BVES






PREVENTIVE AND PROTECTIVE FIRE SECURITY WITH LARGE SCALE LITHIUM ION STORAGE SYSTEM

INSTRUCTIONS AND INFORMATION FOR PLANNERS, BUILDING OWNERS, EMERGENCY SERVICES, INSURANCE COMPANIES AND APPROVAL BODIES

2ND EDITION 12/11/2021

BG ETEM Energie Textil Elektro Medienerzeugnisse

GDV DIE DEUTSCHEN VERSICHERER

DEUTSCHER FEUERWEHR VERBAND

DGUV Fachbereich Feuerwehren Hilfeleistungen Brandschutz

AGBF bund im Deutschen Städtetag

VdS

DISCLAIMER

CONTENT

1. INTRUDUCTION

Large scale lithium ion storage systems are stationary storage systems which are produced individually or in mini-series. These are stationary systems with capacities starting from approx. 50 kWh.

Large scale lithium ion storage systems are to be considered safe as soon as all the relevant regulations and standards are observed and implemented. The purpose of this document is to provide everyone involved in a project with the same information regarding the legal and technical standards, and to present measures related to the preventive and protective fire security of Large scale lithium ion storage systems in order to guarantee that all safety-related standards are upheld.

Today, Large scale lithium ion storage systems are used for a range of different applications all over the world. When creating this document, storage applications were taken into account which are realised in conjunction with renewable energy generation plants, in industry and commerce, in power stations, for grid applications and in the rapid charging infrastructure field. The storage systems can be built as stand-alone items or within buildings. The storage of lithium ion cells and batteries is excluded.

The instructions and recommendations provided are based on the generally recognised technical rules, recommendations by fire services, fire security experts, assessors, insurance companies, accident insurance providers, manufacturers and experts from the field of lithium ion storage. The information includes the current information on hazards and tried and tested measures to prevent damage, as well as standards for safe lithium ion mass storage systems. This publication contains instructions on the avoidance of fire and its impact, and describes possible structural, system-related and organisational protective measures and opportunities for prevention.

Such measures must be determined within the scope of individual risk analyses. This document presents a range of different options as examples. Measures relating to the protection of material assets, environmental protection or protection against interruptions to operation may deviate from the personal protection measures.

One important protective measure for battery storage in general and Large scale lithium ion storage systems in particular is the use of a suitable overvoltage protection. Choosing the right overvoltage protection devices is a challenge for manufacturers and installers, particularly for installations with high available DC short circuit current and the maximum safety standards.

The guidelines offer important information and instructions on protection in individual cases, as well as recommendations relating to operational and insurance matters. If the cell or battery technology originally selected is changed at a later date, for example when cell modules are used or when a system is expanded, the effectiveness of the measures that have been taken must be reassessed. In addition, as a rule, with used batteries, it should be possible to confirm their safety in advance by means of a detailed risk analysis.

The overview below shows the three pillars, “construction, property insurance and operation” with the related topic areas. With regard to “construction” and “operation”, national, autonomous and private laws should be taken into account, which will be covered below.

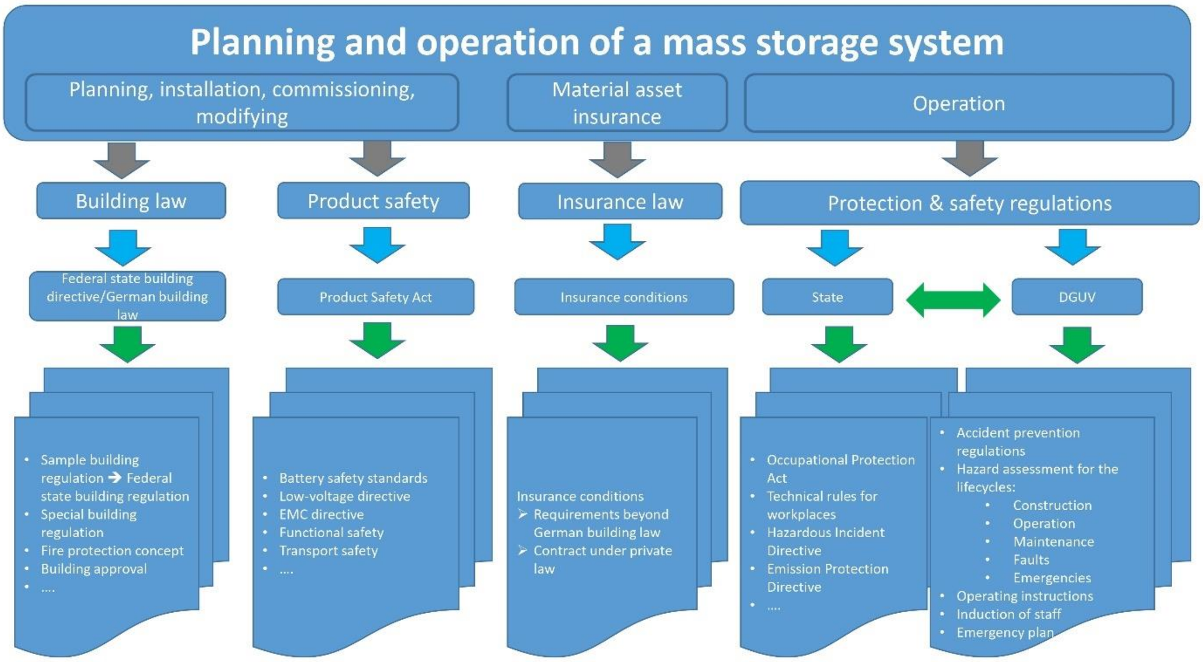


Diagram 1: Overview of the regulations and other specifications to be observed when planning and operating a large scale storage system (not conclusive)

2. GENERAL INFORMATION

2.1 STRUCTURE OF A LARGE SCALE STORAGE SYSTEM

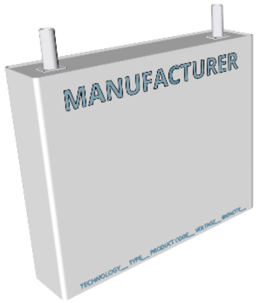


Diagram 2: Cell (shown here as a prismatic cell); in most cases, cells are not delivered individually, but in the form of battery packs or modules, and are inserted into the battery system.

Diagram 3: Battery pack or module; assembly of multiple cells to create an easy to handle unit in a housing.

Diagram 4: Battery system or battery; assembly of battery packs or modules, which form a functioning unit, in a housing.

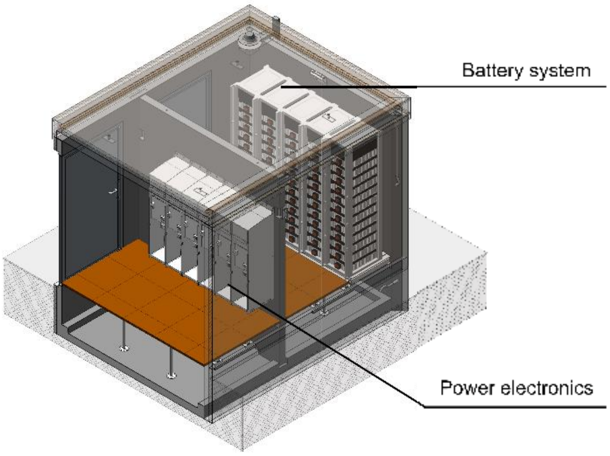


Diagram 5: Large scale storage system; contains all the components needed for operation (e.g. battery system, power electronics, energy management, extinguishing device, air conditioning, container, etc.). The mains connection or a “client system” (as defined in EnWG Section 3) is not an inherent part of the mass storage system.

2.2 SAMPLE APPLICATIONS OF STORAGE SYSTEMS

Large scale lithium ion storage systems are used in different environments. The generally valid standards, which apply regardless of the installation situation, include the production, installation and operation of the storage system in accordance with the current generally recognised tech-nical rules (see Chapter 3.2). The installation site of the large scale storage system should be selected in such a way that hazards from water penetration (e.g. heavy rain, defective water pipes, etc.) can be excluded as being improbable. This notwithstanding, several basic standards and potential hazards should be taken into account in all cases.

Open space installations can be installations of storage systems which are used for the interim storage of renewable energies (photovoltaic or wind energy), for example.

Diagram 6: Open space installation of a lithium ion mass storage system in container format

Storage systems within a built area (e.g. a residential area, a business park or an industrial zone) are installed in order to flatten load peaks of large consumer units, for example, or to make it possible to use renewable power more directly.

Diagram 7: Lithium ion mass storage in a residential area

Lithium ion mass storage **inside a building** serves among other things to buffer energy from photovoltaic systems (e.g. in business parks and industrial zones, or in agriculture), or to provide short-term high power levels for rapid charging facilities or a large number of charging devices used in parallel, e.g. in car parks.

Diagram 8: Lithium ion mass storage inside a building

See Chapter 8 for the relevant definitions.

2.3 AVAILABILITY REQUIREMENTS FOR THE USAGE VARIANTS

In some cases, the different usage variants entail very different availability requirements. As an example, several requirements are listed here in relation to individual applications.

TABLE 1: EXAMPLES OF AVAILABILITY REQUIREMENTS IN THE DIFFERENT AREAS OF APPLICATION.

Power stations Application examples: • Power storage/coverage of peak loads • Power distribution/grid operator • Balancing energy/grid stability • Renewable energies (PV/wind energy, etc.)	**Availability requirement** Due to impact of a failure of the energy storage Low: - Longer operation interruption or total failure is acceptable Moderate: - Temporary failure is acceptable High: - Short operation interruption is acceptable
Emergency power application Application examples: • Power storage if the grid supply fails • Emergency lighting • Safe termination of processes • Supply to system-relevant installations	**Availability requirement** Due to impact of a failure of the energy storage High: - Failure not permitted/unacceptable ….
Charging infrastructure systems Application examples: • Car parks • Rapid charging facilities	**Availability requirement** Due to impact of a failure of the energy storage Low: - Longer operation interruption or total failure is acceptable

2.4 INSTRUCTIONS THAT ENABLE HAZARDS AND MEASURES TO BE CATEGORISED

The following instructions apply generally to lithium ion cells and must be observed when designing the battery system itself or when considering fire security measures.

The heat (energy) released during a fire or thermal runaway is currently mainly in the region of 4 to 11 times that of the electrochemically storable nominal energy of lithium ion cells. To date, no correlation has been found between the absolute heat and for example the cell structure or cell chemistry. When assessing the risk, the highest value should therefore be assumed, unless data on the cell used is available. This is generally not the case; furthermore, the level of the heat being released is very difficult to determine and is frequently erroneous.

Should lithium ion batteries fail, hydrogen fluoride and phosphorous pentafluoride or phosphoric acid may be formed, depending on the composition of the batteries. Also, additional toxic, carcinogenic substances such as polycyclical aromatic hydrocarbons (PAH) may also emerge. Furthermore, depending on the composition of the batteries, heavy metals are released in the form of nickel and cobalt oxides.

The cathode material used in a lithium ion cell can contain chemically bound oxygen, which is released within a cell when fire occurs, and is available for combustion there. For this reason, a burning cell or the internal cell fire cannot itself be extinguished.

3. BASIC PRINCIPLES

3.1 INSTRUCTIONS REGARDING GERMAN BUILDING LAW

As a basic principle, the relevant federal state building laws and statutory federal state regulations must be observed. **All structural installations must be considered on a case-by-case basis.**

In all cases, the relevant building approval, including the fire security concept/certificate must be taken into account. The building owner or the operator is responsible for ensuring that the specifications in the respective building approval are fulfilled. It may be that further requirements arise in relation to property protection which go beyond the building law. We recommend that the insurance company be involved in the planning at an early stage.

3.2 THE SAFETY OF LITHIUM ION STORAGE SYSTEMS – STANDARDS, CERTIFICATES AND GENERAL INSTRUCTIONS

An overview of the requirements that should generally be fulfilled, and possible standards that should be applied in this regard, is given here. When these requirements are met, a safe lithium ion mass storage system can be installed and operated which is free of unacceptable risks[1]. These requirements apply to **battery safety, electrical safety, EMC safety, functional safety, operational safety and transport safety,** which are listed below.

ELECTRICAL SAFETY (LOW VOLTAGE DIRECTIVE 2014/35/EU)

Electrical safety in larger lithium ion storage systems can be realised by observing the following standards, for example:

- DIN EN 61140 (VDE 0140-1) – Protection against electric shock – joint requirements for systems and operating means
- Battery only
    - IEC 61010-1 – Safety requirements for electrical measurement, control, regulation and laboratory equipment – Section 1: General Requirements (IEC 61010-1:2010 + Cor. :2011); German version EN 61010-1:2010
    - IEC 60730 – Automated electrical regulation and control – Section 1: General Requirements (IEC 60730-1:2013, modified + COR1:2014); German version EN 60730-1:2016

POWER ELECTRONICS AND BATTERY SYSTEM

- IEC 62477-1 – Safety requirements for power semiconductor inverter systems and equipment – Section 1: General Requirements (IEC 62477-1:2012); German version EN 62477-1:2012
- IEC 62909-1 – Bi-directional, grid-connected power converters
- Section 1: General Requirements
- IEC 62109-1 – Safety of power converters for use in photovoltaic energy systems – Section 1: General Requirements (IEC 62109-1:2010); German version EN 62109-1:2010

[1] Definition in accordance with product safety: Risk = hazard x degree of probability

INSTALLATION

- IEC 60364 series VDE 0100 series – Installation of low-voltage systems
- IEC 61439-1 Low-voltage switchgear combinations – Section 1: General Specifications (IEC 61439-1:2011)
- German version EN 61439-1:2011DIN EN 62271-101 High-voltage switch devices and switch systems Section 101: Synthetic inspection
- DIN EN 62271-202 High-voltage switch devices and switch systems Section 202: Pre-fabricated stations for high voltage/low voltage
- VDE AR E 2510-2 Stationary electrical energy storage systems, intended for connection to the low-voltage grid
- DIN EN IEC 62485-2/VDE0510-485-2 Safety requirements for secondary batteries and battery systems
- Technical connection requirements of the grid operator

BATTERY SAFETY (PRODUCT SAFETY DIRECTIVE 2001/95/EC)

The requirements for battery systems that arise from the standards in the Low-Voltage Directive are not sufficient in themselves. For this reason, battery-specific standards that are currently not harmonised in any EU directive, must be taken into account in all cases:

- IEC 62619 – Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries, for use in industrial applications
- IEC 63056 – Secondary cells and secondary batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and secondary batteries for use in energy storage systems
- IEC 62485-5 – Safety requirements for batteries and battery systems – Section 5: Lithium ion batteries for stationary applications (IEC 21/903/CD:2016)
- IEC 62933-2-1 Electrical energy storage systems –
  Section 2-1: Unit parameters and test procedures – General specifications
  (IEC 62933-2-1:2017); German version EN IEC 62933-2-1:2018.

Several fundamental considerations are also included here:

- DIN IEC/TS 62933-5-1 VDE V 0520-933-5-1:2020-04 Electrical energy storage systems (EES systems) Section 5-1: Safety considerations for grid-integrated EES systems – General specification (IEC TS 62933-5-1:2017)
- IEC 62933-5-2 Electrical energy storage systems (EES systems) Section 5-2: Safety requirements for grid-integrated EES systems – electrochemical systems

With regard to second life lithium ion batteries, DKE/AK 371.0.14 has developed a pre-standard, whereby the entire vehicle batteries in areas not accessible to non-professionals can be used in compliance with the requirements necessary for the stationary use (e.g. the low-voltage directive 2014/35/EU mentioned above); see also DKE/AK 371.0.14 "Stationary use of lithium ion batteries from the vehicle sector, including second life applications".

EMC ELECTROMAGNETIC COMPATIBILITY (EMC DIRECTIVE 2014/30/EU)

Compliance with the requirements for electromagnetic compatibility is of relevance to safety and can be implemented for the specific area of use and components, for example by applying the following standards:

- Electromagnetic compatibility (EMC) – Section 6-1: Generic standards – interference stability for living areas, shop and commercial areas and small businesses (IEC 61000-6-1:2016); German version EN IEC 61000-6-1:2019
- Electromagnetic compatibility (EMC) – Section 6-2: Generic standards – interference stability for industrial areas (IEC 61000-6-2:2016); German version EN IEC 61000-6-2:2019
- Electromagnetic compatibility (EMC) – Section 6-3: Generic standards – interference stability for living areas, shop and commercial areas and small businesses (IEC 61000-6-3:2020); German version EN IEC 61000-6-3:2020
- Electromagnetic compatibility (EMC) – Section 6-4: Generic standards – interference emission for industrial areas (IEC 61000-6-4:2018); German version EN IEC 61000-6-4:2019
- DIN EN 55011 (VDE 0875-11) Industrial, scientific and medical equipment – Radio interference – Threshold values and measuring procedures; (CISPR 11:2015, modified + A1:2017); German version EN 55011:2016 + A1:2017
- DIN EN 55014 Electromagnetic compatibility – requirements for household appliances, electrical tools and similar electrical appliances
- IEC 62311 Evaluation of electrical and electronic facilities in relation to restriction of exposure of persons in electromagnetic fields (0 Hz to 300 GHz)
- German Social Accident Insurance (DGUV) regulation 15 – Electromagnetic fields

FUNCTIONAL SAFETY

In addition, the risk analysis and assessment is designed to minimise risks throughout the life stages and system levels of the system. For this purpose, further standards are needed, since these are not yet binding in the standards for battery systems listed to date. Functional safety requirements therefore need to be fulfilled and also taken into account. The following standards can be used here:

- DIN EN 61508 (VDE 0803) – Functional safety of safety-related electrical/electronic/programmable electronic systems
- ISO 26262– Road vehicles – Functional safety
- DIN EN ISO 13849-1; – Safety of machines – Safety-related parts of control systems – Section 1: General design principles
- DIN EN 62061 (VDE 0113-50) – Safety of machines – Functional safety of safety-related electrical/electronic/programmable electronic control systems

Other functional safety standards can also be used if they are comparable to the standards listed, and if the necessary safety level is attained.

TRANSPORT SAFETY

The European Agreement on the International Transportation of Dangerous Goods by Road (ADR) requires every lithium ion battery to conform to a certified type according to the UN manual on tests and criteria, Section III, Sub-section 38.3 (in short: UN38.3 tests). In addition, the manufacturer must provide a test summary (UN manual on tests and criteria, Section 38.3.3). Batteries that do not conform to any tested type may only be transported under an ADR special provision. Batteries must be transported in accordance with the condition, configuration and quantity, in compliance with the respective current valid ADR, or at national level, in compliance with the Regulations for the Conveyance of Hazardous Goods by Road, Rail and Inland Navigation (GGVSEB).

3.3 FURTHER REGULATORY SPECIFICATIONS

The retention of extinguishing water and the areas of responsibility must be inspected according to the federal state law and on a case-by-case basis.

Burning lithium ion mass storage systems can lead to the creation of larger quantities of contaminated extinguishing water. In some circumstances, the fire can only be effectively extinguished when larger quantities of extinguishing water, possibly mixed with extinguishing additives, are used.

Section 5 of the Water Management Act (WHG) – General duty of care – and Sections 32 and 48 WHG – Maintenance of clean groundwater and water bodies – state that an inspection must be made by the installer or operator/owner as to whether construction and/or organisational measures are required in order to retain extinguishing water, independently of the directive on the retention of extinguishing water and the ordinance on systems for handling water-hazardous substances (AwSV). For this purpose, coordination with the authorities responsible (e.g. with regard to water law, and environmental and nature conservation) may be necessary.

Note: When planning, it must be taken into account that as a standard, there can be no prospect of fire-fighting measures being taken by the fire services to retain extinguishing water.

Retention of electrolytes, e.g. by upstanding the container base in order to retain leakage, is not usually necessary due to the nature and quantities of the electrolytes used.

The directive on the implementation of the German Pollution Control Act (BImSchV) may also apply.

3.4 RISK ASSESSMENT AND PROTECTIVE MEASURES

Within the scope of the individual risk analysis, effective measures must be specified in order to find a suitable protection concept. Different options will be listed below as examples. The measures for attaining the protection targets for the protection of material assets and protection against interruptions to operation may deviate from the measures for personal protection or environmental protection.

The risk assessments and the resulting measures to be taken must be determined taking into account the requirements stipulated in German building law, occupational protection law, environmental protection, insurance-related requirements and the interests of the operator, and may go beyond the minimum standards stipulated in the building law. The relevant companies or organisations should therefore always be involved in the planning at an early stage. It is assumed that measures such as sufficient minimum distances to building systems, protection against unauthorised access, emergency exits, no additional fire loads in the installation room and the area surrounding the storage system etc. will be taken and upheld.

In addition to these measures, depending on the anticipated level of risk (identification in Sections 3.4.1 to 3.4.4) further measures are taken which are listed as examples in the table in Section 3.4.5.

3.4.1 PERSONAL PROTECTION

The following decision tree can be used in order to identify the anticipated level of risk with regard to **personal protection**. The measures to protect individuals who work in and on the lithium ion mass storage system must be identified by means of the hazard assessment on the basis of the occupational protection law of the federal state and the professional association. For example, particular requirements may apply to emergency exit routes. In the risk assessment below, the hazards for individuals outside or close to the lithium ion mass storage system will be considered. This can in particular be the effects of fire and smoke.

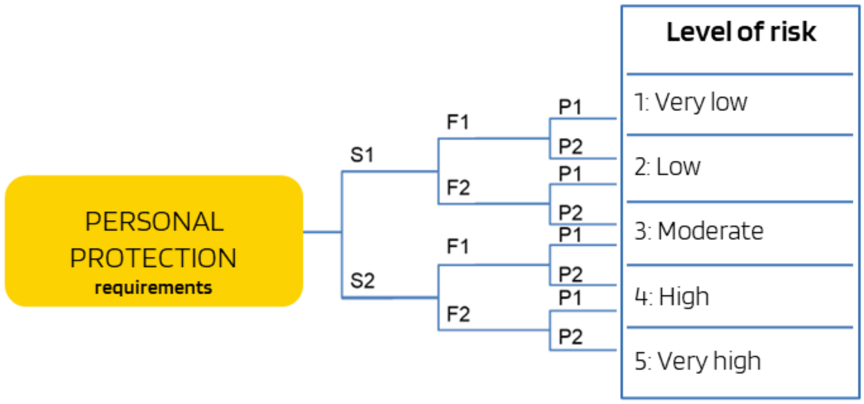


Diagram 9: Assessment of level of risk

S – Size or extent of the damage
- S1 Low degree of severity of injury, usually reversible
- S2 Serious degree of severity of injury, usually irreversible or fatal

F – Frequency and/or duration
- F1 Frequency rare to less frequent and/or short duration of the exposure to the hazard
- F2 Frequent to constant and/or long duration of the exposure to the hazard

P – Prevention of the hazard
- P1 Option of preventing the hazard or limiting the damage under certain circumstances
- P2 Not possible, or hardly possible

3.4.2 AVAILABILITY

The following decision tree can be used in order to identify the anticipated level of risk with regard to availability.

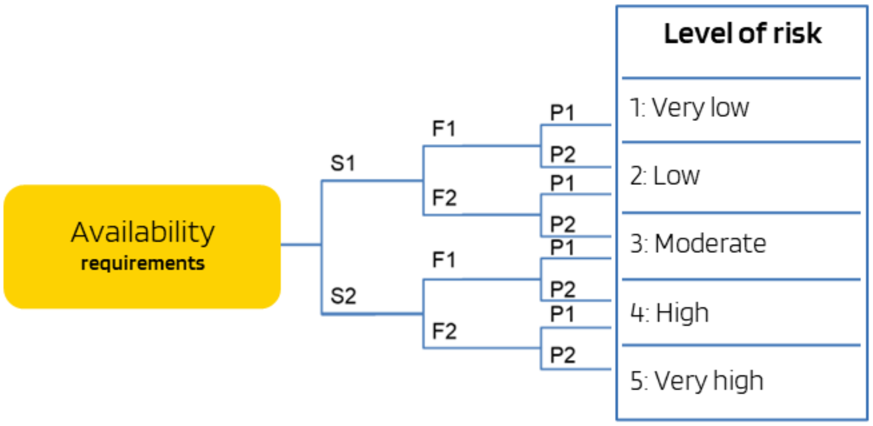


Diagram 10: Assessment of level of risk

S – Impact of a failure of the energy storage

S1 No interruption to operation, or only of a short duration
S2 Long duration of interruption to operation, failure of emergency power supply, etc.

F – Frequency and/or duration

F1 Frequency rare to less frequent and/or short duration
F2 Frequent to constant and/or long duration

P – Prevention of the interruption to operation

P1 Option of preventing the interruption to operation or for limiting it to a short duration
P2 Not possible, or hardly possible

3.4.3 PROTECTION OF MATERIAL ASSETS

The following decision tree can be used in order to identify the anticipated level of risk with regard to the protection of material assets. In the risk assessment below, the risks to material assets outside or close to the storage system will be considered. This can in particular be the effects of fire and smoke.

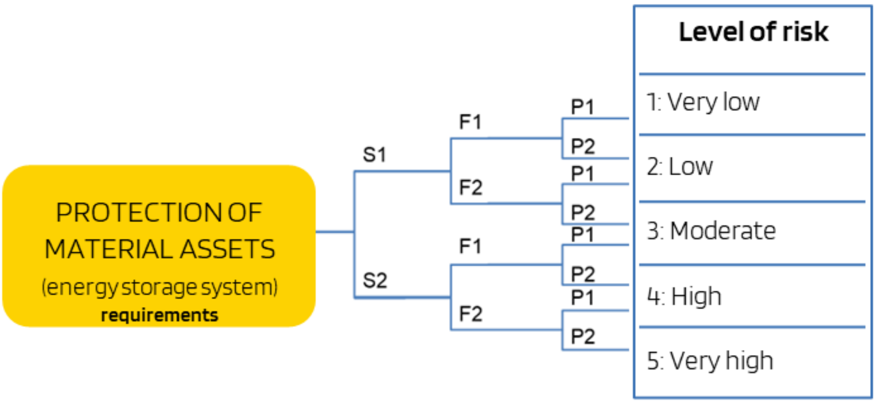


Diagram 11: Assessment of level of risk

S – Impact of total loss of the energy storage
S1 No to low material damage
S2 High material damage, long interruption to operation

F – Frequency and/or duration
F1 Frequency rare to less frequent and/or short duration
F2 Frequent to constant and/or long duration

P – Prevention of total loss
P1 Option of preventing the total loss or for limiting it to a low damage level
P2 Not possible, or hardly possible

RECOMMENDED PROTECTIVE MEASURES

The generally recognised rules of technology must be taken into account for the installation and operation (see Chapter 0). In addition to these measures, further measures may need to be taken depending on the anticipated level of risk with regard to the protection of material assets.

3.4.4 ENVIRONMENTAL PROTECTION

The following decision tree can be used in order to identify the anticipated level of risk with regard to environmental protection. In the risk assessment below, the impact of fire, smoke and contaminated extinguishing water outside or close to the storage system will be considered.

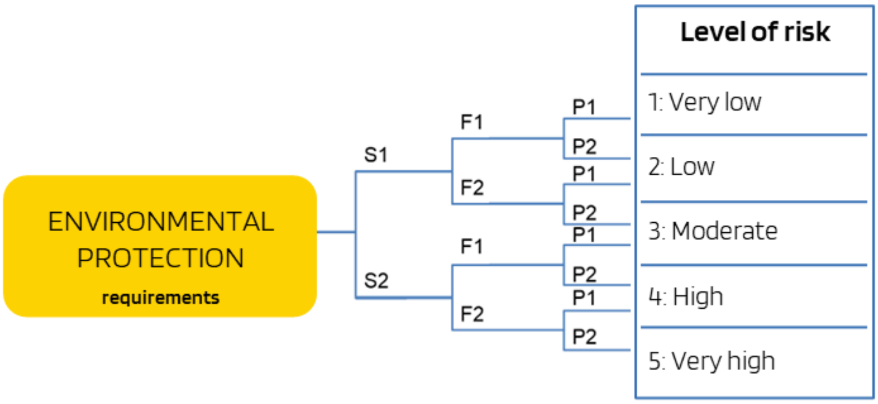


Diagram 22: Assessment of level of risk

S – Environmental damage if fire occurs in the energy storage

- S1 No to low environmental damage
- S2 High level of environmental damage, high costs for damage reparation in the area surrounding the energy storage

F – Frequency and/or duration

- F1 Frequency rare to less frequent and/or short duration
- F2 Frequent to constant and/or long duration

P – Prevention of environmental damage

- P1 Option of preventing environmental damage or for limiting it to a low damage level
- P2 Not possible, or hardly possible

3.4.5 OVERVIEW OF THE POSSIBLE PROTECTIVE MEASURES, DEPENDING ON THE LEVEL OF RISK

The measures stipulated in the generally recognised rules of technology for the installation and operation (see Chapter 3.2) should be taken into account in all cases. In addition to these measures, further measures may need to be taken depending on the calculated level of risk. The table below contains possible protective measures, which are listed as examples depending on the level of risk. These can be adapted according to the hazard assessments for the specific item in question.

TABLE 2: OVERVIEW OF THE POSSIBLE PROTECTIVE MEASURES, DEPENDING ON THE LEVEL OF RISK

Level of risk / Recommended measures	Personal protection			Availability			Protection of material assets			Environmental protection		
	Low	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
Automatic fire alarm system with local alarm		X										
Automatic fire alarm system with forwarding of the fire alarm to a constantly manned unit*			X			X		X	X			
Structural separation between the installation area of the battery and the power electronics **without** classified fire resistance	X			X			X					
Structural separation between the installation area of the battery and the power electronics **with** classified fire resistance		X	X		X	X		X	X			
Protection of the surrounding area against the impact of a fire from inside to outside through structural separation/enclosure of the entire storage system with classified fire resistance or extended distances to other building facilities		X	X					X	X			
Protection of the battery storage against the impact of a fire from outside through structural separation/enclosure with classified fire resistance or extended distances to other building facilities					X	X		X	X			
Guided smoke gas discharge into the outside air (discharge fire gases may not lead to a hazard in the outside area)		X	X		X	X			X			
Retention of extinguishing water (responsibility of the operator)											X	X
Stationary automatic extinguishing system (as described in Chapter 5)			X			X			X		X	X

* A constantly manned unit as defined in this document can be e.g. a process control technology/control room, a certified security service, emergency call and service control unit, the control unit of a company fire service or the public fire brigade. By contrast, a fire alarm system as required in building law should generally be connected to the unit triggering the alarm (e.g. the integrated control room) according to the technical connection conditions, which can then directly alert the public fire brigade.

Not all aspects of the location can be exhaustively assessed in the table below. There, measures should be taken that are adapted taking into account the local conditions. We generally recommend that the existing fire alarm system be used for early detection of faults, in order to identify conditions that may cause fire in good time.

SAMPLE EXPLANATION OF THE MEASURES LISTED IN THE TABLE

Fires are detected at an early stage by an automatic fire alarm system. As a result, people located in the area can be warned in good time, and in addition, intervention services can be alerted. This can also reduce the extent of the damage.

Through structural measures, the surrounding area (persons, material assets, the environment) can be protected from the impact if a fire in the storage system occurs. In addition, the storage system can be protected from the impact of fire from the outside, which helps to protect material asset value and availability (see also Chapter 4.2).

The environmental protection measures are aimed particularly at avoiding soil or water pollution. An automatic extinguishing system provides early fire-fighting measures, as a result of which the fire brigade will not require so much extinguishing water or none at all, for example, which in turn would have to be retained or captured.

4. STRUCTURAL FIRE PROTECTION – PREVENTIVE FIRE AND HAZARD PROTECTION MEASURES

4.1 HAZARD ASSESSMENT

Due to the extensive normative regulations and specifications (see Chapter 3.2) regarding the inspections to be conducted as part of the certification process for the battery cells, it can be assumed that lithium ion batteries per se can be classified as being relatively safe. Rather, the aim is to protect the storage systems from an external fire incident, in order to prevent cell decomposition processes initiated by external combustion heat. A separation of the lithium ion batteries from inverters and transformers is desirable in order to further minimise risk. When installing the systems, the current valid norms and application and installation regulations should be observed and implemented. The specified regular checks/technical inspections during operation are regarded as important elements in minimising the risk of fire.

It may be that there is an increased risk of cell damage in comparison with new lithium ion batteries when "second life" batteries are used due to their greater age. This should be taken into account if necessary.

4.2 FIRE AND EXPLOSION PROTECTION REQUIREMENTS

The spread of fire can be effectively prevented by means of structural fire protection measures. This can be achieved through sufficient distance apart from other buildings or structural systems, or structural separations with fire resistance duration standards. According to the current findings, between 5 and 10 metres distance from other items appears to be sufficient, whereby these values and others must always be decided on the basis of the specific individual case.

If the lithium ion mass storage system is located inside a building, it should be considered, in cooperation with the fire protection certification body, the building supervision authority and the fire protection service unit, as to whether this room is a "room with a risk of explosion or increased risk of fire" as defined in Section 29, para. 2 no. 2 SBR. In such cases, fire-resistant solid separating walls with at least fire-retardant, sealing and self-closing closures are required. If no classification as defined in Section 29, para. 2 no. 2 SBR occurs, the separating walls between the installation site of the storage and the remaining parts of the building should usually have at least the fire resistance capability of the supporting and reinforcing parts of the building storey, or at least be fire-retarding (cf. Section 29, para. 3 SBR). The focus should again be on creating solid separating walls. In order to prevent disadvantages arising from building laws, with very large lithium ion storage systems (e.g. 1,000 kWh), the fire protection certification body/bodies or the fire protection service unit should in some cases be asked to award special structure status, so that further requirements can be issued, with transparent arguments as to why they are necessary. It should be noted that the evaluation or classification as a special structure must be made by the building approval authority responsible following specialist consultation, and that the structure cannot be generally assumed to have such a status.

If energy storage systems are intended to be installed and operated in garages (not inside vehicles), these must as a rule be separated in a fire-resistant manner from the remaining garage space. The open laying of high-voltage lines (greater than 1,000 V AC or 1,500 V DC), which may be entailed by the installation of a stationary lithium ion energy storage system in garages, is not permitted in garages, among other things in order to ensure safety for the emergency services.

As long as the system is operated in normal mode (the mode for which it is designed) within the design parameters, premature age-related damage and the formation and release of electrolyte steam is not to be expected. With regard to the possibly limited lifespan/duration of use of the storage system or the individual lithium ion batteries, the instructions issued by the manufacturer must be observed in all cases. During correct operation within the design parameters, it is unlikely that an explosive atmosphere will be created; i.e. a classification into an explosion protection zone is not necessary during normal operation, unless anything else arises from the risk analysis of the manufacturer.

Should there be thermal runaway of the battery modules – for example, during operation beyond the design parameters – it must be assumed that at the start of the thermal runaway, flammable gas mixtures are discharged without a permanent, effective ignition of the gases first occurring. During this phase, a collection of flammable gas mixtures is possible, which can lead to an explosion during subsequent ignition.

In order to guide a pressure increase that arises when damage occurs within the installation site – e.g. electrolytes (which may also be flammable) emitting gas under pressure or as a result of an extreme fire spread – into the free air in a targeted manner, and to avoid a risk to the stability of the room closure, pressure release devices are required which comply with the current technical developments and knowledge gained from fire incidents.

These pressure release devices must ideally be attached directly to the outside wall. If this is not possible due to the local conditions, these openings must be guided into the free air in a targeted manner, e.g. via the roof. The room-closing function of the surrounding walls, with requirements for the fire resistance capacity, must also be guaranteed when pressure levels rise.

The installation sites of the lithium ion mass storage systems are not usually living areas as defined in the building laws. From a fire protection perspective, a secured exit from the installation site of the storage system is therefore regarded as being sufficient to enable persons to be rescued.

In order to be able to guarantee safe extinguishing operations for the emergency services, secure access is required. If possible, this access should be on the ground floor, and be located on the outside wall in order to enable the emergency services to safely extinguish fires from a shielded position or from a safe area. In general, access to the lithium ion batteries should be designed in such a manner that the jet pipe distances can be maintained according to DIN VDE 0132.

To be able to indicate to emergency services on the access door to the installation site of the lithium ion mass storage system that lithium ion batteries are present, a label similar to that used on photovoltaic systems (for a sample, see Annex C – Labelling) is recommended. This label must be attached to the wall on the lock side at approximately eye level, and not directly on the access door, for example. This ensures that the notices remain visible even when the access door is open.

To ensure sufficient extinguishing water supply, the current specifications in work sheet DVGW W 405 in conjunction with the professional fire services association ("AGBF") 2018-04 recommendation "Supply of extinguishing water from hydrants in public areas" are considered to be sufficient. With regard to fire protection for the system technology, additional, "voluntary" measures are feasible that go beyond the statutory building requirements. These measures usually arise from operator systems in relation to system availability, or result from standards issued by the property insurer and their risk assessment, including from a financial perspective. In this regard, fine spray extinguishing systems or gas extinguishing systems are of relevance, which are triggered by automatic alarms with a smoke parameter. For further instructions regarding fire detection, see Chapter 5.2 and on extinguishing facilities, Chapter 5.4.

The use or installation of fire alarm systems with automatic reporting to the operator is also widespread. A fire alarm system connected to an alarm-triggering unit is not seen as being mandatory by the fire brigade services, and must be coordinated with the fire protection service unit responsible for the local area. Due to the characteristic fire behaviour of lithium ion batteries, preventive fire protection cannot usually prevent a total loss of the system affected by fire. A fire alarm system used can also be used to inform the operator following internal fire detection, but also for separating the mass storage system from the power grid or separating the storage system from e.g. a photovoltaic system. Therefore, the purpose of the preventive fire and hazard protection measures could and should be to avoid fire affecting the batteries. The implementability required by law regarding the requirements specified in the statutory federal state regulations or fire protection concept must be taken into account.

5. SYSTEM TECHNOLOGY FIRE PROTECTION – FIRE ALARM AND FIRE EXTINGUISHING TECHNOLOGY

5.1 SCENARIOS AND PROTECTION TARGETS

If extinguishing systems are planned, different scenarios must be considered, which each pursue different protection targets. A possible differentiated consideration is explained in brief below:

SCENARIO 1 – Fire within the lithium ion battery storage system (fire or thermal runaway at “cell level”).

Protection target: With thermal runaway of a cell, the spread to adjacent cells or the thermal runaway of a module must be prevented. A thermal runaway of the system is avoided as a result; in the best case, the fire brigade is not required to intervene with an active fire-fighting operation. The effectiveness of the fire protection system, such as that of an extinguishing system installed, must be proven for the battery type used.

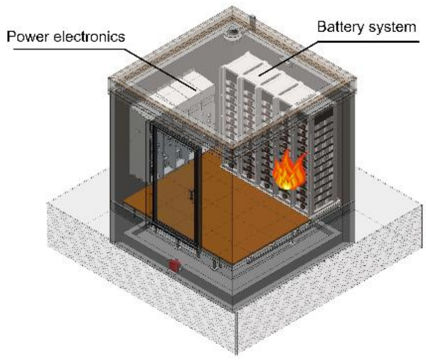


Diagram 13:
Presentation of scenario 1

When a thermal runaway incident occurs in an individual cell, the battery system should be designed such that no external fire emerges from the battery system, or no breakage of the battery housing occurs (see IEC 62619, VDE-AR-E 2510-50 or UL1973). The stationary battery storage systems must meet the standards of IEC 62619, including Chapter 7.3.3. The alternative standard given in the norm, according to Chapter 7.3.2 (internal short-circuit check – cell) is not suitable for this proof of fulfilment. Standards specified in IEC 62619, Chapter 7.3.3, VDE-AR-E 2510-50 para. 6.2.4, 6.2.5, 6.2.6 or UL1973 Chapter 39 (fire spread check) can be fulfilled by structural measures or special fire protection encasements in such a way that when cell runaway occurs, the spread to adjacent cells or the runaway of a module or a runaway of the system or an external fire from the battery system or a battery housing breakage is avoided.

Note: To fulfil the protection target, an extinguishing system or other facilities (e.g. encasements) can be used as an option.

SCENARIO 2 – Fire impact on the lithium ion battery storage system (fire incident occurs within the installation site) and a reliable differentiation as to whether this is a fire of the lithium ion battery or the power electronics cannot be made.

Protection target: With fires occurring close to the lithium ion batteries (e.g. a fire in the power electronics, etc.), the impact must be reduced in such a manner that it can be ensured that the fire does not spread to the batteries.

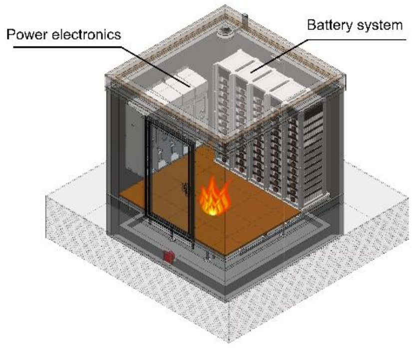


Diagram 14:
Presentation of scenario 2

SCENARIO 3 – Fire impact in the area of the secondary electronics (power electronics, air conditioning device, etc.). The fire occurs within the installation site, but in qualified fire protection terms, is separate from the lithium ion battery storage system.

Protection target: When fires occur close to the secondary electronics, the impact must be reduced in such a way that it can be ensured that the fire does not spread to the installation area of the battery.

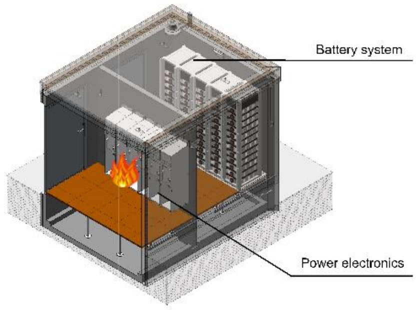


Diagram 3:
Presentation of scenario 3

SCENARIO 4 – Fire from the outside onto the battery storage system (external fire incident outside the installation site).

Protection target: Ensure that a fire incident cannot spread to the battery storage system. Possible measures: structural separation with sufficient fire resistance, spatial separation or extinguishing systems.

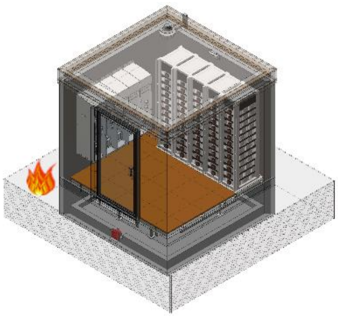


Diagram 16:
Presentation of scenario 4

5.2 FIRE DETECTION – TRIGGERING OF EXTINGUISHING SYSTEMS – FIRE ALERT

The operation of lithium ion mass storage systems requires certain ambient conditions. The mass storage system may only be operated within the temperature range specified by the manufacturer. In general, continuous air conditioning is essential in order to remain within the operating parameters. In a development phase, high circulation cooling levels lead to strong dilution of smoke gases being released. Possible causes of fire can be the electrical components (power electronics, cables, connection terminals, etc.), as well as the battery itself. Not all detection systems are suitable for the purpose, due to the potential causes of fire and the spatial arrangement. Fires in the electrics are one of the most frequent causes of fire, but can be successfully extinguished if they are detected at an early stage. If the fire is based on an internal battery error, small quantities of pyrolysis gases are produced as a result of the heating plastic housing surrounding the battery. However, with the air conditioning running, these quantities are not sufficient to generate an early fire warning with standard fire detection elements. At the same time, however, a damaged battery also releases highly flammable electrolyte gases. This is a clear sign for an imminent thermal runaway of the battery. The target must be to detect fire as early as possible, to initiate intervention measures at short notice and to prevent major damage. The table below is a recommendation. It can be extended by additional systems at any time.

The necessity of installing a fire detection system and automatic extinguishing system can arise as follows:

1. PERSONAL PROTECTION
An automatic fire alarm system within the item increases personal protection, since an early warning to persons on site inside and outside the system enables early measures to be taken, such as warning against access or flight.

2. AUTOMATIC EMERGENCY SHUTDOWN OF THE MASS ENERGY STORAGE SYSTEM IN ORDER TO PREVENT FIRES DEVELOPING
With an early automatic shutdown of the battery storage system (e.g. release of the system, opening of all AC and DC power switches), a fire can potentially already be prevented as it is developing.
A connection between the fire alarm system and the system control is expedient.

3. TRIGGERING OF AN AUTOMATIC EXTINGUISHING SYSTEM
In addition, an automatic extinguishing system can be triggered if a higher requirement is necessary, or in compliance with an official stipulation, or due to demands made by the property insurer.

4. FORWARDING OF THE ALARM TO A CONSTANTLY MANNED UNIT
In addition, if required, the fire alarm can be forwarded to a constantly manned unit.

Whn planning fire alarm systems in battery storage systems, the protection targets, the scale and the type of fire detection must be determined. The following must be taken into account:

- Which areas or system parts (fire loads) should be monitored
- Which fire scenario is anticipated (e.g. flames or smouldering fire, overheating, chemical reaction of a rechargeable battery).

The following items should be taken into account as a general rule:

- Detection properties of the fire detection elements
- Air flow, thermal properties in all operating states
- Arrangement of the system parts to be monitored
- Valances/bulkheads/openings
- Automatic triggering of extinguishing systems
- Automatic shutdown of systems (fire incident-control matrix)
- Accessibility for maintenance, servicing and replacement
- Time required for assembly and cabling

Battery storage systems release different fire characteristics, depending on the fire load. The fire detection elements selected depend, among other things, on the anticipated fire characteristics/decomposition products, the spatial geometry and the ventilation conditions. The use of a smoke suction system (“SSS”) is recommended for detection purposes. The relevant evidence of suitability must be provided.

TABLE 3: OVERVIEW OF FIRE CHARACTERISTICS WITH ASSIGNMENT TO FIRE TYPE

Fire type	Fire characteristic							
	Smoke			Heat			Flames	
	OSD EN 54-7	SSS EN 54-20	Linear smoke detector EN 54-12	Heat detector EN 54-5	Linear heat detector EN 54-22	Multi-sensor detector EN 54-29,-31	UV EN 54-10	IR EN 54-10
Flaming fire Battery accident Cable Coolants	+	+	+	o	o	+	o	o
Smouldering fire Synthetic materials Cables/lines Battery accident	o	+	o	-	-	o	-	-
Start of battery accident Release of electrolytes	-	+*	-	-	-	-	-	-

Legend: **+** = highly suitable **o** = fairly suitable **-** = not suitable
* Certification required from an independent body, e.g. in accordance with the VdS recognised protection concept for lithium ion systems (for further information, see www.vds.de and instructions from the manufacturer)

TRIGGERING OF AUTOMATIC EXTINGUISHING SYSTEMS

Automatic extinguishing systems must be triggered in compliance with VDE 0833-2 in dual alarm dependence type B by fire detection elements that are authorised in accordance with EN 54. Video-based systems are not approved in accordance with EN 54, and may only be used as additional, image-supported verification. They are therefore not permitted for triggering automated extinguishing systems.

ALARM EQUIPMENT

Alarm equipment must be installed in compliance with the valid norms and guidelines. Installation can be completed in accordance with an alarm concept coordinated with the operator, including with acoustic EN 54-3 and/or also visual EN 54-23 signal generators.

5.3 HAND-HELD FIRE EXTINGUISHERS

A hand-held fire extinguisher can be suitable for fighting fires that impact on cells/batteries from the outside. No suitable hand-held fire extinguishers for fighting cell/battery fires themselves are currently available on the market.

Due to the low aisle widths, the minimum distances specified in VDE 0132 may not always be met for mass storage systems. For this reason, no hand-held fire extinguishers should be provided in these systems.

If necessary, hand-held fire extinguishers should be provided outside the storage system to enable persons to extinguish fires. With regard to extinguishing fires on burning persons, see also the DGUV information booklet 205-001 “Operational fire protection in practice”; in such cases, fire blankets are not suitable; see the sheet “Use of fire blankets” included in the DGUV information relating to operational fire protection.

The necessity of providing hand-held fire extinguishers for smaller/medium-sized storage systems in other operation rooms that are not electrical operation rooms is explained in ASR A2.2 “Measures against fire” in conjunction with DIN VDE 0132 “Fire-fighting and technical assistance for electrical systems”.
Staff must be inducted in battery-specific fire-fighting procedures. This also applies in particular with regard to electrical hazards.

5.4 EXTINGUISHING SYSTEMS

Preliminary note:
In standard cases, no persons are present in the battery storage system, if a fire occurs, it is only possible for safety reasons to approach to a limited extent, and rapid fire development can be anticipated; therefore, semi-stationary and manual extinguishing equipment can only be used or are effective to a limited degree.

At hazardous sites, where a fire in the battery storage system may create a risk to persons or the surrounding area, and for reasons of material asset protection, it may be necessary to install fire alarm and/or extinguishing systems. A fire alarm and extinguishing system is designed to extinguish or control a developing fire and to prevent the spread of a fire. A differentiation should be made between fires in the area surrounding the battery storage system and fires in the battery itself. Burning cells cannot be extinguished, although a spread of fire (to additional cells and/or modules) can be effectively prevented with suitable extinguishing systems, and as a result, a fire throughout the entire battery storage system can be stopped. The certification or authorisation for the battery type and area of use must be provided for this purpose. As a basic principle, it should be determined when planning whether a fire extinguishing system, a system for controlling fires or flame suppression system as shown in Table 4 should be installed. If an extinguishing system is used, an accident in the battery must be detected as early as possible. Once propagation, i.e. the spread of the runaway battery cells/battery modules, takes hold, extinguishing is almost impossible.

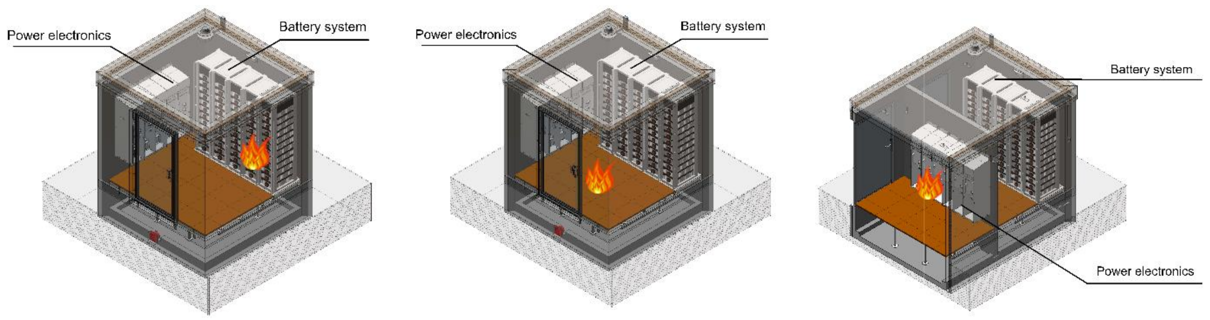
5.4.1 AUTOMATIC EXTINGUISHING SYSTEMS

Automatic extinguishing systems detect a fire and fight it independently. The relevant regulations and standards for planning and installing automated extinguishing systems should be taken into account.
A check should be made as to whether the battery storage system should be switched off in case of fire (emergency shutdown). Note: The batteries remain live even after emergency shutdown.

Clear information regarding the suitability of the extinguishing system for protecting battery storage systems and limitations or usage limits must be contained in their permissions such as VdS or UL and their comments and/or related manuals (evidence of effectiveness and operational safety).

5.4.1.1 EXTINGUISHING AGENTS FOR AUTOMATED EXTINGUISHING SYSTEMS

Note: When extinguishing gases are used, VdS 3518, “Safety and health protection when using fire extinguishing systems with extinguishing gases” should be observed.



Scenario 1 Scenario 2 Scenario 3

Diagram 17: Graphic depiction of scenarios 1 to 3 as given in Chapter 5.1; for descriptions of the scenarios and protection concepts, see Chapter 5.1.

TABLE 4: OVERVIEW OF EXTINGUISHING AGENTS FOR AUTOMATED EXTINGUISHING SYSTEMS, BASED ON THE PROTECTION AREAS FOR SCENARIOS 1, 2 AND 3

Extinguishing agent	Protection areas/ fire loads											
	Open integrated batteries in the installation area			Closed battery cabinets in the installation area			Electrical operating rooms Switching systems			Cable floors Interim floors in electrical operating room		
Scenario	1	2	3	1	2	3	1	2	3	1	2	3
Water - Sprinkler - Spray water	O* O*	O* O*	This scenario does not provide for batteries in the protection area	- -	O* O*	This scenario does not provide for batteries in the protection area	Does not apply here, since in this area, no batteries are present	O* O*	O* O*	Does not apply here, since in this area, no batteries are present	O* O*	O +
Water mist - Low pressure - Medium pressure - High pressure	O* O* O*	O* O* O*		- - -	O* O* O*			O* O* O*	O* O* O*		O* O* O*	+ + +
Water with extinguishing agent additives (wetting agents)	O*	O*		-	O*			O*	O*		O*	+

Foam agent additive a) - Heavy foam/ - Medium foam/ - Light foam	 O* - -	 O* O* O*		 - - -	 O* O* O*			 O* O* O*	 O* O* O*		 O* O* O*	 + + O
CO2 c)	+	+		+	+			+	+		+	+
IG 01 argon b), c)	+	+		+	+			+	+		+	+
IG 100 nitrogen b), c)	+	+		+	+			+	+		+	+
IG 55 b), c)	+	+		+	+			+	+		+	+
IG 541 b) , c)	+	+		+	+			+	+		+	+
HFC-227ea b), d)	-	-		-	-			-	+		-	+
FK-5-1-12 b), e)	-	O		-	O			O	+		O	+
Powder	-*	-*		-*	-*			-*	-*		-*	-*
Aerosol f)	-	-		-	-			-	-*		-	-*

Legend: **+** = highly suitable **o** = fairly suitable **-** = not suitable
* In some cases, suitability must be evaluated due to the anticipated residues following triggering of the automated extinguishing system.

The fire-fighting measures described in Chapter 6.1 to be conducted by emergency fire-fighters and the extinguishing agents recommended there, together with the specifications/recommendations stipulated in DIN VDE 0132 are independent of the above table, and remain valid!

a) According to DIN VDE 0132, foam may only be used by emergency fire-fighters in voltage-free system parts; if necessary, adjacent systems should also be disconnected from the voltage (risk of voltage transfer via foam carpet). The dissemination of foam via automated extinguishing systems is not regulated in detail in DIN VDE 0132, and must be evaluated within the scope of the specialist planning by the installer of the extinguishing system as part of a risk assessment/hazard assessment, taking into account the relevant valid installer standards.

b) The flooding area must be sufficiently sealed off, so that a concentration of extinguishing gas and the required retention time is achieved.

c) Certification is required from an independent body, e.g. in accordance with the VdS recognised protection concept for lithium ion systems (for further information, see www.vds.de and instructions from the manufacturer)

d) No longer permissible in new systems due to the F-GAS regulation.

e) Within the extinguishing agent group with ISO label FK-5-1-12, there is a clear application instruction from the manufacturer 3M™ for the Novec™ 1230 fire extinguishing agent: The manufacturer refers to the technical product data sheet dated January 2020, page 10 (https://multimedia.3m.com/mws/media/124688O/3m-novec-1230-fire-protection-fluid.pdf)
Once it has been triggered, the thermal runaway cannot be stopped by the fire extinguishing agent. For this reason, it should not be used for this specific application or for this risk. Fire extinguishing systems with this fire extinguishing agent can be installed close to lithium ion batteries in order to quickly extinguish external fires.
When FK 5-1-12 is used in the area surrounding the battery storage system, e.g. to protect the power electronics (scenario 2), in all cases, when the fire is detected, a differentiation must be made using suitable detection methods between pyrolysis products and gas-emitting, flammable electrolyte vapours. The extinguishing system for protecting the area surrounding the battery storage system may only trigger when it has been ensured that no battery fire is simultaneously present. The requirements for fire detection set out in Section 5.2 must be met.
Additional products are available on the market under the same ISO label. Since at the time of going to press not information on these products was known from the manufacturers or distributors in question, these should as a rule not be used unless clear evidence of effectiveness for the specific protection targets of the system in question can be provided.

f) According to DIN EN 15276-2, the use of aerosol extinguishing systems is permitted for fires, as long as the involvement of certain materials in the fire is excluded. These include chemicals that have their own oxygen reserve, or other oxidation agents. Depending on the cell type used, oxygen reserves or other oxidation agents can occur in the cathode material used. For this reason, an inspection and corresponding evidence of the effectiveness of the extinguishing system in individual cases is required.

Note:

The type of fire-fighting system and extinguishing agents used depends on the protection target and application.

When an inert gas extinguishing system is used, for example, for very early detection of the fire or cell fault, the damage can be limited to one single cell or module.

When water-based extinguishing systems are used, critical fire gases can be suppressed, for example. These smoke gas scrubs can be expedient when in the case of fire, emissions may lead to danger in the surrounding area.

5.4.2 SEMI-STATIONARY EXTINGUISHING SYSTEMS

Experience has shown that semi-stationary extinguishing systems in lithium ion storage systems are only effective when works fire brigades are deployed, since only these brigades can guarantee correspondingly short intervention times. Semi-stationary extinguishing systems have fixed installed pipes in an area to be protected and open extinguishing nozzles. In contrast to stationary extinguishing systems, semi-stationary extinguishing systems usually do not have their own water supply, but are supplied via a connection to the water feed by the fire brigade. Water as an extinguishing agent can sometimes be used with the addition of wetting or foam agents. With battery storage systems, the use of semi-stationary extinguishing systems makes sense under certain circumstances.

For this system to be used effectively, the following conditions must be met:

- The area to be protected is fully monitored by an automated fire alarm system
- Detection occurs as early as possible
- The intervention time (as per VdS 2395-1: the period between the fire alarm and the filling of the stationary pipe conduit system) by the fire brigade is not longer than 5-8 minutes
- The area for connecting the hose lines to the extinguishing system can be safely accessed, and
- The structural installation can withstand the static load caused by the extinguishing water, or the water can be discharged and captured in a targeted manner.

Semi-stationary extinguishing systems are suitably only for fire control or flame suppression as support for a fire-fighting operation by the fire brigade. The effects of the fire can be reduced; however, a high level of fire damage can be expected.

5.4.3 EVIDENCE OF EFFECTIVENESS

Evidence of effectiveness must be provided by fire and extinguishing tests that imitate real-life situations, with corresponding repeat attempts. The evidence of effectiveness must be oriented to the protection target or the corresponding scenario, be conducted by an independent test body and be recorded in a test agreement.

Examples of possible protection targets are:

- Tolerable scale of damage
- Protection of the equipment itself
- Protection of the environment
- Fire suppression and extinguishing
- High degree of availability

However, other or additional protection targets can be defined in relation to the protection area/item, time orientation, fire load and extinguishing impact.

In general, as far as possible, test scenarios from the guidelines and standards must be used when determining effectiveness. If these are not available, the concept for determining effectiveness must be coordinated with all those involved and with the approval authorities.

The determination of effectiveness must:

- Take into account the normal conditions of use of the extinguishing system(s)
- Take into account conditions of use that are inexpedient for the extinguishing system(s)
- Fulfil the standards for personal and material asset protection, and
- Verify the safety for the normal design of the extinguishing system(s)

These requirements may entail several attempts under different conditions of use. The fire and extinguishing tests must be documented together with the results.

6. PREVENTIVE FIRE PROTECTION

6.1 RECOMMENDATIONS FOR USAGE TACTICS

With regard to the procedure for operations involving stationary lithium ion mass storage systems, DIN VDE 0132 “Fire-fighting and technical assistance for electrical systems” should be observed.

The choice of extinguishing means for the fire brigade is water, including with mass storage systems; here, wetting agents can be added. The known jet pipe distances as defined in DIN VDE 0132 must be maintained in all cases. Despite the cooling measures that may be required, it must be ensured inside buildings in particular that unnecessary water damage is avoided. In order to minimise hazards that may arise from the possible extreme fire spread (increased heat emissions, splitter effect), the extinguishing operation should be carried out from a sheltered position as far as possible. Any gases and vapours that are released (such as electrolytes) and which do not emerge from the battery as burning, may under certain circumstances lead to the formation of flammable atmospheres. The installation rooms must therefore be ventilated with fresh air as soon as possible, and preferably immediately. Gases and/or vapours that are released must be overcome with a spray jet whenever possible. In order to determine whether cooling measures are required from the fire brigade, in practice, the “critical” temperature of approx. 80 degrees Celsius (cf. DIN VDE 0132) on the outer side of the lithium ion battery (module housing) has been proven to be a good indicator.

When fighting a fire, the full protective clothing as defined in DGUV Information 205-014 (e.g. DIN EN 469 Protective clothing for fire brigades – standard requirements for protective clothing for fire brigade activities) with breathing apparatus suited to the surrounding air must be worn, since the thermal risk during fire-fighting is assigned a higher priority than the hazard caused by chemical substances. Following completion of the fire-fighting operation, it must be considered, particularly when there are large quantities of chemicals being discharged, whether a procedure according to FwDV 500 is required analogous to hazard group GG II C.

Should any dismantling work be required as part of the risk prevention measures on system components, this must be conducted by an electrician. However, it is mandatory here that the person leading the fire-fighting operation checks whether these measures are still necessary in order to avert danger, or whether the place where the incident occurred can already be transferred to the operator.

With regard to the frequently discussed matter of the creation of hydrogen fluoride (hydrofluoric acid, HF) due to the chemical components of the electrolytes (e.g. lithium hexafluorophosphate $LiPF_6$), it should be mentioned that currently, with stationary mass storage systems, it can be assumed that hydrofluoric acid that is created is chemically “neutralised” or “deflagrated” by calcium components in surrounding walls (plaster, etc.) and/or in foundations made of concrete, thus rendering acute danger unlikely. The creation of fluoric acid cannot currently be conclusively evaluated, however. HF measurements are recommended as orientation.

With regard to a targeted preparation for a fire-fighting operation, inspections of the item have been shown to be expedient in which the fire-fighters can be inducted into the local conditions and special features in direct contact with the system operators, in order to be sufficiently prepared if needed to fight a fire.

INSTRUCTIONS AFTER THE FIRE HAS BEEN EXTINGUISHED/TRANSFER OF THE SITE AFFECTED

- After the emergency response measures, the affected site may only be left after being secured. Any potential hazard areas must be blocked off.
- The site must be transferred to the person responsible (system operator, a person authorised by them, building owner, possibly the electrical works or the police) with the necessary safety instructions following termination of the emergency response measures.
- If necessary, the system must be switched off from the mains by a specialist company before the affected site is left and secured against being switched back on.
  Note: The lithium ion battery remains live even after emergency shutdown.
- The installation rooms must naturally continue to be ventilated as far as possible.
- The instructions/recommendations in the DGUV Information sheet 205-035 or vfdb regarding fire-fighting operation hygiene in cases of fire and on the handling of cold fire scenes must be observed.

Additional aspects that must be observed, but which should not be classified as primary emergency measures, and which are therefore not the responsibility of the fire brigade, are:

- The storage and interim storage of destroyed or damaged lithium ion storage systems must be implemented taking into account the structural and organisational conditions, and in accordance with the manufacturer’s specifications.
  Furthermore, see also protective measures during activities in contaminated areas TGRS 524 and VdS 2537 – Guidelines for cleaning up fire damage.
- Destroyed or damaged lithium ion rechargeable batteries (critically defective lithium ion rechargeable batteries) must be transported in accordance with the special ADR instructions (e.g. ADR 2021 SV 376) and according to the assigned packaging instructions.

7. ORGANISATIONAL MEASURES

The organisational measures are essential for ensuring the safe operation of a mass storage system. With this in mind, they should already be defined during the planning, installation and commissioning phases.

7.1 SAFE OPERATION OF A LITHIUM ION MASS STORAGE SYSTEM

Following the installation of a mass storage system, the operator is responsible for its safe operation ("Responsibility"). They must produce and document a hazard assessment, from which measures for the safe operation of the mass storage system can be derived.

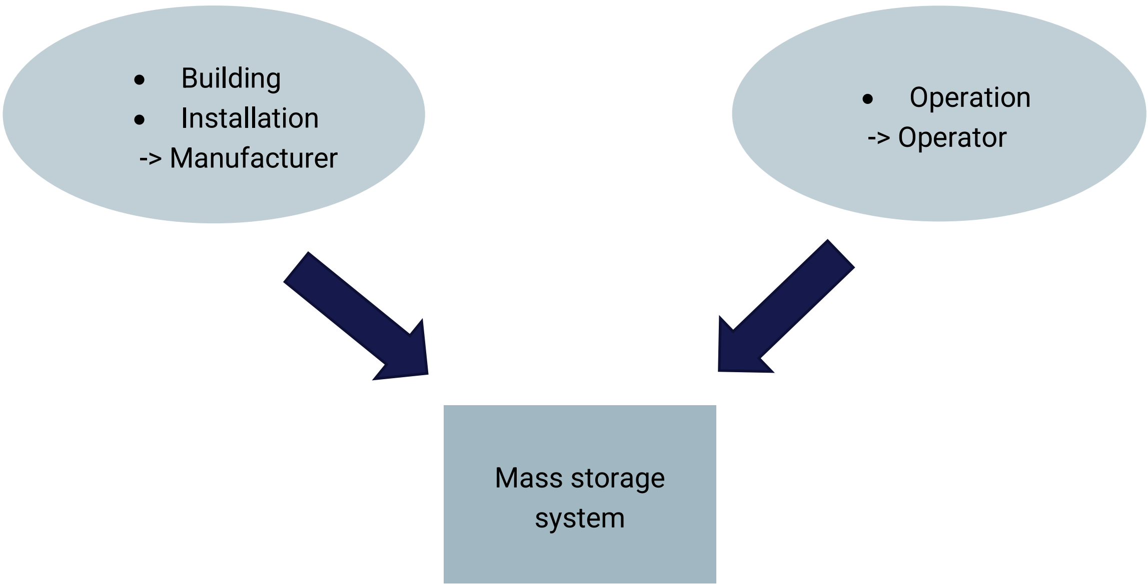


Diagram 48: Responsibilities

When the operation of the mass storage system is transferred to a subcontractor, e.g. due to a lack of expertise on the part of the operator, the subcontractor must produce the hazard assessment.
Work during operation must be conducted in compliance with the occupational and health protection specifications. This must be agreed contractually.

Hazard assessment:
When assessing the hazard, a safe system is assumed to be in place, the acceptable remaining risks of which are described for the operator in the operating instructions. The operator must assess/evaluate the interface between the installation site and the mass storage system.
The installation site of a mass storage system can be e.g. a field with a photovoltaic field/park, but also as a system integrated in a building, such as a hospital.

The following process steps must be considered and documented in the hazard assessment:

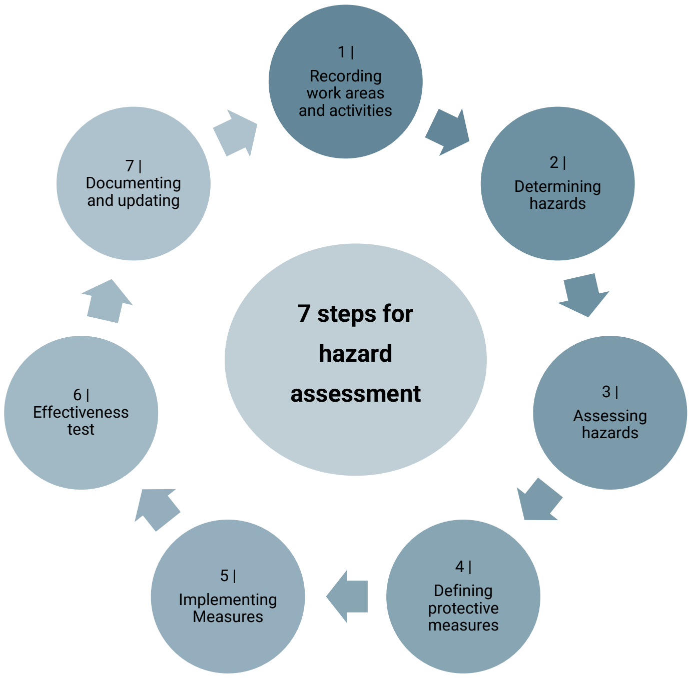


Diagram 9: 7 steps for hazard assessment

The different operating states of the mass storage device must be considered, among other items:

- Normal operation
- Maintenance/servicing
- Emergency operation (interference/fire, emergency exits, etc.)
- ...

The necessary information required for safe operation, maintenance and servicing is included in the operating instructions and documents produced by the manufacturer.
The operator or their authorised representative must implement the requirements relating to the surrounding area for the specific site of the mass storage device, as specified in the operating instructions and/or building approval.

TABLE 5: PROCESS STEPS AND SAMPLE PROCESS CONTENT WHEN ASSESSING THE HAZARD

Content, hazard assessment

Process step:	Process:
(1) **Specification of work areas and activities**	**Work areas:** • Rechargeable battery area • Control area • Outside area • .... **Activities:** • Replacement of rechargeable battery packs (→ AuS – work on live parts, DGUV regulation 103-111/112)

	• Inspection of the charging level
	• Visual checks
	• Inspection of safety technology (fire alarm system, extinguish system, etc.)
	• Maintenance of air conditioning device
	• Emergency measures (fire and explosion protection)
	  ○ Alarm alert plan and evacuation plan
	  ○ Flight and rescue plan
	  ○ Fire brigade plan
	• Fire protection officer
	• Fire protection regulations
	• Authorised switching personnel
	•
	• ...
	
	These items must be taken into account for the relevant type of mass storage system operation.

(2) **Determination of hazards**	• The hazards must be determined in accordance with the "Overview of hazard factors" Annex B – Hazard factors given below. • We recommend that all hazard factors are taken into account, and that "not present" should be noted for factors that do not apply. This provides evidence that a comprehensive assessment has taken place.
(3) **Assessing the hazards**	• The hazards must be assessed according to the frequency of their occurrence and the potential degree of severity of injury.

(4)
Determining specific occupational protection measures
	• Specific occupational protection measures must be determined using the STOP principle (substitution, technical, organisations, personal protection measures).
	In practice, this means that existing hazards must be avoided, and when this is not possible, personal protective equipment (PPE) should be selected as a final measure.
	
	  ○ This can mean, for example, that work is only possible when the system is switched off.
	  ○ Non delivery of pressure release openings
	  ○ Determination of specific emergency measures (flight and rescue options) if a hazard arises (in particular during maintenance and servicing work, rechargeable battery replacement, etc.) emergency measures according to Section 10 of the occupational protection act and Section 22 DGUV, specification 1, basic principles of prevention and standards for operating aisles and maintenance aisles as defined in DIN VDE 0100-729 – installation of low-voltage systems: requirements for operating sites, rooms and special-type systems
	
	• Specific occupational protection measures must be communication via operating instructions and through in-person induction of staff.

(5) **Implementation of measures**	• Staff must be informed of the measures specified through documented instructions. • The necessary materials, e.g. tools and personal protective equipment (protective shoes, helmet, protective glasses, clothing) must be procured and made available.
(6) **Inspection of the effectiveness of the measures**	The effectiveness of the measures taken must be determined through discussion and observation among staff during work. If necessary and expedient, the measures for ensuring the fulfilment of the safety standards must be adjusted.
(7) **Continuation of the measures**	The specified measures must be regularly checked (→ we recommend annually!) in order to supplement technical changes and add new knowledge that affects occupational and health protection. We recommend that this is done when accidents occur that are narrowly avoided, or after work accidents, critical situations, reconstruction work on the system, etc.

When producing the hazard assessment, staff, safety officers, the safety expert, the medical officer and the works council should be involved.

You can also contact the insurance company responsible for the company for support.
For further information, see Annex B – Hazard factors.

8. ABBREVIATIONS AND EXPLANATION OF TERMS USED

TABLE 6: ABBREVIATIONS

Abbreviation	
BImSchV	Directive on the implementation of the German Federal Pollution Act
DVGW	Deutscher Verein des Gas- und Wasserfaches e. V.
EMC	Electromagnetic compatibility
EnWG	Law on electricity and gas supply (Energy Management Act)
IR	Infra-red alarm
FBR	Federal state building regulation
SBR	Sample building regulation
OSD	Optical smoke detector
PAH	Polcyclical aromatic hydrocarbons
SSS	Smoke suction system
TCC	Technical connection conditions
UV	Ultraviolet flame alarm
VdS	VdS Schadenverhütung GmbH
vfdb	Vereinigung zur Förderung des Deutschen Brandschutzes e. V. (German fire protection association)

The following terms and definitions are based on EN and IEC standards as far as possible. Reference is made to the corresponding standard in or before the definition.

DEFINITIONS ACCORDING TO PREN 14972

- **3.1.12 Fire control**
  Restriction of the size of the fire by distributing water in order to reduce the heat release rate and to pre-wet adjacent flammable substances, while the gas temperature on the ceiling are checked and the radiation is limited in order to avoid damage to building structures.
  EXAMPLE: By cooling items, surrounding gases or pre-wetting adjacent flammable substances, or a combination of all three.
- **3.1.13 Extinguishing fire**
  Full elimination of a flaming or smouldering fire.
- **3.1.14 Fire suppression**
  Drastic reduction of the heat release rate and prevention of a renewed spread of the fire during system operation.

DEFINITIONS ACCORDING TO IEC 63056 – Rechargeable batteries containing alkaline or other non-acid electrolytes – Safety requirements for lithium rechargeable batteries and batteries for use in industrial applications – draft 2020

- **Cell**
  Secondary cell with which electrical energy is derived through emplacement/outplacement reactions of lithium ions or through oxidation/reduction reactions between the negative electrode and the positive electrode.

  NOTE 1: The cell typically contains an electrolyte consisting of a lithium salt and an organic solvent compound in liquid, gel or solid form, and has a metal or laminate housing. It is not prepared for use in a device, since it has not yet been fitted with its final housing, is connection arrangement and its electrical control equipment.

- **Module**
  A group of cells that are connected in rows and/or parallel switching with or without protective equipment (e.g. fuse or PTC) and monitoring circuits.

- **Battery pack**
  Energy storage device consisting of one or more electrically connected cells or modules and one monitoring circuit, which provides information (e.g. cell voltage) to a battery system in order to influence the safety, performance and/or lifespan of the battery.

  NOTE 1: It may contain a protective housing and be fitted with connection terminals or other connection arrangements.

- **Battery system**
  Battery
  A system containing one or more cells, modules or battery packs NOTE 1 on the term: It has a battery management system, which switches off in cases of overload, overcurrent, over-discharge and overheating.
  NOTE 2 on the term: Switching off due to over-discharging is not obligatory when there is an agreement between the cell manufacturer and the client. NOTE 3 on the term: The battery system can comprise cooling or heating devices.

- **Inspection of spread (battery system) according to** *IEC 62619 Section* **7.3.3**
  a) Requirement

  "This inspection assesses the ability of a battery system to resist the occurrence of an incident of thermal runaway of a single cell, so that the occurrence of such an event does not lead to a fire in the battery system." c) Acceptance criteria

  "No external fire from the battery system or no battery housing breakage."

CONSTANTLY MANNED UNIT

A constantly manned unit as defined in this document can be e.g. a process control technology/control room, a certified security service, emergency call and service control unit, the control unit of a company fire service or the public fire brigade. By contrast, a fire alarm system as required in building law should generally be connected to the unit triggering the alarm (e.g. the integrated control room) according to the technical connection conditions, which can then directly alert the public fire brigade.

ANNEX A – SYSTEM-SPECIFIC HAZARDS AND RISKS

In general, the following risks should be considered in order to keep the potential for damage as low as possible – regardless of the installation variant of the mass storage system.
For this purpose, the manufacturer of the storage system must produce a risk analysis and risk assessment. Generally, the following points, among others, are taken into account here (not conclusive):

- Operation outside the operating parameters specified by the manufacturer, including
    - Temperature of the system and individual components
    - Air humidity
    - Overcurrents and overvoltages
    - Charging and discharging depth and cycles
- Fire and deflagration through internal and external causes
- Risk to emergency services (see also Chapter 6.1)
- Mechanical impact through internal and external causes
- Electrical impact from lightning strike
- Electromagnetic fields, absorption and emission
- Risk during operating and maintenance procedures
    - Operating and maintenance staff
    - Damage
- Chemical and biological (e.g. hazardous substances)
    - Emergence of dangerous gases and liquids
- Site-related environmental influences, including
    - Ambient temperatures
    - Air humidity
    - Air pollution
    - Corrosive media [air containing salt or ammonia]
    - Wind speeds
    - Solar radiation [infra-red/UV]
    - Precipitation
    - Flooding
    - Earthquakes
    - Landslides

The operator is obliged, on the basis of the presented risk analysis and risk assessment, to assess the hazards in accordance with the occupational safety directive and to derive suitable protective measures.

ANNEX B – HAZARD FACTORS

Non-conclusive overview of possible hazard factors:

1. Mechanical hazards 1.1 Machine parts moved without protection 1.2 Parts with dangerous surfaces 1.3 Moved transport means, moved work equipment 1.4 Uncontrolled moved parts 1.5 Falling, slipping, stumbling, toppling over 1.6 Falling 1.7 ..... **2. Electrical hazards** 2.1 Electric shock 2.2 Light arcs 2.3 Electrostatic charges 2.4 ..... **3. Hazardous substances** 3.1 Skin contact with hazardous substances (solid substances, liquids, humid conditions) 3.2 Inhaling of hazardous substances (gases, vapours, mist, dust, including smoke) 3.2 Swallowing of hazardous substances 3.3 Physical-chemical hazards (e.g. fire and explosion hazards, uncontrolled chemical reactions) 3.4 ..... **4. Biological working materials** 4.1 Risk of infection from pathogenic micro-organisms (e.g. bacteria, viruses, fungi) 4.2 Sensitising and toxic impact of micro-organisms 4.3 ..... **5. Fire and explosion hazards** 5.1 Flammable solid substances, liquids, gases 5.2 Explosive atmosphere 5.3 Explosive substances 5.4 ..... **6. Thermal hazards** 6.1 Hot media/surfaces 6.2 Cold media/surfaces 6.3 ..... **7. Hazard from specific physical impact**	**8. Hazards from work environment conditions** 8.1 Climate (e.g. heat, cold, insufficient ventilation) 8.2 Illumination, light 8.3 Suffocation (e.g. from oxygen-reduced atmosphere), drowning 8.4 Insufficient emergency exit and traffic routes, insufficient safety and health protection labelling 8.5 Insufficient space to move at the workplace, inappropriate arrangement of the workplace, insufficient areas for breaks or sanitary facilities 8.6 ..... **9. Workload** 9.1 Heavy, dynamic work (e.g. manual handling of loads) 9.2 One-sided dynamic work, body movement (e.g. frequently repeated movements) 9.3 Posture work (forced posture), physical strain 9.4 Combination of static and dynamic work **10. Physical factors** 10.1 Inappropriate work assignments (e.g. mainly routine tasks, over- and underqualification) 10.2 Insufficient work organisation (e.g. work under high time pressure, changing and/or long working hours, frequent night shifts, no thought-through work procedure) 10.3 Insufficient social conditions (e.g. lack of social contact, poor management behaviour, conflicts) 10.4 Insufficient workspace and work environment conditions (e.g. noise, climate, narrow space, insufficient attention paid to signals and process features, insufficient software design) 10.5 ..... **11. Other hazards** 11.1 Caused by people (e.g. attack, rampage, unauthorised access) 11.2 Caused by animals (e.g. bites, stings)

7.1 Noise 7.2 Ultrasound, infrasound 7.3 Whole-body vibrations 7.4 Hand-arm vibrations 7.5 Non-ionised radiation (e.g. infra-red radiation (IR), ultraviolet radiation (UV), laser radiation) 7.6 Ionising radiation (e.g. X-ray radiation, gamma radiation, particle radiation (alpha, beta and neutron radiation) 7.7 Electromagnetic fields 7.8 Under- or overpressure 7.9 …..	11.3 Caused by plants and plant-based products (e.g. sensitising and toxic effects) 11.4 …..

Excerpt from the legal bases and information:

- Occupational Protection Act
- Operational Safety Directive
- Workplace Guidelines
- DGUV V 1 Fundamental prevention principles Select the specification of the professional association responsible
- DGUV specification 3 Electrical systems and operating means
- DGUV regulation 103-012 Work under voltage on electrical systems and operating means
- *Basic quality principles for hazard assessments*
- …..

ANNEX C – LABELLING

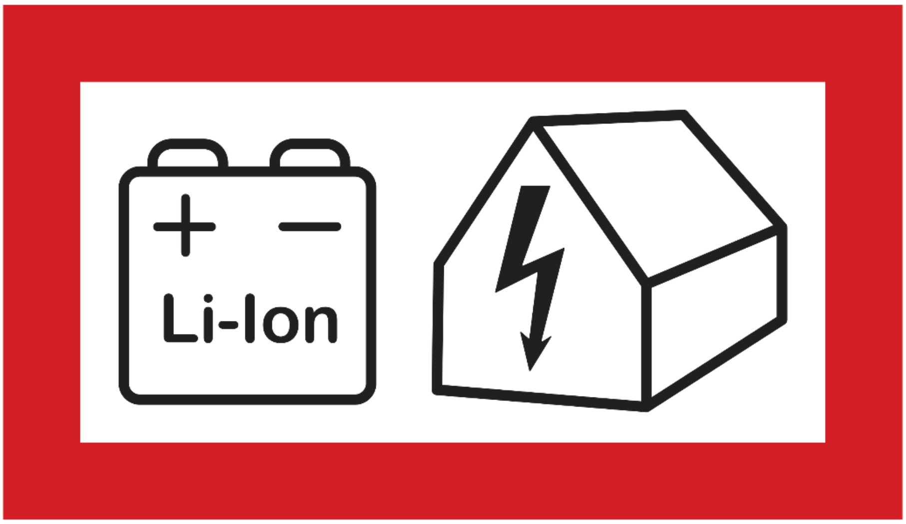


Diagram20: Recommendation submitted to the DKE for the labelling of lithium ion batteries

LIST OF DIAGRAMS AND ILLUSTRATIONS

ACKNOWLEDGEMENTS

The following companies and institutions, among others, were involved in the production of this document:

- Betonbau GmbH & Co KG
- Branddirektion München, Abteilung Einsatzvorbeugung
- Commeo GmbH
- DMT GmbH & Co. KG
- DNV Energy Systems Germany GmbH
- Gothaer Allgemeine Versicherung AG
- IBS - Institut für Brandschutztechnik und Sicherheitsforschung Gesellschaft m.b.H.
- Karlsruhe Institute of Technology (KIT)
- Siemens AG
- Smart Power GmbH
- Solarwatt GmbH
- VDE Renewables GmbH