoms
mg/m^3	ppm	
35	50	Irritation to eyes, nose and throat (2 hours' exposure)
70	100	Rapid eye and respiratory tract irritation
174	250	Tolerable by most people (30–60 minutes' exposure)
488	700	Immediately irritating to eyes and throat
>1,045	>1,500	Pulmonary oedema, coughing, laryngospasm
1,740–3,134	2,500–4,500	Fatal (30 minutes' exposure)
3,480–6,965	5,000–10,000	Rapidly fatal due to airway obstruction, may also cause skin damage
Values in mg/m^3 are approximate calculations from ppm, where mg/m^3 = ppm x gram molecular weight/24.45 (molar volume of air at standard temperature and pressure)		

Figure 16 Summary of toxic effects following acute exposure to ammonia by inhalation. Source: Public Health England

5.1.5 Hazard reduction from ammonia as a refrigerant

Ammonia can safely be used as a refrigerant provided the system is properly designed, constructed, operated, and maintained [16]**.** Modern ammonia systems are totally contained closed-loop systems with fully integrated controls, which regulate pressures throughout the system. Also, every refrigeration system is required by codes, which are effective, mature and constantly updated and revised, to have safety relief valves to protect the system and its pressure vessels from over pressurization and possible failure [21].

Ammonia refrigeration facilities should be aware of the potential hazards of ammonia releases and of the steps that can be taken to prevent such releases. They should be prepared to respond appropriately if releases do occur. The steps recommended by the United States Environmental Protection Agency (US EPA) are reproduced below. They must be considered from the moment of designing and manufacturing the system, together with a proper maintenance programme:

- Establish training programs to ensure that the ammonia refrigeration system is operated and maintained by knowledgeable personnel.
- Consider using a spring-loaded ball valve (dead-man valve) in conjunction with the oil drain valve on all oil out pots (used to collect oil that migrates into system components) as an emergency stop valve.

- Develop and require refrigeration maintenance personnel to follow written, standard procedures for maintaining the system including routine procedures such as oil draining. Consider developing in-house checklists to guide maintenance personnel while they execute these procedures.
- Remove refrigeration oil from the refrigeration system on a regular basis. Never remove oil directly from the refrigeration system without pumping down and properly isolating that component.
- Provide barriers to protect refrigeration equipment.
- Develop and maintain a written preventive maintenance program and schedule based on the manufacturers recommendations for all of the refrigeration equipment. This includes but is not limited to: i) compressors, ii) pumps, iii) evaporators, iv) condensers, v) control valves, vi) ammonia detectors, vii) all electrical safety equipment, including high pressure cutouts, high temperature cutouts, low pressure cutouts, low temperature cutouts, low oil pressure cutouts, and automatic purge systems, viii) emergency response equipment including air monitoring equipment, respirators, suit (which should be used by trained personnel)
- Perform regular vibration testing on compressors. Document and analyze results for trends.
- Maintain a leak-free ammonia refrigeration system. This includes investigating and documenting all reports of leaks and odours. Test for leaks all piping, valves, seals, flanges, etc at least 4 times a year. Repair immediately any leak found.
- Consider installation of ammonia detectors where substantial leaks could occur, which should be tied to an alarm company/emergency response. These detectors should be calibrated, and all ammonia alarms and sensors must be checked regularly.
- Replace and document the replacement of pressure release valves (including relief valves) on a regular schedule and stamp the replacement date on the valve
- Ensure that the ammonia refrigeration system is routinely monitored. Consider using a daily engine room log, recording process parameters (e.g., temperature and pressure levels) and reviewing the log on a regular basis. Consider the use of computer controls to monitor the process parameters.
- Ensure that good housekeeping procedures are followed in the compressor/recycle rooms.
- Ensure that refrigeration system lines and valves are adequately identified (e.g., by colour coding or labelling) by using an in-house system.
- Post properly placards and warning signs in areas where ammonia is being used as a refrigerant or being stored (e.g. in front of machinery room doors) according to standards. Properly identify the chemicals within the piping system(s); label all process piping, i.e. piping containing ammonia, as "AMMONIA." Label must use black letters with yellow background. (This requirement is not the same as the in-house colour coding system and has to follow any applicable labelling standards).
- Periodically inspect all ammonia refrigeration piping for failed insulation/vapour barrier, rust, and corrosion, including any that is covered by insulation. Replace all deteriorated refrigeration piping as needed. Protect all un-insulated refrigeration piping from rust and/or corrosion by cleaning, priming, and painting with an appropriate coating.
- Carry out regular inspections of emergency equipment
- Consider using the compressor room ammonia detector to control the ventilation fans.
- Identify the king (master) valve and other emergency isolation valves with a large placard so that they can easily be identified by emergency responders, in case of an emergency. These valves should be clearly indicated on the piping and instrumentation diagrams (P&IDs) and/or process flow diagrams.
- Establish emergency shutdown procedures and instructions on what to do during and after a power failure.
- Consider installing a solenoid valve in the king valve line operated by a switch located outside of the compressor/recycle room.
- Establish written emergency procedures and instructions on what to do in the event of an ammonia release
- Regularly conduct emergency response drills.

- Stage a realistic emergency response spill exercise with the local fire company.
- Mount a compressor room ventilation fan manual switch outside of the compressor room (machinery room) and identify it with a placard for use in an emergency. Good practice would be to have ventilation switches located outside and inside of each door to the compressor room.
- Mount windsocks in appropriate places and incorporate their use into the facility emergency response plan. In addition to the emergency response plan, consider developing additional materials (posters, signs, etc.) to provide useful information to employees and emergency responders in case of an emergency. In developing emergency information, consider whether materials should be developed in languages other than the national language (English in the case of the United States).
- Keep piping and instrumentation diagrams (P&IDs), process flow diagrams, ladder diagrams, or single lines up-to-date and incorporate them into training programs for operators. A good suggestion is to laminate the P&ID and ladder diagrams and post nearby to the equipment.
- Frost accumulates on evaporator coils. Take appropriate measures to prevent this and to defrost the coils. Once the pressure in the evaporator is brought up, then fully open the valve.

5.1.6 Probability of ammonia risks occurring

Quantitative risk assessment (QRA) is a tool that can be used to determine the likelihood of catastrophic events occurring. The release and dispersion of ammonia have been studied frequently. The greatest concern of companies that use ammonia as a refrigerant should be related to leaks that trigger the formation of toxic clouds, and that can cause explosions. According to the State Environmental Institute of Brazil (INEA), the **most common causes of accidents are failures in the design of the cooling system and damage to the equipment caused by: vibration, corrosion, and excessive heat, as well as due to improper maintenance or lack of maintenance of its components.** These include relief valve pressure, compressors, condensers, pressure vessels, purging equipment, evaporators, pipes, pumps and instruments in general [22].

Ammonia in its gaseous state is not flammable, but if it is in large quantities and the presence of an intense energy source, it can be ignited and cause an explosion. However, the risk of flammability of ammonia manifests itself only in extreme fire conditions and in confined places. Additionally, if in contact with water, an exothermic reaction is produced, producing heat that, in contact with other gases, can cause fire or explosion. Ammonia requires a minimum ignition energy of 680 mJ, while methane, ethane and propene require 0.21–0.26 mJ and hydrogen gas requires 0.02 mJ, according to ISO 817:2014. This means it needs around 3,000 times more energy to be ignited than common combustible gases used for cooking and heating in households.

In case of an ammonia fire, the U.S. National Institute for Occupational Safety and Health (NIOSH) recommends as emergency response for anhydrous or liquefied ammonia amounts of 200 L or less to isolate 30 m in all directions, and then protect persons downwind during the day for 100 m, and then protect persons downwind during the night for 100 m [23].

The estimation of consequences and frequencies of accidents is an area that needs specialized study, they can also be assessed through software (e.g. ALOHA) that takes as input local characteristics and type of hazard [24], even though at the moment the software analysis is currently geared chiefly towards industrial applications. The estimation comes from analysing how often these accidents occur, the system complexity (for number of parts involved), amount of hazardous materials, and the number of casualties that have been produced in past accidents (injured or dead). It also takes into account the industrial processes followed to produce the equipment in use. Mannan [25] estimates probability of failure of steel pipes at $3x10^{-7}$ and of a steel vessel at $2x10^{-6}$. For an industrial refrigeration plant using ammonia, the acceptable individual risk tolerance limit probability stated by government agencies for accidents is **10^{-6}/year** [22].

5.2 Explosion risk of systems using ammonia as refrigerant: Perspective in Hungary

The following sub-section provides an overview of how safety requirements regarding ammonia as a refrigerant are implemented in a EU Member State, Hungary based on different Directives. This section has been prepared by EMI.

5.2.1.1 Legal background to explosion protection:

The legal basis for explosion protection can be traced back is the XCIII Occupational Safety and Health Act from 1993 which has been modified several times since its publication. The following legislation and standards have been taken in consideration in our case, for Hungary:

- National Fire Protection Regulation entered into force by Decree 54/2014 (XII.5.) of the Ministry of the Interior
- Decree 30/2019 (VII.26.) of the Ministry of the Interior and modification of Decree 54/2014 (XII.5.) of the Ministry of the Interior
- Decree 3/2003 (III.11.) about minimum safety requirements for workplaces in potentially explosive atmospheres
- MSZEN 60079-10-1 Explosive atmospheres. Part 10-1: Classification of areas. Explosive gas atmospheres
- MSZEN 1127-1 Explosive atmospheres. Explosion prevention and protection. Part 1: Basic concepts and methodology
- MSZ 13463-1 Non-electrical equipment for use in potentially explosive atmospheres. Part 1: Basic method and requirements.
- MSZEN 60079-20-1 Explosive atmospheres. Material characteristics for gas and vapour classification.

5.2.1.2 Places with explosive risk

Chapter XI of the above mentioned National Fire Protection Regulation deals with explosion protection. It stipulates that the explosion protection must be provided during the processing, use and storage of an explosive substance. Possible solutions are given in the Chapter "Protection against explosion of the Fire Protection Technical Guideline" (TvMI) valid from 15.01.2021.

5.2.1.3 Regulations about ammonium technologies explosion hazard

Ammonia is an explosive gas, therefore it is subject to general European legislation on explosive technologies (directives) and their harmonized Hungarian legislation. They are the following:

1) Directive of the European Parliament and of the Council 2014/34/EU and the harmonized Hungarian version of it, the Decree 35/2016 (IX.27.) of the Ministry of National Economy
2) EC Directive 1994/9 and the harmonized Hungarian version of it, the Decree 3/2003 (III.11.)

These two directives and Hungarian legislation generally cover the explosion protection activity. Areas of potentially explosive technologies are divided into *zones* and determine what equipment can be used in each zone.
In addition to the above, there is national (Hungarian) legislation that complements and clarify them and in some cases even facilitate them. We consider such legislation to be primarily the National Fire Protection Regulations issued by Decree 54/2014 (XII.10.) of the Ministry of the Interior. Article 99 states

that during the processing, storage and distribution of explosive substances, protection must be ensured by protection measures, and these measures must be documented.

This obligation may be fulfilled by complying with harmonized European directives, but also by complying with the requirements set out in chapter protection against explosion of the the Fire Protection Technical Guideline (TvMI) issued for the implementation of the National Fire Protection Regulations.

The Fire Protection Technical Guideline conditions are stated below:

„6. Installation conditions in potentially explosive atmospheres

6.1. The explosion protection requirement set out in § 99 of the National Fire Protection Regulations is fulfilled if the design of the structure is in accordance with 6.2.-6.6. and with the relevant standards and regulations.
6.2. The equipments used in potentially explosive atmospheres have a suitable explosion-safe design.

6.3. General installation conditions

6.3.1. If, in the case of flammable gases / vapors / mists during zoning, the total volume of explosive zones formed around the explosive technology reaches 20% of the volume of the room or the floor area of the vertical projection of the zones exceeds 20% of the floor area of the room, the whole room shall be classified as explosive in terms of fire risk and should be designed according to point 6.3.2. – 6.3.3."

Note:
The classification of a room as explosive does not automatically result that explosion-safe products should be used for the entire volume of the room (excluding hazardous areas), see point 6.3.6.

„6.3.2. The room or contiguous group of rooms must be separated from non-explosive areas by fire-extinguishing structures adequate to the main risk class of the building.

6.3.3. To separate rooms within a group of rooms consisting of explosive atmospheres, a fire-resistant partition wall may be used which corresponds at least to the relevant risk class of the building.

6.3.4. Such rooms which are not considered as explosive but operates with explosive technologies must be separated from other rooms by a fire-resistant partition wall corresponding at least to the relevant risk class of the building.

6.3.5. In a room with explosive technology, close to the used technology or even in the whole room only such construction products, construction methods, electrical and non-electrical tools and equipments can be used which, by themselves or as a result of their use, do not constitute a source of ignition for the explosive atmospheres."

Note 1:
If this is unavoidable, the methods described later should be used to prevent the formation and spread of the explosive atmosphere.

Note 2:
Lighting protection

Solutions for building being explosive in terms of lightning protection, or explosive at limited extend can be found in the in Fire Protection Technical Guideline about protection against electrical equipment, lightning protection and electrostatic charge.

„6.3.6. If within a room, due to the explosive zoning, the explosive volume formed around the explosive technologies (caused by explosive gases / vapors / mists / dusts) or a set of explosive volumes reaches 40% of the air volume of the room

a) the whole volume of the room must be declared as explosive
b) the zoning of the volume outside the original zoning must be zone 2 for gases / vapors / mists, and zone 22 for dusts
c) in the extended zones thus defined, the most dangerous group of gases or dust occurring in the room and the associated strictest temperature class or minimum limit temperature must be taken into account"

Note:
By the zoning for explosive zones within rooms with a smaller volume consideration should be given to classifying the entire room independently of the air volume ratio.

„6.4. Other explosion protection measures

6.4.1. In determining the risk posed by explosive technology, during the design process to prevent the spread of the explosive zone other protective measures may be also taken

6.4.2. In case it is neccessary, based on the risk analysis related to explosive technologies, the separation of the room operating with explosive technologies from rooms not operating with those, under normal operating conditions, can also occur with a foreground directly vented to the open air or pressurized to 50 Pa, avoiding the expansion of the explosive zone."

Note:
It is advisable to use fire protection structures in this forecourt (fire protection class A1 or A2) to delimit.

„6.4.3. To keep the concentrations of gaseous, vaporous, misty explosive atmospheres at acceptable values:

a) In rooms containing explosive technology, such ventilation
is provided, due to its volume, which effectively dilutes the explosive atmosphere so that its concentration does not reach the 20% of the lowest explosion limit (ARH) (or even less, predetermined but still safe %)."

Note 1:
Determining the position of the gas sensor is the responsibility of the designer taking into account the given zone classification, location of the emission source, relative density of the combustible gas / vapor, air flow conditions, temperature conditions, etc.

Note 2:
The above should be taken into account when zoning.

Note 3:
If the standard sets lower flammability / inflammation limit concentration (LEL Lower Flammable Limit) and these values are stricter than ARH 20%, then these values can also be used to apply efficient ventilation.

Note 4:
The lower flammability limit (LEL) and the lower flammability limit (LOC) are equally usable terms and have the same meaning. Their definition is currently set in point 3.55 of the MSZ EN IEC 60079-0 standard.

Note 5:
The upper flammability limit and the upper flammability limit are equally usable terms and have the same meaning. Their definition is currently set in point 3.90. of the MSZ EN IEC 60079 -0 standard.

„b) Turning the explosive atmospheres into an explosive state can be prevented by inerting or by using protecting welding gas or by adjusting the oxygen concentration limit (the concentration limit is a

substance, mixture dependent value, can be determined by calculation, but in all cases the value is above 4% by volume).
The amount of shielding gas or inert gas must be scaled to the amount required for normal operation and emergency response, taking into account the requirements of the relevant standards. The oxygen concentration limit must be verified by testing."
Note 1:
The adequacy of the oxygen concentration limit shall be verified during the fire test. Testing of the oxygen concentration limit is included in CEN / TR 15281: 2006 - Guidance on inerting to prevent explosions.

Note 2:
By the reduction of oxygen concentration and the use of inerting gases the life-saving aspects need to be taken into account.

„6.4.4. At unexpected, dangerous rise of the concentrations of explosive substance

a) if the concentration of the explosive atmosphere exceeds 20% of the ARH, a visual signal warns workers in the vicinity of the technological equipment and those working within the scope of the work and, if necessary, the ventilation degree of the room or of the technology must be increased."

Note:
The degree of air exchange is determined by the hazard of the particular technology and by the quality of the emitting source.

„b) if the concentration of the explosive atmosphere exceeds 40% of the ARH, an audible and visual alarm warns those around the technology and those in the technological supervision room (instrument room),

b.a) the ventilation degree of the room or of the technology must be increased if needed

b.b) the release, production, composition of or supplying a hazardous equipment with the explosive atmosphere must be eliminated, even by closing the relevant technological lines,

b.c) if the technology allows, the full technology system should be shut down if needed. "

Note 1:
In case the standard sets lower and upper flammability limits (LEL - Lower Flammable Limit) (UFL - Upper Flammable Limit) and those are stricter than ARH 20 % or ARH 40%, then these values can also be applied for effective ventilation.

Note 2:
If the quality of the explosive zones has been calculated according to the standard MSZ EN 60079-10-1 by taking into account the level of emissions, the operational safety of the ventilation and the degree of ventilation it is not necessary to increase the air flow volume of the designed and operating fan or fans in case of dangerous gas concentration detection, unless otherwise provided by law or standard.

"6.4.5. The application of the methods set out in points 6.4.3. - 6.4.4. is supervised by an explosion safe automatic system:
a) which can carry out the interventions at the expected concentration levels,
b) its operational safety is ensured by a redundant system depending on the risks,
c) if the risk assessment for the explosive technology states it, for normal and / or emergency operation an adequate uninterruptible power supply must be available until the process system is shut down.

6.5. Reducing the effects of an explosion, methods of protection

6.5.1. If, due to technology, the possible explosion cannot be ruled out, the harmful effects of the explosion must be minimized by one of the methods detailed in points 6.5.2. - 6.5.5.

6.5.2. The explosive equipment or structure may be designed to the largest explosion pressure or to the reduced explosion pressure. In case of design to reduced
explosion pressure, it can be made either with a pressure relief or an explosion suppressor
connecting systems.

6.5.3. To protect potentially explosive atmospheres for conducting explosion overpressure, to prevent the necessary oversizing of the device splitting discs and explosive doors (explosion overpressure drain / blow surfaces) can be used. Their directed openings can reduce the explosion pressure from the structures. The direction of the blowdown should be chosen with respect to prevent any damage to other structures and workers on site. "

Note:
Sizing standards: MSZ EN 14491, MSZ EN 14797

"6.5.4. Explosive devices are equipped with explosive suppressor equipment according to the relevant standard.

6.5.5. In other closed technology systems, the spread of explosion may be prevented by the following equipment:
a. in case of gases, vapors, mists
a.a) flame arresters,
a.b) detonation locks,
a.c) anti-flame retardants,
a.d) fire barriers,
a.e. flow restrictors; and
a.f) quick-closing valves and dampers

b) in case of liquids:
b.a) liquid seals

c) in the case of powders
c.a) fire barriers,
c.b) sparks,
c.c) quick-closing valves, dampers,
c.d) rotary cell feeders,
c.e) exhaust ducts,
c.f) pressure relief valves,
c.g) relief valves,
c.h) Q-tubes,
c.i) double gate valves and
c.j) material seals

6.6. Explosion overpressure drainage surfaces, structures in the external boundary structures of buildings or rooms

6.6.1. If protection methods set out in points 6.3 to 6.5. do not provide adequate safety based on a risk analysis to prevent the building from collapsing, in an explosive room, the explosion pressure on building structures can be reduced by applying a fissile building structures or by one which opens in the event of an explosion.
Note:
Determining the appropriate, acceptable risk levels is subject of the methodology used.

6.6.2. Designing the size of the explosion overpressure surface happens according to Chapter Nine."

Note:
The methods of other relevant standards for sizing can also be taken into account: MSZ EN 14491, MSZ EN 14797

5.2.1.4 National practice in Hungary

Ammonia is a toxic gas on the one hand and an explosive gas on the other. In addition, it has an unbearable effect on the olfactory system even already at 20 PPM concentration. Therefore, it is needed to protect against poisoning and explosion at the same time.

Ammonia is predominantly used as a refrigerant in refrigeration systems. These systems are closed; the gas can only be released into the environment in the event of a failure. In addition, the toxic effect, as mentioned earlier, can be detected by smell even at very low concentrations it, in fact it is unbearable. An explosion may occur above at least 15 percentage volume.

The mechanical room should be ventilated intensively, 4 times hourly. The air inlet should be close to the pavement through jalousies, the outlet will be served by explosion-safe ventilators, as ammonia is lighter than the air (dr=0,59).

The concentration is to be continuously measured. The emergency ventilator should start automatically at 500 PPM, and it supply 15 times air change. At 20% of the allowed limit the operation will be switched off.

The ventilators vent out the used air at the side or the top of the building. The environment of the used air outlet should be treated in three-meter diameter as zone 2. It is also recommended to drive the air with ammonia into water storage.

The architectural design of the mechanical room should be organized by the above mentioned requirements (TvMI 6.). In Hungary, the machinery room of system working with ammonia is not classified as explosive danger zone. In spite of this it is recommended to design the ventilators, the lighting and the gas (concentration) according Zone 2 requirements.

If we use emergency lighting in the machine room, it could be design by normal requirements, but should be automatically switched off by ARH 20% situation.

The electrical and mechanical equipment deployed in the Zone 2 should be met with the regulation of the following requirements:

- Operational group: II
- Operational subgroup: IIA, IIB, IIC
- Category: 3, 2, or 1
- Temperature class: T1-T6

5.2.1.5 Potential solutions based on the use of Hungarian and EU standards

In the design of the operation and testing environment regarding the Hungarian regulation and best practice, two main potential solutions are recommended.

One potential solution is the general solution. In this case we consider the MSZ 60079-10-1:2016 standard based on EU directives and we classify the zones, using electrically and mechanically explosion proof equipment and exclude the ignition sources.

The other potential solution is the design using national regulation of TvMI (Fire Protection Technical Guideline), which allows the establishment of the area without the explosive proof equipment to prevent the explosion through ventilation (but including fire proof gas concentration sensors, ventilators and optionally emergency lighting).

The selection of the concrete design solution should depend on the environmental situation and the economical assessment of the alternative. Praxis shows advantages for the second option in many cases.

5.3 Conclusions from study of associated risks and risk mitigation measures

The previous sections have demonstrated that the onus on safety for a thermal storage system using ammonia falls primarily on the system designer and manufacturer to ensure that strict design and operation standards are met, with clear controls, fail-safes and safety measures in place for operators to follow. This responsibility is followed by the party or parties responsible for periodic inspection and maintenance, who must have clear plans and follow them according to pre-approved procedures.

Although this report does not intend to provide an impact analysis of such measures, they must be taken into account for future commercialization and maintenance models. Safety measures and maintenance plans should be part of the integrated cost of the system, and cannot be dissociated from the future final product.

6 Conclusions

This deliverable has presented the main EU standards and legislation related to system design and operation, which must be respected irrespective of location. Standards related to refrigeration systems have been used as the main guide for the thermal part of MiniStor, since there are no specific directives for thermal energy storage. Since MiniStor is a composite product, existing standards were also consulted for the electrical energy storage. The main obstacles for exporting electricity to the grid are set by regulatory authorities in local markets, rather than through standardization.

It has been found that the standards define, based on type of refrigerant and not on final use of the building, where they can be placed and maximum amounts of refrigerant. Analysed local legislation in demo site countries, defines specific limits for mandatory supervision based on the amount of ammonia stored. It also details maintenance procedures and their responsibility. Based on the standards, it was decided that the best location for the *ammonia-related* MiniStor components is in an outdoor area that meets specific requirements, or inside a machinery room that complies with the conditions described in previous sections. Layout configurations must be studied in order to determine if only the ammonia-related parts or the whole thermal storage system should be placed in the regulated area. Together with the necessary safety equipment needed, these decisions will have an impact on market price and future commercialization, for which measures should also be studied to be a competitive technology. *These safety measures should be contrasted with existing technologies to handle hazardous flammable materials already present in the household, such as natural gas, propane, etc.*

On the other hand, it is acknowledged that **ammonia can be safely used as a refrigerant provided the system is properly designed, constructed, operated, and maintained**. It is important to recognize, however, that ammonia is toxic and careless management can be a hazard to human health. For this reason, this deliverable has examined relevant manufacturing standards and safety measures that must

be met in order to reduce potential hazards. The **MiniStor system uses 59.1 kg maximum of ammonia**, which places it in a category that according to the most restrictive French legislation does not need stringent government supervision (lower than the limit value of 150 kg). However, the deliverable has also taken into account aspects that are applied to systems of much larger magnitude. It has also examined those standards that apply to all its components such as pressure vessels and heat exchangers.

The main gaps identified through this deliverable relate to the lack of standards and directives related to thermal energy storage systems as specific elements. From the point of view of refrigeration systems, the closed loop thermal storage elements are not changing the temperature of a fluid (gas, liquid) for immediate use, but for release at a future time at the convenience of the end-user. An additional gap identified is that standards and risk mitigation measures have in mind primarily industrial applications.

At the European level, there is no uniform national legislation based on the type and size of the ammonia system, except for France, which has been regarded as too strict by ammonia-related stakeholders. Standard EN-378 is the most influential standard for the design of MiniStor. However, although it has been approved and is valid for all the European Union, it still needs specific transposition to the national level of standards of each Member State. This will facilitate the development of future systems by the industry.

Specific safety measures and standards that assure the same level of quality of industrial levels and promote zero-leak manufacture must be developed for smaller amounts of ammonia such as those that could be used in domestic settings. Another identified gap is the influence that state-of-the-art manufacturing and operation measures for these storage systems can have towards the design and application of novel systems, as reflected in standards for use of thermal storage systems in domestic settings.

7 References

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Appendix I - EN 378 Maximum limit calculations for refrigerant ammonia

The following section presents the calculations made to determine the maximum amount of refrigerant that can be used *within an occupied space* according to the standard EN-378 based on its flammability and toxicity. The results from this calculation provide an indication that system placement must be outdoors in order to not to have refrigerant limits.

Calculation procedure

Input data:

- Practical limit of ammonia: 0.00035 kg/m3
- LFL: 0.116 kg/m3
- (Estimation) Dimensions of the smallest room with ammonia-containing parts: 5x10x2.2 m
- Access category of the room: A – General Access (anyone can enter, since it's residential)
- Toxicity class of the refrigerant: B
- Flammability class of the refrigerant: 2L

Toxicity calculations:

Table C.1 — Charge limit requirements for refrigerating systems based on toxicity

Toxicity class	Access category		Location classification			
			I	II	III	IV
B	a		For sealed sorption systems, toxicity limit × Room volume and not more than 2,5 kg, all other systems, toxicity limit × Room volume		No charge restriction[a]	depending on the location of the ventilated enclosure
	b	Upper floors without emergency exits or Below ground floor level	Toxicity limit × Room volume	Charge not more than 25 kg[a]		
		Density of personnel <1 person per 10 m²	Charge not more than 10 kg[a]	No charge restriction[a]		
		Other		Charge not more than 25 kg[a]		
	c	Density of personnel <1 person per 10 m²	Charge not more than 50 kg[a] and emergency exits are available	No charge restriction[a]		
		Other	Charge not more than 10 kg[a]	Charge not more than 25 kg[a]		

[a] For open air, EN 378-3:2016, 4.2 applies and, for machinery rooms, EN 378-3:2016, 4.3 applies.

For locations classified as I or II (means that at least one ammonia containing part -i.e. a pipe- is in direct contact with the air in the room) the limit = toxicity limit x room volume.

So, the Limit = 0.00035 x (5 x 10 x 2.2) = 38.5 gr

For locations classified as III (means that all ammonia containing parts are located in a machinery room) there's no charge restriction.

Flammability calculations:

Table C.2 — Charge limit requirements for refrigerating systems based on flammability

Flammability class	Access category		Location classification			
			I	II	III	IV
2L	a	Human comfort	According to C.2 and not more than m_2 [a] × 1,5 or According to C.3 and not more than m_3 [b] × 1,5		No charge restriction [c]	Refrigerant charge not more than m_3 [b] × 1,5
		Other applications	20 % x LFL × Room volume and not more than m_2 [a] × 1,5 or According to C.3 and not more than m_3 [b] × 1,5			
	b	Human comfort	According to C.2 and not more than m_2 [a] × 1,5 or According to C.3 and not more than m_3 [b] × 1,5			
		Other applications	20 % × LFL × Room volume and not more than m_2 [a] × 1,5 or according to C.3 and not more than m_3 [b] × 1,5	20 % × LFL × Room volume and not more than 25 kg [c] or according to C.3 and not more than m_3 [b] × 1,5		
	c	Human comfort	According to C.2 and not more than m_2 [a] × 1,5 or According to C.3 and not more than m_3 [b] × 1,5			
		Other applications	20 % × LFL × Room volume and not more than m_2 [a] × 1,5 or according to C.3 and not more than m_3 [b] × 1,5	20 % × LFL × Room volume and not more than 25 kg [c] or according to C.3 and not more than m_3 [b] × 1,5		
		<1 person per 10 m²	20 % × LFL × Room volume and not more than 50 kg [a] or according to C.3 and not more than m_3 [b] × 1,5	No charge restriction [c]		

[a] m_2 = 26 m³ × LFL.
[b] m_3 = 130 m³ × LFL.
[c] For open air, EN 378-3:2016, 4.2 applies and, for machinery rooms, EN 378-3:2016, 4.3 applies.

The flammability limit is the greatest among these three options:

1. Value from C.2 Table
2. M1 x 1.5 = 4 x LFL x 1.5 = 4 x 0.116 x 1.5 = 696 gr
3. 150 gr

So, it is necessary to obtain the Value from C.2. Table.

For human comfort appliances (HVAC), Access Category A and for locations classified as I and II the limit is [M2 x 1.5] because since the refrigerant class is B2L, it is not possible to apply C.3. Requirements.

So, Table C.2. Limit = M2 x 1.5 = 26 x LFL x 1.5 = 26 x 0.116 x 1.5 = 3.016 gr

Since the Table C.2. Limit is the greatest among the other two options, 3.016 gr is the flammability limit.

For locations classified as III (means that all ammonia containing parts are located in a machinery room) there's no charge restriction.

All the previous calculations reach the following conclusions:

- The toxicity limit for locations I & II = 38.5 gr
- The flammability limit for locations I & II = 3.016 gr
- There are no limits for locations classified as III

Considering this, since the maximum ammonia amount of the system can be up to 59.1 kg, it is necessary to place all ammonia containing parts in a machinery room (Location III).

Data: Ammonia (B2L)

Practical limit	0.00035	kg/m3
LFL	0.116	kg/m3

Smallest room with parts that contain refrigerant

Access Category	A	(Dwellings)
Area	50	m2
Height	2.2	m
Volume	110	m3

Change values of yellow cells

Toxicity calculations

1) Table C.1

Access Category A / Toxicity Class B

Location Classification:

I & II	38.5	gr
III	No restriction	

2) 20 x Practical limit

20 x 0,00035 = 7 gr

Higher value: 38.5 gr

FINAL LIMIT (gr): 38.5

Flammability calculations

1) Table C.2

Access Category A / Flammability class 2L / Human comfort appliances

Location Classification:

I & II	3,016 gr	*Necessary to meet C.2. requirements*
III	No restriction	

Are the C.2 requirements met? YES *(YES/NO)*

2) m1 x 1,5

4 · 0,116 · 1,5 = 696 gr

3) 150 gr for sealed systems

150 gr

Higher value: 3,016 gr

C.2. Requirements

If refrigerant charge is greater than (m1 · 1,5 = 4 · LFL · 1,5)
(m1 · 1,5 = 4 · LFL · 1,5) = 696 gr

then the maximum charge in a room must be:

$$m_{max} = 2{,}5 \times \mathrm{LFL}^{5/4} \times h_0 \times A^{1/2}$$

h_0 is the height factor of the appliance:

- 0,6 for floor location;
- 1,8 for wall mounted;
- 1,0 for window mounted;
- 2,2 for ceiling mounted,

Appliance	h0	m max
Floor location	0.6	718.04 gr
Wall mounted	1.8	2,154.12 gr
Window Mounted	1	1,196.73 gr
Ceiling mounted	2.2	2,632.81 gr

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Appendix II – Safety data sheets main materials used in the TCM reactor and PCM units

Section 1: Identification of the substance/mixture and of the company/undertaking

1.1 Product Information

Product Name: SU58 phase-change material

Product Number: No information available

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses: Thermal storage media

Uses advised against: No information available

1.3 Details of the supplier of the safety data sheet

Company: Sunamp Ltd.
1 Satellite Park
Macmerry
East Lothian
EH33 1RY
Telephone: +44 (0)1875 610001
Email: info@sunamp.com

1.4 Emergency telephone number

+44 (0)1875 610001

Section 2: Hazards identification

2.1 Classification of the substance or mixture

Not a hazardous substance or mixture.

2.2 Label elements

Not a hazardous substance or mixture.

2.3 Other hazards

This substance/mixture contains no components considered to be either persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) and levels of 0.1% or higher.

Section 3: Composition/information on ingredients

3.1 Substances

Component	CAS-No	EC-No	Weight %	CLP Classification – Regulation (EC) No 1272/2008
Sodium acetate trihydrate	6131-90-4	612-115-9	≥95%	-
Proprietary non-hazardous additives	Not applicable	Not applicable	≤5%	-

Section 4: First aid measures

4.1 Description of first aid measures

If inhaled, move person to fresh air. If not breathing, give artificial respiration. If irritation persists, contact medical professional.

In case of skin contact wash off with soap and water, if irritation persists, contact medical professional.

In case of eye contact rinse eyes with water as a precaution. If irritation persists, contact medical professional.

If swallowed do not induce vomiting, rinse mouth with water. Never give anything by mouth to an unconscious person.

4.2 Most important symptoms and effects, both acute and delayed

None reasonably foreseeable.

4.3 Indication of any immediate medical attention and special treatment needed

Treat symptomatically.

Section 5: Firefighting measures

5.1 Extinguishing media

Suitable extinguishing media: Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

5.2 Special hazards arising from the substance or mixture

Carbon oxides, sodium oxides.

5.3 Advice for firefighters

Wear self-contained breathing apparatus for firefighting if necessary.

Section 6: Accidental release measures

6.1 Personal precautions, protective equipment and emergency procedures

Avoid dust formation. Ensure adequate ventilation. Use personal protective equipment.

6.2 Environmental precautions

No special environmental precautions required.

6.3 Methods and materials for containment and cleaning up

Sweep up and shovel. Keep in suitable, closed containers for disposal.

6.4 Reference to other sections

For disposal see section 13.

Section 7: Handling and storage

7.1 Precautions for safe handling

Provide appropriate exhaust ventilation at places where dust is formed. Wear personal protective equipment.

7.2 Conditions for safe storage, including any incompatibilities

Store in a cool, dry and well-ventilated place. Keep container tightly closed.

7.3 Specific end use(s)

Apart from the uses mentioned in section 1.2 no other specific uses are stipulated.

Section 8: Exposure controls

8.1 Control parameters

Components with workplace control parameters
Contains no substances with occupational exposure limit values.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166 Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices.
Wash and dry hands.

The selected protective gloves have to satisfy the specifications of EU Directive 89/686/EEC and the standard EN 374 derived from it.

Full contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de,
test method: EN374

If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Body Protection
Impervious clothing. The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Respiratory protection
For nuisance exposures use type P95 (US) or type P1 (EU EN 143) particle respirator. For higher level protection use type OV/AG/P99 (US) or type ABEK-P2 (EU EN 143) respirator cartridges. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
No special environmental precautions required.

Section 9: Physical and chemical properties

9.1 Information on basic physical and chemical properties

Appearance:	White to off-white
Physical state:	Solid
Odour:	No data available
Odour threshold:	No data available
pH:	7 – 10 in 10 wt% H_2O solution
Melting point/freezing point:	58 °C
Initial boiling point and boiling point range:	>115 °C
Flash point:	No data available
Evaporation rate:	No data available
Flammability (solid, gas):	The product is not flammable
Upper/lower flammability or explosive limits:	Not applicable
Vapour pressure:	No data available
Vapour density:	No data available
Relative density:	1.4 – 1.5 g/litre
Water solubility:	Soluble
Partition coefficient: n-octanol/water	No data available

Auto-ignition temperature: No data available

Decomposition temperature: No data available

Viscosity: No data available

Explosive properties: No data available

Oxidizing properties: No data available

9.2 Other safety information

No data available.

Section 10: Stability and reactivity

10.1 Reactivity

No data available.

10.2 Chemical stability

Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions

No data available.

10.4 Conditions to avoid

Exposure to moisture may affect product quality.

10.5 Incompatible materials

Strong oxidizing agents.

10.6 Hazardous decomposition products

Other decomposition products - No data available.

In the event of fire: see section 5

Section 11: Toxicological information

11.1 Information on toxicological effects

Acute toxicity

Component	LD50 Oral	LD50 Dermal	LD50 Inhalation
Sodium acetate	2,720 mg/kg (rat)	>28,269 mg/kg (rabbit)	-

Skin corrosion/irritation
No data available

Serious eye damage/eye irritation
No data available

Respiratory or skin sensitisation

No data available

Germ cell mutagenicity
No data available

Carcinogenicity
IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

Reproductive toxicity
No data available

Specific target organ toxicity - single exposure
No data available

Specific target organ toxicity - repeated exposure
No data available

Aspiration hazard
No data available

Additional Information
To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

Section 12: Ecological information

12.1 Toxicity

No data available

12.2 Persistence and degradability

No data available

12.3 Bioaccumulative potential

No data available

12.4 Mobility in soil

No data available

12.5 Results of PBT and vPvB assessment

This substance/mixture contains no components considered to be either persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) and levels of 0.1% or higher.

12.6 Other adverse effects

This substance/mixture contains no components considered to be either persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) and levels of 0.1% or higher.

Section 13: Disposal considerations

13.1 Waste treatment methods

Product

Offer surplus and non-recyclable solutions to a licensed disposal company.

Contaminated packaging

Dispose of as unused product.

Section 14: Transport information

14.1 UN number

ADR/RID: - IMDG: - IATA: -

14.2 UN proper shipping name

ADR/RID: Not dangerous goods

IMDG: Not dangerous goods

IATA: Not dangerous goods

14.3 Transport hazard class(es)

ADR/RID: - IMDG: - IATA: -

14.4 Packaging group

ADR/RID: - IMDG: - IATA: -

14.5 Environmental hazards

ADR/RID: no IMDG Marine pollutant: no IATA: no

14.6 Special precautions for user

No data available

Section 15: Regulatory information

This safety datasheet complies with the requirements of Regulation (EC) No. 453/2010.

15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture

No data available

15.2 Chemical Safety Assessment

For this product a chemical safety assessment was not carried out

Section 16: Other information

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sunamp Ltd. shall not be held liable for any damage resulting from handling or from contact with the above product.

Section 1: Identification of the substance/mixture and of the company/undertaking

1.1 Product Information

Product Name: SU11 phase-change material

Product Number: No information available

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses: Thermal storage media

Uses advised against: Processes involving extreme heat use advised against or:

uses other than the above

1.3 Details of the supplier of the safety data sheet

Company: Sunamp Ltd.
1 Satellite Park
Macmerry
East Lothian
EH33 1RY
Telephone: +44 (0)1875 610001
Email: info@sunamp.com

1.4 Emergency telephone number

+44 (0)1875 610001 (not 24 hours)

Section 2: Hazards identification

2.1 Classification of the substance or mixture

Not a hazardous substance or mixture.

2.2 Label elements

Not a hazardous substance or mixture.

2.3 Other hazards

This substance/mixture contains no components considered to be either persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) and levels of 0.1% or higher.

Section 3: Composition/information on ingredients

3.1 Substances

Component	CAS-No	EC-No	Weight %	CLP Classification – Regulation (EC) No 1272/2008
Dimethyl adipate	627-93-0	211-020-6	≥99	-
Proprietary additives	-	-	≤1%	-

Section 4: First aid measures

4.1 Description of first aid measures

If inhaled, move person to fresh air. If not breathing, give artificial respiration. If irritation occurs, contact medical professional.

In case of skin contact wash off with plenty of soap and water. Immediately remove any soiled clothing. If irritation occurs, contact medical professional.

In case of eye contact rinse eyes with water for 15 minutes, removing contact lenses if easy to do so. If irritation occurs, contact medical professional.

If swallowed do not induce vomiting, rinse mouth with water. Never give anything by mouth to an unconscious person. Consult a medical professional.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labelling (see Section 2.2) and/or in Section 11.

4.3 Indication of any immediate medical attention and special treatment needed

Treat symptomatically.

Section 5: Firefighting measures

5.1 Extinguishing media

Suitable extinguishing media: Use alcohol-resistant foam, dry chemical or carbon dioxide.

5.2 Special hazards arising from the substance or mixture

Carbon oxides. Combustible.

5.3 Advice for firefighters

Wear self-contained breathing apparatus for firefighting if necessary. The action of heat on drums leads to an increase in pressure with the risk of bursting and subsequent explosion.

Section 6: Accidental release measures

6.1 Personal precautions, protective equipment and emergency procedures

Ensure adequate ventilation. Avoid breathing vapours, mist or gas. Use personal protective equipment.

6.2 Environmental precautions

Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

6.3 Methods and materials for containment and cleaning up

Keep in suitable, closed containers for disposal.

6.4 Reference to other sections

For disposal see section 13.

Section 7: Handling and storage

7.1 Precautions for safe handling

Ensure adequate ventilation. Wear personal protective equipment. Avoid breathing vapours, mist, spray.

7.2 Conditions for safe storage, including any incompatibilities

Store in cool place, in a bunded area. Keep container tightly closed in a dry and well-ventilated place. Containers which are opened must be carefully resealed and kept upright to prevent leakage.

7.3 Specific end use(s)

Apart from the uses mentioned in section 1.2 no other specific uses are stipulated.

Section 8: Exposure controls

8.1 Control parameters

Components with workplace control parameters
Contains no substances with occupational exposure limit values.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166 Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices.
Wash and dry hands.

The selected protective gloves have to satisfy the specifications of EU Directive 89/686/EEC and the standard EN 374 derived from it.

Full contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested: Dermatril® (KCL 740 / Aldrich Z677272, Size M)

Splash contact
Material: Nitrile rubber

Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested: Dermatril® (KCL 740 / Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de,
test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Body Protection
Impervious clothing. The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Respiratory protection
For nuisance exposures use type P95 (US) or type P1 (EU EN 143) particle respirator. For higher level protection use type OV/AG/P99 (US) or type ABEK-P2 (EU EN 143) respirator cartridges. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

Section 9: Physical and chemical properties

9.1 Information on basic physical and chemical properties

Appearance:	Clear, colourless
Physical state:	Liquid
Odour:	Ester-like
Odour threshold:	No data available
pH:	No data available
Melting point/freezing point:	11 °C
Initial boiling point and boiling point range:	109 - 110 °C at 19 hPa - lit.
Flash point:	110 °C - closed cup
Evaporation rate:	No data available
Flammability (solid, gas):	Not flammable
Upper/lower flammability or explosive limits:	Upper explosion limit: 8.1 %(V) Lower explosion limit: 0.8 %(V)
Vapour pressure:	0.08 hPa at 20 °C
Vapour density:	No data available

Relative density:	1.062 g/mL at 20 °C
Water solubility:	25 g/l at 20 °C
Partition coefficient: n-octanol/water	1.03 at 25 °C
Auto-ignition temperature:	400 °C at 1,013 hPa
Decomposition temperature:	No data available
Viscosity:	3 mPas @ 20 °C
Explosive properties:	No data available
Oxidizing properties:	No data available

9.2 Other safety information

No data available.

Section 10: Stability and reactivity

10.1 Reactivity

Hazardous reactions will not occur under normal conditions.

10.2 Chemical stability

Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions

Hazardous polymerization will not occur.

10.4 Conditions to avoid

Direct sunlight, extremely high or low temperatures, and incompatible materials.

10.5 Incompatible materials

Acids, bases, oxidizing agents, reducing agents.

10.6 Hazardous decomposition products

Carbon monoxide and carbon dioxide.

In the event of fire: see section 5

Section 11: Toxicological information

11.1 Information on toxicological effects

Acute toxicity

Component	LD50 Oral	LD50 Dermal	LD50 Inhalation
Dimethyl adipate	>5,000 mg/kg (rat)	>2,250 mg/kg (rat)	11 mg/litre 4 hours (rat)

Skin corrosion/irritation

Skin - rabbit
Result: No skin irritation – 4h

Serious eye damage/eye irritation
Eyes - rabbit
Result: No eye irritation

Respiratory or skin sensitisation
No data available

Germ cell mutagenicity
OECD Test Guideline 474
Rat - male and female
Result: negative

Carcinogenicity
IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

Reproductive toxicity
No data available

Specific target organ toxicity - single exposure
No data available

Specific target organ toxicity - repeated exposure
No data available

Aspiration hazard
No data available

Additional Information
To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

Section 12: Ecological information

12.1 Toxicity

Toxicity to daphnia and other aquatic invertebrates: static test EC50 - Daphnia magna (Water flea) - 72 mg/l - 48 h (OECD Test Guideline 202)

Toxicity to algae static test - Pseudokirchneriella subcapitata - > 100 mg/l - 72 h (OECD Test Guideline 201)

12.2 Persistence and degradability

Biodegradability Result: 84 % - Readily biodegradable (OECD Test Guideline 301C).

12.3 Bioaccumulative potential

Does not bioaccumulate.

12.4 Mobility in soil

No data available

12.5 Results of PBT and vPvB assessment

This substance/mixture contains no components considered to be either persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) at levels of 0.1% or higher.

12.6 Other adverse effects

Harmful to aquatic life.

Section 13: Disposal considerations

13.1 Waste treatment methods

Product

Offer surplus and non-recyclable solutions to a licensed disposal company.

Contaminated packaging

Disposal must be made according to official regulations. Container remains hazardous when empty, and may contain residues that can develop flammable vapours upon heating. Do not cut, drill, grind, weld or perform similar operation on or near empty containers.

Section 14: Transport information

14.1 UN number

ADR/RID: - IMDG: - IATA: -

14.2 UN proper shipping name

ADR/RID: Not dangerous goods

IMDG: Not dangerous goods

IATA: Not dangerous goods

14.3 Transport hazard class(es)

ADR/RID: - IMDG: - IATA: -

14.4 Packaging group

ADR/RID: - IMDG: - IATA: -

14.5 Environmental hazards

ADR/RID: no IMDG Marine pollutant: no IATA: no

14.6 Special precautions for user

No data available

Section 15: Regulatory information

This safety datasheet complies with the requirements of Regulation (EC) No. 453/2010.

15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture

No data available

15.2 Chemical Safety Assessment

For this product a chemical safety assessment was not carried out.

Section 16: Other information

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sunamp Ltd. shall not be held liable for any damage resulting from handling or from contact with the above product.

SAFETY DATA SHEET

according to Regulation (EC) No. 1907/2006

Version 6.1
Revision Date 02.09.2020
Print Date 30.03.2021

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1 Product identifiers

Product name : Calcium chloride

Product Number : 449709
Brand : Aldrich
Index-No. : 017-013-00-2
REACH No. : 01-2119494219-28-XXXX
CAS-No. : 10043-52-4

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Manufacture of substances

1.3 Details of the supplier of the safety data sheet

Company : Merck Life Science UK Limited
New Road
The Old Brickyard
GILLINGHAM
Dorset
SP8 4XT
UNITED KINGDOM

Telephone : +44 (0)1747 833-000
Fax : +44 (0)1747 833-313

1.4 Emergency telephone

Emergency Phone # : +44 (0)870 8200418 (CHEMTREC)

SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

Classification according to Regulation (EC) No 1272/2008
Eye irritation (Category 2), H319

For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 Label elements

Labelling according Regulation (EC) No 1272/2008
Pictogram

Signal word Warning

Hazard statement(s)
H319 Causes serious eye irritation.

Precautionary statement(s)	
P264	Wash skin thoroughly after handling.
P280	Wear eye protection/ face protection.
P305 + P351 + P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P337 + P313	If eye irritation persists: Get medical advice/ attention.
Supplemental Hazard Statements	none

2.3 Other hazards

This substance/mixture contains no components considered to be either persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) at levels of 0.1% or higher.

SECTION 3: Composition/information on ingredients

3.1 Substances

Formula	:	$CaCl_2$
Molecular weight	:	110.98 g/mol
CAS-No.	:	10043-52-4
EC-No.	:	233-140-8
Index-No.	:	017-013-00-2

Component	Classification	Concentration
calcium chloride		
	Eye Irrit. 2; H319	<= 100 %

For the full text of the H-Statements mentioned in this Section, see Section 16.

SECTION 4: First aid measures

4.1 Description of first-aid measures

General advice
Show this material safety data sheet to the doctor in attendance.

If inhaled
After inhalation: fresh air.

In case of skin contact
In case of skin contact: Take off immediately all contaminated clothing. Rinse skin with water/ shower.

In case of eye contact
After eye contact: rinse out with plenty of water. Call in ophthalmologist. Remove contact lenses.

If swallowed
After swallowing: immediately make victim drink water (two glasses at most). Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

4.3 Indication of any immediate medical attention and special treatment needed
No data available

SECTION 5: Firefighting measures

5.1 Extinguishing media

Suitable extinguishing media
Use extinguishing measures that are appropriate to local circumstances and the surrounding environment.

Unsuitable extinguishing media
For this substance/mixture no limitations of extinguishing agents are given.

5.2 Special hazards arising from the substance or mixture
Hydrogen chloride gas, Calcium oxide
Not combustible.
Ambient fire may liberate hazardous vapours.

5.3 Advice for firefighters
In the event of fire, wear self-contained breathing apparatus.

5.4 Further information
Suppress (knock down) gases/vapors/mists with a water spray jet. Prevent fire extinguishing water from contaminating surface water or the ground water system.

SECTION 6: Accidental release measures

6.1 Personal precautions, protective equipment and emergency procedures
Advice for non-emergency personnel: Avoid inhalation of dusts. Avoid substance contact. Ensure adequate ventilation. Evacuate the danger area, observe emergency procedures, consult an expert.
For personal protection see section 8.

6.2 Environmental precautions
Do not let product enter drains.

6.3 Methods and materials for containment and cleaning up
Cover drains. Collect, bind, and pump off spills. Observe possible material restrictions (see sections 7 and 10). Take up dry. Dispose of properly. Clean up affected area. Avoid generation of dusts.

6.4 Reference to other sections
For disposal see section 13.

SECTION 7: Handling and storage

7.1 Precautions for safe handling
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities
No data available

7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

SECTION 8: Exposure controls/personal protection

8.1 Control parameters

Ingredients with workplace control parameters
Contains no substances with occupational exposure limit values.

8.2 Exposure controls

Appropriate engineering controls
Change contaminated clothing. Wash hands after working with substance.

Personal protective equipment

Eye/face protection
Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU). Safety glasses

Body Protection
protective clothing

Respiratory protection
required when dusts are generated.
Our recommendations on filtering respiratory protection are based on the following standards: DIN EN 143, DIN 14387 and other accompanying standards relating to the used respiratory protection system.

Control of environmental exposure
Do not let product enter drains.

SECTION 9: Physical and chemical properties

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: powder Color: white
b)	Odor	odorless
c)	Odor Threshold	Not applicable
d)	pH	No data available
e)	Melting point/freezing point	Melting point: 775 °C at 1,013 hPa
f)	Initial boiling point and boiling range	1,935 °C at 1,013 hPa
g)	Flash point	No data available
h)	Evaporation rate	No data available
i)	Flammability (solid, gas)	The product is not flammable.
j)	Upper/lower flammability or explosive limits	No data available
k)	Vapor pressure	0.01 hPa at 20 °C
l)	Vapor density	No data available

m)	Relative density	2.15 g/cm3 at 25 °C
n)	Water solubility	81.3 g/l at 25 °C - completely soluble
o)	Partition coefficient: n-octanol/water	Not applicable for inorganic substances
p)	Autoignition temperature	No data available
q)	Decomposition temperature	No data available
r)	Viscosity	No data available
s)	Explosive properties	No data available
t)	Oxidizing properties	No data available

9.2 Other safety information
No data available

SECTION 10: Stability and reactivity

10.1 Reactivity
No data available

10.2 Chemical stability
The product is chemically stable under standard ambient conditions (room temperature) .

10.3 Possibility of hazardous reactions
No data available

10.4 Conditions to avoid
no information available

10.5 Incompatible materials
Strong acids, Borane/boron oxides, Zinc, Calcium oxide, Methyl vinyl ether, Strong oxidizing agents, Calcium chloride is attacked by bromine trifluoride

10.6 Hazardous decomposition products
Hazardous decomposition products formed under fire conditions. - Hydrogen chloride gas, Calcium oxide
Other decomposition products - No data available
In the event of fire: see section 5

SECTION 11: Toxicological information

11.1 Information on toxicological effects

Acute toxicity
LD50 Oral - Rabbit - male - 500 - 1,000 mg/kg
(OECD Test Guideline 401)
LD50 Dermal - Rabbit - male and female - > 5,000 mg/kg
Remarks: (ECHA)

Skin corrosion/irritation
Skin - Rabbit
Result: No skin irritation - 4 h

(OECD Test Guideline 404)

Serious eye damage/eye irritation
Eyes - Rabbit
Result: Moderate eye irritation
(OECD Test Guideline 405)

Respiratory or skin sensitization
No data available

Germ cell mutagenicity
Mutagenicity (mammal cell test): chromosome aberration.
Chinese hamster fibroblasts
Result: negative
Ames test
S. typhimurium
Result: negative
(Lit.)

Carcinogenicity

IARC: No ingredient of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

Reproductive toxicity
No data available

Specific target organ toxicity - single exposure
No data available
Acute oral toxicity - After uptake of large quantities:, Stomach/intestinal disorders, Nausea
Acute inhalation toxicity - Possible damages:, mucosal irritations

Specific target organ toxicity - repeated exposure
No data available

Aspiration hazard
No data available

Additional Information
RTECS: EV9800000

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

SECTION 12: Ecological information

12.1 Toxicity

Toxicity to fish	static test LC50 - Pimephales promelas (fathead minnow) - 4,630 mg/l - 96 h (US-EPA)
Toxicity to daphnia and other aquatic invertebrates	static test EC50 - Daphnia magna (Water flea) - 2,400 mg/l - 48 h (OECD Test Guideline 202)
Toxicity to algae	EC50 - Pseudokirchneriella subcapitata - 2,900 mg/l - 72 h (OECD Test Guideline 201)

12.2 Persistence and degradability
The methods for determining the biological degradability are not applicable to inorganic substances.

12.3 Bioaccumulative potential
No data available

12.4 Mobility in soil
No data available

12.5 Results of PBT and vPvB assessment
This substance/mixture contains no components considered to be either persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) at levels of 0.1% or higher.

12.6 Other adverse effects
No data available

SECTION 13: Disposal considerations

13.1 Waste treatment methods

Product
Waste material must be disposed of in accordance with the national and loc No mixing with other waste. Handle uncleaned containers like the product See www.retrologistik.com for processes regarding the return of chemicals and containers, or contact us there if you have further questions. Notice Directive on waste 2008/98/EC.

SECTION 14: Transport information

14.1 UN number
ADR/RID: - IMDG: - IATA: -

14.2 UN proper shipping name
ADR/RID: Not dangerous goods
IMDG: Not dangerous goods
IATA: Not dangerous goods

14.3 Transport hazard class(es)
ADR/RID: - IMDG: - IATA: -

14.4 Packaging group
ADR/RID: - IMDG: - IATA: -

14.5 Environmental hazards
ADR/RID: no IMDG Marine pollutant: no IATA: no

14.6 Special precautions for user

Further information
Not classified as dangerous in the meaning of transport regulations.

SECTION 15: Regulatory information

15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture
This material safety data sheet complies with the requirements of Regulation (EC) No. 1907/2006.

Other regulations
Take note of Dir 94/33/EC on the protection of young people at work.

15.2 Chemical Safety Assessment
For this product a chemical safety assessment was not carried out

SECTION 16: Other information

Full text of H-Statements referred to under sections 2 and 3.

H319 Causes serious eye irritation.

Further information
The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

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SAFETY DATA SHEET

according to Regulation (EC) No. 1907/2006

Version 7.0
Revision Date 14.05.2020
Print Date 30.03.2021

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1 Product identifiers

Product name : Ammonia

Product Number : 294993
Brand : Aldrich
Index-No. : 007-001-00-5
REACH No. : 01-2119488876-14-XXXX
CAS-No. : 7664-41-7

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Manufacture of substances

1.3 Details of the supplier of the safety data sheet

Company : Merck Life Science UK Limited
New Road
The Old Brickyard
GILLINGHAM
Dorset
SP8 4XT
UNITED KINGDOM

Telephone : +44 (0)1747 833-000
Fax : +44 (0)1747 833-313

1.4 Emergency telephone number

Emergency Phone # : +44 (0)870 8200418 (CHEMTREC)

SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

Classification according to Regulation (EC) No 1272/2008
Gases under pressure (Liquefied gas), H280
Acute toxicity, Inhalation (Category 3), H331
Skin corrosion (Sub-category 1B), H314
Serious eye damage (Category 1), H318
Short-term (acute) aquatic hazard (Category 1), H400
Long-term (chronic) aquatic hazard (Category 2), H411

For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 Label elements

Labelling according Regulation (EC) No 1272/2008

Pictogram

Signal word Danger

Hazard statement(s)

H280	Contains gas under pressure; may explode if heated.
H314	Causes severe skin burns and eye damage.
H331	Toxic if inhaled.
H410	Very toxic to aquatic life with long lasting effects.

Precautionary statement(s)

P260	Do not breathe gas.
P273	Avoid release to the environment.
P280	Wear protective gloves/ protective clothing/ eye protection/ face protection.
P303 + P361 + P353	IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water.
P304 + P340 + P311	IF INHALED: Remove person to fresh air and keep comfortable for breathing. Call a POISON CENTER/ doctor.
P305 + P351 + P338 + P310	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a POISON CENTER/ doctor.

Supplemental Hazard information (EU)

EUH071	Corrosive to the respiratory tract.

2.3 Other hazards

This substance/mixture contains no components considered to be either persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) at levels of 0.1% or higher.

SECTION 3: Composition/information on ingredients

3.1 Substances

Formula	:	H_3N
Molecular weight	:	17.03 g/mol
CAS-No.	:	7664-41-7
EC-No.	:	231-635-3
Index-No.	:	007-001-00-5

Component	Classification	Concentration
Ammonia, anhydrous		
	Press. Gas Liquefied gas; Acute Tox. 3; Skin Corr. 1B; Eye Dam. 1; Aquatic Acute 1; Aquatic Chronic 2; H280, H331, H314, H318, H400, H411 M-Factor - Aquatic Acute: 1	<= 100 %

For the full text of the H-Statements mentioned in this Section, see Section 16.

SECTION 4: First aid measures

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance.

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact
Take off contaminated clothing and shoes immediately. Wash off with soap and plenty of water. Take victim immediately to hospital. Consult a physician.

In case of eye contact
Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.

If swallowed
Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

4.3 Indication of any immediate medical attention and special treatment needed
No data available

SECTION 5: Firefighting measures

5.1 Extinguishing media

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

5.2 Special hazards arising from the substance or mixture
Nitrogen oxides (NOx)
Not combustible.

5.3 Advice for firefighters
Wear self-contained breathing apparatus for firefighting if necessary.

5.4 Further information
Use water spray to cool unopened containers.

SECTION 6: Accidental release measures

6.1 Personal precautions, protective equipment and emergency procedures
Wear respiratory protection. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Evacuate personnel to safe areas.
For personal protection see section 8.

6.2 Environmental precautions
Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

6.3 Methods and materials for containment and cleaning up
Clean up promptly by sweeping or vacuum.

6.4 Reference to other sections
For disposal see section 13.

SECTION 7: Handling and storage

7.1 Precautions for safe handling
Avoid contact with skin and eyes. Avoid inhalation of vapour or mist.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities
Keep container tightly closed in a dry and well-ventilated place. Store in cool place.

Contents under pressure.

7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

SECTION 8: Exposure controls/personal protection

8.1 Control parameters

Components with workplace control parameters

Component	CAS-No.	Value	Control parameters	Basis
Ammonia, anhydrous	7664-41-7	STEL	35 ppm 25 mg/m3	UK. EH40 WEL - Workplace Exposure Limits
		TWA	25 ppm 18 mg/m3	UK. EH40 WEL - Workplace Exposure Limits
		TWA	20 ppm 14 mg/m3	Europe. Commission Directive 2000/39/EC establishing a first list of indicative occupational exposure limit values
	Remarks	Indicative		
		STEL	50 ppm 36 mg/m3	Europe. Commission Directive 2000/39/EC establishing a first list of indicative occupational exposure limit values
		Indicative		

8.2 Exposure controls

Appropriate engineering controls
Avoid contact with skin, eyes and clothing. Wash hands before breaks and immediately after handling the product.

Personal protective equipment

Eye/face protection
Tightly fitting safety goggles. Faceshield (8-inch minimum). Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

The selected protective gloves have to satisfy the specifications of Regulation (EU) 2016/425 and the standard EN 374 derived from it.

Full contact
Material: butyl-rubber
Minimum layer thickness: 0.3 mm
Break through time: 480 min
Material tested:Butoject® (KCL 897 / Aldrich Z677647, Size M)

Splash contact
Material: butyl-rubber
Minimum layer thickness: 0.3 mm
Break through time: 480 min
Material tested:Butoject® (KCL 897 / Aldrich Z677647, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Body Protection
Complete suit protecting against chemicals, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Respiratory protection
Where risk assessment shows air-purifying respirators are appropriate use a full-face respirator with multi-purpose combination (US) or type AXBEK (EN 14387) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

SECTION 9: Physical and chemical properties

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: Liquefied gas Colour: colourless
b)	Odour	stinging, Do not attempt to smell the product as it is hazardous.
c)	Odour Threshold	No data available
d)	pH	ca.10 - 12 at 50 g/l at 20 °C
e)	Melting point/freezing point	Melting point/range: -78 °C - lit.
f)	Initial boiling point and boiling range	-33 °C - lit.

g)	Flash point	Not applicable
h)	Evaporation rate	Not applicable
i)	Flammability (solid, gas)	The product is not flammable.
j)	Upper/lower flammability or explosive limits	Upper explosion limit: 25 %(V) Lower explosion limit: 16 %(V)
k)	Vapour pressure	8,600 hPa at 20 °C
l)	Vapour density	0.6 - (Air = 1.0)
m)	Relative density	0.7 g/cm3 at -33 °C - liquid
n)	Water solubility	531 g/l at 20 °C - OECD Test Guideline 105
o)	Partition coefficient: n-octanol/water	Not applicable for inorganic substances
p)	Auto-ignition temperature	651 °C
q)	Decomposition temperature	> 450 °C -
r)	Viscosity	No data available
s)	Explosive properties	No data available
t)	Oxidizing properties	No data available

9.2 Other safety information

Dissociation constant	9.25 at 25 °C
Relative vapour density	0.6 - (Air = 1.0)

SECTION 10: Stability and reactivity

10.1 Reactivity
No data available

10.2 Chemical stability
Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions
No data available

10.4 Conditions to avoid
No data available

10.5 Incompatible materials
No data available

10.6 Hazardous decomposition products
Hazardous decomposition products formed under fire conditions. - Nitrogen oxides (NOx)
Other decomposition products - No data available
In the event of fire: see section 5

SECTION 11: Toxicological information

11.1 Information on toxicological effects

Acute toxicity
No data available
LC50 Inhalation - Rat - male - 4 h - 4.93 mg/l
Remarks: (ECHA)

Skin corrosion/irritation
Skin - Rabbit
Result: Corrosive - 4 h
(OECD Test Guideline 404)
Remarks: (Regulation (EC) No 1272/2008, Annex VI)

Serious eye damage/eye irritation
Causes serious eye damage.

Respiratory or skin sensitisation
No data available

Germ cell mutagenicity
Ames test
Escherichia coli/Salmonella typhimurium
Result: negative
OECD Test Guideline 474
Mouse - male - Bone marrow
Result: negative
(in analogy to similar products)

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

Reproductive toxicity
No data available

Specific target organ toxicity - single exposure
No data available

Specific target organ toxicity - repeated exposure
No data available

Aspiration hazard
No data available

Additional Information

Repeated dose toxicity - Rat - male and female - Oral - 35 Days - No observed adverse effect level - 250 mg/kg - Lowest observed adverse effect level - 750 mg/kg
(in analogy to similar products)
RTECS: BO0875000

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

Liver - Irregularities - Based on Human Evidence

SECTION 12: Ecological information

12.1 Toxicity

Toxicity to fish	flow-through test LC50 - Pimephales promelas (fathead minnow) - 0.75 - 3.4 mg/l - 96 h Remarks: (in analogy to similar products)(ECHA)
Toxicity to daphnia and other aquatic invertebrates	static test LC50 - Daphnia magna (Water flea) - 101 mg/l - 48 h Remarks: (ECHA)
	EC50 - Daphnia pulicaria - 1.16 mg/l - 48 h Remarks: (Lit.)

12.2 Persistence and degradability

Biodegradability	Result: - rapidly biodegradable Remarks: Readily biodegradable.

12.3 Bioaccumulative potential

No data available

12.4 Mobility in soil

No data available

12.5 Results of PBT and vPvB assessment

This substance/mixture contains no components considered to be either persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) at levels of 0.1% or higher.

12.6 Other adverse effects

Very toxic to aquatic life.
No data available

SECTION 13: Disposal considerations

13.1 Waste treatment methods

Product

Offer surplus and non-recyclable solutions to a licensed disposal company. Waste material must be disposed of in accordance with the Directive on waste 2008/98/EC as well as other national and local regulations. Leave chemicals in original containers. No mixing with other waste. Handle uncleaned containers like the product itself.

Contaminated packaging

Dispose of as unused product.

SECTION 14: Transport information

14.1 UN number

ADR/RID: 1005 IMDG: 1005 IATA: 1005

14.2 UN proper shipping name

ADR/RID: AMMONIA, ANHYDROUS
IMDG: AMMONIA, ANHYDROUS
IATA: Ammonia, anhydrous
Passenger Aircraft: Not permitted for transport
Cargo Aircraft: Not permitted for transport

14.3 Transport hazard class(es)

ADR/RID: 2.3 (8)	IMDG: 2.3 (8)	IATA: 2.3 (8)

14.4 Packaging group

ADR/RID: -	IMDG: -	IATA: -

14.5 Environmental hazards

ADR/RID: yes	IMDG Marine pollutant: yes	IATA: no

14.6 Special precautions for user

No data available

SECTION 15: Regulatory information

15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture

This safety datasheet complies with the requirements of Regulation (EC) No. 1907/2006.

15.2 Chemical safety assessment

For this product a chemical safety assessment was not carried out

SECTION 16: Other information

Full text of H-Statements referred to under sections 2 and 3.

EUH071	Corrosive to the respiratory tract.
H280	Contains gas under pressure; may explode if heated.
H314	Causes severe skin burns and eye damage.
H318	Causes serious eye damage.
H331	Toxic if inhaled.
H400	Very toxic to aquatic life.
H410	Very toxic to aquatic life with long lasting effects.
H411	Toxic to aquatic life with long lasting effects.

Relevant changes since previous version

2. Hazards identification

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

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