CNBOP-PIB

Report on the 2nd International Scientific Conference

Fire Safety of Photovoltaic Installations, Energy Storage, Electric Vehicles, Points and Charging Stations, and Smart Home Solutions

Patronage:

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July 2024, Józefów

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1. General information

Organizer: Centrum Naukowo-Badawcze Ochrony Przeciwpożarowej im. Józefa Tuliszkowskiego – Państwowy Instytut Badawczy (CNBOP-PIB) in Józefów.

Co-organizers:

- Akademia Pożarnicza
- WSB Academy in Dąbrowa Górnicza
- European Fire Safety Alliance
- Institut für Feuerwehr- und Rettungstechnologie (IFR) der Feuerwehr Dortmund
- District Headquarters of the State Fire Service in Otwock
- Provincial Headquarters of the State Fire Service in Warsa
- "Fire Protection" Magazine of the Association of Fire Service Engineers and Technicians SITP
- National Association of Manufacturers of Fire Protection and Rescue Equipment
- PIME Association Polish Chamber of Energy Storage
- Polish Association of New Mobility
- PZU LAB SA
- School of Aspirants of the State Fire Service in Poznan

Honorary patronage: Komendant Główny Państwowej Straży Pożarnej

Date of the conference: 12 June 2024

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Chairman of the organization committee: Ilona Masna, M.A.

2. Purpose of the conference

The conference, as intended by its organizers and partners, is a cyclical venue for the presentation and dissemination of research results, current information, knowledge review and solutions. It serves to exchange views and experiences of various communities interested in fire safety in the field of increasingly used technologies such as photovoltaic installations, energy storage, electric vehicles together with their charging points and stations, and others referred to as smart home solutions. The conference was addressed to manufacturers, designers and installers of electric batteries, officers and civilian employees of the State Fire Service, specialists and experts in fire protection, managers, users and owners of buildings, as well as other people interested in the above topics.

Circumstances prompting the subject of the conference are past experience, research and its results, new technical solutions and technologies offered, the growing number of facilities equipped with PV installations, energy storage and charging stations, statistics of incidents involving PV installations, energy storage, charging points and electric vehicles, including challenges for fire protection related to their increasingly widespread use. In addition, ongoing research and performed forecasts contribute to the development of this area, as well as experiences and solutions in this area in other countries.

3. Past experience

The issue of fire safety of photovoltaic installations in the research and work of CNBOP-PIB is not a new issue. In 2021, the Institute published in open access thematic items in this area, including*: Wybrane zagadnienia użytkowe i bezpieczeństwa w instalacjach fotowoltaicznych (Selected Utility and Safety Issues in Photovoltaic Installations)*, and *Ocena ryzyka pożarowego w instalacjach fotowoltaicznych (Fire Risk Assessment in Photovoltaic Installations)*. Defining safety concepts to minimize risks. Guidelines have also been issued in 2024 for the fire protection of garages in buildings designed for charging electric and plug-in hybrid cars. The guidelines in question in the chapters respectively include: basic, most important definitions, abbreviations and symbols, formal basis, related documents and key test results, a set of requirements and recommendations for the products used, design, execution and operation of electrical installations, characteristics of places in construction facilities for charging electric and plug-in hybrid cars.

CNBOP-PIB has also set up test stands to confirm (test) the functionality of products (PV system components) relevant to fire safety and the safety of rescue teams, such as:

- ❖ arc detection and interruption of arc fault in DC circuits of PV systems and alarm signalling,
- ❖ PV power disconnection and signalling of PV system operating states for emergency crews.

These stands allow testing and functional testing of various configurations of PV installations in terms of fire safety, compliance with fire protection conditions, safety of emergency crews. They are also used for knowledge dissemination, didactics and training, including the development of model design documentation for PV installations for buildings, the development of technical standards for fire protection, such as guidelines, requirements for products, test methods, etc.

Regardless, CNBOP-PIB conducts – independently, as well as with technological partners – numerous other activities, research and works, the results and experience of which authorize the formulation of conclusions, definition of threats, assessment of their risks, determination of needs and requirements for fire protection, as well as their dissemination. Electric vehicle battery research conducted at the Institute for several years has provided specific experience, knowledge and test results for various products. These tests have recently been expanded to include technical security systems dedicated to the detection and control of fire at electric vehicle charging points, as well as equipment and supplies designed for rescue operations during incidents involving electric vehicles.

The research and experience gained, in connection with cooperation with the State Fire Service and technology partners, additionally contributed to the development in 2023 of a guide for rescuers entitled *Prowadzenie działań ratowniczych podczas zdarzeń z udziałem pojazdów z napędem elektrycznym (Conducting rescue operations during incidents involving electric vehicles)*, as well as the preparation and implementation of a dedicated training course on conducting rescue and firefighting operations involving electric vehicles.

4. Course of the conference

The CNBOP-PIB scientific conference was divided into three thematic sessions on the following topics:

1. New solutions for fire protection and rescue – risks, protection measures, operation.
2. Fire safety of electric batteries – causes of failure, hazards, extinguishing methods.
3. Fire safety of energy storage facilities – hazards, protection measures, operation.

At the end of the conference, a panel discussion was organized with the participation of invited guests, experts and conference participants, which allowed to exchange knowledge and answer questions that arose.

4.1. First session

During the first session moderated by the Manager of CNBOP-PIB Certification Department, Mr. Michal Chmiel, Ph.D., the following issues were discussed:

- ❖ selected aspects of software testing of fire protection equipment – a lecture by Mr. Michał Pietrzak, M.Sc., specialist of CNBOP-PIB Certification Department;
- ❖ presentation of projects implemented by ZG OSP RP: “First Rescuer”, “Smoke Detector under every thatch” – a lecture by firefighter Artur Białkowski, Coordinator of the National Program “First Rescuer” and firefighter Robert Klonowski, Coordinator of the National Program “Smoke Detector under every thatch”;
- ❖ results of testing the solution for notifying emergency services on the example of the LORA system – lecture by Mr. Junior Brigadier Grzegorz Mroczko, M.Sc., specialist of CNBOP-PIB Department of Technical Assessments;

- practical applications of HSR-type communication systems (LoRa) – lecture by Mr. Grzegorz Sypek, M.Sc., representative of NEURON Sp. z o. o. Sp. k.;
- development of notification and warning systems – lecture by Mr. Krzysztof Baranowski, Vice President of Digitex Ltd. Sp.k.,;modern solutions for the security of users' property on the example of the GRAND VERTICAL PARKING device – lecture by Mr. Marcin Karkut, representative of the GRAND Group Sp. z o.o.;
- selected methods of extinguishing electric cars – a lecture by Mr. Dariusz Stachlewski, representative of INTERVENT Corp. Ltd.;
- systems for early detection and suppression of fires of electric vehicles and energy storage, based on existing water infrastructure in garages and single-family houses – a lecture by Mr. Dariusz Kot, representative of Prywatne Przedsiębiorstwo Produkcyjno-Handlowe "GRAS".

4.1.1. Selected aspects of software testing of fire protection equipment

The lecture presented basic information on software testing starting with the definition of software itself and identifying the purpose of its examination and testing. At the beginning, software was identified as a collection of information in the form of a set of instructions, procedures, interfaces and data intended for devices and equipment to achieve their designated purposes. It was mentioned that software is found in numerous devices such as cell phones, computers, control panels, detectors, integrators, traffic control and cars. It was also pointed out that all of these devices work properly due to well-functioning software. It was emphasized that this is why it is so important that the software is properly verified and tested and also supervised to eliminate as many errors as possible, so that unnecessary problems are avoided at the use stage. Testing itself was identified as a process involving all activities aimed at confirming the compliance of proposed solutions with the requirements specification, while the intention of testing itself was identified as reducing the number of errors in the user environment. This was followed by information on the software development life cycle. It has been determined that the cycle in question consists of individual phases that take into account the creation, as well as the functioning of the software in the application environment. It was concluded that the development of software is a complex process, in which the expected functionality of the device is obtained, but which also allows to change it, also at the stage of already using this product. Again, it was emphasized that there are many methods, types and models of testing, nevertheless, before implementing them, it is necessary to first identify at what levels testing is done. Five levels were presented during the presentation. The introduction described modular testing referring to testing at the development stage of software code, which involves verifying a small portion of code and aims to confirm that it works as intended. Integration and system tests were then discussed, where internal integration tests involve verifying interactions between individual cooperating or dependent modules while external tests refer to verifying interactions with other systems. In addition, system tests have been identified, which are verification of the entire application or finished and independent segments, and, at the very end, acceptance tests have been identified to confirm the software's compliance with requirements or specifications.

Later in the presentation, the basic methods and types of tests performed were identified. Black-box and white-box methods were identified as the most common testing methods you hear about most often. Both of these methods differ significantly in terms of their approach to the testing itself, namely what will ultimately be verified. And so, in case of a black box, the results of actions are verified, that is, it is checked whether after performing a certain action we will get the intended result. In this method, one does not go into the details of the code itself. In case of the white box, on the other hand, we focus directly on the code, i.e. we look at whether it works correctly and reacts in the intended way with respect to the actions being implemented. Moving forward, several types of testing have been identified. For example, functional tests, non-functional tests, retests and regression tests are described. According to the speaker, extremely important tests are regression tests, which are performed when you change the software you have, and these tests are not intended to confirm that the change you made works correctly, but focus more on verifying that other functions of the software still work as intended.

At the end of the speech, information was presented, about the new offer of CNBOP-PIB concerning the voluntary certification scheme designed to verify software used for fire protection equipment. It was specified that the work is at an advanced stage in connection with which the certification program should be launched this year and will include software testing based on the Institute’s prepared requirements. Software testing is planned for fire protection equipment mainly in the area of fire protection equipment signalling and control panels and fire protection equipment integration systems, but also other fire protection equipment where software will be able to be verified.

4.1.2. Presentation of projects implemented by ZG OSP RP: “First Rescuer”, “Smoke Detector under every thatch”

At the beginning, Mr. Artur Białkowski presented data indicating that mortality in Poland due to cardiovascular diseases is up to 70% higher than in other European Union countries. It is estimated that 34,000 people in Poland suffer sudden cardiac arrest (SCA) every year. It was also pointed out that with timely and effective cardiopulmonary resuscitation (CPR), up to 75% of victims can be saved, where this statistic in Poland is only about 5% ÷ 7%. Three objectives of the First Rescuer program were presented, which state:

- creating the largest network of First Responders to rescue faster and more effectively,
- using the latest technology to reduce the time it takes to save a life,
- training 120,000 instructors and 5 million people in first aid in Poland within 5 years.

During the lecture, a cell phone application called “Rescuer” was presented, which is designed, among other things, to locate and direct to the nearest point with an Automated External Defibrillator (AED). In addition, an outline of the first responder academy was presented, which aims to train and expand people’s awareness of first aid focusing on aspects related to CPR/AED, haemorrhage, paediatric cases, safety, among others.

The second part of the lecture featured Mr. Robert Klonowski, who presented a program titled “A smoke detector under every thatched.” To begin with, the data in terms of the number of injured people and fatalities from 2002 to

2020 was presented, based on which it can be concluded that the number of injured people during this period is increasing (average: 3690), while the number of fatalities remains at a similar level (average: 531). A new strategy called “FLORIAN 2050” was also indicated, one of the goals of which is preventive activity in a systems approach to minimize fatalities and casualties in fire incidents. One system solution that is designed to achieve these goals is the “Smoke Detector Under Every Thatch” program. This program is implemented by all willing volunteer fire departments and aims to improve fire safety primarily in rural areas. The main activities under this program are home fire safety tests, optionally combined with the installation of smoke detectors in residents’ homes. In addition, the most at-risk provinces were identified by taking into account the number of residential fires in each municipality per 1,000 residents (the period between 2013 ÷ 2023). Based on the analysis, five most vulnerable areas were identified according to the data, these are the warmińsko-mazurskie, podlaskie, lubuskie, dolnośląskie and podkarpackie provinces. Finally, a website (https://www.testbezpieczenstwa.pl/) was presented, where one can find detailed information on the “Smoke Detector Under Every Thatch” program.

4.1.3. Results of testing the solution for notifying emergency services on the example of the LORA system

Mr. Grzegorz Mroczo began the presentation by identifying the procedure for testing innovative products – TWI (Issue 2 of 12 March 2015). It was indicated that this procedure is intended to evaluate through testing by raters the suitability for use in fire protection of innovative products and solutions. The basis for directing a product for testing is that it meets the essential requirements of the regulations related to the marketing of products and their overall safety. Testing is carried out through practical evaluation of the products by rescuers of the Fire and Rescue Units of PSP in exercises and rescue and firefighting operations. Identification and discussion of the benefits of using the procedure for testing innovative products was carried out in terms of:

- evaluating the suitability of using the tested products in fire protection for its intended use,
- inspiring manufacturers to be innovative,
- receiving feedback on the product before the start of mass production,
- receiving information from testing firefighters for other rescuers on the functionality and features of the tested products,
- improving products/solutions,
- maintaining a database of products on the CNBOP-PIB website.

Marking of products after successful completion of the innovation product testing procedure:

CNBOP-PIB TESTOWANIE OPINIA

CNBOP-PIB TESTOWANIE REKOMENDACJA

The presentation also identified products currently undergoing testing, i.e.: vehicle fire control sheets, unmanned aerial vehicles to support rescue operations, and communication systems for emergency service notification, alerting and civil protection.

In the following part of the speech, an example of the implemented process of testing the product – a hybrid HSR communication system, which is designed to activate emergency sirens for the notification of TSOs and to activate emergency sirens for alerting and protecting the public (through two communication paths in the form of DMR and LoRa digital radio paths) was presented. The purpose of conducting these tests is to confirm the feasibility of using two transmission paths for redundancy and to determine the available communication range of two transmission paths for redundancy. The testing scheme provides:

- assessment of functional compatibility of equipment,
- checking DMR communications in selected locations in Otwock County and assessing coverage,
- verification of LoRa communication in selected locations in Otwock County and evaluation of coverage,
- checking the redundancy of DMR and LoRa radio communications.

According to the above program, tests were carried out based on which identifying results were obtained:

- positive assessment of the functional compatibility of equipment,
- verification of DMR communication in selected locations in the Otwock district and evaluation of coverage – availability was determined at 82% (the maximum range obtained in the tests is 15.7 km for a specific location),
- verification of LoRa communication in selected locations in Otwock County and evaluation of coverage – the availability was determined to be 41% (the maximum coverage obtained during testing for a specific location is 10.4 km),
- confirmation of the redundancy of DMR and LoRa radio communications in laboratory conditions, however, at this stage of real-world testing no such confirmation has been obtained.

Conclusions:

1. The establishment of DMR and LoRa communication and its range depends, among other things, on:
   - topography of the area,
   - the degree of afforestation/urbanization of the area,
   - presence of high voltage lines,
   - heights of antenna masts,
   - local radio communication conditions.
2. Scheduled to perform a 2nd round of tests with a higher mast by the end of June to confirm the redundancy of DMR and LoRa communications for the selected sites.

4.1.4. Practical applications of HSR-type communication systems type LORA

At the beginning, Mr. Grzegorz Sypek identified the need for fire protection to be more proactive, rather than reactive. He also stressed the fact that legislation, unfortunately, still has not kept up with the constant development of technology. It has been identified that LoRa is part of solutions belonging to a group called LPWAN (a type of wireless wide area telecommunications network designed to enable long-distance communication at low bit rates and low power consumption). LoRa (Long Range) itself has been defined as a long-range, low-power wireless data transmission technology based on the use of the Chirp Spread Spectrum Modulation (CSS) technique designed by default for Internet of Things (IoT) systems. It then outlined what LoRaWAN™ is, describing it as an open wireless communication protocol that enables encrypted two-way communication between LPWAN-type network infrastructure elements based on LoRa modulation.

The next section presented the topology of the LoRa network identifying the division into four levels starting with end elements (nodes), gateways (base stations), network servers and application servers. The different elements were identified as:

- terminal elements (nodes) – devices consisting of a sensor/IO module and a radio module for converting data into a radio signal, e.g. smoke detectors, limit detectors, vibration detectors, etc.,
- gateways (base stations) – devices that receive signals transmitted by nodes via the LoRaWANTM wireless communication protocol,
- network server – devices responsible for communication i.e. receiving, sending, and encrypting and decrypting data,
- application server – a device responsible for processing data and performing specific operations, operating on the basis of private or public clouds.

The key advantages of LoRa technology are also outlined, identifying such elements as reliability, scalability, redundancy, adaptability, fault tolerance, low power consumption, long range, two-way communication, data security and a large number of endpoints. At the end of the lecture, examples of practical application of LoRa technology in the field were presented:

- public alert and warning systems,
- fire detection (smoke detectors),
- monitoring the position of fire doors and gates (position detectors),
- detection of flooding of premises and flood protection,
- detection of forest fires (temperature, humidity, concentration of H2, CO2, CO),
- measurement of precipitation and snow thickness,
- monitoring of air quality,
- handling of mass events, e.g. people counter,
- waste management, street lighting and parking infrastructure management.

4.1.5. Development of notification and warning systems

Mr. Krzysztof Baranowski began his talk by presenting information on Digitex's business, highlighting its work with a number of transmission technologies, including: NXDN, DMR, TETRA, IP (VPN) and GSM in 20 different countries. The next section discusses selective notification systems in the country. It has been identified that as of today, the most popular system used by the fire department is the DSP-50 analogue selective alarm system (more than 10,000 devices are installed in Poland). It is an analogue system, the use of which was initiated in 1995 and which, despite some limitations, responded to the needs of previous years. However, due to newly emerging needs, work has begun on a digital equivalent of the said selective alert system. In addition, modern solutions used in current installations including hybrid power, universal siren controllers and integrations with LoRa technology were presented.

4.1.6. Modern solutions for the security of users' property on the example of the GRAND VERTICAL PARKING device

Mr. Marcin Karkut began the lecture by explaining what a *grand vertical parking* lot is, classifying it as a device with a permanent foundation requiring a building permit and acceptance, nevertheless emphasizing his opinion that it is not a construction object. The entire structure of the device is mobile (anchored structure with the possibility of disassembly) and has an approval for use issued by the Office of Technical Inspection. It was determined that the principle of operation of the parking lot is based on rotational operation on the principle of a vertical carousel. The lecture went on to identify both the advantages of the device and the security mechanisms used, both of which are indicated below.

Advantages of *grand vertical parking*:

- ❖ Polish product and proprietary production technology based on many years of research and development work,
- ❖ patented solutions for safety and prediction of emergency events, among others,
- ❖ modularity of the design allowing the machines to be put together with side or rear planes and a common housing and control,
- ❖ architectural versatility limited only by our imagination,
- ❖ various models of the device – the possibility of parking from 6 to 16 cars.

Security mechanisms of *grand vertical parking*:

1. Security mechanisms:
    - obstacle detection systems to prevent collisions,
    - sensors to detect the presence of vehicles and people on the platforms,
    - automatic locks to secure vehicles while parking,
2. Monitoring and Management:

- 24-hour video monitoring of the system,
- alarm system in case of detection of irregularities,
- regular technical inspection and maintenance of the system,

3. Different variants of device operation:
   - standby mode,
   - full occupancy mode,
   - Firefighter mode – Automatic relocation of the burning vehicle to the very top or bottom of the device (depending on the needs of the firefighting operation)

4.1.7. Selected methods of extinguishing fires of electric cars

Mr. Dariusz Stachlewski began the presentation by stating that it is necessary to identify the problem in order to solve it effectively. Based on the conducted analysis, it was possible to identify the main causes of the problem of extinguishing electric cars and lithium-ion batteries.

The identified problems are presented under seven headings as follows:

1. A car fire or physical damage to the battery during an accident initiates a physical-chemical reaction inside the batteries leading to self-heating of the battery and intensive fire development,
2. The self-heating process inside the batteries can start up to 72h after the accident/car fire has been extinguished,
3. The batteries are difficult to access and enclose. Pouring water on the housing cannot stop the heating process inside the batteries,
4. The batteries produce up to 1000 volts of current,
5. Breaking inside with existing tools is too dangerous for rescuers and may cause arcing and burning,
6. Burning batteries generate temperatures of up to 1,000 °C, which exposes the burning vehicle to total destruction as well as the impact on nearby objects (e.g. in garages, car parks or narrow streets),
7. Risks posed during transport by rail or sea.

The lecture continued with the presentation of the new ‘CutLanca’ solution, which combines cutting and extinguishing functions. CutLanca also allows the deactivation of lithium-ion batteries. CutLanca, according to a study and report from the Polish Institute of Energy, can safely apply fog to high-voltage equipment up to 265 kV. The advantages of the proposed solution were identified and discussed, identifying the following aspects:

- the fog jet provides a shield for thermal radiation,
- the phase transformation of water into steam cools the fire gases,
- cuts and pierces through any material,
- extinguishes the fire inside allowing you to operate from a safe position outside the danger zone,

- the water vapour inertifies the flammable gas mixture.

The lecture went on to present some recommended methods for extinguishing electric vehicles when the battery is already on fire:

1) Penetration of abrasive water mist through the vehicle structure and battery casing (time: several seconds). The pressurised mist jet then penetrates and flushes out the individual spaces and cells of the battery (each cell must be penetrated and flushed out). There is complete cooling of the inside of the cells and complete cessation of the combustion process, and there is a cessation of the physical and chemical reaction by flushing out the inside of the individual cells and neutralising the combustion mixture. Finally, it remains to extinguish smouldering vehicle components, if necessary.
2) An electric vehicle fire should be divided into two parts:
   - fire in the car equipment (as in any other vehicle),
   - and battery fire.
3) The car should be extinguished just like any other car. One should get an idea of where the battery has been placed and make the first penetration into the interior with a jet of water mist as soon as possible (using a solid obstacle such as a door or boot lid, one can also penetrate through the floor, so as not to be in the path of a possible ejection of ignited gases). It is necessary to penetrate the interior of the battery, penetrate and flush out each cell, which will break the physical and chemical reaction and ensure that the self-heating process is completely stopped. In the end, all that remains is to extinguish smouldering vehicle components, if necessary.

The lecture also identified problems occurring in magnesium extinguishing and recommended a suitable extinguishing method in the form of a water mist application so that only water vapour reaches parts made of magnesium (bearing in mind that up to 98% of the water can evaporate). It was also recommended that only ricochets be used, aiming the water mist at the metal parts in such a direction that the vapour generated reaches the magnesium parts.

Finally, it has been identified that CutLanca has a positive test report from the Institute of Energy (High Voltage Department) confirming the safe application of the water mist jet to high-voltage equipment, thus minimising the danger (from electricity) during extinguishing actions on equipment, machinery and electrical vehicles (tests were performed according to EN 3-7+A1:2008). CutLanca also enables the effective deactivation of lithium-ion batteries.

4.1.8. Systems for early detection and suppression of fires of electric vehicles and energy storage, based on existing water infrastructure in garages and single-family houses

Mr Dariusz Kot began by pointing out that the solution being presented included fire suppression activities for electric vehicles and energy storage facilities, with the focus on garage facilities for the purposes of the lecture. It was identified that a major problem in a garage fire situation is the difficulty of approaching the incident due to the very high temperature, and it is therefore important to try to nip this fire in the bud before it develops. The CNBOP-PIB guideline on fire protection of garages in construction works for charging electric and plug-in hybrid cars was identified as one of the documents that identifies risks regarding the charging of electric cars in garages. These guidelines make recommendations for protecting each point and loading bay by SUG with a supply of extinguishing agent to control the fire for at least 30 minutes, and to limit the spread of fire to vehicles on adjacent stands for at least 30 minutes (not required for SUG protection).

It was pointed out that, according to the regulations, the developer is obliged to ensure proper fire protection in buildings, in accordance with the provisions of the Ordinance of the Minister of Internal Affairs and Administration of 7 June 2010 on fire protection of buildings, other buildings and areas. According to the provisions of § 19.2, hydrants 33 must be used in the garage:

1) single-storey enclosed buildings with more than 10 parking spaces;
2) multi-storey.

The minimum water intake capacity measured at the nozzle outlet is:

1) for hydrant 25 – 1.0 dm^3 /s,
2) for hydrant 33 – 1.5 dm^3 /s (approximately 5400 l/h) – 90 l/min,
3) for hydrant 52 – 2.5 dm^3 /s (approximately 9000 l/h – 150 l/min.

The fire water supply system shall be capable of drawing water simultaneously for 60 minutes on one floor of a building or in one fire zone from two adjacent internal hydrants or two adjacent valves 52.

During the lecture, it was pointed out that GRAS uses DN33 internal hydrants for the i-Sprink sprinkler system, which must be available at the facility due to the previously cited regulation. Instead, the system is used for early detection and localisation of the fire and serves to suppress and control the fire in its early stages, preventing the fire from spreading to other vehicles.

It also concludes with i-Sprink home solutions for early detection and automatic fire suppression of electric vehicles and home energy storage, as well as UTOs (personal transport equipment). The components of this system are identified, identifying such components as:

- HWG-19 GRAS indoor hydrant,
- ball valve with actuator,
- sprinkler systems,
- pendant sprinklers,
- fire location indicator,
- smoke/heat detector,
- acoustic-optical sounder,
- power supply with battery backup.

Advantages of the i-Sprink home system were identified as immediate detection of fire danger, automatic or manual switching of the system, video monitoring, an accessible client application and twenty-four-hour security seven days a week.

4.2. Second session

During the second session, moderated by a specialist from CNBOP-PIB Department of Studies and Research Projects Mr. Jarosław Tępiński, Ph.D., discussed were issues related to:

1) cause-and-effect relationships of electric battery failures – lecture by Jarosław Tępiński, Ph.D., specialist in CNBOP-PIB Department of Studies and Scientific Projects;
2) toxic hazards in battery fires – presentation by Brigadier General Paweł Rochala;
3) methodology of extinguishing batteries in laboratory conditions with the use of various extinguishing agents – lecture by Mr Piotr Mortka, specialist from Laboratory of Fire Extinguishing Agents and Equipment – BU.

4.2.1. Cause-and-effect relationships of electric battery failures

At the beginning, Mr Jaroslaw Tepinski identified that the safe use of batteries requires maintaining their cells within a certain voltage and temperature range. He also emphasised that, in terms of safety, one of the key steps in using batteries is the charging process. It was discussed that the following causes are most likely to lead to battery failure:

- internal manufacturing defects (material, construction, assembly, presence of impurities,
- mechanical damage to the battery (e.g. crushing, penetration of solids),
- thermal:
  - exposure to high external temperatures,
  - exposure to flames,
  - interaction of heat from neighbouring cells,

- ❖ electric:
  - short circuit,
  - overcharge / over-discharge,
  - overload,
  - overvoltage.
- ❖ change in performance of construction materials over time.

The interaction of the above factors can lead to an increase in temperature in an individual cell or area of the battery. Overheating results in battery failure.

The presentation also discussed the separator as one of the key safety features of the battery cells, whose function is to ensure that the electrodes are isolated from each other. It has been described that, as a result of the high temperatures inside the cell, the separator melts or deforms and thus creates a physical barrier blocking the reactions taking place in the cell, preventing further temperature increases.

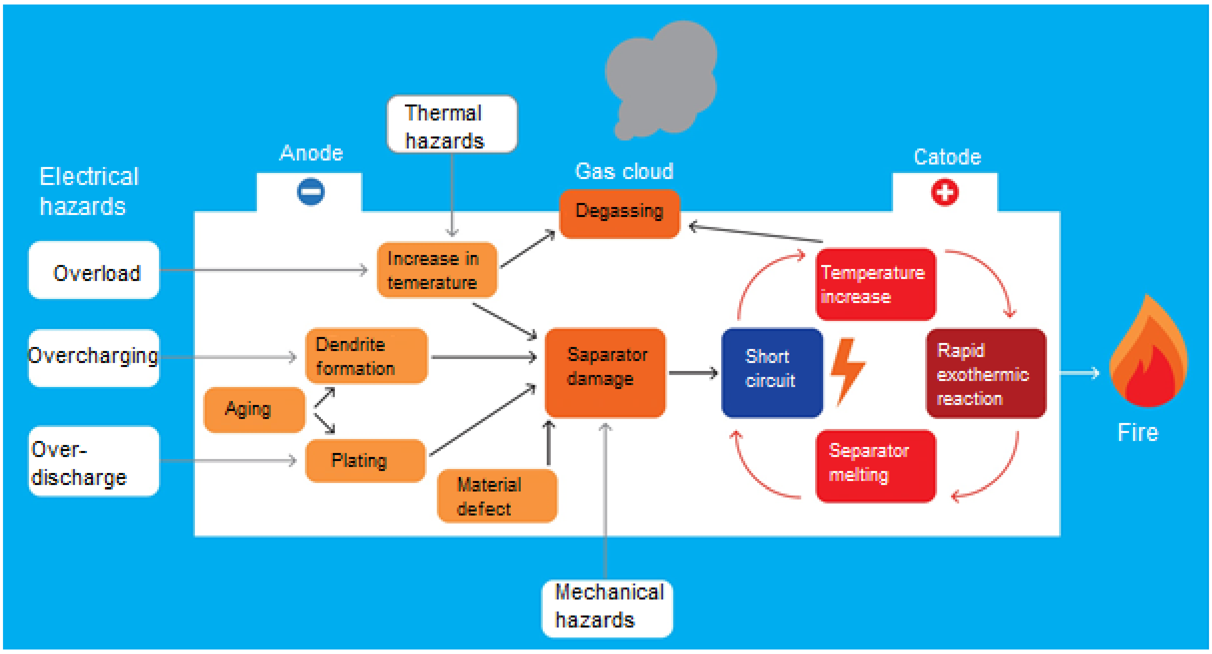

Figure 1. Cause-and-effect relationships leading to battery cell failure

Source: elaborated by Jarosław Tępiński, Ph.D., Material from the conference entitled “Fire safety of photovoltaic installations, energy storage, electric vehicles, their charging points, smart home solutions”, CNBOP-PIB, Józefów 12.06.2024.

Next, the five main risks caused by the battery are as follows:

- fire:
    - resulting from battery failure,
    - covering the battery,
- electric shock, following:
    - mechanical damage to the battery,
    - damage to the battery due to overcharging, over-discharge or overloading,
    - external thermal effects,
    - as a result of internal defects, changes in the performance characteristics of the battery materials,
- inhalation of toxic combustion products and compounds released during battery failure conditions,
- skin contact with chemicals released during battery failure,
- hydrogen explosion resulting from chemical reactions during battery failure.

It is also important to be able to identify battery failure. Accordingly, the signs that may indicate its malfunction are as follows:

- battery failure messages,
- temperature rise on the battery surface,
- deformation of the battery casing,
- opening of structural relief valves,
- white or greyish-white gas vapours emanating from the battery,
- sparking,
- battery sounds (crackling, hissing, bubbling, squeaking),
- smell of burning,
- dark or black smoke coming from the battery,
- flames, including jet flames, emanating from the battery.

At the end of the lecture, it was also presented what risks exist for building structures where electric batteries have been used. Based on the analysis, the following risks were identified:

1. A battery fire, due to the release of large quantities of flammable gases, is characterised by a high rate of development.
2. Toxic and corrosive chemicals released in the process of battery failure, which become particularly dangerous if they are allowed to be stored in confined spaces.
3. It is possible that large quantities of smoke are emitted, which can significantly impede or even prevent evacuation and direct access by rescue teams. As a consequence, this can lead to a significant rise in temperature and further development of the fire, which may even cause structural damage to the building,.
4. Once the battery fire has been extinguished, re-ignition of the hot cells is possible.

4.2.2. Toxic hazards in battery fires

At the beginning, Mr Paweł Rochala reminded us that the principle of a galvanic cell has still been the same for over 150 years and boils down to the relationship: anode + electrolyte + cathode = current. Also discussed was the fact that the use of batteries has the effect of heating them up, which in case of large devices is sometimes not just a loss of energy, as in a small laptop battery or screwdriver, but a failure factor. This is because each cell has a critical operating temperature, beyond which uncontrolled chemical self-heating can occur. Therefore, the batteries must be cooled, and the larger they are, the more carefully, since cooling failure risks a violent exothermic reaction.

The lecture identified that it is difficult to talk about the possibility of extinguishing a burning battery, while the firefighting operations carried out are most often aimed at:

- thermal insulation of the surroundings of the reaction site to avoid a domino effect (environmental disaster with giant batteries),
- "controlled" burning of the battery and dilution of the poisons by ventilation or wind to "acceptable" concentrations, i.e. unverifiable by the average air consumer.

Several chemicals extracted during thermal decomposition of batteries are presented and discussed, identifying the occurrence of such compounds as: Hydrogen Fluoride (HF), Hydrogen Chloride (HCl), Bromine (HBr), Lithium (Li), Aluminum (Al), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Magnesium (Mn), Nickel (Ni), Lead (Pb), Zinc (Zn), Fluoride (F-), Chloride (Cl-), Bromide (Br-).

Most of the elements and constituent substances of batteries, as well as their combustion products, have long had Material Safety Data Sheets. Accordingly, it was concluded that decontamination of people and equipment should be mandatory after an extinguishing operation.

The lecture ended with conclusions on toxic hazards in battery fires, which identified:

1. Manufacturers and distributors of batteries should declare their fire properties, including smokeability and toxicology, including the amount of individual smoke components.
2. Declarations of battery manufacturers and distributors should be verified by third parties, including aging tests. Only after such verification should the batteries be allowed on the market. The tests should be repeated in a controlled manner, supervising the products used on the market.
3. Considered should be the limit of the size of the battery (smokeability and/or mass) above which its use will be possible only in fire-separated battery rooms.
4. Inspection and maintenance rules and battery life periods should be defined.
5. Each battery should have a nameplate with the following information: components, safety certificate number of the national research institute, basic principles of safe use, critical temperature of thermal decomposition. In addition, it should be equipped with an information leaflet on the properties of hazardous

constituent substances and thermal decomposition, instructions for use exclusions and emergency procedures, based on worldwide experience, the use of certain types of batteries in given applications (e.g., home, garage or industrial) can be ruled out in advance due to low thermal run-up temperatures.

6. The issue of disposing of used batteries needs to be considered in advance. No safe technology within national reach should prompt delaying decisions implementing their mass and large-scale use. At the same time, it is worth tracing the effective social resistance that such plants have encountered in Poland.
7. Procedures for rescue and firefighting operations of fires involving batteries should include immediate decontamination of people and equipment.
8. In case of large battery fires, operations in the vicinity of them should be carried out in gas-tight clothing.

4.2.3. Methodology of extinguishing batteries in laboratory conditions with the use of various extinguishing agents

Mr. Piotr Mortka identified at the beginning of the lecture that lithium-ion battery fires are an everyday occurrence, while the combustion characteristics of such a battery are still not very well known. To date, no effective method has been developed to extinguish a fire in a short period of time, and efforts are currently focused on minimizing the effects or trying to minimize the use of water during firefighting operations. As a result, there is a constant need to look for new technical and tactical solutions to optimize procedures leading to more efficient service operations. Based on this, steps have been taken at CNBOP-PIB to carry out relevant research to find an alternative way to extinguish lithium-ion battery fires using low-cost and readily available means. This paper focuses on selected extinguishing agents for li-ion battery fires, i.e. vermiculite sorbent, quartz sand and dedicated granules.
It was indicated that the following measuring instruments were used during the research process:

- K-type sheathed thermocouples suitable for temperatures up to 1200 °C,
- ThermoSpot-Vision pyrometer by Laserliner with a display range of -15 °C to + 500 °C,
- camcorder, camera,
- second meter,
- Gil Air 3 individual aspirators,
- “Gilibrator 2” gas flow meter, XAD-2 resin sorption tubes,
- Shimadzu QC 2010SE gas chromatograph equipped with Zebron ZB-5 30 m 0.25 mm ID 20 μm 340 °C column.

In the next part of the lecture, the course of testing the extinguishing effectiveness of the verified extinguishing agents was discussed, which is also illustrated in the figure below.

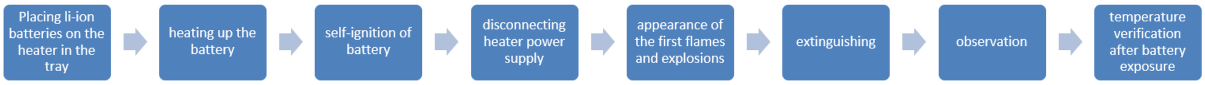

Figure 2. Course of assessing the extinguishing effectiveness of the extinguishing agents used

Source: elaborated by Piotr Mortka, Eng., Piotr Stojek, M.Sc., Tomasz Lutoborski, M.Sc., Justyna Gniazdowska, M.Sc., Material from the conference entitled "Fire safety of photovoltaic installations, energy storage, electric vehicles, their charging points, smart home solutions", CNBOP-PIB, Józefów 12.06.2024.

Moreover, physicochemical tests were conducted, the methodology of which included, in case of dust, air sampling in the fire zone using individual aspirators on cellulose ester membrane filters, followed by weight analysis. For PAHs, the methodology involved sampling with individual aspirators on XAD-2 synthetic resin tubes, followed by desorption of the samples with hexane, concentration of the sample in a stream of inert gas (nitrogen) and then chromatographic analysis.

The results from the surveys were described by Mr. Mortka based on the received data d in the table below.

Table 1. Test results – evaluation of firefighting effectiveness

Test No.	Extinguishing agent used	Fire extinguished [YES/NO]	Afterburn temperature [°C]	Observations and insights
1	Quartz sand	YES	< 100	Once covered, the flame was immediately extinguished. Explosions could be heard inside the tray. No smoke was noted. When the battery is unearthed, there is no sign of embers. Sand did the best job of absorbing heat.
2	Sorbent with vermiculite	YES	< 180	After the battery was sealed tightly, the flame immediately went out. Explosions could be heard inside the tray. A marginal release of smoke was reported. When the battery is unearthed, there is no sign of embers.
3	Fire extinguishing granules	YES	< 500	After the battery was sealed tightly, the flame immediately went out. Explosions could be heard inside the tray. Intense release of smoke was reported. After the battery was unearthed, numerous clusters of embers were observed.

Source: elaborated by Piotr Mortka, Eng., Piotr Stojek, M.Sc., Tomasz Lutoborski, M.Sc., Justyna Gniazdowska, M.Sc., Material from the conference entitled "Fire safety of photovoltaic installations, energy storage, electric vehicles, their charging points, smart home solutions", CNBOP-PIB, Józefów 12.06.2024.

Subsequently, the analyses revealed that the concentrations of the inhalable fraction of total dust, which can be classified as soot dust, and hydrocarbons from the group of polycyclic aromatic hydrocarbons (PAHs) were as follows:

Table 2. Test results – chromatographic analysis

Harmful substance	Concentration of inhalable fraction [mg/m³]		
	Quartz sand	Sorbent with vermiculite	Fire extinguishing granules
Soot dust	2,77	3,13	2,25
Naphthalene	0,0651	0,1353	0,0343
Acenaphthylene	0,0198	0,0296	0,0103
Acenaphthen	0,0004	0,0008	0,0004
Fluorene	0,0046	0,0096	0,0037
Fenantrene	0,0096	0,0161	0,0057
Anthracene	0,0013	0,0027	0,0009
Fluoroanthene	0,0011	0,0035	0,0024
Pyrene	0,0006	0,0023	0,0019
Benzo(k)fluoroanthene	< 0,0001	0,0003	0,0005
Chryzen	< 0,0001	0,0002	0,0005
Benzo(k)fluoroanthene	0,0001	0,0003	0,0003
Benzo(b)fluoroanthene	0,0001	0,0003	0,0003
Benzo(a)pyrene	< 0,0001	0,0002	0,0003
Indeno(1,2,3-cd)pyrene	< 0,0001	0,0002	0,0002
Dibenzo(a,h)anthracene	< 0,0001	0,0002	0,0001
Benzene(g,h,i)perylene	< 0,0001	0,0001	< 0,0001
PAH SUM	0,103	0,202	0,062
Multiplicity of the NDS Soot dust	0,69	0,78	0,56
Multiplicity of NDS of PAHs	0,02	0,70	0,52

Source: elaborated by Piotr Mortka, Eng., Piotr Stojek, M.Sc., Tomasz Lutoborski, M.Sc., Justyna Gniazdowska, M.Sc., Material from the conference entitled "Fire safety of photovoltaic installations, energy storage, electric vehicles, their charging points, smart home solutions", CNBOP-PIB, Józefów 12.06.2024.

As a result of the analyses, the concentrations of PAHs in the residues of the fire extinguishing agent taken from the interior of the burn area were as follows:

Table 3. Test results – chromatographic analysis

Harmful substance	Concentration of PAH in the residue of the extinguishing agent [μg/g]		
	Quartz sand	Sorbent with vermiculite	Fire extinguishing granules
Naphthalene	0,078	0,833	10,50
Acenaphthylene	0,040	0,000	2,97
Acenaphthen	0,011	0,066	0,89
Fluorene	0,000	0,275	27,87
Fenantren	0,159	2,453	66,24
Antracen	0,158	0,436	14,41
Fenantrene	0,071	0,000	10,82
Pyrene	0,101	2,202	8,32
Benzo(a)anthracene	0,000	0,790	1,94
Chryzen	0,007	1,602	3,92
Benzo(k)fluoroanthene	0,000	0,000	0,96
Benzo(b)fluoroanthene	0,000	0,000	0,96
benzo(a)pyrene	0,000	0,091	0,33
Indeno(1,2,3-cd)pyrene	0,002	0,063	0,17
Dibenzo(a,h)anthracene	0,002	0,049	0,13
Benzene(g,h,i)perylene	0,002	0,043	0,09
PAH SUM	0,631	8,902	150,52

Source: elaborated by Piotr Mortka, Eng., Piotr Stojek, M.Sc., Tomasz Lutoborski, M.Sc., Justyna Gniazdowska, M.Sc., Material from the conference "Fire safety of photovoltaic installations, energy storage, electric vehicles, their charging points, smart home solutions", CNBOP-PIB, Józefów 12.06.2024.

The lecture concluded with a discussion of the conducted extinguishing effectiveness tests, which showed that quartz sand was the best of the extinguishing agents tested. The fine grains tightly covered the battery, allowing the fastest fire extinguishing in this research and reducing the generation of some toxic substances. Of the materials used in the study, sand is also the easiest to decontaminate. The dense packing and polar nature of the Si-O bonds provides a compact hydrophilic surface that does not allow PAHs to be deposited in the crystal lattice, as well as does not favour the deposition of PAHs on the grain surface, facilitating the process of extracting these compounds from grains. Quartz sand, which is used as a construction aggregate, can be used in the production of asphalt concrete after contamination, such as from quenching, which would still involve its contamination with PAH group compounds formed in the manufacturing processes of these asphalts. It was independently identified that the vermiculite sorbent tightly covered the burning battery, which, as in the case of quartz sand, allowed the fire to be extinguished, while during the process a significant amount of toxic substances escaped from underneath its layer.

Extinguishing pellets proved to be the least effective agent used during the test fires. The time and temperature required to melt the granules and form the cell's insulating layer resulted in the release of the greatest amount of impurities into the residual extinguishing agent. However, this effect may be less significant in more developed fires occurring at higher temperatures, where there has been an early burning of all available organic matter.

4.3. Third session

The third session, moderated by Deputy Head of CNBOP-PIB's Laboratory of Fire Alarm Systems and Fire Automation, Mr. Tomasz Popielarczyk, Ph.D., addressed issues related to:

1) construction, operation and applied safeguards in battery energy storage – lecture by Mr. Krzysztof Strukowicz, President of the Board of the Polish Chamber of Energy Storage (PIME);
2) fire protection of electricity storage facilities (a review of selected foreign requirements) – a lecture by Mr. Kamil Wleciał, M.Sc., Chief Fire Officer, representative of the National Fire Service Headquarters;
3) possibility of using batteries from an electric vehicle for home energy storage – lecture by mł. bryg. Wojciech Klapsa, M.Sc., Head of CNBOP-PIB's Laboratory of Combustion Processes and Explosions.

4.3.1. Construction, operation and applied safeguards in battery energy storage

Mr. Krzysztof Strukowicz presented and discussed several examples of completed energy storage installations, including two storages built in shipping containers and set up in an area with several meters of separation between the containers, a storage facility cooperating with the railroad catenary located in a substation room, a storage facility in a hydroelectric power plant built in the main power supply point (GPZ), and an energy storage facility in concrete containers cooperating with a 500kWp photovoltaic installation.

The conducted lecture also presented information in the area of services provided by energy storage facilities, i.e.:

- ❖ remuneration for readiness to deliver power to the system. Opportunities to participate in the market for: "stand alone" storage, storage at the customer's site, storage in combination with RES,
- ❖ execution of balancing capacities through the Balancing Provider in 15-minute modes in off-take or generation modes via stand-alone storage, storage in combination with RES, storage at the customer's site,
- ❖ intervention bid power reserve under which customers are compensated for the execution of bids purchased by PSE. An order to reduce off-take or increase off-take issued to storage at the customer's site,
- ❖ non-frequency services performed for Distribution System Operators consisting of removal of network congestion and voltage regulation,
- ❖ taking advantage of price differences between off-peak and peak hours. Consumers with energy storage will be able to use storage to optimize costs through dynamic tariffs and reduce the cost of the power fee.

It was also emphasized that in case of energy storage, it is extremely important to protect against allowing a fire phenomenon due to the fact that if a fire occurs, it cannot be extinguished and must wait until it burns out. Various ways of securing were also presented, as indicated below:

1. Battery system safety features:
   - multi-level BMS system,
   - control of battery cell voltages,
   - temperature control of battery cells,
   - current control of battery chains,
2. Current path protection:
   - high-voltage DC fuse systems for battery chain voltage,
   - high-voltage DC contactor systems for battery chain voltage,
   - high-voltage DC high-speed circuit breakers for battery chain voltage,
3. Fire safety features:
   - detection of fire hazards,
   - fire detection,
   - fire separation,
4. DC and AC path overvoltage protection:
   - varistors,
   - thyristor protection systems,
   - sparkplugs.

4.3.2. Fire protection of electricity storage facilities – a review of selected foreign requirements

Beginning with a lecture on selected foreign requirements, Mr. Kamil Wleciał first defined what electricity storage and energy storage system are based on legal provisions. Among others, the Act of 10 April 1997 was cited – Energy Law (Polish Journal of Laws: Dz. U. z 2024 r. poz. 266), which defines an energy storage facility as an installation capable of storing electricity and injecting it into the power grid, and PN-EN IEC 62933-5-2:2020 *Electrical energy storage (EES) systems - Safety requirements for grid-integrated EES systems. Electrochemical-based systems* identifying that energy storage systems (ESS) are one or more devices, connected together, capable of storing energy for future delivery of electricity. The lecture identified a number of documents that can provide technical knowledge in the subject area, i.e.:

- **PN-EN IEC 62485-5:2021-08** Safety requirements for secondary batteries and battery installations – Safe operation of stationary lithium ion batteries,
- **PN-EN IEC 62619:2023-02** Secondary cells and batteries containing alkaline or other non-acid electrolytes. Safety requirements for secondary lithium cells and batteries, for use in industrial applications,
- **PN-EN IEC 63056:2020-12** Secondary cells and batteries containing alkaline or other non-acid electrolytes. Safety requirements for secondary lithium cells and batteries for use in electrical energy storage systems,
- **PN-EN-IEC-62933-5-2:2020-07** Electrical energy storage (EES) systems - Safety requirements for grid-integrated EES systems. Electrochemical-based systems,
- **NFPA 855** Standard for the Installation of Stationary Energy Storage Systems (2023),
- **FM Global 5-33** Electrical Energy Storage Systems, January 2017 Interim Revision January 2024,
- **PGS 37-1** Lithiumhoudende energiedragers: energieopslagsystemen (EOS),
- **CFA Design Guidelines and Model Requirements**: Renewable Energy Facilities, Version 4, August 2023.

Due to the scope of the lecture in the remainder of the material, the presenter mainly focused on providing detailed information directly on foreign requirements, i.e. NFPA 855, FM Global 5-33, PGS 37-1 and CFA Design Guidelines and Model Requirements.

Starting with the provisions of NFPA 855, a breakdown of the requirements for energy storage facilities is presented, classifying them in internal and external applications, where they are located as follows:

1. **Internal**:
   - energy storage systems (ESS) in buildings designed for energy storage,
   - ESS in buildings of a different purpose,

2. **External**:
   - "remote locations": ESS located more than 30.5 m from buildings, building lot boundaries, public roads, stored flammable materials, hazardous materials, highly stacked goods, and other hazards unrelated to the electrical grid infrastructure,
   - locations near exposure facilities: all outdoor ESS locations that do not meet the requirements for "remote locations",
   - specific outdoor locations, such as ESS installations on building rooftops,
   - mobile ESS installations.

For the above classification, the NFPA standard specifies a number of requirements, examples of which are identified in the table below.

Table 4. NFPA 855 requirements

NFPA 855 requirements for indoor ESS		
Requirement	**Building dedicated to energy storage systems**	**Energy storage system in a building of a different purpose**
Size and separation	YES	YES
Maximum stored energy	NO	YES
Height	YES	YES
Fire barriers	YES	YES
Fire and smoke detection	YES	YES
Fire control and extinguishing	YES	YES
Water supply	YES	YES
Marking	YES	YES
Equipment rooms	NOT PERMITTED	YES
Technology-specific requirements	YES	YES
NFPA 855 requirements for external ESS		
Requirement	**"Remote" locations**	**Near exposed objects**
Maximum size	YES	YES
Distance from facilities	NIE	YES
Distance from escape routes	NIE	YES
Units with input capability	YES	YES
Vegetation control	YES	YES
Housing made of non-combustible materials	YES	YES
Size and separation	NO	YES
Maximum stored energy	NO	YES
Smoke and fire detection	YES	YES
Fire control and extinguishing	YES	YES
Water supply	YES	YES
Marking	YES	YES
Equipment rooms	NOT PERMITTED	NOT PERMITTED
Technology-specific requirements	YES	YES

Source: own elaboration based on material of st. kpt. Kamila Wleciała, M.Sc. Eng., National Fire Service Headquarters, material from the conference entitled "Fire safety of photovoltaic installations, energy storage, electric vehicles, their charging points, smart home solutions", CNBOP-PIB, Józefów 12.06.2024.

NFPA requirements for distance from buildings were also described, where ESS located outdoors must be at least 3 meters away from lot boundaries, public roads, buildings, flammable materials, hazardous materials, highly stacked goods, other hazards unrelated to the electrical grid infrastructure. In certain cases, it is permissible to reduce the distance to 0.9 m (for example, when the ESS housing has a 2-hour fire resistance). On the other hand, ESSs located outdoors should be at a distance from escape routes (required by AHJ) that ensures safe evacuation in the event of a fire, but at a distance of no less than 3 m (0.9 m when tests show that a fire in an ESS will not adversely affect escape routes).

It was also pointed out that it is allowed to install ESS on the exterior walls of buildings when all the following conditions are met:

- the maximum stored energy of individual ESS units must not exceed 20 kWh,
- ESS system must meet the applicable requirements specified in Chapter 4 (general requirements for ESS),
- ESS system must be installed in accordance with the manufacturer's instructions and their listing,
- individual ESS units must be separated from each other by at least 0.9 m,
- ESS system must be separated from doors, windows, openings in buildings or HVAC inlets by at least 1.5 m.

ESS can also be installed on the roof, as long as this will not impede firefighting efforts.

The lecture also presented some selected requirements from NFPA i.e.:

1. The maximum stored energy in ESS (with lithium-ion batteries) located in fire-separated areas (fire areas) in buildings with other uses and in outdoor ESS (e.g., containers) should, as a rule, not exceed 600 kWh. This limitation does not apply to ESS in buildings intended for energy storage and outdoor ESS classified as "remote locations" (more than 30.5 meters from buildings).
2. ESS should consist of groups with a maximum stored energy of 50 kWh each, which should be at least 0.9 m from each other and from the walls in the room or storage area.
3. The room or rooms in which the ESS is located should be separated from other areas of the building by fire partitions with at least 2-hour fire resistance (separation by partitions with 1-hour fire resistance is permitted in certain cases e.g. when the ESS complies with UL 9540).
4. ESS equipment should be placed only on floors that can be accessed by fire department ladders, unless the AHJ approves a higher location.
5. Areas containing ESS systems located in buildings or structures must be equipped with a smoke detection system or radiation energy detection system in accordance with Section 4.8 (among others, in accordance with NFPA 72).

6. Fire control and extinguishing devices shall be provided in rooms or areas within buildings and exterior "walk-in units" containing ESS. Sprinkler systems shall be installed in accordance with NFPA 13 or equivalent (other types of fire extinguishing devices permitted upon confirmation of their effectiveness),.
7. Outdoor walk-in ESS units or ESS cabinets must not exceed dimensions of 16.2 m × 2.6 m × 2.9 m, not including HVAC and other equipment. Outdoor walk-in ESS units or ESS cabinets that exceed the above dimensions shall be treated as indoor installations and meet the requirements in 9.5.1 (for indoor ESS).
8. In accordance with NFPA 70 National Electrical Code (NEC) (2023). Provide means to disconnect the ESS from all wiring systems, including other power systems, utility equipment and associated wiring in the premises.
9. Sites where non-mechanical ESS are installed shall be equipped with a permanent source of water for firefighting purposes. Upon approval by AHJ, this requirement may be omitted for dedicated ESS buildings and outdoor walk-in units located more than 30.5 meters from other facilities.

Selected topics from FM Global 5-33 requirements are presented next. The following issues were described:

1. ESS location requirements with lithium-ion batteries similar to those in Appendix G of NFPA 855, while requirements are specified for the distance between adjacent outdoor container ESSs depending on the type of cells, i.e.:
   - for LFP cells, it is necessary to ensure a distance of at least 1.5 m from the walls of the container with openings (doors, vents),
   - in case of NMC cells and the fire resistance of the container walls less than 60 min. a distance of at least 4 m must be provided from the container walls with openings (doors, vents), and in case where a resistance of at least 60 min. is provided – 2,4 m,
2. Any prefabricated container or enclosure with an area exceeding 46.5 m^2 shall be treated as a building.
3. Distance of ESS from buildings should be taken in accordance with FM Global 1-20.
4. Manual, remote and local disconnection of ESS should be provided.
5. ESS should be equipped with BMS (battery management systems).
6. Automatic disconnection of the ESS in the event of elevated cell temperatures or detection of gases whose volatilization precedes thermal runaway should be ensured.

The next document discussed was the requirements of PGS 37-1. At the beginning, issues related to distances and the location of the energy storage, which consists of up to 6 units, were described, where it was identified that the distance between the battery system for stationary energy storage (niderl. Batterijsysteem voor stationaire energieopslag – EOS) set sideways is at least 1.0 m. If there is an unprotected opening (ventilation) in the side wall(s) of the units, the distance is at least 2.5 m, as long as the openings are on both sides of the space between these containers. It was also indicated that the smallest distance between EOS placed in a single row must be at least 2.5 meters. For EOS consisting of more than 6 units, the distance between EOS units shall be at least 2.5 meters, with at least 4.5 meters on one side due to accessibility for emergency services.

The lecture concluded with a discussion of selected water supply issues in accordance with the CFA *Design Guidelines and Model Requirements*. According to the requirements, where a water supply system meeting the requirements of AS 2419.1-2021: *Fire hydrant installations* is available, the number of outdoor hydrants in the area with energy storage should be calculated according to the aforementioned standard as for open yards. In the absence of such a water supply system, a hydrant system meeting the following requirements must be provided:

1. Water supply of min. 288 m^3 or a system as for open yards, providing a capacity of at least 20 dm^3/s for a period of not less than 4 h, whichever is greater.
2. The amount of water in the tanks should be calculated on the basis of the required number of hydrants (e.g., in the case of accumulator installations with a total area of more than 27,000 m^2, it is required that 4 external hydrants operate with a capacity of 10 dm^3/s for 4 h, which corresponds to a minimum water reserve in the tanks of 576 m^3).
3. Each facility must be within the range of the firefighting current throw (10 m) administered from a 60 m long hose line from a hydrant.

Water for firefighting purposes must be provided for each ESS unit.

In the absence of such a water supply system, water for firefighting purposes stored in tanks should be provided, which should be arranged in such a manner that at a distance of no more than 120 m from each battery container there will be a tank with a capacity of at least 45 m^3, with the total amount of water stored in the tanks not less than 288 m^3. Where a water supply system that meets the requirements of AS 2419.1-2021: *Fire hydrant installations* is available – water supply shall be provided in the same manner as in a compact system.

4.3.3. Possibility of using batteries from an electric vehicle for home energy storage – tests

At the beginning of the speech, Mr. Wojciech Klapsa identified that the last lecture in this session would be on the possibility of using "used" batteries (batteries that have an efficiency of 70% ÷ 80%) from electric vehicles for home energy storage. It has been identified that such a solution has benefits in terms of both economic (the use of such batteries is cheaper) and environmental (a form of recycling). Forms of energy storage have also been identified, dividing them into storage facilities:

- industrial – large capacities, collection of energy from renewable sources (e.g., photovoltaic farms),
- domestic (professional / amateur) – small capacity.

It was also pointed out that, in order to be approved for use, the batteries in question should meet the basic regulations of the law on electric batteries for vehicles (*Regulation No. 100 of the United Nations Economic Commission for Europe – Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train*) and energy storage (PN-EN IEC 62619:2023-02 – *Secondary cells and batteries containing alkaline or other non-acid electrolytes. Safety requirements for secondary lithium cells and batteries, for use in industrial applications*).

The lecture also answered in the affirmative the question of whether the regulations cover home energy storage, based on the provisions of the Act of 24 April 2009 on batteries and accumulators, which identifies the following in two places:

- article 6. 2) industrial cell, industrial battery - cell and battery that are intended exclusively for industrial, professional purposes or for use in electric vehicles, in particular, specified in Annex No. 1 to the Act,
- annex No. 1, item 8. Batteries and accumulators that are designed for use in conjunction with a solar cell plate, photogalvanic devices and other renewable energy devices.

This was followed by a presentation of the differences in the studies in the context of the documents cited earlier. The indicated differences are presented in the following table.

Table 5. Comparison of automotive battery tests

Regulation 100	PN-EN IEC 62619:2023-02
Vibration test	-
Test with rapid temperature changes and thermal cycle test	- (Propagation test)
Mechanical shocks	Drop test
Mechanical integrity	Impact test
Fire resistance	-
External short-circuit protection	External short-circuit protection
Overload protection	Overload protection
Over-discharge protection	Over-discharge protection
Protection against overheating	Protection against overheating
Overcurrent protection	BMS tests

Source: elaborated by mł. bryg. Wojciech Klapsa, M.Sc. Eng., material from the conference entitled "Fire safety of photovoltaic installations, energy storage, electric vehicles, their charging points, smart home solutions", CNBOP-PIB, Józefów 12.06.2024.

As an example, it was also identified that for batteries used in electric cars, a test with rapid temperature changes and thermal cycling tests are performed with exposure to 5 cycles at 60±2 °C for 6 h, -40±2 °C for 6 h, 20±10 °C for 24 h. For energy storage, on the other hand, an overheating protection test is performed using exposures: temperature 25±5 °C start, ramp-up 5±2 °C/min, temperature 85±5 °C for 3 h.

Later in the lecture, photographs of tests conducted for recycled cells were presented, describing how the test was conducted. The conducted tests included verifications of cells with both damaged and undamaged BMS/EMS. It was concluded that the primary and main risk to the cells would be smoke and the release of toxic gases rather than the fire itself.

Concluding, the advantages of the process in question are presented, identifying that recovered vehicle batteries can be used as energy storage in the home or business once they have been professionally adapted for this application, but the need to equip them with suitable housing, cooling systems, power distribution modules and other necessary components were highlighted. It was also found that appropriate acceptance tests should be performed to verify the correct adaptation process.

4.4. Discussion panel

Panel moderator: Jarosław Tępiński, Ph. D., Department of Studies and Scientific Projects, CNBOP-PIB.

The following persons participated in the discussion panel:

- st. bryg. w st. spocz. mgr inż. Krzysztof Biskup, President of the European Fire Safety Alliance.
- Mr Krzysztof Bukała, PIME Team Coordinator for the Safety of Energy Storage Facilities,
- Mr Krzysztof Kochanowski, Vice President of the PIME Management Board,
- mł. bryg. Wojciech Klapsa, M.Sc. Eng., Head of CNBOP-PIB's Laboratory of Combustion Processes and Explosions,
- Mr Grzegorz Kozioł, PV / BESS Solution Manager, Huawei Polska Sp. z o.o.,
- Mr Piotr Mortka, Eng., CNBOP-PIB's Laboratory of Fire Extinguishing Agents and Equipment,
- st. bryg. w st. spocz. Paweł Rochala,
- Mr Krzysztof Wincencik, PIME expert.

The panel covered fire safety issues, but the moderator divided the panel into individual modules to keep the discussion clear. The discussed modules included issues related to electric batteries, regulatory documents at European Union level on the use of batteries, photovoltaic modules, electric vehicle testing, home energy storage and, finally, the very important topic of electricity storage in the context of cyber security, lightning protection and surge protection. At the beginning of the panel before the discussion itself began, Mr Piotr Mortka was asked to present a video on methods of extinguishing lithium-ion batteries using quartz sand, a vermiculite-based sorbent and a dedicated extinguishing preparation. The session moderator also asks to characterise the course of the battery fire. Mr Mortka, based on tests carried out on batteries that could normally be used in homes or electric scooters, identified that such fires are characterised by high energy levels where, without appropriate personal protective equipment, it is difficult to even approach such a fire, so any extinguishing by a normal user has virtually no chance of success.

Moving on to the main part of the discussion, st. bryg. w st. spocz. Krzysztof Biskup, M.Sc. was asked whether the European Union institutions, which so often encourage the energy transition, see the need to ensure the safety of the installations that are necessary for this transition.

At the beginning of his speech, Mr. Krzysztof Biskup identified that in the European Fire Safety Plan, fire safety issues of the energy transition have been identified by experts as one of the biggest challenges we face not only in the European Union but in the world in general. By 2050, energy consumption is expected to increase by 50%, with households seeing an even greater increase. Considering also that around 20%÷30% of all causes of fires in private homes and dwellings are fires originating from electrical appliances and installations, while, based on analysis by the European Forum for Electrical Safety, more than half of homes and dwellings in the European Union have outdated electrical installations, we can see that the problem is quite serious. Given these figures and the fact that more and more equipment of not necessarily proven origin will be installed on current installations, the risk of fires is very high. After many years of discussions with the European Commission and other Institutions, it was persuaded to also include fire safety provisions in the Energy Performance of Buildings Directive (the so-called Building Directive), which was adopted in April 2024. The provisions introduced include an obligation for Member States to ensure that, when improving the energy performance of a building, the fire safety of the building is not impaired, and it has been identified that if additional electrical equipment is installed, such as heat pumps, photovoltaic panels, energy storage or charging infrastructure for electric cars, particular attention should be paid to fire risks. In addition, the European commission is required to develop and publish guidelines on the fire safety of covered garages and car parks by the end of 2025, particularly with regard to charging infrastructure for electric vehicles. An additional provision that has been successfully introduced in the Buildings Directive is the requirement for Member States to offer guidance and training provided to institutions in Member States that are responsible for implementing this Buildings Directive (it is recommended that this training also covers fire safety). It was also identified that Member States have two years (from 14 April 2024) to implement the Buildings Directive into national legislation.

Moving on to a module related to photovoltaics, mł. bryg. Wojciech Klapsa, M.Sc., was asked to give his opinion on the fire risk caused by installed photovoltaic modules, and whether these modules should be assessed for such risks. Starting with the issue of evaluation, it is Mr Klapsa's opinion that such verifications should be carried out as much as possible, especially as when these devices are imported, they often have certain documents and certifications that often do not specify any aspects in terms of fire safety. Therefore, it is also important to adequately educate users and installers on how to read and identify this information on the documents accompanying such products, so that informed decisions can be made that often affect the fire safety of the entire building. Two product standards were also cited: EN IEC 61730-1, which deals with the safety assessment of a photovoltaic module, and EN IEC 61730-2 for testing. These documents specify the testing as well as the evaluation methods for photovoltaic modules that can be used to confirm their safety. As far as the question of whether photovoltaic panels should be tested for flame spread is concerned, according to the harmonised standard EN IEC 61730-1, if the panels are part of a roof covering then they should be tested for flame spread, whereas in the case of panels that are mounted on the roof then it is recommended that such tests are carried out.

Mr Klapa was also asked to present his opinion on what tests should be completed at the approval stage for batteries from electric vehicles that are planned for use in domestic energy storage. In Mr Wojciech's opinion, the way the product is used would be important in this context, but these tests should at least be complemented by a check of the functionality of the applied safety features, taking into account two aspects, i.e. how strongly the energy storage facilities pose a risk to the environment and how the environment will affect the applied energy storage facilities. Finally, the question still arose as to whether it is safe to build traction battery energy storage on one's own? In this case, it was confirmed that it is not safe to do so and may even be a fire hazard.

Next, st. bryg. w st. spocz. Paweł Rochal was asked how he assesses the safety of installations made from traction batteries and how the use of such batteries in domestic energy storage in other countries. First, the American NFPA 855 standard was identified, which allows an electric car to be the energy storage for a single-family building on a common or emergency use basis. However, in order to use it in such an application, a number of conditions must be met, such as demonstrating compliance with the standard in question and carrying out the relevant tests. In terms of recycling batteries for use in domestic energy storage, it is important to realise that, from the get-go, such batteries will have a smaller range of applications. This is due to the fact that batteries from electric cars, which have a capacity of around 70%, are usually used, whereas according to Dutch guidelines, batteries for domestic use become waste as soon as their capacity falls below 30%. Therefore, in such cases, we really only have about 40% of the battery's efficiency to draw on. In addition, in other countries, such energy stores, depending on their application, have to undergo various tests, such as environmental tests, impact resistance, crush resistance, while in Poland they end up as waste, and we make a product out of this without implementing the relevant assessments and tests to confirm their safe use. Finally, there was a further question about the safety of using batteries in single-family homes (in this case, we are already talking about batteries that have not been developed from traction batteries). As part of the response, it was stated that we should assume that this is a product that is supposed to work faultlessly and safely over a certain period of time and not assume that it may be unsafe but we should reckon and be aware of the risks involved.

Another question was addressed to Mr Gregory Kozioł regarding what kind of tests are carried out on energy storage cells to check their safety. As an introduction, it was pointed out that there are many different types of tests related to the electrical handling of battery cells and independent tests related to mechanical handling. It was also pointed out that, regardless of the ongoing research in energy storage technology, we have different cell performance. Consequently, it is also important to select the right cell technology for the dedicated energy storage application. Coming directly back to security, the main thing to look out for is a reputable supplier and compatible solutions. The next question was on the safety features implemented in home energy storage. Based on our own experience, the implementation of solutions that prevent the spread of fire was identified. If we focus on domestic energy storage, self-extinguishing solutions based on phenolic resin melanin and potassium compounds are implemented in individual modules, where such a system is activated in an elevated temperature situation to prevent a fire from starting. Furthermore, one-way valves are also used to reduce pressure and access to the inside of the module is cut off.

In the ensuing discussion, the opinion of Mr Krzysztof Bukała was sought on the impact of the new battery module cooling solutions on reducing fire risk. The important role of structural safeguards such as valves or materials that limit temperature or fire emissions, electro-chemical separations of parts and active BMS (solutions to spread energy between cells) was highlighted. However, it was pointed out that the use of these safety features entails an increase in the cost of such a device, which may subsequently translate into the fact that solutions without adequate safety features will be used more often simply because of their lower price.

The next question on the cyber security of energy storage was addressed to Mr Krzysztof Kochanowski. At the beginning, it was identified that cyber security issues are extremely important because they largely regulate the flow of unproven technologies. The cybersecurity regulation introduces a strict approach to the use of certain protocols available only within the European Union, which largely excludes, among other things, the import of installations from outside the European Union. It is also important to note that a battery passport will be in effect starting in 2027. Such passports will include a QR code through which it will be possible to identify a lot of useful information such as what is in the battery, where it comes from, what it is made of, its capacity and power, what are the hazardous substances contained in the battery and what fire extinguishing agents can be used. As can be seen, battery passports will have a great deal of extremely useful information for the aware consumer, so it will be very important to develop user awareness so that they can have as much knowledge as possible to deliberately choose good and proven solutions and technologies.

Mr. Krzysztof Wincencik was then asked to give his opinion on whether lightning poses a threat to energy storage facilities and whether Polish normative requirements mandate the use of lightning protection in energy storage facilities. In terms of risk, it has been clearly identified that we have to reckon with the fact that the storm poses a threat to storage facilities, however, at the moment there is not enough data in Poland due to the relatively small number of installations and such events associated with them to determine how big this risk is. Nevertheless, based on data from abroad, it can be concluded that of course such events occur and lead to damage to energy storage facilities. In terms of regulations on the use of lightning protection, the use of such protection on building structures was discussed, but nevertheless it was identified that at the moment there are no indicated requirements in the regulations for energy storage facilities. Therefore, the use of such safeguards for the time being depends on the decision of the insurer, designer or owner. Finally, opinions were also solicited on whether additional lightning and overvoltage protection measures should be required for small-scale microgeneration energy storage facilities. As part of the response, it was stated that energy storage facilities up to 20 kWh are currently to be implemented not as part of a building permit but on a notification, which may involve moving such storage to an open space (outside the building). At this stage, it again comes down to the owner's awareness where quality clashes with the price of the installation, but it is nevertheless recommended that the use of appropriate safeguards be taken into account in such cases.

4.5. Conclusion and summary of the conference

The given presentations, results of research, projects, discussed theses and formulated conclusions in the area of the conference topics allow to conclude that its purpose was fulfilled. Based on the presentations, it can also be concluded that technological advances and increasingly ambitious climate targets adopted at the European and global level are influencing the dynamic development of renewable energy sources (RES) and electromobility. Electric vehicles, as well as renewable energy sources that are significantly dependent on weather conditions, use electrochemical batteries – so-called electric batteries – to store energy. The safe use of these batteries in appliances, electric vehicles and installations that use renewable energy sources requires maintaining their cells within certain voltage and temperature ranges. Loss of control over the cell's temperature rise can lead to an effect known as thermal runaway, a highly exothermic and self-sustaining process that results in a chain reaction by initiating a temperature rise in subsequent, often undamaged cells, which can eventually lead to a fire in the battery and the device it powers. A battery fire is characterized by high dynamics of development and intense smoke and fire gases. The recalled facts, results and information authorize the conclusion that these intensely developing technologies still require a lot of work and effort to secure them in the context of both prevention and the conduct of rescue and firefighting operations, taking into account their anticipated widespread use in the near future. In view of the above, it is extremely important to continue the ongoing work and research to develop appropriate methods and measures designed to effectively protect these installations and systems against fire. Therefore, it is equally important to improve and adapt the tactics of conducting rescue operations, including firefighting. Hence, new methods, solutions and proposals in the area of firefighting devices were presented at the conference, inter alia, in the presentation paper: *Selected methods of extinguishing electric car fires* where an extinguishing device was presented in the context of conducting rescue operations involving electric vehicles. Dedicated firefighting devices and techniques for their use in referencing vehicle battery fires or energy storage facilities are being worked on, researched, tested and implemented. Security effectiveness, safety and risks to rescuers remain a theme in this work. *Standard rules for dealing with incidents involving electric and hybrid cars* issued by the General Headquarters of the State Fire Service in May 2023 currently do not provide for interference with the battery housing and do not provide for the possibility of using this method to extinguish such fires. However, the work, projects and studies undertaken in this area provide new knowledge and some further approximations, among which the position of battery manufacturers, who express the view that they cannot take responsibility for interference with battery design in various states of operation, cannot escape attention. Tests on the feasibility of using extinguishing lances to extinguish electric vehicles and, in particular, to extinguish batteries during thermal runaway were carried out, among other things, as part of the BRAFA project in Austria. For this firefighting test, a 1-meter-long stainless steel firefighting lance with an insulated (up to 1,000 volts) handle and "Storz D" connector was used. A separate holding bar was available as an accessory, as an extension of the arm. Among the conclusions of this research were the following: The introduction of the lance has been difficult and shows that practice, experience and dedicated knowledge of how to operate and the dangers of using the lance are necessary. This is especially important when the lance is used in battery areas. The lance was held by a firefighter and he had to correct its position while driving it into the battery. During this activity, the firefighter touched the uninsulated striker plate and received a brief electric shock that caused no further effects or injuries. After the lance was properly driven in, the fire was quickly brought under control and completely extinguished. About 4 minutes later, the lance was removed and the battery showed no further external response. A later thrust of a firefighting lance into this battery at another location again resulted in a violent reaction. It concludes that the lance makes it possible to effectively extinguish fires, but its use requires experience, skill in its use and comprehensive knowledge of battery construction, how it works and the dangers to rescuers when interfering with its design. Qualifications and competencies backed by training and skills improvement are prerequisites for use in rescue operations by the fire department. More information on the results and conclusions of this study can be found in the project report: BRAFA Brandauswirkungen von Fahrzeugen mit alternativen Antriebssystemen. The project was implemented from 2019 to 2021. Detailed information is available at: https://www.itna.tugraz.at/forschung/bereiche/vuu/projektbeispiele/brafa.html

QR code:

Submitting the above report, the organizer of the conference, addressing thanks to its co-organizers and participants, would like to extend an invitation and express the hope that the next undertakings under CNBOP-PIB initiatives entitled: *Bezpieczeństwo Nowych Technologii* (*Safety of New Technologies*) will meet with as much interest, lively discussion, as well as constructive and practical conclusions as this year's BNT II conference.

Access to the conference videos and teaching materials will be made available on CNBOP-PIB website at https://www.cnbop.pl/.

Chairman of the Scientific Committee of the Conference

st. bryg. Jacek Zboina, D.Sc., Ph.D. Eng.