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The Effects of Storing Electric Scooters and Bicycles in Office Buildings on Fire Safety

Abstract

In recent years, we have seen more and more electric vehicles on the streets, and the author looks at electric bicycles and electric scooters, which are considered as "personal transport". With the increase in the number of office buildings, it has become topical to study the storage of these vehicles in office environments. The study covers the fire safety hazards of electric scooters and electric bicycles, the lithium-ion batteries that pose a risk and their safe storage for fire safety. This will be followed by a summary of the hazards and rules of storage in office buildings, with the aim of informing and alerting the general public to the storage rules to be observed and the rules of conduct to follow in the event of a fire. The author suggests extending the rules on storage and informing the owners of electric scooters and electric bicycles about the dangers of their vehicles.

Keywords: e-scooter, e-bicycle, office building storage, fire protection

Introduction

In recent years, more and more electrically powered vehicles have appeared on the streets, with electric bicycles (hereinafter: e-bikes) and electric scooters (hereinafter: e-scooters) becoming increasingly popular and appearing in increasing numbers on public roads. More and more people are also choosing this form of transport for commuting, as they are relatively fast, can travel longer distances and can be stored in a small space. As the number of these means of transport has increased, so has the number of office buildings. Thanks to the increasing use of e-scooters and bicycles, it has become relevant to study the storage of these vehicles in office environments. In this article, the investigation covers the fire safety hazards of e-scooters and e-bikes,

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the lithium-ion (Li-ion battery) batteries that pose the hazard, and their safe storage for fire safety. The author's aim is to raise awareness of the dangers and rules for storing e-scooters and bicycles in office buildings and to inform the general public about the storage and charging rules to be followed in Hungary. The author proposes to extend the rules on storage, to inform the owners of e-scooters and e-bikes on a wide range of measures to avoid the dangers hidden in their vehicles, and to develop the relevant legislation to protect both the operators of the building and the workers in the office buildings.

The author identifies as a scientific problem related to the topic that despite the recent widespread social use of electric scooters, few publications of scientific value have been written on the problems of operation, technical service and fires generated by the devices, and therefore the availability of the Hungarian and international literature is limited.

The legal regulation of the storage of electric scooters has not been elaborated, the methods and technologies of preventing and fighting electric scooter and bicycle fires in residential buildings and office buildings, the aspects of the mandatory design of safe storage rooms for the safety of residential buildings have not been conclusively proven.

The author assumes that the storage of e-scooters and bicycles will require fire safety investments due to enhanced fire safety measures that may require extra infrastructure to the existing ones. These extra investments include smoke detection systems and fireproof storage areas.

Furthermore, the author assumes that inadequately and inappropriately located storage facilities for e-scooters and e-bikes may obstruct traffic routes, increasing the fire risk. In many cases, transport routes are also escape routes, the restriction of which is critical for fire safety.

The author assumes that storing and charging e-scooters and e-bikes in office buildings increases the risk of fires, as Li-ion batteries are prone to overheating and explosion, especially if not properly stored and maintained.

The research methods include research and processing of the relevant national and international literature, legislation, representation of numerical data and statistical analysis. The research method primarily used by the author is the empirical method, based on experience in the field under study.

Charging, storage and hazards of electric scooters and e-bikes

First, it is important to clarify what we mean by e-scooter and e-bike. E-scooters are two-wheeled means of transport that are powered by an electric motor, so they do not require human effort to operate. E-scooters are generally lightweight and portable due to their small size. They usually require only a small control panel to control the speed, and in most cases the electric drive is provided by a Li-ion battery. They are ideal for urban commuting or short trips. The European Commission's Road Traffic (Electric Scooters) Regulations 2023 defines electric scooters as "a type of electric passenger transport vehicle with a bodywork, two axles and at least one electric motor,

mainly powered by electricity, designed to carry one person in a standing position, without a seat". E-bikes are powered by an electric motor that helps you pedal or even move the bike autonomously. These motors usually assist the pedals or provide full electric propulsion for the e-bike, allowing the user to move more easily, faster, with less or no effort. Additional requirements for e-bikes are laid down in Regulation (EU) No. 168/2013 of the European Parliament and of the Council.

The use, storage and charging of e-scooters and e-bikes is not without risk, and their batteries can in some cases catch fire posing a serious safety risk. Particular attention must be paid to extinguishing these fires, as Li-ion batteries require special care. It is not enough to extinguish the flames from the battery, because the Li-ion will feed the flames until the chain reaction is over. The process can be stopped by cooling, for which water is an excellent solution.[2]

Legal regulations

The storage of e-scooters and e-bikes must comply primarily with Decree 54/2014 (XII. 5.) of the Ministry of the Interior (in Hungarian: Országos Tűzvédelmi Szabályzat, hereinafter used its Hungarian abbrevation: OTSZ) in Hungary. Chapter III of the OTSZ defines the objectives of the protection of life, community and property, which everyone is obliged to comply with. Chapter VI provides for protection against the spread of fire, setting out requirements for the design of fireproof storage areas. Section 39 of the OTSZ provides for regulations for office buildings. The author proposes to amend this section if large quantities of e-scooters and e-bikes are stored and charged in the designated area of the office building. Chapter VIII provides for the evacuation of the building and Chapter X for the protection against heat and smoke, which sets out general requirements for the design of the office building.

For special fire protection solutions related to the charging and storage of electric passenger vehicles, the Technical Guidelines for Fire Safety (in Hungarian: Tűzvédelmi Műszaki Irányelvek, hereinafter used its Hungarian abbrevation: TvMI) are applicable, for special installation solutions related to the design of protection against fire spreading, the TvMI 1.6:2024.02.01. Annex P of the TvMI, which covers the protection of electric passenger car charging points against fire spread, the safety equipment of vehicle storage facilities including electric passenger car charging points and the design of passenger car charging points in existing buildings. The protection against heat and smoke shall be in accordance with the TvMI, TvMI, paragraph 16.2, Heat and Smoke Protection, TvMI 3.5:2024.02.01, which covers the design of vehicle storage areas for electric passenger car charging points. The design and installation of fixed fire extinguishing systems is covered by point 7.5 of the TvMI, Design and Installation of Fixed Fire Extinguishing Systems, TvMI 6.5:2024.02.01, which covers the design of vehicle storage facilities including charging points for electric passenger vehicles. The above listed Fire Safety and Technical Directives apply to electric passenger vehicles,

[2] Magyar Tűzoltó Szövetség 2023c.

but can provide a basis for the development of fire safety legislation for the storage of e-scooters and bicycles in office environments.

In Hungary, fire brigade intervention, the issue of the electric drive battery, is regulated by the Fire Tactics Code. The Code contains provisions for hybrid vehicles, which are defined as "a vehicle in which, in addition to the conventional internal combustion engine, there is also an electric engine and a battery pack which is essential for propulsion". The regulation specifies water as the extinguishing agent for batteries, which can also be used for e-scooters and e-bikes.

Danger during charging electric scooters and e-bikes, preventive measures against fires caused by them

The most dangerous parts of e-scooters and e-bikes from a fire safety point of view are the batteries that make them work. The most advanced, mass available, high-energy-density, and long-life Li-ion batteries currently available power most of these vehicles. These batteries are less sensitive to operating temperatures but can be extremely flammable. Their flammability is based on a phenomenon called thermal runaway,[3] which only occurs under certain conditions.[4] An important thing to know about thermal runaway is that it is an unstoppable chain reaction that occurs as a result of the sudden release of energy stored in the battery, at temperatures of around 400 degrees Celsius. It cannot be extinguished by conventional means; it can burn back out after extinguishing while the battery is still charged. Its danger starts at 60 degrees Celsius and reaches critical levels at 100 degrees Celsius. The biggest problem is that it is not known when it will actually ignite. Ignition can be caused by an internal short circuit due to internal mechanical damage, an external short circuit due to deformation, excessive current consumption during overcharging or fast charging, or a discharge. If one cell of the battery is damaged, it will almost certainly spread to the other cells.[5]

"The fire suppression method should suppress any Li-ion batteries fire and control any rise in battery temperature. If not sufficiently cooled, thermal runaway reactions may continue and the battery re-ignite. […] It is more important to cool the cells in a large battery pack, to prevent heat propagation, than to extinguish fires from a single cell. Li-ion battery firefighting strategies should be based on not only extinguishing the burning cell, but include cooling the burning cell as well as its adjacent cells."[6]

[3] "A severe failure of li-ion batteries can lead to heat generation at a rate that causes what is known as a heat runaway. This can result in extremely intense combustion in one or more cells, causing damage through sputtering from the battery, toxic and flammable gas emissions and intense self-sustained combustion that is very difficult to control." See: https://katasztrofavedelem.hu/37082/li-ion-akkumulatorok-veszelyei

[4] Magyar Tűzoltó Szövetség 2023a.

[5] Veresné Rauscher 2022.

[6] Ghiji et al. 2020.

Water is the most suitable extinguishing agent to control a chain reaction involving a violent flame, smoke, shell rupture or even an explosion.[7]

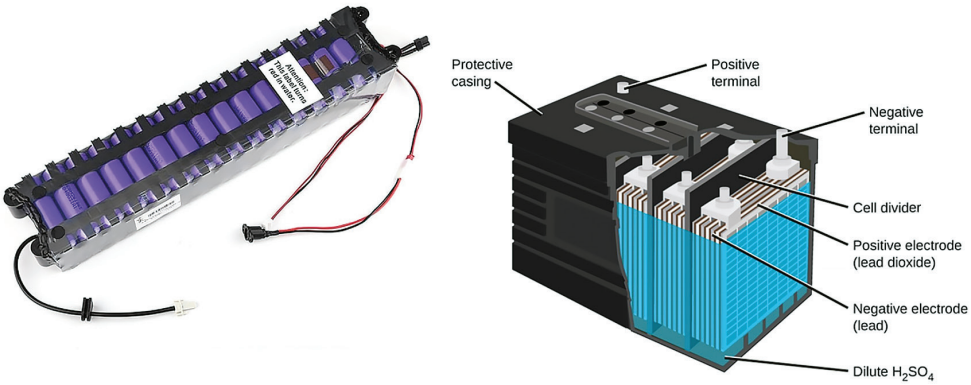

Figure 1: Xiaomi Mijia M365 e-roller battery and an electric bike battery
Source: Gayathri *2023; www.li-ion.hu/Elektromos-bicikli-roller-funyiro-akkucsere-akkufelujitas*

Figure 2: Electric bicycle and electric scooter
Source: www.li-ion.hu/Elektromos-bicikli-roller-funyiro-akkucsere-akkufelujitas

The first and most important basic rule is to always follow the manufacturer's instructions for charging and storage. The instructions may contain specific information that is unique to the product in question, so that the vehicle can be charged more safely. Always use a suitable, undamaged and manufacturer-issued cable for charging. Using

[7] Magyar Tűzoltó Szövetség 2023b.

a damaged cable is dangerous, and a cable not manufactured for the specific device will not provide proper charging and will overload the charging head.

It is very important to create a charging point (hereinafter: e-charging point) in the covered lobbies of office buildings, in storage areas and garages for e-scooters and e-bikes, where only and exclusively e-scooters and bicycles are charged, in order to avoid overloading the electricity network by employees charging their e-scooters and e-bikes individually. It is also proposed to install an external disconnection system to cut the power supply to the storage or charging facility in the event of an emergency. A fire can easily occur during 'home charging' and an e-charging point should be provided to prevent this and to prevent fires.

Charging should preferably be carried out in dry conditions, indoors, ideally at room temperature, but charging these devices is prohibited below 0 °C and above 40 °C. The device/accumulator under charging should never be exposed to direct sunlight, heat, rain or moisture, and must not be covered. A covered battery or charger may overheat or catch fire.

It is very important to regulate the times when devices can be charged: never leave the battery on the charger overnight. If the office building has a permanent porter service, a security guard can rush to the scene immediately when the fire alarm and smoke alarm are triggered and alert the fire brigade instantly. If the premises has a sprinkler or mist extinguishing system, it can be activated and start extinguishing any vehicle on fire until the fire brigade arrives. It is therefore extremely important that employees in office buildings do not leave a vehicle/battery charging overnight. Although modern batteries and chargers have electronics designed to prevent overcharging, if these electronics fail, it is unlikely that anyone in the office building will immediately notice if they start smoking. It is therefore advisable to provide smoke detectors in enclosed rooms where e-scooters and bicycles are stored. Another important criterion is that the vehicle/battery to be charged should be charged on a solid, flat surface, away from flammable objects.[8]

Should any of the following occur to the attention of the vehicle owner – or anyone else in the building – charging must stop immediately:

- strange burnt smell around the charger
- the battery is leaking fluid
- the battery is humped, deformed, discoloured
- the battery area is unusually hot
- smoke is spreading from the battery[9]

Rules on the design of storage facilities for electric scooters and e-bikes

The owner, operator or occupier of the building shall designate an appropriate storage space for e-scooters and e-bikes, taking into account the following:

[8] See: https://nfcc.org.uk/our-services/position-statements/e-bikes-and-e-scooters-fire-safety-guidance/
[9] Magyar Tűzoltó Szövetség 2023a.

- For enhanced fire safety, it is recommended that existing e-bikes storage facilities are upgraded or modified, where possible, so that they are easily accessible, easy to use and secure for employees and they do not feel the need to store their vehicles inside the building.
- The manager responsible for the operation of the building must take into account the risks of enclosed spaces for charging e-scooters and e-bikes, bicycle storage, escape corridors and common areas, and the provision of fire and smoke protection.
- It is forbidden to load or store e-scooters and e-bikes on the escape route, as this significantly impairs the ability of the occupants to escape.[10]
- If e-scooters and e-bikes pose a risk to the fire safety of the building, they must necessarily be included in the building risk assessment and the building fire safety plan.
- E-scooters, e-bikes and their batteries should be stored in a cool place out of the sun, if possible. Avoid storage and charging in places that are too hot or too cold.[11]
- The number of charging sockets should be set so that even at maximum capacity, no one needs to use an extension lead or adapter.
- No flammable material may be stored in the affected area.
- Where possible, battery charging stations should be located outdoors, in a secure area, on the ground floor, in a safe place where the owner does not have to worry about theft or damage to the device.

Ágoston Restás and his co-authors in their paper[12] also state that fire prevention measures for electric car charging stations include "People acting in case of fire must be trained in the safe charging process and they should be familiar with the location of the charging equipment. They have to know how to deenergise and the measures to be taken in case of an emergency." This clause may also apply to persons acting in the event of a fire at charging points for e-scooters and e-bikes.

If the storage and charging is still to be carried out indoors, the author recommends the installation of a fire alarm system in accordance with Annex 14 of the OTSZ. In addition to the fire alarm system, a gas concentration detection system can accelerate the early detection of a Li-ion fire, as it is capable of detecting the content of evolving gas, smoke, hydrogen, carbon monoxide and carbon dioxide before the fire starts. Heat build-up can be detected at an early stage using an infrared camera. Furthermore, in accordance with Annex 14 of the OTSZ, it is recommended that the premises be equipped with fire extinguishing equipment, which may be a sprinkler or a water mist extinguishing system.

Point 3.2 of the TvMI[13] on protection against heat and smoke states that open motor vehicle storage facilities do not need to be equipped with heat and smoke

[10] See: https://nfcc.org.uk/our-services/position-statements/e-bikes-and-e-scooters-fire-safety-guidance/
[11] Pinnington 2024.
[12] Terjék et al. 2021.
[13] National Directorate General for Disaster Management of Hungary: Technical Directive on fire safety, Protection against heat and smoke 2024.

ventilation, which means that open storage facilities for e-scooters and e-bikes do not need to be equipped with it. Where a large area of e-scooters and e-bikes is stored in covered storage, heat and smoke ventilation may be appropriate. In this case, air supply may be provided by natural ventilation, mechanical heat and smoke ventilation or a combination of these.[14]

"One of the most important means of prevention is to comply with the fire safety requirements set out in the OTSZ:
(a) the design, construction, alteration, extension, modernisation, restoration, renovation, use and change of use of the installation, building or part of a building,
(b) the installation, maintenance, alteration, removal or use of a fixed fire protection system prescribed by law or by a decision of a public authority,
(c) the use of other means to ensure the fire protection of the building,
(d) other uses and activities affecting fire protection.
Where the Regulation does not provide for the cases referred to in the preceding points, the application of the fire safety provisions of the relevant technical requirements or equivalent solutions or designs shall comply with the level of safety laid down in the Regulation."[15]

In Hungary, official statistics on the number of fires involving e-scooters and e-bikes are currently not available, and there is also a lack of aggregated statistics on fires involving e-scooters and e-bikes in the European Union. Most of the statistics published by the authorities on this subject have been collected in the United Kingdom, and the author wishes to draw attention to the fact that Li-ion powered e-scooters and e-bikes are not without danger, that their charging and storage requires great care, and that their storage may require changes in legislation. Figure 3 shows the cumulative data on fires involving e-scooters and e-bikes in the UK from 2017 to 2023.

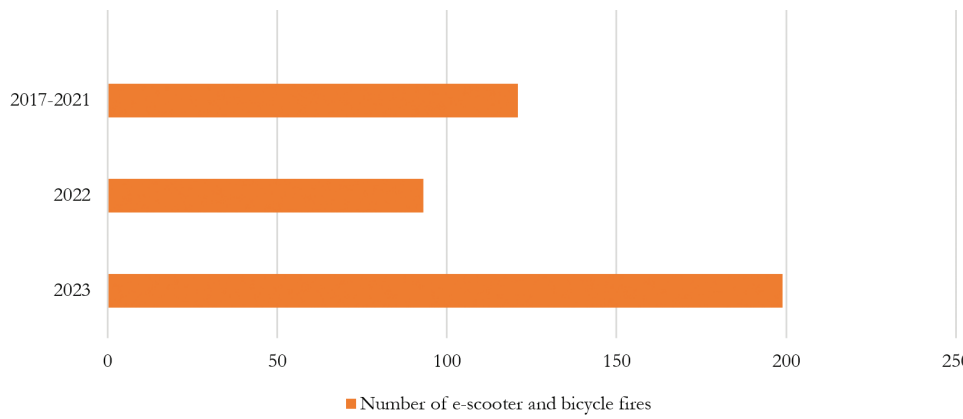

Figure 3: Number of fires involving electric scooters and bicycles in the UK
Source: Government of the United Kingdom 2024

[14] Farkas et al. 2022.
[15] Muhoray 2016: 19.

The data in Figure 3 shows that between 2017 and 2021, a total of 121 e-scooter and e-bike fires were reported to the UK's Product Safety and Standards Agency. The number of fires caused by e-scooters and e-bikes rose to 93 in a single year in 2022, rising to 199 in 2023.

The author proposes to compile statistics on the data on fires caused by e-scooters and e-bikes in Hungary for all fires caused by e-scooters and e-bikes received by the professional emergency services. A further proposal of the author is to extend the document entitled "Special fire safety installation solutions for charging and storage of electric passenger cars in a single structure",[16] issued by the National Directorate General for Disaster Management of the Ministry of the Interior, to include the parts on the storage of e-scooters and e-bicycles. In view of the statistics for Hungary, it may be necessary to extend the relevant TvMI to cover e-scooters and e-bicycles.

Extinguishing fires from electric scooters and e-bikes in an office building environment

Li-ion batteries burn at extremely high temperatures, emitting toxic gas. Depending on the capacity of the battery, very serious fires can develop, which can only be extinguished by using large quantities of water. With smaller capacity batteries – under appropriate storage conditions – there is a chance that the flames will be extinguished quickly, but even in this case it is not worth taking the risk, call 112 for help and wait for the fire brigade to arrive.[17]

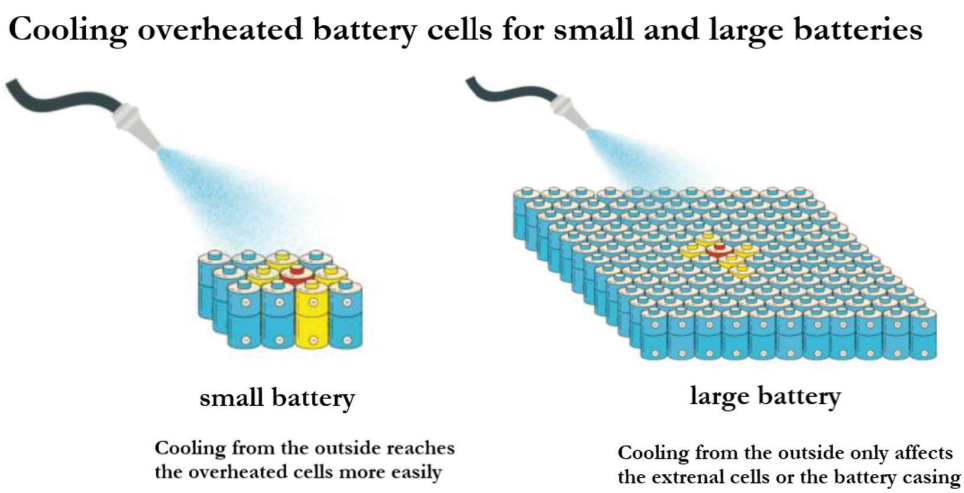

Figure 4: Cooling overheated battery cells for small and large batteries
Source: Magyar Tűzoltó Szövetség 2023c

[16] Belügyminisztérium Országos Katasztrófavédelmi Főigazgatóság 2024a.
[17] Magyar Tűzoltó Szövetség 2023c.

If the battery starts to burn or smoke, the device must be disconnected from the power supply. If possible, the damaged equipment should be removed from the room and away from combustible materials. If it is safe to do so, small appliances that have been disconnected can be cooled in a bucket of water.

It is extremely important to pay attention to prevent the inhalation of smoke and fumes. All occupants should leave the room and close the door after leaving to slow down the spread of fire and smoke. Gases, vapours and fumes emitted from a damaged battery are extremely toxic and flammable, so it is especially important to prevent their inhalation.

Paragraph 5(11) of Article 5 of Act XXXI of 1996 on Fire Prevention, Technical Rescue and Fire Brigades states that "anyone who detects a fire or an imminent threat thereof shall immediately report it to the call centre, the operations control centre of the disaster management directorate or the fire brigade, or, if this is not possible, to the police or the ambulance service, or to the mayor's office of the municipality". In the light of this and in accordance with the before mentioned information, the person detecting the fire should call 112 for help and wait for the fire brigade to arrive. If the battery has not been properly cooled, there is a good chance that it will re-ignite.[18] A series of images shows the progression from ignition to explosion of an electric scooter under charge in Figure 5. The scooter's battery started to heat up at 9:00:38, reaching the ignition point at 9:00:51. The increase in activity energy continued until 9:00:52, at which point the flashover occurred. Burning of the mature fire lasted until 9:01:06, after which the fire started to decay.[19]

Figure 5: Electric scooter being charged catches fire before exploding
Source: London Fire Brigade 2023

Restás and his co-authors set out the measures to be taken in case of fire for electric cars, which are also used for e-scooters and e-bikes:

- "The manual call point must be operated. This starts the fire alarm and the fire protection equipment.
- De-energisation shall be performed by using on-site fire protection switches.

[18] Belügyminisztérium Országos Katasztrófavédelmi Főigazgatóság 2024c.
[19] Érces 2015: 19.

- The switching devices used for disconnection must be secured against reconnection.
- People should start the firefighting with the available fire extinguishers, if it can be started safely.
- The professional firefighters must be informed of the measures taken so far, the condition of the charging equipment and to give them the Fire Alert Plan and its annexes.
- If necessary, the evacuation of the building shall be carried out in accordance with the provisions of the Fire Alert Plan.
- After the successful firefighting, the condition of the reconnection of the equipment is a joint permission from the maintenance company and the Disaster Management
- All fires must be reported to the appropriate Disaster Management Branch Office."[20]

Based on current research, the available literature classifies fire extinguishing agents into different categories. The first and most important extinguishing agent is water, which appears to be the most cost-effective and most commonly used extinguishing agent. In addition to its good extinguishing and cooling properties, it can reduce or even stop the phenomenon of heat build-up, but its use also carries risks. The extinguishing water can react chemically or conduct electricity, causing a short circuit. This can cause further heat build-up in other parts of the burning battery. The next method of extinguishing is the use of a water jet, which has the advantage of being able to be used over long distances, depending on the jet pattern, and can be accurately directed. Compared to a bound water jet, a sprinkler system can be used over shorter distances, with the advantage of better flame cooling and less secondary damage during extinguishing, but with the disadvantage of not being effective in confined spaces of vehicles and other equipment stored in protected areas. Added materials can be used to reduce the surface tension of the extinguishing water, thus achieving a more direct extinguishing effect on different surfaces, but this method of extinguishing also requires the use of a foaming agent. Water mist extinguishing, compared to sprinkler extinguishing, is capable of producing smaller droplet sizes, thus allowing more economical use of water and even better cooling effect.[21]

There are some studies in the international literature using other types of extinguishing agents for Li-ion battery fires. These extinguishing agents include foam, which cools and seals the surface of the material to be extinguished, forms a barrier between the burning material and the surrounding air – combustible gases – but can also have a corrosive effect.[22] In case of powder extinguishing, effective extinguishing can be achieved in the airspace, but it does not cool the battery and has a more limited blanketing effect. Extinguishing with carbon dioxide chokes the combustion and with it the breathing, which can pose a danger to bystanders, rescuers and the

[20] Terjék et al. 2021.
[21] Pántya 2023: 23–24.
[22] See: https://scottyfire.com/product/foam-fast-foam-systems/

intervention forces. No extinguishing agent remains after application, but the cooling capacity required for Li-ion batteries is low. Halon is an extinguishing agent with similar effects to carbon dioxide, but their use was banned in 1994. Liquid nitrogen has a good cooling capacity and is non-toxic, but is difficult to transport and store, and fire brigades do not stock this type of extinguishing agent.[23]

Summary

The research has shown that storing and charging e-scooters and e-bikes in office buildings increases the risk of fires, as Li-ion batteries are prone to overheating and explosion, especially if not properly stored and maintained. Failure of batteries and charging with batteries other than their own chargers can cause fires, which can spread dramatically quickly in confined spaces. Figure 4 shows that it only takes a few seconds for a failed battery to ignite and burst into flames.

The storage and charging of e-scooters and e-bikes inside buildings requires increased attention, and a safe charging and storage unit with minimal fire risk can be created by properly designing the storage and charging room, installing fire alarms, providing heat and smoke protection and fire extinguishers. Inadequately designed and inappropriately located storage areas can obstruct traffic routes, increasing the fire risk. In many cases, transport routes are also escape routes, the restriction of which is critical for escape, therefore these must always be left clear and storage facilities must not be provided.

The author's first assumption, that the storage of e-scooters and e-bikes requires fire safety investments, can be considered valid. Enhanced fire safety measures may require extra infrastructure, investments that include smoke and gas detection systems and the construction of fireproof storage areas. It is also recommended to install a hand-held fire extinguisher capable of extinguishing electrical fires in the storage facilities, if no sprinkler or mist extinguishing system is installed. Hand-held fire extinguishers specially designed for Li-ion battery fires (Lith-Ex) are specifically designed for use in an office environment, so their use may also be necessary in the part of the building used for storing e-scooters and e-bikes. The author feels it is particularly important to draw the attention of the owner of the electric vehicle to the fact that damaged vehicles must not be stored and charged inside the building, and that charging with a damaged charger or with a charger not belonging to the device is prohibited. If possible, charging points should be located at the entrance to the vehicle storage area to facilitate access by firefighters in the event of a fire.

The author identifies as a problem the fact that no summary statistical data on e-scooter and e-bike fires in all countries of the EU and Hungary have been published, and no representative data can be obtained to support the need for legal regulation of e-scooters and e-bikes. As part of the legal regulation to be established, the author proposes to extend Annex 14 of the OTSZ with rules on the construction of premises for the storage and charging of a larger number of e-scooters and bicycles and

[23] Pántya 2023: 25–26.

to limit the number of e-scooters and e-bikes stored at the same time in the same place. The author also proposes to make it compulsory to affix a short, graphically illustrated storage and charging code on the walls of the premises where e-scooters and e-bikes are stored, and to include instructions for staff using the storage facilities, including what to do in the event of a fire and the rules of conduct to be followed, and to incorporate them into legislation.

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