BEREDSKABS STYRELSEN

Theme booklet

Response to fires in electric and hybrid cars

Theme booklet: Action in case of fire in electric and hybrid cars

Cover photo: Bjørn Nielsen/www.bpln.dk

Contents

About the Emergency Management Agency's learning materials

Textbook
A textbook contains an in-depth professional review of a subject area in rescue preparedness. The textbook is aimed at anyone who needs a thorough knowledge of the subject.

Theme booklet
A theme booklet is a supplement to other teaching and learning materials. The focus in the book is on one or more subject areas. As a rule, a theme booklet addresses a specific subject group, e.g. technical managers or investment managers.

Method booklet
The method booklet has a current focus on, we have updated it within a subject area in rescue preparedness. The method booklet is aimed at e.g. firefighters and team leaders who need up-to-date knowledge of the current situation on a daily basis
subject.

Student
booklets Student booklets are locally based publications produced according to guidelines from the Swedish Emergency Management Agency's Center for Education. It often contains locally rooted cases. Student booklets are aimed at the firefighter level and are a supplement to other learning materials.

Teaching video Teaching
videos are shorter or longer videos that review one or more academically defined areas within the various areas of action. The videos can be viewed by all targets

groups.

Preface

In connection with the green transition, the Danish emergency services want the best possible handling within their own sector of the challenges associated with an increased use of lithium ion batteries (Li-ion) as propellant in various forms of transport, including electric and hybrid vehicles.

In December 2020, a political agreement was reached on a green transformation of road transport, which is estimated to lead to up to one million zero- and low-emission cars in 2030 in Denmark.
According to Statistics Denmark, electric and hybrid cars, measured on an annual basis, make up an increasing share of new car sales.

This development is expected to continue further in the coming years, together with an increase in the efforts of the rescue services, both in terms of passenger electric cars, but also for other means of transport, such as buses and ferries.

On that basis, the rescue services will often be faced with having to be deployed to these new types of efforts. In the spring of 2021, the Danish Emergency Management Agency published a new thematic booklet on the emergency response's efforts in the event of a fire in electric and hybrid cars.

Even before publication, however, it was clear that the theme booklet would not stand alone, partly because the use of Li-ion batteries is constantly developing with, among other things, larger battery packs, partly because firefighting only forms part of the efforts of the rescue services in connection with electric and hybrid cars.

The theme booklet has been created in collaboration with Danske Beredskaber. A special thank you must go to North Jutland Emergency Services, Hovedstadens Emergency Services and East Emergency Services for their contribution to the work.

The theme booklet replaces the publication 'Fire response in electric and hybrid cars' from March 2021.

The National Emergency Management Agency January 2023

About the theme booklets

The development of energy-efficient Li-ion battery packs is progressing rapidly. In several areas within transport, a general increase in the use of battery packs with a high voltage, which i.a. for usability reasons are made more and more compact.

Today, e.g. several passenger electric cars with battery packs of up to 1000 V. The term electric car will most often cover both pure electric cars, hybrid electric cars and plug-in hybrid electric cars of the passenger vehicle class.

The themed booklets 'Fire response in electric and hybrid cars' and 'Special conditions for rescue in electric and hybrid cars' should be read in conjunction. The two booklets describe the safety and health conditions as well as the intervention tactics that should be observed in the event of traffic accidents or fires where an electric car has been involved.

An extinguishing or rescue effort for a car accident with an electric car that touches the battery package, can be difficult for the rescue services and other actors at ska to handle instead.

This is due, among other things, to the high voltage in voltage-carrying cables and in the vehicles' Li-ion batteries, where there is a significantly higher voltage than in the cars' ordinary 12 V batteries.

In a damaged electric car, it can also be kom necessary to gain correct access to the live parts and thereby ensure that cables and wires are de-energized. A fire in the high-voltage battery or the risk of fire can further complicate the effort.

Attention is drawn to the fact that the theme booklet deals with electric cars with high-voltage batteries up to 1000 V.

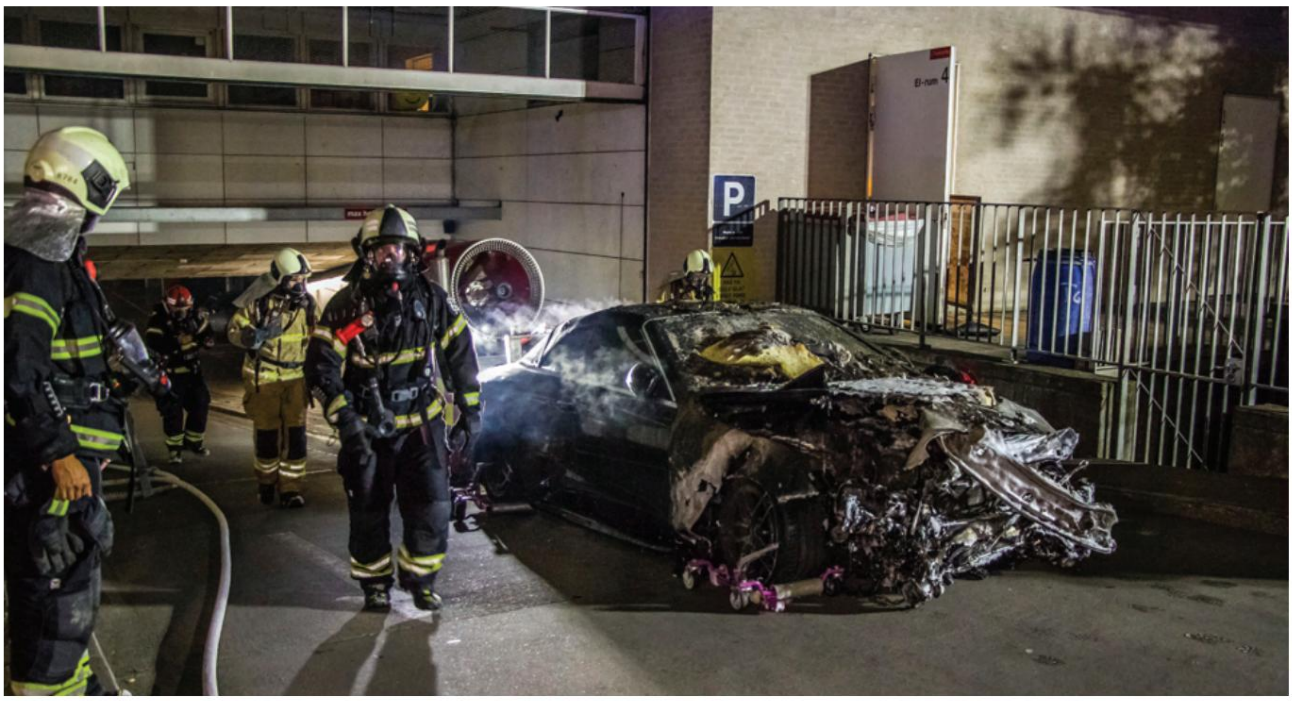


Photo: Bjørn Nielsen/ www.bpln.dk

Structure and use of the theme booklets

The target group is primarily the technical management of the municipal rescue services, while some will be relevant for the individual firefighter. In the individual sections, there are a number of fact boxes, which are important reading for the deployed personnel.

The starting point is some general principles for response tactics and cooperation with other emergency response actors in the response area.
The descriptions of the possible tasks of other actors at the scene of the accident (the police, the emergency services and the transporter) are only input for inspiration for a task solution, which is not necessarily covered by the emergency response act.
Any implementation falls under the responsibility of the relevant authority at the site of the damage.

The structure of the theme booklets is built on the basis of an operative approach, where the sections gradually provide the rescue services with such knowledge that a proper investment in electric cars can be carried out in terms of safety, health and the working environment. The sections cannot stand alone, as they are based on some general principles for effort management, etc.

The theme booklets are based on national and international knowledge about electric cars as well as experiences from the municipal rescue services. They build on existing learning materials, but with updated knowledge of special risks and intervention tactics, as previously published material only describes conditions surrounding electric and hybrid cars to a limited extent.

The conditions described can be used in the demonstration and training of operational competences in the rescue service in order to raise awareness of the potential risks.

The themed booklets describe the response team's options for action and general considerations about the working environment and protective equipment that the technical manager should observe. In general, the theme booklets illuminate a number of points of attention on an overall level. Depending on the situation, the technical management is handled by the team leader or a task leader.

Individual sections can be used in whole or in part as a reference work in relation to operational tactical priorities during the first operation. The material is also intended as inspiration for a Celtic rescue service's own operative teams, including the content of the action cards.

Finally, there are a number of appendices with various background knowledge, such as characteristics of electric cars, use of tools and protective equipment, etc.

Information from the alarm, security center and AMK

For the efforts of the rescue services, it is important information that the accident involves an electric car. All stages before the arrival of the rescue services - from the alarm and duty center, the Emergency Medical Coordination (AMK) and the first patrol car can contribute to this.

Relevant information can come from those first present at the scene of the accident. It can be e.g. be the police, emergency services, passengers in the electric car or other people at the scene of the accident who can contribute to an early identification of whether it is an electric car.

Alternatively, as early as possible, regive information should be given to the first units that there is an accident involving an electric car. This gives the crew the opportunity to take the right measures, including calling in additional units and special equipment.

A question guide has been drawn up, which can be used in the event of an alarm and by the first vehicles at the scene of the accident (see 'Action card – Ask eguide for the control centre, AMK and first vehicle).

There may also be a need to call the emergency services for traffic accidents, where they are not normally called because of the risk an electric car can cause. There may also be situations where the police or the emergency services are the first to arrive at the scene of the accident. Here, their safety is taken care of, as well as the need for a joint approach to handling the inmates. Separate annexes and action cards have been prepared for inspiration.

Technical help
Via the website "motorregister.skat.dk" under the "Find vehicle" tab, information about a vehicle's fuel can be obtained by entering the registration number. However, there are exceptions to this, as registration numbers for special vehicles with e.g. police, defense and emergency services are not publicly available.

There are a number of software solutions and information systems which can advantageously be obtained in advance. The systems have in common, that they can best be used via a tablet or corresponding unit. This can be done both online and offline.

The joint European organization for the safety classification of vehicles (Euro NCAP) has, in collaboration with CTIF (International Technical Committee for Fire Prevention and Extinguishing), published an App – Euro Rescue1.

It can be downloaded in the App Store and Google Play as a freeware. The program contains all approved European car brands and describes the construction of the vehicle, including what potential hazards there may be.

Other systems work with a subscription scheme, which gives access to information about the vehicle's data, location of central components, etc.

Summary of general conditions

Increased attention When handling traffic-damaged electric cars, including freeing people and extinguishing fires, the crew should be trained in a number of special aspects of the effort. Eg. Some electric cars have high voltage batteries up to 1000 V.

Depending on the situation, the technical management is handled by the team leader or a task leader.
Often, an effort with electric cars will entail extra tasks and a number of risks, which suggests that there is a greater need for an effort leader to supervise or assist the technical management.

The manufacturer's own instructions (rescue sheets) are followed as far as possible, with the caveat that the electric car will most often be damaged.

In addition to the high-voltage battery, the electric car itself will be able to have high voltage in e.g. cables which have not been de-energized. There is also a risk of that the high-voltage battery may catch fire. Both parts should be part of the risk assessment.

- The location of the main switch is identified and it is disconnected as far as possible.
  In a damaged electric car, however, it can be complicated to gain correct access to the live parts and thereby ensure that cables and wires are de-energized.

- It is recommended that safety hoses with a total water output of min. 400 l/min – also without visible smoke from high
  volt battery.

- Wind direction and the safety of persons outside the danger zone are taken into account due to the risk of fire and the development of smoke and dangerous gases from the high-voltage battery.

A fire in an electric car can quickly develop violently Photo: Bjørn Nielsen/ www.bpln.dk

Tools and equipment
Tools used when cutting or touching the electric car's parts should be approved for 1000 V. Safety mats or safety covers can be used.

The technical manager should set aside a mark for cuts in the bodywork based on an assessment of the placement of cables (coloured orange) with high voltage, if cuts are made in the electric car.

Thermal cameras can be used to monitor the battery's temperature, which can indicate the development of a fire in the Li-ion battery.

Personal safety Protective
clothing and protective equipment (PPE – Personal Protective Equipment) should be well known for work up to 1000 V when handling, touching or cutting the electric car's bodywork or cables. Rubber safety gloves can be used with advantage.

Due to the risk of fire, the smoke diver's hole should prepare for deployment with full respiratory protection, which is provided in case of smoke, risk of fire in the high-voltage battery or suspected development of dangerous gases.

You should work with a safety distance during extinguishing work due to the risk of electricity. There should be increased attention in efforts where both water and voltage are handled
the electric car.

Consideration should be given to the fact that water - such as rain/snow and extinguishing water - increases conductivity significantly. The risk of arcing should be considered when selecting PPE and proper tools and equipment.

Acting at the scene of the
accident Several authorities are part of the effort in connection with traffic accidents, if there is a danger to people or animals, and the rescue services have been called.

The deployed forces should have information as early as possible that an electric car is involved in the accident.

- The site of injury should be marked as a workplace with high voltage as early as possible at a distance of min. 1 m from the electric car. This can be done by blocking off with black/ yellow mine strip and visible marking with danger signs on and around the elbi
only.

- If there is a development of smoke or gas from the high-voltage battery, it is ensured by blocking that no one stays in the smoke plume except for personnel wearing full respiratory protection.

The police and the health emergency services can, if they arrive at the scene of the accident before the emergency services, assist with the above.

In an emergency, an emergency evacuation of injured persons who cannot get out of the vehicle themselves can be carried out, if contact with damaged parts of cables and bodywork can be avoided.

Two people should be present when working with voltage, so that a shoulder push can be carried out if necessary.

Use of equipment and protective equipment

A rescue effort or a traffic accident with an electric car entails special risks compared to a similar effort in a conventional petrol or diesel-powered passenger car.

In relation to the use of equipment and protective equipment, it is important that the crew is instructed and trained in using this and that they are aware of the special risks before they are deployed.

In the event of a rescue operation, electrical components cover both obvious electrical components, such as cables, wires and the high-voltage battery itself, to components that are assessed as potentially conducting voltage - especially metal parts, bodywork, chassis, vans, etc.

EN 50110-1 states that screens, barriers, enclosures or insulating coverings of electrical parts can be used with advantage when working near live parts.

Personal protective equipment (PPE – Personal Protective Equipment) together with electrically insulating covering and insulated tools are essential measures to address risks when working with electric cars under voltage.

Personal protective equipment, such as protective glasses and rubber gloves, should be used in case of direct or risk of contact with the electrical and voltage-conducting components of the electric car.

In principle, electric cars should not be touched without the correct PPE, including safety gloves approved for 1000 V. The following list indicates European standards for different types of personal protective equipment (PPE), where the latest editions of these should be used:

Subject	Personal protective equipment (PPE)
Main	Suitable home - EN 50365:2003
Eyes	Suitable visor or glasses - EN 166:2002
Body	Emergency suit - EN 61482-1 and 2
Feet/Body	ESD approved footwear – EN 15090:2012, type F2A
Hands	Suitable gloves EN 60903:2004
Other coverage	"Rubber mats" DIN VDE 0680/1 IN 61111 , IN 61112

Consideration should be given to the fact that water – such as rain/snow and extinguishing water – significantly increases conductivity. The risk of arcing should be considered when selecting PPE and proper tools and equipment.

You can read more about requirements for PPE and the use of mist in appendix 3 on 'Tools, equipment and protective equipment'.

Assessment of voltage in the electric car In the specific effort, it will be the effort leader or the team leader who assesses whether the electric car and not least the high-voltage battery is sufficiently intact for it to be secured, i.e. be de-energized, cf. the manufacturer's description or rescue sheets.

However, the high-voltage battery will not be de-energized. But disconnecting the main switch will result in no voltage coming from the battery.

In practice, the mere fact that the electric car has been in an accident (where the emergency services have been called) will make it difficult to assess whether the high-voltage battery is still intact.

If there is doubt about this, it should be assumed as a starting point that no safety functions in the electric car work normally, and that it is therefore assumed that 'all' parts of the electric car can potentially be energized.

The assumption that there may be voltage on the electric car means that, according to EN 50110-1, suitable and sufficient personal protective equipment (PPE) should be used for work under voltage. PPE, insulated tools and electrically insulating covering of conductive materials minimize the possibility of contact in the areas of the electric car where there may be a risk of contact during work.

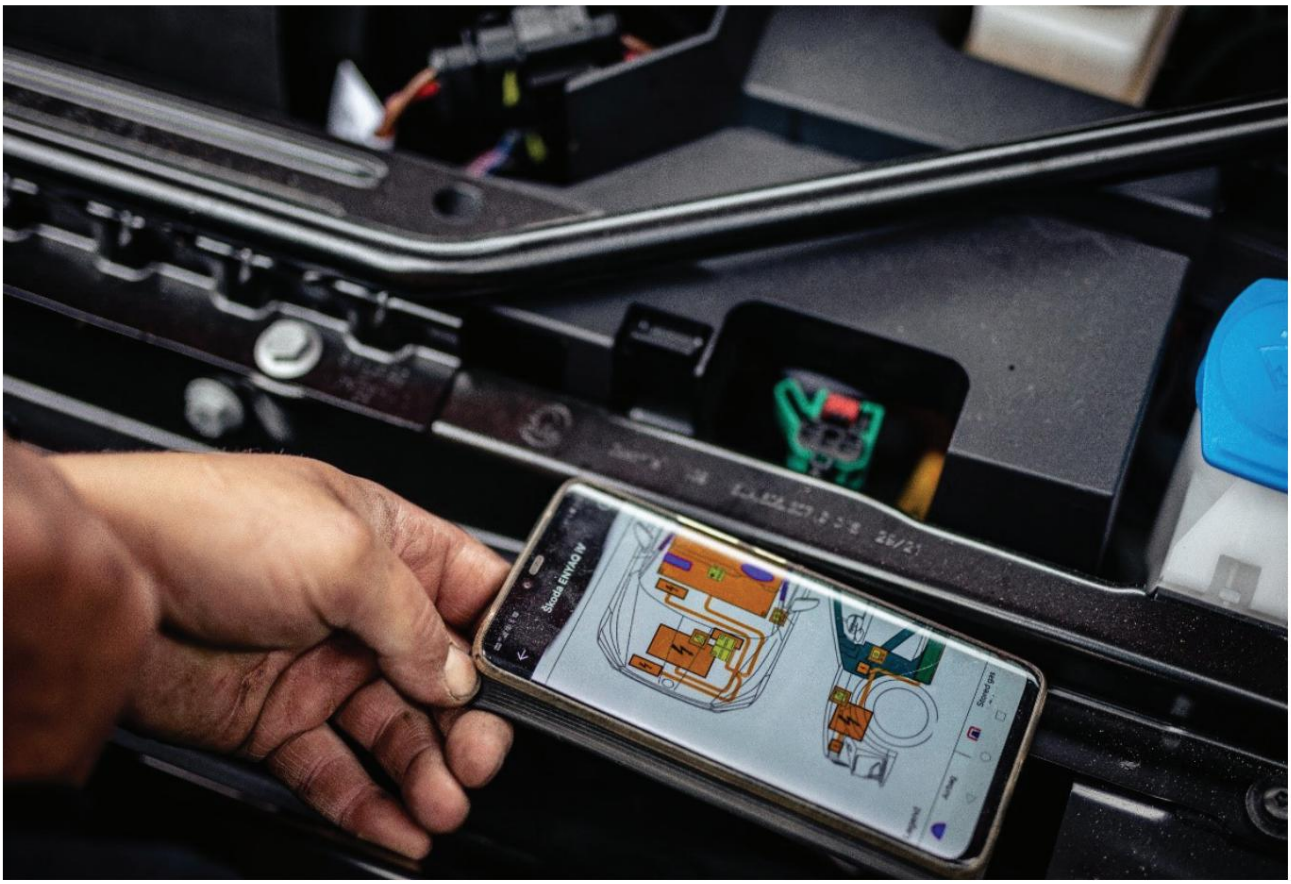
In general, it would not make sense to carry out a control measurement of voltage in the electric car in an investment context. Components with voltage will not necessarily be visible.
They can also be damaged, so that voltage can be conducted via any randomly conducting material in the electric car, simply by small mechanical impacts on the body etc.

The rescue service is not expected to be able to carry out this measurement, as it will require external competences (e.g. an electrician) to assess the possibility of use and carry out the correct type of measurement in relation to the voltage level.

The emergency crew should pay extra attention to whether the high-voltage battery starts emitting fumes, sounds, sparks, etc. This may indicate that a heat effect in the high-voltage battery is developing. In addition, as with all work with cars, attention should be paid to the regular 12 V battery.

Internationally, there are e.g. rescue sheets and other information from manufacturers and rescue services that can contribute to the assessment of voltage in the electric car. However, it is important to be aware that they do not necessarily cover all situations where an electric car has an accident or catches fire.

It also requires that the team leader and the crew have access to rescue sheets on the effort itself. The crew should have trained in the use of this type of information in advance, so that it can best be used in a situation where the electric car is expected to be deformed.



Rescue sheets indicate the structure of the electric car

Photo: The National Emergency Management Agency

Tools and marking In electric cars, marking/signage is used by the manufacturer, which warns the crew and other emergency responders against the danger of electric shock. This marking/ signage is visible in the places in the car where there is a risk of coming into contact with the high voltages from the high-voltage battery.

Orange colored cables will be high voltage. It is recommended that all contact or work with the electrical components – even without visible damage – be carried out using insulated tools approved for 1000 V, as well as the use of approved safety gloves and other PPE.

In an effort with electric cars, the work area should be blocked off and separated against the risk of high voltage. As a general rule, this will correspond to a cordon off of a danger area with a min. distance of 1 m to the electric car. Blocking can be done physically with e.g. black/ yellow mine strip or marking in the form of fire hoses and a statement of the danger area.

A further visibility of the risk of contact with voltage in and around the electric car can be made by marking the electric car with stickers or magnets with a danger sign for high voltage.

Markings with mine strips and danger signs are maintained at the end of the effort, when the crew is released from the scene of the accident and delivers the crashed electric car to other actors such as the police and transporter.

When handing over, information about the condition of the electric car, the status of the switching equipment, including the charging cable, disconnection of the main switch, ignition and any safety devices, should be clearly communicated to the new person responsible at the scene of the accident, corresponding to the instructions in EN 50110-1 for communication when working on electrical installations .

See possibly more in Appendix 6: Handing over and moving a damaged electric car.

IMPORTANT REGARDING VOLTAGE ON THE ELECTRIC CAR

- Pay attention to the labeling of the vehicle for components with high voltage.
- The high-voltage battery cannot be de-energized.
- Avoid touching or cutting orange cables.
- Due to visible and hidden damage in the electric car, a control measurement of voltage will be required in the electric car could not be done in practice.
- Possibility of using step mats, safety cover etc.
- Tools, instruments and accessories should meet DS/EN 61010-1 or equivalent.
- Use of personal protective equipment (PPE) approved for 1000 V.
- The risk of arcing should be taken into account when choosing PPE, insulated tools and equipment.
- The workplace (danger area) where the electric car is located is demarcated and clearly marked at a distance of min. 1 m from the electric car.
- Handing over to the police or carrier when the scene of the accident is released.

Special conditions for rescue in electric and hybrid cars

addition to th , with high voltage, another and more vio ourse can develop.

It is important that the deployed personnel take these risks into account, both in the tactical prioritization of the effort, as well as by using the right material, equipment and personal protective equipment (PPE), and that they can handle risks around the high-voltage batteries (up to 1000 V).

The individual manufacturer's own response instructions (rescue sheets) are followed as far as possible2.

There is a focus on fire in electric cars or situations where there is a risk that a fire could occur in the electric car's high-voltage battery. The theme booklet is based on the existing knowledge and experience, i.a. from the efforts of the rescue services in the event of a fire in electric cars or the Li-ion battery with a location in the open or in a building.

Handling a fire in an electric car, where the high-voltage battery burns or is at risk of starting to burn, will often place different demands on the technical management than in a similar effort in a conventional passenger car.

The theme booklet illuminates the operational tactical possibilities and can thereby support the operations manager's and team manager's handling of this type of operation - regardless of where the electric car is located. Both when it comes to an offensive effort, Possibly. with acute danger to life or a defensive effort, which allows for better 'planning' of the effort, as both types will contribute to a number of special conditions in relation to a safe working environment.

It is necessary that the operational forces are familiar with the special characteristics and risk points of electric cars, so that a proper response can be carried out, based on the assessment of the possibility of ventilation of fire smoke, response time and and passing on informa end of the ef

As a supplement to the theme booklet, knowledge can be usefully sought in the Emergency Management Agency's booklet on 'Special conditions for rescue in electric and hybrid cars', which includes describes special risks when freeing people stuck in electric cars.

Risk of fire A fire can occur spontaneously in the high-voltage battery due to a number of defects. The risk of damage to battery cells such as blows, shocks and penetration of the battery's membranes as well as overheating of the battery pack can lead to sudden and violent fires.

The risk of fire is also present - even if there is no identification that a fire is building up in the battery. The fire can break out several hours and days after the incident has occurred.

Due to the response time of the rescue services, it will often be an advanced fire, which can make it difficult to assess the cause of the fire. Identification of whether it is a fire in the electric car itself or a fire in the battery however, should be done as early as possible. It is important to be aware that an initially simple fire in an electric car can quickly change if it reaches the battery.

If it is an effort with a need for freeing trapped people or handling the electric car, where contact cannot be avoided, you can read more about priorities, protective equipment and the five phases of the release in the themed booklet 'Special conditions for rescue in electric and hybrid cars' in the section on response tactics and technical management.

Special circumstances in the course of a fire Fire, smoke and the damage/ deformations that can be clearly seen on the electric car help to indicate a possible risk of a damaged high-voltage battery. It can be heat generation, 'thermal runaway', sounds, smoke generation, unnatural smells or liquid running out of the battery.

Damage to the battery such as blows, shocks and punctures of the battery's membranes as well as overheating of the battery can cause a risk of violent fires. The causes of a fire in an electric car's high-voltage battery can generally be divided into three types of conditions.

- Indirect impact: Heat impact which affects the battery from the outside, for example overheating when an electric car is set on fire or a fire in a building where an electric car is parked.

- Internal impact: Electrical short circuit, where an internal error occurs in the battery's cells, e.g. due to an overcharge.
- Direct impact: Mechanical deformation (bent, penetrated, crushed etc.), where e.g. a severe traffic accident causes a defect in the battery, which causes a short-circuit resulting in a fire as well as the release of dangerous gases etc.

A fire sequence in the event of a fire in a high-voltage battery develops quickly. Most often there is a noise from the battery. Next, the battery develops smoke, and eventually burns, possibly with smaller jet flames or less explosive discharges, in step with the 'ignition' of the units in the battery pack.

Extinguishing attempts with suffocating extinguishing agents have proven ineffective and futile, as Li ion batteries burn by a self-oxidizing process. The process can 'feed' itself without the introduction of oxygen from the outside. This can cause severe temperature increases of up to approx. 1,000o.

If effective cooling of the overheated battery is not initiated, the battery fire will continue until there is no more combustible material present. This process typically lasts from 2 hours to up to a day.

RISKS WHEN COOLING THE HIGH VOLTAGE BATTERY

- Fire in Li-ion can emit especially HF gas in 'peaks' with high concentrations. Discharge of gas from the Li-ion battery can be whitish, thick and smelly and settle along the ground, but also appear as thick fire smoke.
- It is important that the battery is located for effective cooling/extinguishing of flames. Placing the high-voltage battery in the bottom of the car, luggage compartment, under the bonnet or in the middle of the car between the front seats.
- Attention to re-ignition of the battery after switching off.

capacity, but t ve a voltage from 400 up to 1000 V. High-v tteries based on Li-ion ology ha rgy stored using chemicals. iments h n that Li-ion batteries in themselves are no more fire-hazardous than other batteries, provided the batteries are not damaged or charged with well-known equipment.

If the task leader or team leader assesses that there is a risk of a fire starting before the rescue effort is completed, special considerations should be taken. A simple fire sequence in an electric car's high-voltage battery can quickly change very violently, and the fire smoke from a high-voltage battery can create large amounts of e.g. HF gas.

Location of the high-voltage battery will typically be at the bottom of the car in newer 'pure' electric cars, which depend on a large battery. But the batteries can also be located in the trunk, under the bonnet or in the middle of the car between the seats. Cooling should be as direct to the high voltage battery as possible. Coverings can possibly removed to achieve a better effect.

When a fire develops in the electric car, it is taken into account that persons without respiratory protection are not exposed to fire smoke, gas or stay in the plume of smoke.

In the event of a fire developing in the electric car or suspicion of it, full respiratory protection is used to avoid exposure to fire smoke. If there is a fire in closed rooms without possible ventilation, it can be a challenge for the response time.

The purpose of installing fire hoses with a high water capacity is to provide protection against people in the danger area (protection) – and to cool or, if possible, limit fire development to the surrounding environment and other vehicles (extinguishing). It is therefore recommended that it is laid out

Whether a fire in the b e extinguishe cooled sufficiently with 4 assessment, which should re tactics so that unnecessary amounts of extinguishing water are not used.

Work is carried out with a safety distance corresponding to water output, beam pattern and extinguishing agent. The following are recommended distances for extinguishing electrical fires (c-tap pipe with pressure of 5 bar - DIN VDE 0132). The safety distance can be projected to the safety hose.

- Unknown low voltage <1000 V, 200 l/min: – diffuse beam - min 1 m; total beam - min 5 m
- Unknown high voltage >1000 V, 200 l/min: – diffuse beam - min 5 m; total beam - min 10 m

There are four safety factors in the course of a fire in electric cars, which the response team should be aware of:

- **Gases/vapours/fumes:** Some of the chemicals in a Li-ion battery (often volatile organic solvents) can develop flammable vapors with a low flash point if they leak. •For example, HF gas can be developed, which is not flammable, but is a poisonous and colorless gas with a pungent smell.

  The gas is easily soluble in water and can end up in the extinguishing water as hydrofluoric acid. Hydrofluoric acid is a colorless solution that can cause corrosive damage on contact.

- **'Thermal runaway':** When exposed to high temperatures, the Li-ion battery can enter a critical state that starts an internal self-reinforcing decomposition process ('thermal runaway'), which ends with each battery cell heating up strongly from the inside when it has stored chemical energy is released.

•'Thermal runaway' can only be slowed down by cooling the battery's cells, which is made more difficult by the fact that, for safety reasons, the batteries are well wrapped in protective measures and placed in safe or hidden places in the car.

•There may be a risk of pressure bursting a closed battery case regardless of battery type4.

- **Reignition of the battery:** For the safety of the crew in the event of an accident with a Li-ion battery, the task leader/team leader should be aware that a fire can spontaneously occur in the battery due to defects. •This also even if there has previously been no identification of a fire is under development. These conditions can occur up to several hours and days after the incident has occurred. Disclosure of information to carrier etc. is important.

- **Stranded energy:** There may be stranded energy left in the battery cells that have not caught fire or are otherwise affected bored
  - •These constitute a major risk for the response team when the electric car is handled during or after the response. Stranded energy cannot be 'drained' by an electric car.
  - •In addition, attention should be paid to the fact that the high-voltage battery cannot be de-energized.

During a fire in a Tesla while charging on 1 January 2016 in Brokelandsheia in Norway, a fire broke out in the electric car's high-voltage battery. The fire lasted 23 hours and the car ended up being completely burnt out. After the extinguishing effort was over, there was still 400 V high voltage for approx. ¼ of the battery.
Photo: Østre Agder Fire Service

Experiments with 'thermal runaway'
'Thermal runaway' is a description of a temperature rise in the high-voltage battery, where the heat in the internal components causes pressure on the battery cells. It initiates a process of acceleration of increased temperature and release of additional energy. The problem of 'thermal runaway' can occur if the battery cells or the thin partition/membrane that keeps the components in the battery pack apart are damaged or punctured in some other way, which can cause a short circuit.

It is important to be aware of damage and deformations on the damaged electric car makes the risk of developing 'thermal runaway' and fire in the high-voltage battery more likely. The risk of 'thermal runaway' is seen when the critical temperature (down to around 90o) is exceeded in the high-voltage battery.

It can be difficult to identify whether there is a development of heat and thus a risk of fire. Identification of this, e.g. in the event of over-wake of a thermal camera, however, should be done as early as possible. Other signs of an incipient fire in the battery can be fumes, smoke, noise etc. from the high-voltage battery.

QR kode til video om 'thermal runaway'

QR code for video with 'thermal runaway' incident

In 2016, two full-scale trials with electric cars and fire were carried out in Norway. An experimental report 'Full-scale fire test of an electric car'5 has been prepared which, among other things, contains a description of the course of the fire, including temperature development etc. The first test described in the test report describes a 'thermal runaway', triggered by a collision from behind by the electric car.
The speed corresponds to a collision with 70 km/h.

The Swedish research institute RISE has published a number of reports on Li-ion batteries and electric cars6

The American National Transportation Safety Board (NTSB) has published an investigation report 'Safety Risks to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles'7 based on three accidents with electric vehicles that have subsequently triggered the efforts of the rescue services. The report conclusions describe the same type of modus operandi in accidents with electric cars that lead to 'thermal runaway'. In the video, the NTSB explains about the incidents and what you should be particularly aware of if. with the effort.

Video on the NTSB's report on electric car fire safety.

The main switch

High-voltage batteries in an electric car have high electrical direct current and contain a significantly greater amount of energy than the ordinary 12 V batteries in a passenger car with a petrol or diesel engine.

When working in an electric car, it is essential for the crew to disconnect the main switch, if this has not happened, and thus de-energize all the electric car's systems. The main switch is located differently, depending on the brand or model.

Electric cars typically have one or more 12 V batteries, which are disconnected in the usual way. There will continue to be voltage on the 12 V part until one of the battery poles is dismantled in the 'normal' way. Please note that the battery pack itself (Li-ion) cannot be de-energized.

A distinction is made between securing ordinary 12 V batteries and high voltage battery.

Please note that the high-voltage battery itself cannot be de-energized.

If an electric car has been involved in a traffic accident, and it has subsequently caught fire, the main switch will very likely be disconnected. This means that there will be no voltage in the electric car's systems, except in the high-voltage battery itself.

It should be noted that if the battery pack is mechanically deformed, parts of the electric car's chassis etc. be tense.

There are a number of indicators that the main switch may have been disconnected in connection with a traffic accident. These can be:

- High energy accident, without the items below
- Deployed airbags or seat belt tensioners
- Rear or frontal collision
- Side collision

Electric cars during charging If a non-intact electric car is connected to charging, there will be an increased risk for people who come into direct contact with the electric car. The reason for this is that a voltage path can be created through the earth conductor, which means that the person can get a shock when contacting one pole.

The electric car is relatively safer if the ground connection through the charging cable is removed - you then have to touch two parts of the car to be able to get voltage through it. However, most electric cars lock the plug when the cable is connected, which means that it is difficult to get the cable out. Ordinary release tools will typically not be good known according to EN IEC 60900, which is prescribed when working under voltage.

If the car is in an accident, however, all normal safety measures in the car must be assumed not to work. The high voltage battery terminals may be directly exposed or electrically connected to chassis parts that are normally insulated.

Correct personal protective equipment (PPE) should therefore be used, so that when switching off or releasing, you cannot come into (electrical) contact with several different conductive parts of the car at the same time. Foot mats and safety covers can be used with advantage.

+

SAFETY NON-INTACT ELECTRIC CARS

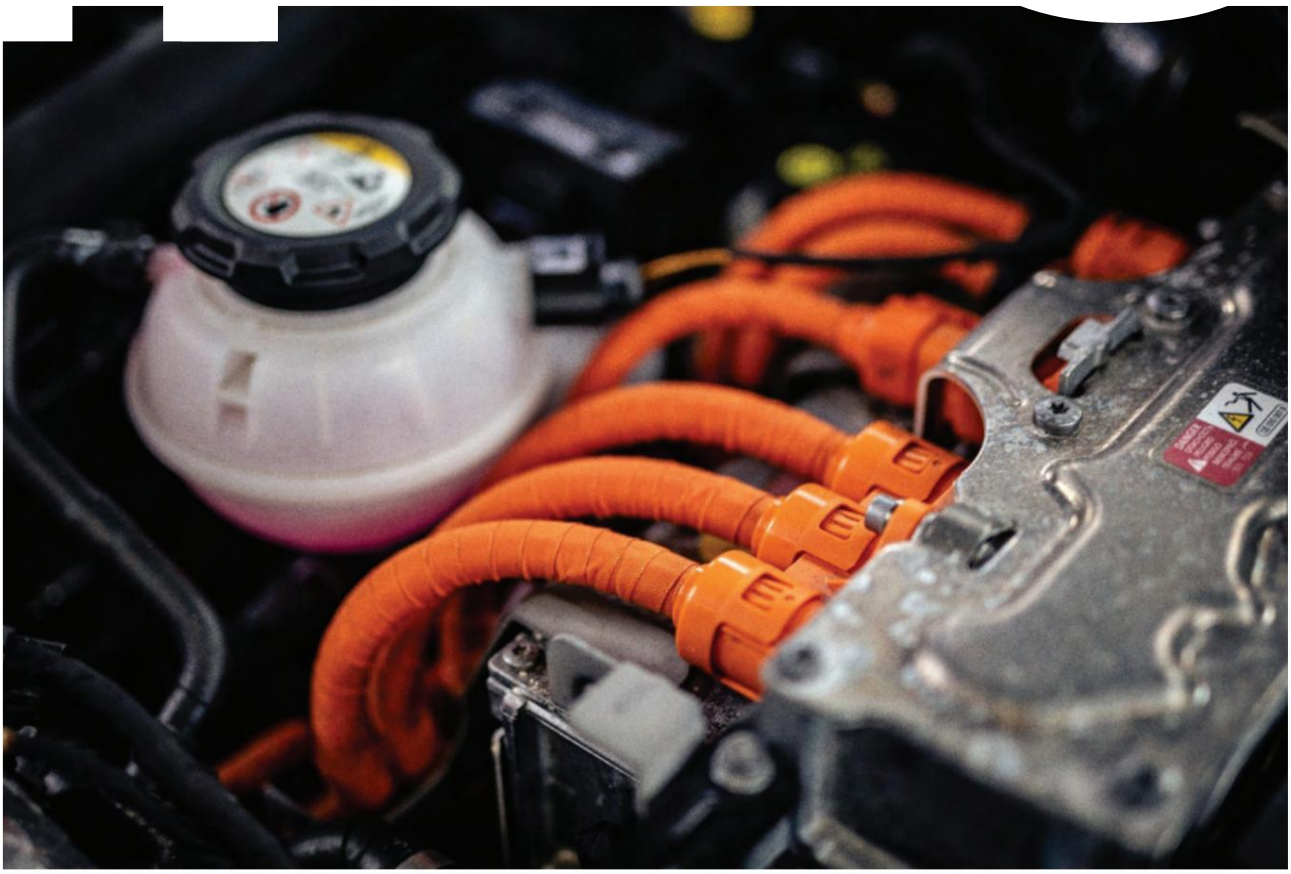
The following measures are particularly important to achieve the best safety when handling a non-intact or burning electric car:

- If the electric car is connected with a charging cable to a charging stand, this should, if possible, be removed or disconnected completely before any further work is carried out directly on the electric car, for example by disconnecting the power supply to the cable by disconnecting the group in the HPFI/electrical panel.
- Insulated mats can be used, the ground conductor/charging cable cannot be interrupted of the.
- If possible, the main switch in the car should be disconnected before further work on and near the electric car - location can be found via relevant notices in the rescue sheets.
- Note, however, that if the high-voltage battery is damaged or the electric car is mechanically damaged, be it in the form of pressure or breakage of metal parts, it should be considered unsafe and with a risk of accidental voltage on the car, even if the charging cable and main switch are disconnected.
- If direct contact with a damaged electric car is required, it is always recommended to use personal protective equipment (PPE) and equipment as previously described, as well as safety cover.

Location of the high-voltage battery
Depending on the car brand, the high-voltage battery can be located in different places in the electric car. Certain car brands have the batteries located in the same place, regardless of model, whereas other car brands have the batteries located in different places. Larger battery packs will often be located at the bottom of the electric car, but can also be in the boot, under the bonnet or in the middle of the car, between the front seats.

In general, access to the high-voltage battery can be very complicated, due to the membranes in the battery pack and a location where accessibility can be extremely limited due to damage to the bodywork.

The location of the high-voltage battery and whether it is damaged has an impact on the technique and response tactics that the crew should use during the response.



Cables with high voltage will most often be orange, as here in the engine compartment

Photo: The National Emergency Management Agency

You can read more about safety, special risks and applicable legislation, regulations and standards in Appendix 2 on 'Safety when working with electric cars'.

IMPORTANT KNOWLEDGE FOR THE FIREFIGHTER

- Personal protective equipment (PPE) that is approved for 1000 V: Safety gloves, protective mask (protection against electric arcs), safety helmet with visor - alternatively protective glasses/eye protection, approved footwear or foot mat for contact with the electric car and release.
- Safety equipment: Tools approved for 1000 V. Insulating rubber mats can be used to cover conductive material protective cover. High voltage batteries in an electric car have a high electrical direct voltage and contain a significantly larger amount of energy than the ordinary 12 V starter batteries in a passenger car with a petrol or diesel engine.
- When working in an electric car, it is essential for the crew to disconnect the main switch if possible and thus de-energize all the electric car's systems.
- If this is not possible, it is important that a safety distance is taken into account in connection with the extinguishing, depending on water performance and extinguishing technique.
- Be aware that the high-voltage battery itself cannot be de-energized.
- There should be two people present when working under voltage so that there is one, which may occur in the event of an electric shock.
- Marking of the danger area with signs against high voltage - this vertical hole des when releasing the damage site (min. 1 m)
- Assessment of the condition of the car's high-voltage battery, disconnection of the main switch, voltage, damage to cables.
- Extra attention if noises, smoke generation or unnatural smells are observed from the battery or liquid leaking from the battery. This may indicate heat development/'thermal runaway' in the high-voltage battery.
- Marking with a barrier and signage with 'Danger - high voltage' is maintained after the intervention when handing over to the police or transporter. As far as possible, avoid unnecessary twisting of the car during the operation and while it is being loaded onto the sweep

Response tactics - Fire

e

be

re in high ttery with offensive approach.
Direct s f and cooling of the battery/
electric car.

- Fire in high-voltage battery with defensive approach.
  Allow the electric car to burn out or place it in an electric car container or similar option for cooling.

In addition to the above, it will be possible to carry out combination efforts, where an offensive approach is used first and then a defensive approach, e.g. in the event of a fire in an electric car in a building.

Attention is drawn to the fact that a fire developing in the high-voltage battery will be difficult to put out, and that an offensive or defensive approach will too often be about ensuring a fire spread
parts to nearby vehicles, building parts
mv.

In connection with the construction of the accident scene and danger area, it is important that the technical manager ensures that the danger area is large enough so that emergency personnel who have not put on full respiratory protection, as well as other persons, are not exposed to the fire smoke. The same applies to the location of equipment and vehicles, regardless of whether the electric car is located outdoors in a building.

In the event of a fire in the high-voltage battery, there are always a number of factors that the technical manager - early in the response process - should make decisions about:

- Need for additional personnel, as the effort may risk being prolonged
- Fixed or continuous water supply - Logistics
around fire suits, compressed air devices, cleaning point etc.

gas. These elements sh n into accoun
technical manager when t
and the construction of the acc
is placed.

Precautions in the event of a fire in an electric car Common to both the offensive and the defensive intervention methods is that, in the vast majority of interventions, there is no immediate danger of the crew receiving an electric shock from the vehicle's high-voltage system. The battery and the electrical components are a closed system which functions independently and is separated from the rest of the vehicle's construction.

It is of significant importance that the main switch in the electric car is disconnected, if this has not happened automatically.

A risk of electric shock only arises if damage has occurred to the high-voltage electrical components or if a fire has occurred in the high-voltage battery. If the electric car is being charged, there should be a special focus on disconnecting/interrupting the charge.

In order to minimize the risk of damage to personnel and equipment, it is important that the deployed personnel continuously assess the situation in relation to the development of injuries as well as the current risks.

The response time should reflect the time that, after the smoke dive itself, must be set aside for undressing according to stricter procedures (pure firefighter), where the apparatus is taken off last. In practice, this will mean that with an air content of approx. 30 minutes (depending on how hard work is carried out, penetration path etc.), will be a real intervention time of around 20 min. This is already known from efforts with chemical diving, where the smoke divers in situations without an air bank must pull out before the withdrawal signal on the device sounds.

As a starting point, you should stay away from contact with fire smoke and seeping gases and deploy 'with the wind at your back' in the danger area.
If you are working near the danger area, where the crew may otherwise be exposed, for example when the wind direction changes, the correct PPE should be used. All emergency uniforms are washed and replaced.

+

IMPORTANT KNOWLEDGE FOR THE FIREFIGHTER

- Avoid being in the fire smoke for personnel and others without full respiratory protection count

- Pay attention to the real intervention time, when taking account of stricter procedures rer for undressing similar to 'pure fireman'

Safety hose minimum 400 l/min

- Attention to the risk of shock through extinguishing water - Safety distance when extinguishing corresponding to entering a fire with 1000 V - Safety distance to electric car of min. 1 m to avoid contact - Attention to damage development.

Before effort
If damage has occurred to the electric car's high-voltage battery and high-voltage power cables have been exposed, there will be less risk of high voltage in the electric car's bodywork.

It is therefore important that the crew takes the necessary precautions. In addition to the use of emergency suits and smoke diving equipment, the crew should use safety equipment and tools that are approved up to 1000 V.

In the process of securing the car, it is important that there is a focus on personal safety for the crew and any spectators. In case of fire in an electric car battery, where the main switch is not disconnected, there is a minimal risk of the electric car running on its own - if it is in gear.

To avoid this, it is important that the electric car is secured. There is equipment such as a 'plug' to insert into the charging socket, it causes the electric car to go into charging mode so that it cannot drive. Depending on the extent of the fire, this may be an option.

Electric cars have a large torque, which means that the fuse should be effective. Blocking should be done if possible. If the main switch is disconnected, the electric car will not be able to start and drive itself.

In most types of electric cars, capacitors are located at each wheel. These have an auxiliary function during starting and braking and generate current in this connection.

During intervention In the event of a fire in electric cars, personnel within the safety distance should use full respiratory protection. In cases where the electric car burns in the open, the smoke divers should be deployed with the wind at their back and for the shortest possible time. This is to minimize exposure of hazardous substances on the fire suit.

The smoke divers must not come into contact with electrical components. If this cannot be avoided, protective equipment approved for 1000 V should be used.

If the electric car is waiting for charging and it is not possible to disconnect for charging, work is done to maintain the right safety distance. This also applies in the event of a fire in the battery itself. We work with a safety distance corresponding to water output, beam pattern and extinguishing agent. The following are recommended distances for extinguishing electrical fires (c-tap pipe with pressure of 5 bar - DIN VDE 0132). Safety distance can be projected to the safety hose.

ÿ Unknown low voltage <1000 V, 200 l/min: – scattered beam - min 1 m; combined beam - min 5 m **ÿ**

Unknown high voltage >1000 V, 200 l/min: – scattered beam - min 5 m; combined beam - min 10 m

Access to the battery

In order to create access to the essential components of the electric car, it is important that no holes are cut in the bonnet or cut in the car's sides, as there is a risk of hitting components with high voltage if the main disconnect

clean is not disconnected.

Cooling or switching off an electric car's battery can be difficult, due to the location of the battery. Depending on the car make, the battery may be located in different places in the vehicle. Certain car models have the batteries located in the same place, regardless of model, whereas other car brands have placed the batteries in different places.

The battery can be located at the bottom of the car, the trunk, under the bonnet in the middle of the car or between the front seats. This has the effect on extinguishing efforts that it can be problematic to cool or switch off the battery.

It is important to determine the location of the battery as early as possible, as it has an impact on which deployment method (technique and tactics) the response team should use during deployment its.

It is noted that the high-voltage battery itself cannot be de-energized.

Battery frame integrated under seats in the cabin.
Photo: Toyota

Monitoring and cooling the battery If the Li-ion battery's critical temperature (90– 250 oC depending on the type) is exceeded, 'thermal runaway' may occur, which can cause the battery to either burn or burst under pressure.

Therefore, a possible temperature development in either the high-voltage battery or the car fire is monitored, for example, with a thermal camera, which can advantageously be done continuously.

Cooling with water directly on the battery pack can in some cases have an effect. However, it should be noted that the effect should be monitored with a thermal camera, as the location, construction and packaging of the battery can make it difficult to create effective cooling.

Method for lifting the electric car for more direct cooling of the battery pack at the bottom of the car
Photo: Hovedstadens Emergency Services

Response to electric cars on fire, in fully and partially closed spaces

Before action
In case of fire in electric cars in closed or partially closed rooms, e.g. parking garages, the action depends on whether the battery is on fire and whether there are people in danger. If there are persons in danger, an offensive tactic should be used.

If it is only the battery that is on fire, a particular point of attention is the fire smoke, as it contains a large concentration of substances harmful to health.

It should be assessed whether a relatively resource-intensive offensive effort is carried out, with the risks this entails in relation to the spread of smoke, large quantities of extinguishing water on the floor, short response time for the smoke divers, etc., or whether it is possible to remove the electric car from the building. This however, requires the use of special equipment in order for this type of effort to be possible.

During intervention In closed rooms without any form of ventilation (natural or mechanical) there will be a relatively short intervention time, as the intervention time should reflect the time that is set aside after the actual smoke diving to carry out undressing according to the stricter procedures (pure firefighter), where the device is removed last.

In practice, this will mean that with an air content of approx. 30 minutes (depending on how hard work is carried out, penetration path etc.), will be a real intervention time of around 20 min.
This is already known from chemical diving efforts, where smoke divers in situations without an air bank must pull out before the withdrawal signal on the device sounds.

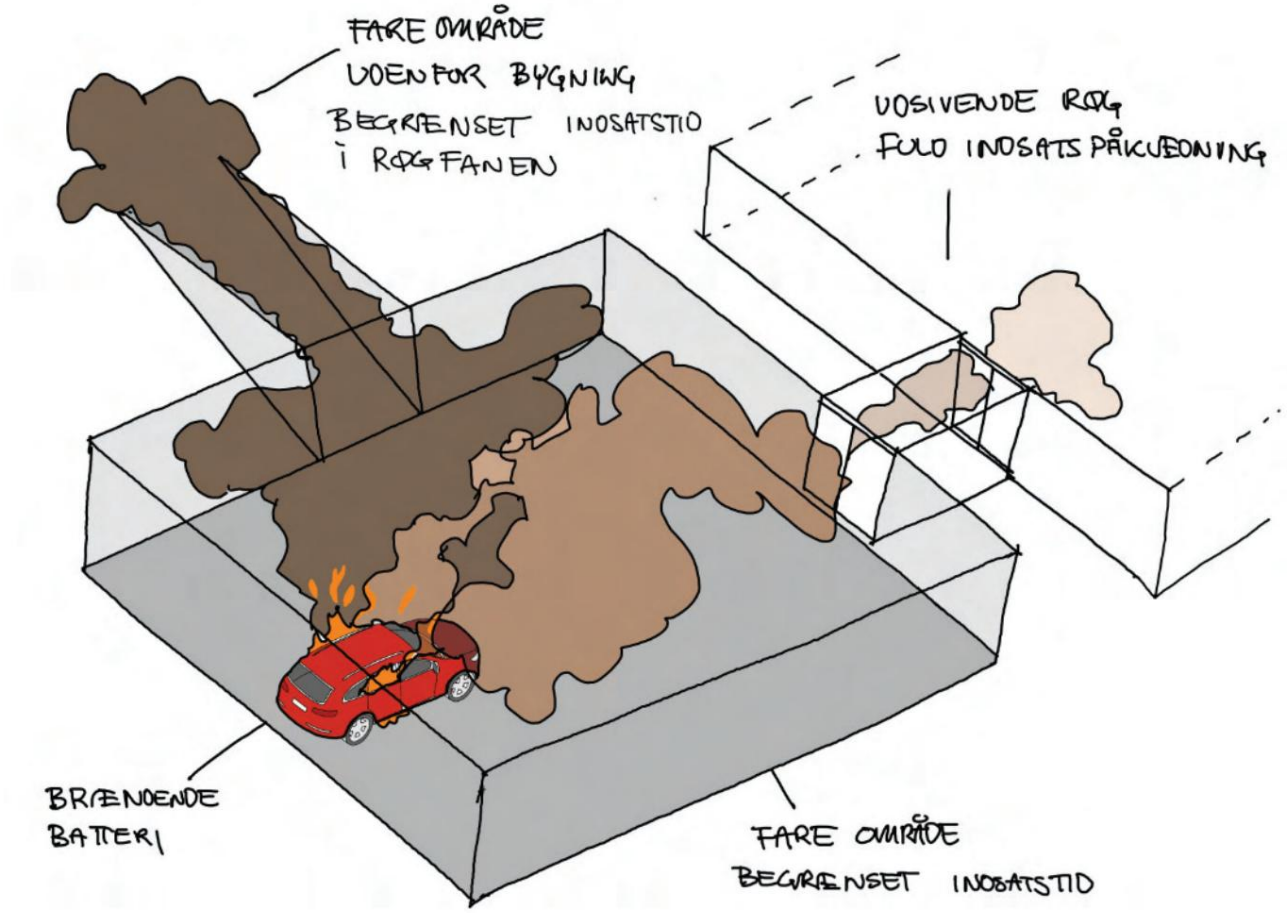


Illustration: The capital's preparedness, 2022

Overall, the response time (with full breathing) is affected by the firefighter's activity level.
The concentration of leaking gases from the battery and fire smoke will probably be lower in rooms with better ventilation, but this is of less importance for the exposure itself, which should be handled regardless of the concentration of well smoke and gases.

It will of course be a concrete assessment, as conditions eg the amount of smoke can change quickly also in the 'adjacent' rooms.

Attention should be paid to whether, for example, is a doorway to the danger area – either as an access route for the smoke divers or a door, which is clamped to make room for the fire hoses.

There may be a distinction is made between whether the crew in the 'adjacent' room works, or whether it is 'only' used as a review room.

In general, staying – working as a walk-through – in smoky rooms should be minimised. In this connection, supplementary ventilation can be considered in relation to risks or benefits.

When the electric car is outside the building, it should be reassessed whether offensive or defensive tactics are used.

QR code for video with med 'thermal Runaway' in the parking garage

After intervention

After the fire has been extinguished, the crew should continuously assess a potential temperature development in the battery, e.g. in the form of temperature measurements or monitoring the development of smoke, vapors or noises, which may be signs of a possible temperature change in the battery.

Due to the process it has gone through, the battery can generate heat and thereby exceed the critical temperature long after the fire has been extinguished and the electric car appears to have cooled down. This can last up to 24 hours after ignition - however, cases have been seen where the battery ignites several days after the first ignition.

In relation to personal safety, as in a 'normal' fire, it should be assumed that the substances (fluorine compounds, metals etc.) are present until all surfaces have been cleaned.

It can be good practice to inform the claims service and others who will be in the room about the effort. Then they can take the necessary precautions in relation to the use of personal protective equipment (PPE) such as disposable gloves, filter mask/respirator, protective suit, etc.

Particular attention should be paid to any extinguishing water that may contain various substances that may be harmful to the environment and health. To the extent that the water is collected in a container, e.g. in connection with immersion ing the battery in water, the water may contain substances that must be handled correctly. See the 'Dangerous substances' app.

Defensive action in case of fire in electric cars

Response to electric cars on fire in the open In the event of a fire in an electric car, a decision should be made quickly as to whether the fire in the electric car should be extinguished or allowed to burn out. That beg depends on an assessment in the specific situation.

If, for example, the electric car is standing and disturbing critical infrastructure, it would make good sense to carry out a quick and aggressive switch-off with subsequent cooling and transport away. The same could apply in a densely built-up area, where the smoke will pose a danger to people if the electric car is not moved.

If, on the other hand, the electric car is in an undisturbed place, the effort may be to let the electric car burn out, without taking into account the consequent pollution that will be caused by switching off the car in the place in question. If a temperature rise is detected in the battery, it must be assumed that a 'thermal runaway' has started, which must be dealt with again.

Special conditions for electric cars in water Electric cars that are under water8, as a rule, people should not be in contact with, unless it can be done in a safe and sound manner. If possible, you should try to switch off the ignition so that the electric car 'shuts down' while it is in the water.

An electric car that has not been involved in an accident or otherwise damaged the battery does not pose a greater risk than other electric cars when it has been removed from the water.

When the electric car is recovered, it is handled in the same way as an effort with an electric car on solid ground. In this process there is a risk that CO and HCL vapors are released. The same also applies if the battery is damaged before the electric car has been driven into the water.

Fire in an electric car where there is no fire in the battery

In the vast majority of cases, when there is a fire in an electric car, it is the electric car itself that burns and not the battery. This type of car fire should therefore be considered an 'ordinary' car fire.

However, it is essential that the crew is aware of the possible heat effect that this fire can have on the battery. As long as the battery is affected by heat, there may be a longer response time than in the case of a conventional car fire.

Working with high voltage

Operations with electric cars involve special risks compared to operations with petrol or diesel-powered cars. Here, it is the risks of working with high voltage – and the use of extinguishing water – that the crew should be aware of.

According to IC 61140:2016 (International Electro technical Commission), the level of high voltage is above 1500 V direct voltage (DC).
When the voltage level is less than or equal to 1500 V DC, according to IEC, it is not high voltage, but low voltage.

For alternating current, the level of high voltage is above 1000 V AC. This means that, in a technical sense, there is no high voltage in the car's electrical system.

When the term 'high voltage' is used in the theme booklet, it must be seen in relation to the voltage found in cars' 12 volt systems.

You can read more about safety and the use of tools in appendix 2 and appendix 3.

Fi[illegible]

[illegible]

is therefore ir[illegible]ıat a stable and sufficient water supply [illegible]d from the start of the effort [illegible]sponding[illegible]400 l/min.

Based on the 112 report, a first response should be put together that reflects the expected water consumption.

When cooling and extinguishing a battery, it should be ensured that equipment, including radiation pipes, approved for extinguishing fires in electrical systems is used.

Thermal camera

The use of a thermal camera can be used to check whether a high-voltage battery is affected by temperature and to monitor the effect of the initiated cooling. However, you should be aware of possible protective cover or covering of the battery, as this can mean significant measurement errors.

[illegible]temperature of the ba[illegible]

Use of a fire blanket In so[illegible]
efforts, it may make sense to use a fire blanket. However, there are a number of conditions that the crew should be aware of about:

- A fire blanket will not be able to extinguish the fire itself in the high-voltage battery – only limit flames and fire smoke.
- Due to escaping gases, a large pressure can arise under the carpet, which can lift it. This is due to leaking gases which are not ignited.

- There is a risk of spot burning of the carpet due to high temperature.
- The crew should be trained in using a fire blanket.
- Space is required around the electric car if the fire blanket is to be used correctly.

Use of fire blanket.
Photo: Østre Agder Fire Service

Use of positive pressure fan A positive pressure fan can be used for several purposes. Outdoors, it can be used to ventilate the smoke away from an area that is to be protected and thereby 'steer' the smoke in a specific direction. As the ventilator has different and limited capacities, the effect will be very dependent on the natural ventilation
the place.

Indoors, such as in parking garages, the positive pressure fans can be used to ventilate away smoke and thereby contribute to prolonging the response time by improving the working environment and visibility as well as minimizing damage to the surroundings. The use should be considered if to the tactical approach that has been chosen to create quality in the effort.

The advance speed of the smoke divers in a building depends on, among other things, of visibility.

Effective ventilation can contribute to safer and more efficient efforts. This requires that the crew is trained in ventilation tactics, including the effect of ventilation on the course of a fire.

It is noted that pressurization is a defensive tactic of, among other things, parking garages, which can cause smoke to spread to stairs and exit routes, which may turn out to be inappropriate.

There are a number of specially manufactured ventilators which have an increased effect compared to traditional ventilators. An example is the LUF60, which has a max. ventilation effect of 90 m3/min.

Use of LUF 60, respectively, for ventilation and towing of electric cars from parking garages or parking garages
Photo: Hovedstadens Emergency Services

Removing a car from a parking garage In general, for extinguishing operations in parking garages and other parking facilities, long attack routes through several building sections should be taken into account.

As part of the effort, it should be considered whether it is appropriate to remove one - or more cars in order to prevent more cars from catching fire - or as a direct measure to remove the burning electric car.

In both cases, the decision about who can take charge of the task should be based on thorough consideration of the risk to the crew, including whether the task can be solved by someone other than the rescue services.

The task of removing cars is planned and coordinated taking into account any other personnel deployed and can possibly be carried out by using "roller skates" under each of the car's wheels.

If it is a question of longer distances or driving on platforms, ramps or inclines, tow vehicles, robots or other devices can possibly be used.

Immersion in a container with water Using a container filled with water is an effective means of cooling a battery. A fire extinguishing container can be designed as a tight-fitting vessel, where nozzles in the bottom and in the sides will be able to create effective cooling of a battery.

The electric car can either be loaded with a crane or pulled in from the back of the container with a winch. During transport to storage area, etc. will a continuous cooling of the battery be possible.

If it is not possible to use a sealed fire-extinguishing container, an alternative would be a less practical solution - an all-friendly container with a tight-fitting bottom and side lining with a reinforced tarpaulin.

Cooling can be done by filling the container with water so that the battery is covered by water.
Loading, transporting and unloading the electric car in the container can be problematic due to the water in the container, as it is not designed for the purpose.

When recirculating the water in the container, the concentration of various substances and the pH can be high. When the effort has been completed and the electric car removed from the fire-extinguishing container, the extinguishing water from the container should be treated in a responsible manner for the sake of the environment and the working environment. The municipal environmental authority should be contacted.

Measurement of dangerous gases New passenger cars today contain a lot of plastic, which is taken into account in extinguishing efforts. This also applies to electric cars, which will also be able to have a different composition ning of the fire smoke due to the Li-ion battery.

There are detectors for detecting, for example, HF gas. A measurement will not necessarily be valid in relation to the situation and what you want to demonstrate. Concentrations of harmful substances and leaking gases can be very local.

In practice, it should be assumed that, as in other fires, there will be dangerous substances and gases present. However, these will most often be handled with the use of an emergency suit, full respiratory protection, other PPE and normal practice for removing the mask, procedure for 'clean fireman' etc.

However, attention should be paid to small flames, 'explosive' puffs, seeping gases, etc. from the battery, as the release of gases from the battery may well 'peak' during the fire.

Contact with extinguishing water should be avoided or minimized as far as possible. This is due to the presence of hydrofluoric acid, which is formed by mixing HF gas and water. However, the concentration of hydrofluoric acid will presumably be limited due to the large amounts of water. Exposure to hydrofluoric acid on the skin may be locally irritating, but will not be life-threatening9 in this type of intervention.

Photo: Andreas Hillergren/ TT/ Ritzau Scanpix

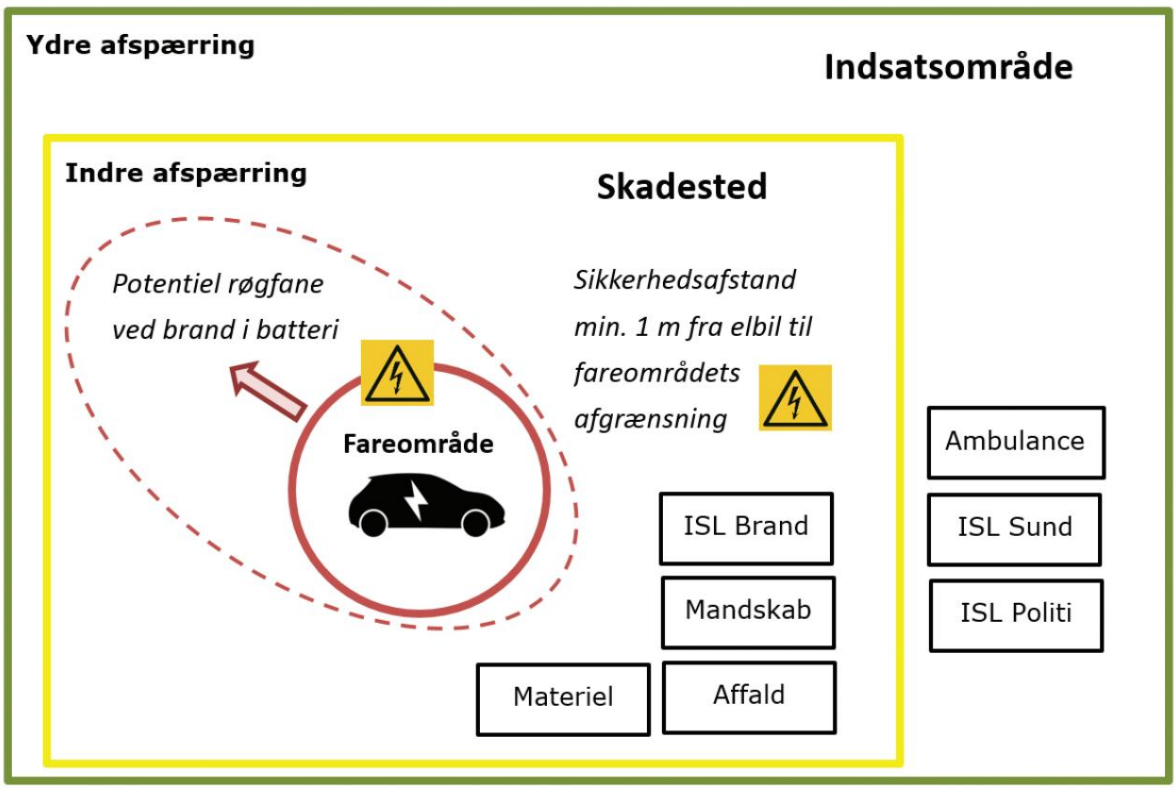
The technical manager's challenges

implemented c ance to the electric car should be min. 1 m. It nt that the technical manager es that th barrier is large enough so that nnel who put on full respiratory protection and other emergency responders around the scene of the accident are not exposed to possible fire smoke.

- Fixed or continuou nly.
- Logistics around fire devices etc.
- Blocking off the danger area with markings for work with high voltage.
- Potential plume of smoke in the event of a fire in the battery pack ken.

This also applies to the location of depots (material, personnel and waste) and investment vehicles. Since there is a risk of a fire developing in the event of damage to the high-voltage battery, there are a number of conditions that the technical director should include in the build-up of the damage site early in the response process. It is:

Furthermore, the technical manager should be aware that the effort risks developing, as the fire smoke from an electric car's high-voltage battery develops large quantities of HF gas and other gases. The described elements should be taken into account by the technical manager when internal containment is established and the structure of the accident site with its facilities is placed.



The structure of the scene in the event of a traffic accident with the need to free trapped persons or risk of fire.

Illustration: The National Emergency Management Agency

The challenges of the operation

Operations with electric cars give rise to a number of dilemmas which differ from similar operations in conventional cars. A task manager should be considered. The team leader is, as a starting point, the technical leader of the effort, and a possible effort leader will be the tactical leader.

Depending on the situation, the two roles are adapted.

In particular, the risk assessment plays an important role in the operations manager and the team leader, as the focus should be on both the tension part and the risk of brand.

The effort can be extremely complicated if it takes place in a closed environment such as a parking garage. Conditions such as large water consumption, long penetration path and response time, concentrated fire smoke and difficult re-establishment will often make the response more resource-demanding.

At the same time, the task leader should consider the consideration for the surrounding society, such as infrastructure and environment and the risk of a possible re-ignition.

When an electric car is involved in a traffic accident - with personal injury or not - then the high-voltage battery is exposed to a mechanical impact that can damage it and thus initiate a process - 'thermal runaway' - even long after the initial response has been completed.

If there is a need to free trapped people, a general distinction is made in the topic heading 'Special conditions for rescue in electric and hybrid cars' between two forms of response to traffic accidents based on whether it is a question of persons in danger of life/threatened or persons who are not is in danger of life/not life-threatening.

Risk assessment in relation to fire smoke and smoke diving

It is essential that the danger area is identified correctly and determined, so that all deployed personnel; fire, ambulance and police, are aware of where there is safe and where is not safe. This places special demands on the incident leader's risk assessment, as the safety of the deployed personnel has the highest priority and should be coordinated in relation to the choice of an offensive or defensive approach.

When fighting a fire in electric cars, especially in closed rooms without ventilation, smoke diving should be carried out in the shortest possible time. Particularly for smoke divers, there will potentially be a long penetration path to the fire itself, where exposure to fire smoke should be taken into account. Options for ventilation can be considered and implemented as early as possible.

In the same way, it should be taken into account that smoke diving in large closed spaces with few exits, such as parking garages, entails the risk of prolonged withdrawal time in a smoky environment, as the distances are longer.

With large rooms, there is also the risk that the smoke divers do not have an overview of the progress of the fire in the entire extent of the room. It should be considered to plan the smoke diving effort in such a way that all deployed personnel have clear and safe escape routes and an understanding of any risks and restrictions. Smoke divers can advantageously use a thermal camera for fire detection.

Attention will always be present in connection with fire smoke, and especially when it comes to a fire in Li-ion batteries, where both vapors in the fire smoke as well as leaking HF gas and other gases harmful to health will be present.

Unignited gases from the battery can form the basis of an explosive environment in closed spaces, which should be included in the risk assessment - especially in the event that a fire has not yet broken out.

Mixing of fire smoke, which is released from an electric car, and HF gas etc. from the electric car's components, however, do not pose an additional risk than the fire emergency suit provides protection against.

The risk assessment should, among other things, include considerations about the temperature of the fire smoke, the concentration of potentially dangerous substances (number of electric cars/high-voltage batteries involved), the total response time for versus the number of smoke diving trips for the individual smoke diver, etc.

It is noted that personal protective equipment (PPE) is used in relation to approval requirements to 1000 V and safety distance in relation to the selected extinguishing tactic.

The smoke from the fire indicates a need to identify the danger area as well as areas that could potentially be affected by smoke. This is done with a view to early preventing other people from being exposed to smoke. It should be noted that not all leaking gases from the high-voltage battery are necessarily visible or smelly if they are not ignited.

In operations where there has been exposure to fire smoke in large quantities or concentrations, attention should subsequently be paid to whether the crew develop symptoms of exposure to the fire smoke. The crew should, after finishing their turn, change into clothing and emergency clothing and take a bath as soon as possible after the effort.

Photo: Hovedstadens Emergency Services

Operation tactics
The operation leader/team leader should assess as soon as possible whether an offensive or defensive approach is needed. The duration of the effort will generally be longer, both in the acute phase and in the subsequent clean-up phase.

There may be extra managerial tasks, for example cooperation with the health emergency services regarding any injured persons etc
ler others at the scene of the accident who have been in the fire smoke or had contact with extinguishing water as well as handing over the electric car to the transporter or the police.

Expected greater consumption of resources
Responding to a fire in an electric car's high-voltage battery generally requires more resources than other types of car fires. A larger amount of water is sometimes required to cool the battery pack and extinguish or limit the fire in the electric car - equivalent to 400 l/min - and this can be over a long period of time.

In the event of a fire in the electric car or the high-voltage battery inside a building, a significantly larger number of smoke divers must also be expected for the response, as there may be a relatively short response time.

It will also be a question of a more complex effort than usual, as resources are used to secure the danger area and ensure that other actors at the scene of the accident do not come into contact with the electric car, as well as managerial tasks such as cooperation with the health emergency services on the injured and handing over the electric car to the transporter or the police.

Logistics in relation to replacement and remediation
Experience shows that fires in electric cars can take from a few to several hours to deal with, which is why it is necessary that supplementary resources should be requested as early in the process as possible.

The potentially relatively short response time may require more resources. There should be a focus on remediation procedures for personnel, their equipment and material, which follow local operational standard procedures.

Requisitioning of special equipment or specialists for rapid remediation of the incident or advice should also be considered as part of the solution. For example, fire-extinguishing containers for transporting electric cars for safe storage, drones or self-propelled extraction robots, fans, etc.

Exposure to fire smoke or leaking gases from the battery If the crew has been exposed to a possible exposure to fire smoke or gas from the high-voltage battery during operations, information should be sought as soon as possible in the 'Dangerous substances' app for the potential health risk, at the same time as subsequent observation of the person is initiated.

On the Emergency Management Agency's app 'Dangerous substances' you can find information about the dangerousness of substances, safety distance, health risk, etc.

Accident on the E45 with electric cars, where the effort lasted several hours.
Photo: Horsens Folkeblad

Disposal of an electric car affected by fire As part of the final effort, it should be ensured that the disposal of the electric car(s) affected by the fire does not entail a risk of the fire spreading to other buildings and the like should the battery re-ignite.

This risk can be handled in different ways.
For example, it can be considered whether the car should be placed in a suitable storage location, at an appropriate distance from buildings and other fire mustache If the car is placed under a roof, consideration should be given to how it can be moved outdoors in the event of a fire.

If the electric car is moved, the recipient should be informed that there may be a risk of re-ignition. Furthermore, the technical manager should consider the extent to which the car owner's insurance company is informed via the police if the car is removed from the scene of the fire.

Before the scene of the accident can be handed over to the police or to a carrier, an instruction should be given by the person(s) concerned. Attention should be paid to the following:

- •Development of fire in the battery
- •Corrosive and flammable liquids
- •Dangerous electrical voltage
- •Avoid contact with the electric car
- •Avoid open flames

The damage site should therefore be secured with mine strips and signs with high voltage. In addition, information should be given about the dangers that can be associated with moving the car, including pulling, pushing and lifting it, as this can in effect cause a change in the state of the battery, such that 'thermal runaway' occurs.

Therefore, the incident leader can advantageously enter into dialogue with the police and the transporter to ensure that the transporter that will remove the car is experienced in towing electric cars. If there is tension in the bodywork, a specialist can be called in, e.g. from the manufacturer of the car, who is able to handle this, including the further process of removal.

Securing society The incident leader should decide early on to what extent offensive or defensive tactics are used when extinguishing a fire in the electric car's battery. Since a fire in an electric car can take a long time to extinguish, the technical manager should assess whether the area around the car will be affected by a prolonged extinguishing effort to such an extent that a quick removal of the car is of crucial importance.

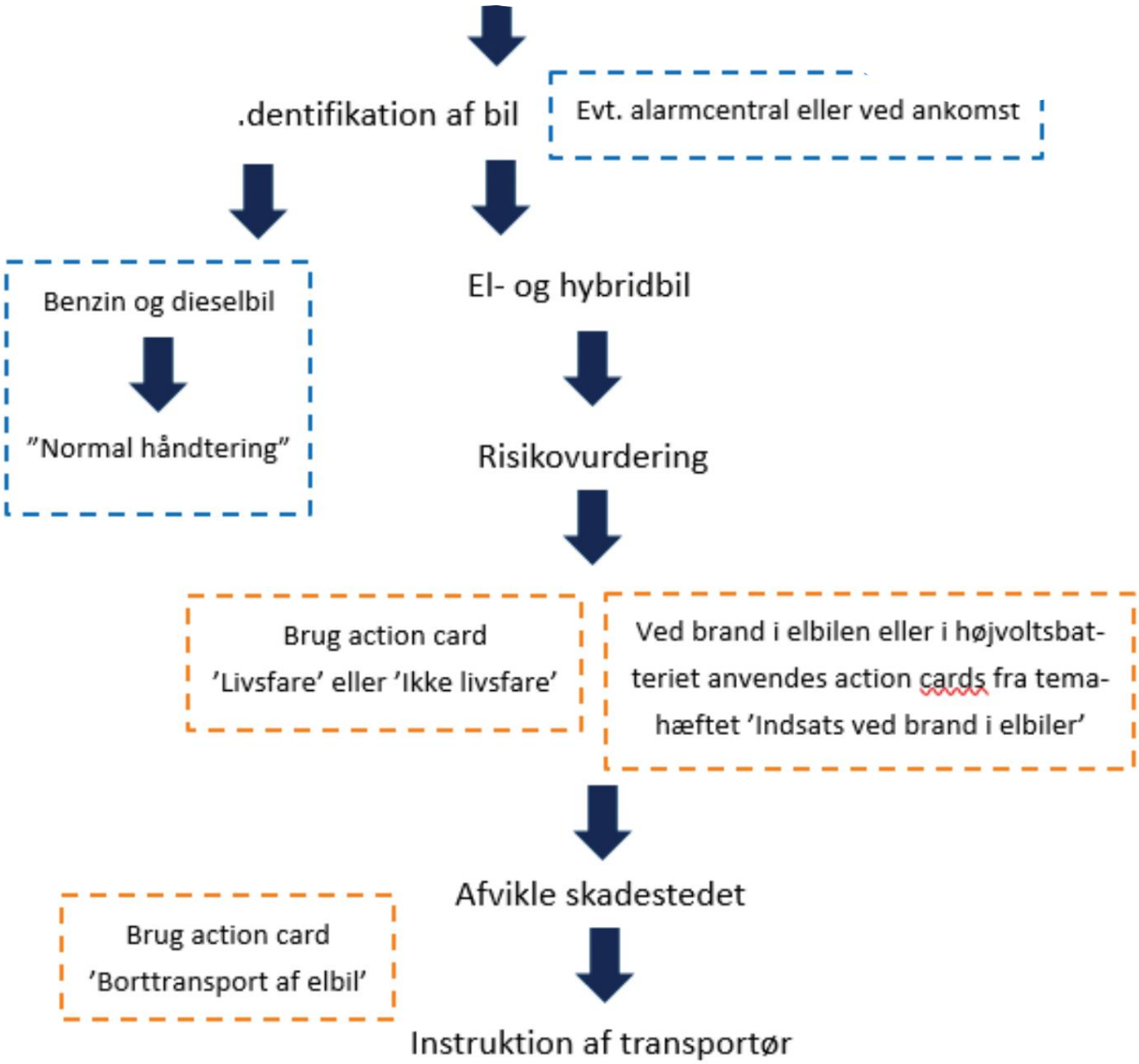
For example, if the car is located on a critical infrastructure or urban area in an area where the potentially toxic fire smoke or gases create a large danger area. This can help determine whether the tactic is a long-term cooling/extinguishing/cleaning of the fire or a removal of the electric car under conditions that suggest this.

The municipal environmental authority should also be involved and possibly in the planning of the disposal of extinguishing water, if this is assessed as particularly polluted.

Overall flow diagram for emergency electric cars When handing over the scene of the accident to the police or when moving the electric car, the electric car should be placed in a quarantine zone with min. 1 m marking with yellow/black mine strip around the car, as well as maintenance of signage for high voltage, fire hazard and chemicals.

You can read more about handover and the role of the police and health services at the scene of the accident in the accompanying appendix and action cards. If the transporter is present, the task leader should explain the measures that have been taken around the electric car, cf. flow in the task, which can be seen in the illustration below. Alternatively, the information should preferably be given to the police so that they can pass on to the carrier:

- It is an electric car and possibly a model.
- Brief on the efforts of the rescue services: fire extinguishing, extrication (damage to cables).
- Assessment of the condition of the car's high-voltage battery, disconnection of the main switch, voltage.
- The risk of 'thermal runaway' during transport to the workshop and what the transporter should do if this happens.
- Challenge of measuring the tension of the bodywork before the car is unloaded.
- That the electric car should be placed min. 5 m away from buildings and other flammable material.



Flow diagram in the event of a traffic accident.

Illustration: The National Emergency Management Agency

Description of actions in action cards

Identification of the car
A conventional petrol or diesel-powered car has a number of characteristic features, such as the fuel tank, tank cover, exhaust pipe, radiator grille, etc. An electric car, on the other hand, can be more difficult to immediately identify, as it can have some of the same characteristic signs as a fuel-powered car. A number of special characteristics will be able to draw attention to the fact that it is an electric car, for example:

- EV, BEV or ZEV for electric cars as well as PHEV or HEV for hybrid cars and others.
- Some car brands, e.g. Tesla, can be recognized via logo or name, e.g. the text: Zero Emission, Electric, driveE or the letter e or E.
- Presence of a cover for the charging connector (possibly behind the tank cover), charging status indicator in the dashboard, missing engine noise, missing exhaust and missing cooling grille.
- High-voltage cables are colored orange, and warning signs will normally be placed in places in the car where risk of coming into contact with high voltages from the battery.

Risk assessment If extrication is required, please refer to the themed booklet on 'Efforts during rescue in electric and hybrid cars, which e.g. describes the 5 phases of liberation. On arrival at the scene of the accident, a 360-degree risk assessment should be carried out, which should include at least the following:

Own risk assessment -
- Own safety at the scene of the accident in relation to the surroundings.
- Tension in the bodywork.
- The risk of triggering voltage during work on the electric car.
- Possibility of disconnecting the main switch.
- Location of the ignition key.
- Securing the electric car against driving, possibly as unblocking.
- Contact with the electric car when released from the car only.
- Risiko for 'thermal runaway'.
- Indications of fire in the high-voltage battery or the electric car.

Material to support the risk assessment
- Resource tools (reference works, database) that can identify the special dangers of the electric car.
- Thermic camera.

Marking the site of injury When it comes to work with high voltage, the danger area should be marked, e.g. with mine strip with clear instructions, marking or signage of what it is that constitutes the danger. It is cordoned off with approved black/yellow mine strip with attached signs indicating that there is a voltage hazard behind the cordon. The barrier should be set up at the necessary distance from the potential danger - as min. 1 m from the electric car.

Main switch In electric cars, there is a main switch for the high-voltage battery. It can be designed in different ways, e.g. a cable being cut or a plug being pulled out of a socket. It is essential that the location of these is identified and that the main switch is disconnected.

The crew should be aware that there will typically be several batteries in the individual electric car, both batteries with high voltage and all friendly 12 V operating batteries. The manufacturer's instructions for disconnection are followed as far as possible relation to deformations.

Tools, equipment and protective equipment During the rescue operation, only tools that are approved for use when working with high voltage (1000 V) may be used. Examples of this are insulated tools or other approved tools, if there is an exceptional need to use them on live parts of the electric car.
Ordinary tools, hydraulic release equipment, etc. is not normally approved for work with voltage, which should be taken into account in the effort.

Personal protective equipment (PPE) should always be used to protect the crew against shock when there is or is suspected to be electrical voltage in the bodywork. This applies to all vehicles at the scene of the accident who come close to or in direct contact with the electric car or bodywork.

This equipment is i.a. safety gloves, protective clothing, boots, helmet with visor, which is approved for 1000 V.

Protection against fire In order to protect against a sudden fire or 'thermal runaway' during a rescue operation, safety hoses are laid out with a total water output of at least 400 l/min, so that a quick and effective protection of people and possible cooling of the fire.

Instruction of the transporter It is of significant importance that a correct and informative handover is given to the transporter, who must transport the electric car away from the scene of damage. In connection with picking up the electric car on a grill or sweeping blade, twisting may occur in the car, which may cause an accidental event with 'thermal runaway' or create an electrical voltage in the bodywork.

The carrier should focus on:

- Risk of fire.
- Heat development.
- Sound.
- Degassing.
- Odors.

When the scene of the accident is left and handed over to other actors, such as the transporter or the police, information on the condition of the electric car and battery pack, the status of switching equipment and any safety devices should be passed on.

Signs and marking of the risk of high voltage are maintained.

Operational tactical understanding - chemistry

The risk assessment
The intervention in the event of a fire in an electric car's high-voltage battery should be regarded as a fire-fighting intervention. Elements from a chemical operation are included when circumstances surrounding the time of operation and exposure to high concentrations of fire smoke and gases are critical.

Whether the individual vehicle is in the open, a garage, in a parking facility or among other vehicles should contribute to the assessment of a dangerous area, which ensures the crew and other actors at the scene of the accident. In order to understand the various operational tactical situations, a distinction can therefore be made between the following:

- Fire in an electric car/battery in a parking facility or closed space (ventilated/non-ventilated)
- Fire in electric car/battery under roof (ventilated/non-ventilated)
- Fire in electric car/battery in the open.

A quick determination of a danger area around the electric car can create a necessary overview for the effort. By articulating the above-mentioned locations or a division between them, the task leader or team leader can make visible a tactical and technical implementation of the task, which takes into account the risks of leaking gases and fire smoke.

Especially in closed spaces, physical barriers (walls, doors, etc.) can help to define, how long the crew can stay in the danger area itself or in adjacent rooms that are less smoky. The danger area is defined as the area where the concentration of fire smoke or gases is so concentrated that residence is assessed to require the installation of fully breathable clothing. In practice, it will be inside buildings and in outdoor areas where there is a suspicion of non-visible, seeping gases or fire smoke.

Consideration should also be given to how far a fire has progressed and whether 'smoke' is fire smoke or gases. If no ignition has occurred, there could be an explosive environment in closed spaces due to the leaking gases from the battery, which are not normally seen in car fires.

Photo 1: Fire in battery pack, the smoke is typically white with small brownish shades.

Photo 2: The fire in the battery pack is strong and has started to spread to the cabin.

Photo 3: The spread of the fire is now in the electric car and adjacent cars.

The three photos show differences in smoke development in the ELBAS project, 2022
Photo: 1-3 Emergency Management Agency

The smoke divers' time on duty
For the crew, it will generally be sufficient to use normal emergency clothing, full respiratory protection and, after the operation, a focus on good practice for handling equipment and being a 'clean firefighter'.

- In a building or closed rooms without ventilation, the intervention time should be as short as possible. This will correspond to the hazard area.
- In adjacent rooms (lower concentrations of fire smoke and gases), the response time can be extended after the response leader's (team leader's) assessment.
- In the open, the intervention time will be comparable to a 'normal' intervention - provided that an intervention suit is used, including full respiratory protection.

For the individual smoke diver, the total intervention time should be estimated at 1 hour. After this, washing and replacing all emergency uniforms should be considered10.

As a starting point, you should stay away from contact with fire smoke and gases and deploy 'with the wind at your back' in the danger area. If work is carried out near the danger area, where large personnel can be exposed, for example when the wind direction changes, the correct personal protective equipment (PPE) should be used.

Meaning of Hydrogen Fluoride (HF gas)
In order to understand the possibility of ignition of the electric car's battery, it is important to have an understanding of e.g. Hydrogen fluoride (HF gas). It is one of the gases that can leak from the battery when it is affected by collision, deformation or an internal overheating process 'thermal runaway'.

Especially in many new cars there is a lot of plastic. The gases are therefore also seen in 'normal' car fires, albeit in different concentrations, due to 'peaks' when the battery cells in the electric car's high voltage battery ignite.

A situation where there is only leakage of, among other things HF gas from the battery, but no ignition, and where the aerosols are tightly packed due to spars such as natural or mechanical ventilation, one can possibly think of the CBRN trace. However, this process will quickly transition to igniting the gas and the electric car. Here you are at the back of the fire trail.

When working in garages and parking facilities/basements, there is a greater probability of contamination by HF gas, so the limited working time should have an increased focus. The concentration of HF gas in a more or less closed space will probably be higher than in a normal car fire, as the fire smoke from an electric car's high-voltage battery can create large amounts of e.g. HF gas.

An isolated focus on HF gas can, however, create an unnecessary image that the amount of HF gas poses a greater danger than the other toxic components in the fire smoke or gases from the battery. This can result in the crew, who have to handle the fire, forgetting that they are used to handling toxic fire smoke gases in advance and thereby showing a limiting increased respect for the 'new' component (HF gas).

In the same way, the amount of HF gas increases in the event of a fire in the battery of an electric car, which in connection with extinguishing water can be converted into hydrofluoric acid. The extinguishing water is handled with as little unnecessary contact as possible, although the hydrofluoric acid will at most be visibly diluted enough not to pose a significant danger to the crew in case of skin contact.

The risk of leakage of a large amount of electrolyte fluid from the battery pack is considered to be minimal. In the event of a leak – where there is no ignition – the leak should be handled as CBRN for larger quantities. The electrolyte is available in both a liquid and a solid variant, just as the ingredients vary according to the battery type. Information can be sought in the 'Dangerous substances' app or from the dealer's safety data sheet for the car battery.

Battery cooling in the ELBAS project, 2022

Photo: The National Emergency Management Agency

Appendix 1: Characteristics of electric and hybrid cars

voltage battery (Li-ion) a.

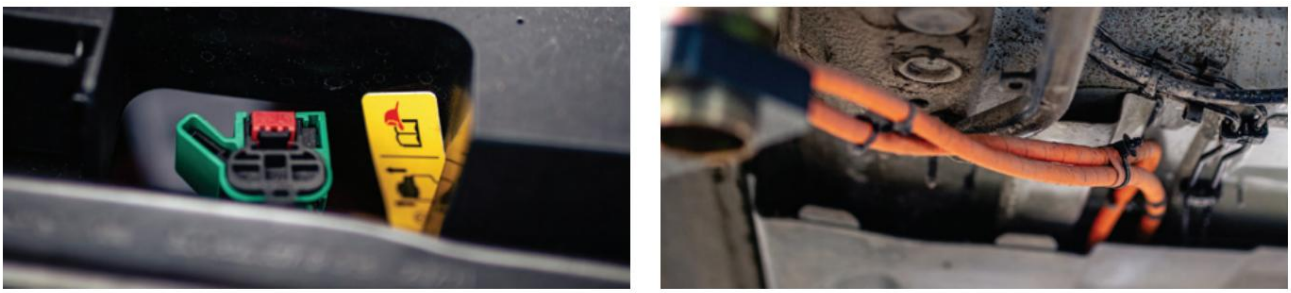
The three photos show different ways of identifying an EV – logo, missing radiator grille, missing exhaust. Photo: The National Emergency Management Agency

Li-ion battery and cables A Li-ion battery in an electric car is a compact, lightweight battery with a high voltage of up to 1000 V. The batteries are basically safe if they are original and used with the equipment for which they were sold along with or approved for. An electric car also has a 12 V battery.

The high-voltage battery consists of smaller battery cells in a battery pack. They are protected by membranes and an outer packaging, which can make it difficult to get in and cool. The battery pack is often located in the bottom of the car, and the electric car's motors are often located directly next to the wheels in order to reduce transmission as well as reduce the number of moving parts.

The high-voltage battery can be connected to various components such as heating systems, air conditioning, etc. Main cables (orange) with high voltage are most often routed protected centrally located in the electric car.

In a non-intact electric car, it cannot be ruled out that the cables are connected to the electric car's chassis or other construction.



Location of the main switch under the bonnet and the high voltage orange cables.

Photo: The National Emergency Management Agency

The theme booklet 'Special conditions for rescue in electric and hybrid cars' has an appendix with a more detailed one description of characteristics, the Li-ion batteries and the cables in an electric car.

Appendix 2: Safety when working with electric cars

High-voltage batteries in an electric car have a high electrical direct current and contain a significantly larger amount of energy than the ordinary 12 V starter batteries in a passenger car with a petrol/ diesel engine.

When working in an electric car, it is essential for the crew to disconnect the main switch and thus de-energize all the electric car's systems. Electric cars typically have one or more 12 volt batteries, which are disconnected in the usual way.

The high-voltage battery itself cannot be de-energized. Cables and high-voltage systems will typically be colored orange.

When the term 'high voltage' is used in the booklet, it must be seen in relation to the voltage normally found (12 V) in cars with conventional petrol/diesel powered engines.

Special risks when working with Li-ion batteries

High-voltage batteries in electric cars, which are based on Li-ion technology, have the energy stored using chemicals. Particularly in the event of a fire involving the battery, fire smoke gases such as e.g. HF gas, CO2, CO and NOxs.

Access to the high-voltage battery can be complicated due to the membranes in the battery pack and a further limitation due to damage to the bodywork series. This has implications for the effort, the tactics used for cooling the battery pack and positioning of the crew in the plume of smoke. Power is turned off with water, which is why a safe distance to the electric car must be respected.

It is important not to cut holes in the bonnet or cut into the car's fenders, as there is a risk of hitting components with high voltage if the main switch is not
offline.

Current legislation, rules and standards The
Emergency Response Act applies to the efforts of the rescue services, and the theme booklet takes as its starting point some general principles for response tactics and cooperation in the response area.

The Electrical Safety Act11 is safety-relevant regarding work methods and protective equipment, as it applies to e.g. electrical installations where the voltage is so high or the current is so great that danger can arise
people.

The Swedish Safety Agency has prepared a number of relevant descriptions of protective equipment and work methods on safe work on electrical installations that are connected to a supply system or have their own supply12.

The standard (EN 50110-1) states which areas it can be used for, including '... when working on or at e.g. electrical installations in vehicles, electrical traction systems and experimental electrical research work when no other rules exist'.

The regulations in the standard are therefore considered to be relevant to the work of the rescue services in terms of working methods, division of responsibilities and personal protection, as no other relevant Danish regulations or requirements have been found.

The themed booklet 'Special conditions for rescue in electric and hybrid cars' has an appendix with a detailed description of risks and applicable legislation.

Appendix 3: Tools, equipment and protective equipment

Current legislation and regulations basically deal with intact electric cars and not the handling of crashed (not intact) electric cars. They must expect to pose a risk to the crew due to minor or major damage to the high-voltage battery.

By starting from relevant rules, standards, etc. for work on, with or in the vicinity of electrical installations, a responsible effort can be ensured in connection with efforts with crashed electric cars. The tactic will in some cases be based on a precautionary principle, as it cannot be ruled out that there is still voltage in parts of the electric car's components.

Depending on the size of the electric car and the performance of the high-voltage battery, many electric cars on the market in 2021 primarily use a battery voltage between 300 and 500 V. However, the trend is towards high-voltage batteries with a higher voltage - between 600 and 900 V - in the new and larger electric cars that come on the market.

Assessment of voltage in the electric car
In the concrete effort, it will be that technology
be a manager who must assess whether the electric car and not least the high-voltage battery is sufficiently intact for it to be secured, i.e. must be de-energized, cf. the manufacturer's description.

In practice, the mere fact that the electric car has been in a traffic accident (where the emergency services have been called) will make it difficult to assess whether the high-voltage battery is still intact.
If there is doubt about this, it should be assumed as a starting point that no safety functions in the electric car work normally, and that it is therefore assumed that 'all' parts of the electric car can potentially be energized.

Tools and marking In electric
cars, marking/signage is used by the manufacturer, which warns the crew and other emergency responders against the danger of electric shock. This marking/ signage is
visible in the places in the car where there is a risk of coming into contact with the high voltages from the high-voltage battery.

From a safety point of view, tools, instruments and accessories are used which meet DS/EN 61010-1 or have the same safety level. Only isolated or hybrid hand tools are used for work on or near energized low-voltage installations (1000 V AC / 1500 V DC) that meet EN IEC 6090013 or equivalent.

When working under voltage, the work area where the electric car is located, cf. EN 50110-1, must be demarcated and clearly marked. In practice, this can be done with black/yellow barrier tape or similar, on which clear signage is applied,
that indicate electrical danger, e.g. according to ISO 7010:201914.

The themed booklet 'Special conditions for rescue in electric and hybrid cars' has an appendix with a detailed description of tools, equipment and protective equipment.

Appendix 4: Technical conditions - batteries and charging sockets

A Li-ion battery in an electric car can be described as a high-voltage battery that is characterized by being a compact, lightweight battery that can withstand many discharges and recharging conditions. The batteries are basically safe if they are original and used with the equipment they were sold with or approved for.

Compared to a conventional petrol/diesel-powered car, a modern electric car is generally designed with a central and low-placed battery pack, e.g. in the bottom of the car. The electric car's motors are often located directly at the wheels, which makes the traditional transmission smoother and reduces the number of moving parts.

Common to all types of electric cars is that they are equipped with motor and transmission systems with voltage, as well as a smaller 12 V battery, which is seen in conventional petrol/diesel powered cars.
In the case of electric cars that do not have a petrol/diesel-driven engine, the risk assessment takes into account the larger dimensions of the high-voltage battery, in addition to the live parts and the supplementary 12 V low-voltage battery. 12 V batteries can also be of the Li-ion type15 and can be placed in connection with the high-voltage battery as a combined high-voltage/low-voltage battery pack.

Chargers and charging sockets Electric cars are characterized by being equipped with a high-voltage battery, which can be charged externally via a charging socket or through wireless induction charging, as well as one or more electric motors. The battery can also be charged via regenerative braking - i.e. that the car regains the energy that would otherwise normally be lost when the car brakes.

Some types of electric cars work by changing the battery. However, charging an electric car will often be via a charging stand. All types of charging via a charging station will basically use alternating current (AC) from the mains. Via a charger or converter (on-board charger/OBC), which is placed in the electric car, the alternating current is converted to direct current (DC), as it can be charged in the electric car's high-voltage battery. The vast majority of fast chargers use DC in the stand, as the car's on-board system has a power limit. Electric cars are charged above the grid in three different ways with power from electricity the web16.

- Normal charging is carried out with one phase, below 22 kW and works by connecting the plug to the socket. Charging time is typically four to eight hours, depending on battery capacity and charge level.
- Fast charging is carried out with three phases, over 22 kW. Duration of charging. again lasts between half and three hours, depending on the size and state of charge of the battery.

- Lightning charging is direct voltage up to 250 kW. The duration of the charge corresponds to refueling a conventional car.

There is no overarching standard that describes what type a charging plug must be.
It is solely up to the manufacturer to choose in relation to the battery capacity of the individual high voltage battery and whether AC or DC is charged into the electric car's system from the charging station.

The theme booklet 'Special conditions for rescue in electric and hybrid cars' has an appendix with a detailed description of the technical conditions.

Appendix 5: Police and health emergency services at the scene of the accident

The police and the health emergency services can partly read in more detail in the sections which, for example, be writes an intervention with an acute danger to the life or health of the injured person, emergency evacuation, construction of the scene of the accident and other actors on the site of the injury.

In the event of a traffic accident with electric cars, there is a significantly greater risk that the crew may be injured due to possible high voltage in the bodywork, a sudden fire in the battery and leaking gases.

Based on this and a risk assessment carried out by the first patrol car or ambulance on the scene, the rescue services should be called, if this has not happened on the report, if the following is visible to the crew:

- All types of high-energy accident (the electric car is deformed).
- Visible electrical cables – orange (dangerous electrical voltage).
- Sparks, smoke, steam from the battery (indication of fire).
- Leakage of fluids and/or noise from the battery.

If one or more of the above points are present, the crew should weigh the risks of working in or near the electric car in relation to available PPE.

In principle, electric cars should not be touched without proper personal protective equipment (PPE). The following list indicates European standards for different types of PPE.

Subject	Personal protective equipment (PPE)
Main	Suitable home - EN 50365:2003
Eyes	Suitable visor or glasses - EN 166:2002
Body	Emergency suit - EN 61482-1 and 2
Feet/Body	ESD approved footwear – EN 15090:2012, type F2A
Hands	Suitable gloves EN 60903:2004

The rescue team can be deployed with the correct equipment and PPE. If the police or the health emergency services have to start the effort before the arrival of the emergency services - e.g. for emergency evacuation or emergency treatment - this should be done with extreme caution.

If a person is deployed without proper PPE, there is a risk of exposure to fire smoke, degassing from the high voltage battery or shock. The possibility of observation should be considered. The Danish Emergency Management Agency's app 'Dangerous substances' provides information on dangerous substances, safety distances, health risks, etc.

On the Emergency Management Agency's app 'Dangerous substances' you can find information about the dangerousness of substances, safety distance, health risk, etc.

Identification of electric car In general, the first vehicle in the accident should be aware of whether it is an electric car that is involved. The alarm center can contribute to a significant coverage, which is carried out by the alarm operator at the time of notification. When sending the correct reason code, a choice must be made: Electric car or not electric car.

This information should be reported to the duty center or AMK as early as possible, so that the rescue response can initiate the necessary procedures and operational tactical considerations to ensure the safety of the crew when handling the electric vehicle.

Via the website "motorregister.skat.dk" under the "Find vehicle" tab, information about the fuel can be retrieved by entering the registration number. However, there are exceptions to this, as registration numbers for special vehicles with e.g. police, defense and emergency services are not publicly available.

Resource persons or other persons at the scene of the accident can, for example, with the help of car mares ket or the entire registration number, contribute to an early identification of whether it is an electric car.

Electric cars are often confusingly similar to a regular petrol or diesel-powered car. A number of electric cars have special characteristics of the vehicle, which draw attention to the possibility of these designations:

- EV, BEV or ZEV for electric cars and PHEV or HEV for hybrid cars.
- Some car brands, e.g. Tesla, can be recognized via logo or name, e.g. the text: Zero Emission, Electric, driveE or the letter e or E.
- Presence of a charging plug (possibly behind the tank cover), charging status indicator in the instrument panel, lack of engine noise, lack of exhaust and lack of cooling grille. However, this does not apply to hybrid cars, as they have both a combustion engine and an electric motor.

Risk of fire Traffic-damaged electric cars run the risk of the battery pack spontaneously bursting into flames. Signs of this can be in the form of smoke, degassing/evaporation, seeping liquids and deformation of the electric car's bodywork. The alarm center can also contribute to a significant cover-up, which is carried out by the alarm operator at the time of notification. The alarm operator can inquire about visible smoke or fire development.

In the event of a fire, dangerous fire smoke is emitted, and particularly large amounts of HF gas will be dangerous for people to inhale. Therefore, staying in a possible plume of smoke should be avoided.

Blocking off
Electric cars damaged in traffic will be at risk for damage to the battery pack or exposed high voltage cables, which can cause shocks when touching the electric car.

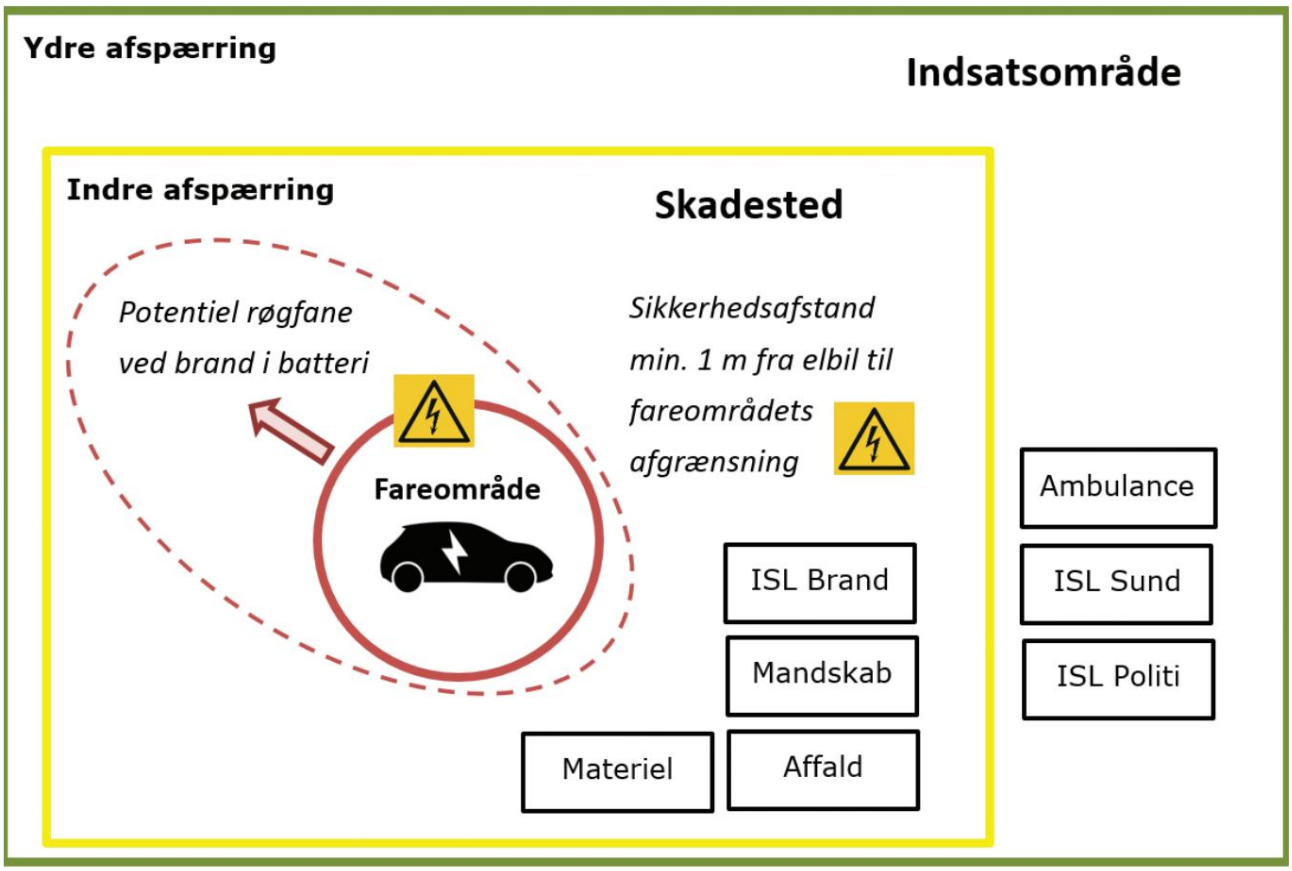
The first vehicle at the scene of the accident should create a barrier that ensures the necessary distance to the electric car (min. 1 m), mark the area with a risk of high voltage and ensure that people without the correct mouth and protective equipment (PPE) come near the electric car.

Emergency evacuation It should, to the greatest extent possible, be the rescue personnel who work in and around the electric car. They are equipped with the right tools and emergency clothing.

In special cases where there is a need to move an injured person in an emergency, this can be done if it is possible to avoid touching the electric car and that the injured person is not trapped, but can be pulled directly out of the electric car. As a safety measure, a colleague should be present to be able to do a shoulder push away from the car.

Use of approved safety gloves up to 1000 V will protect against accidental contact with the electric car.

See detailed description of tasks: Action card – POLICE, Action card – HEALTH DEPARTMENT
TOOL



The structure of the scene in the event of a traffic accident with the need to free trapped persons or risk of fire.

Illustration: The National Emergency Management Agency

Appendix 6: Handing over and moving a damaged electric car

After carrying out a rescue effort in an electric car, it is important that the leader of the effort gives informative instructions to the police or the transporter who must collect the electric car. The tow ring is outside the scope of the emergency response, unless, for example, there is a risk of fire in the high-voltage battery. In general, the manufacturer's instructions for transport should be followed.

The carrier should be aware of the following:

- Development of fire in the battery
- Corrosive and flammable liquids
- Dangerous electrical voltage
- Avoid contact with the electric car
- Avoid open flames
- If the electric car battery has been exposed to fire, there may be residues of toxic fluorine material (Hydrogen fluoride, Phosphorus pentafluoride , Phosphoryl fluoride).

Before the electric car is moved from the scene of damage, it should be assessed whether the high-voltage systems have been damaged. It can, among other things, be high-voltage cables, which are in danger of getting pinched in body parts, or physical damage or deformation of the high-voltage battery itself.

Marking with mine strip is maintained until handover. However, the battery will always be under voltage, even if the main switch is off clean is disconnected.

Be aware that voltage can be disturbed when the car is towed on the wheels. In this way, the engine functions as a generator, which tries to send voltage back to the engine control unit and the battery. If the motor control or the battery is switched off, defective, or unable to absorb voltage, the voltage can become so high that components are destroyed. To avoid disturbing the battery, the electric car should be transported on a sweeper if possible.

Even at very low speeds, wheels connected to electric motors produce voltage that is stored as high voltage in the wheels' capacitors. The manufacturer's instructions are therefore followed.

If the electric car is parked inappropriately or in a nuisance, it may be necessary to move the car to e.g. emergency lane in order to quickly clear the motorway. Before such an emergency evacuation is initiated by the emergency services, the main switch should be disconnected in accordance with the manufacturer's instructions.

Be aware that several types of electric cars go into emergency mode when the main switch is disconnected, which means that the drive wheels (depending on whether there are motors on 2 or 4 wheels) cannot move. In the manufacturer's instructions, it will be indicated which wheels are placed on "roller skates". If an electric car is equipped with electric motor power on all 4 wheels, it may be necessary to use roller skates on all 4 wheels or a crane if the car has to be moved in an emergency.

The high-voltage battery can, if it has been exposed to a violent impact (high-energy accident), develop heat and there is a risk of 'thermal runa way' if it has not yet occurred - even in the case of non-visible damage to the battery pack.

QR code for video with 'thermal runaway' during reading on sweeper blade.

It is therefore important that the electric car is transported away on a sweeper. There must be no unnecessary pulling and twisting in the electric car, as this can create a connection between the cells of the high-voltage battery. The same applies when the electric car is recorded on the sweeper.

A damaged electric car should be placed at a suitable distance from buildings and with a proper marking for high voltage. At the final destination for the electric car, this means that it should be positioned in such a way that a fire does not spread to other vehicles, buildings or storage in the open if the high-voltage battery or the electric car catches fire.

The electric car should be quarantined if possible for at least 48 hours or as prescribed by the manufacturer. The workshop or wrecker should be informed by the carrier about the condition of the car17.

See action card for 'Removal of electric car'.

Appendix 7: Environment

Comparison of electric car and car with conventional fuel Fire in electric cars with Li-ion batteries can develop a number of fumes such as e.g. CO2, CO and NOxs. These are also usually seen in fire smoke where the crew is used to handling them.

Studies of burning electric cars show that more HF is released than in a normal car fire, while the focus should be on CO if

- electric cars

len including battery is 'drowned' by immersing it in water. In case of immersion, there may be a need for a measurement of secreted substances and pH in the extinguishing water and a separate handling of the extinguishing water when discharging.

In order to visualize the emission of flue gas - and thus knowledge about how the fire is handled - a comparison can be made of risks with well-known fires.

In full-scale tests with electric cars and cars with conventional fuel, the exhaust gases were measured. Many of the gases were at comparable levels for the cars with conventional fuel and the electric cars.

The difference in the exhaust gases lay in a greater emission of HF gas from the electric car. Based on one of fullska la trials, it is estimated that for these types of cars with Li-ion batteries of 16.5 kWh. and 23.5 kWh are discharged approx. 1.5 kg of HF gas, while a normal car fire emits just over 0.5 kg. This corresponds to discharging approx. 1 kg more HF gas in the event of a fire in an electric car incl. a high-voltage battery of that size, which overall in terms of the amount of fire smoke must be considered to be minimal.

It should be noted that the available tests have been carried out on batteries which today would be at the small end of the size of a high-voltage battery in an electric car. It has not been possible to find attempts at larger battery packs.

Comparison fire in Li-ion battery and a plastic fire
Below is a comparison of a fire in a Li-ion battery and a plastic fire. The difference is that the plastic fire emits more HF on average over time than the fire in the Li-ion battery, while the fire in the Li-ion batteries has 'peak' time points with much higher amounts of HF and e.g. HCl when the cells in the battery collapse10.

'Peak' time discharge for Li-ion batteries: HF*: 0-6.000 ppm/kg materiale HCL*: 0-10.000 ppm/kg materiale	'Peak' time discharge for plastic fires: HF: 0-1,000 ppm/kg material HCL: 0-1,000 ppm/kg material Average
discharge for Li-ion batteries: HF*: 0-1 ppm/kg material pr. min HCL*: 0-1 ppm/kg material pr. min	Average discharge for plastic fires: HF: 0-45 ppm/kg material pr. min HCL: 0-50 ppm/kg material per. min

**The intervals for the discharge of HF and HCl are given for Li-ion batteries with different chemistries*

In the case of combustion of different types of Li-ion batteries alone, i.e. test without burning a car, where the fire smoke cannot be 'swallowed up' by e.g. cavities in bodywork and fixtures, degassing of up to 20 kg of HF has been observed.

Different chemical compounds and their properties As described, in a fire in an electric car's Li-ion battery, a number of dangerous substances will be released, partly from the battery itself, but also from the car's components, many of which are made of plastic. u

Below are selected substances and their characteristics in pure form. You can read more about u the substances in their pure form, conditions surrounding action and symptoms of poisoning in the app 'Dangerous substances'.

The effort card and its information only apply to a concentration of 100% from the spill or the concentration indicated on the effort card. Chemical Emergency Services should be contacted in case of doubt, for example in case of leakage of large quantities of gas or liquid, so the danger area can possibly be reduced.

Dust	AND	Characteristics	Water
Carbon dioxide, evaporated (CO2)	20 1013	Colorless gas/liquid and odorless. Not flammable*.	Soluble in water. Gas cloud can be suppressed with water mist.
Carbon monoxide (CO, carbon monoxide)	263 1016	Colorless, odorless gas. Highly flammable. Poisonous**.	Moderately soluble in water. Gas clouds can be controlled with scattered water jets.
hydrogen fluoride (HF gas)	886 1052	Colorless gas or fuming liquid with pungent odor. Very toxic.	Soluble in water (hydrofluoric acid). Labeling at different concentrations can be seen in the table. Gas cloud can be suppressed with water mist.
Hydrogen chlorid (HCl)	268 1050	Colorless or white gas/liquid with pungent odor. Poisonous. Corrosive	Soluble in water (Hydrochloric acid). Gas cloud can be suppressed with water mist.

*Description of selected substances from the National Emergency Management Agency 'Dangerous substances' app *Not flammable: Chemical substances and products are perceived as non-flammable when they cannot be ignited in atmospheric air.*

*** IDHL indicates toxicity at an immediately dangerous level. Limit values in the app are calculated for 30 min.*

Note: Hydrofluoric acid is a colorless or brown liquid with a pungent smell, which in its pure form is very toxic. However, in connection with the effort, there will be a large dissolution in the extinguishing water, so the concentration is significantly lower than the weakest solution (< 60%) described in the app.

The two tables below5 show the labeling of hydrofluoric acid at different concentrations.

Chemical compound	Concentration			
	> 7 %	1-7 %	0.1-1%	<0.1%
Hydrofluoric acid on the skin	Causes severe skin corrosion and eye damage.	Causes severe skin corrosion and eye damage.	Causes serious eye irritation.	No labeling.

Chemical compound	Concentration				
	100-10%	10-2.5% 2.5-0.5% 0.5-0.25% < 0.25% Fatal in case of skin contact.			
Hydrofluoric acid on the skin	Fatal in case of skin contact.		Toxic by skin contact	Harmful in case of skin contact.	No marking.

Labeling of hydrofluoric acid at different concentrations

Appendix 8: Working environment

Is it a fire or a chemical attack?
The effort in the event of a fire in an electric car's high-voltage battery should be considered a fire-fighting effort. Although larger quantities can be discharged in certain periods, e.g. HF gas and HCl in a fire in a Li-ion battery than in a normal car fire, the efforts and tactics cannot be changed to a chemical effort.

Especially after the end of the effort, however, there may be advantages in maintaining practices from CBRN. Smoke divers who have been deployed in closed spaces due to fire or risk of fire in Li-ion batteries - have probably been exposed to high concentrations of gases and potentially corrosive and health-damaging extinguishing water. At the same time, fluorine compounds are to be expected on surfaces.

The tasks that must be solved in the danger zone cannot be compared with the definition 'direct contact' in the CBRN understanding. Therefore, the effort can be handled with normal emergency clothing and wearing full respiratory protection.

The smoke divers' response time When responding, the smoke divers use full-coverage response clothing and air-supplied breathing apparatus. The maximum stay for smoke divers in fire smoke or leakage of gases from the high-voltage battery in an electric car should be as short as possible inside a building or closed rooms where there is no ventilation.

In adjacent rooms with smaller concentrations of fire smoke and gases, the response time may be longer. However, it will be a concrete assessment made by the team leader or the effort leader. The assessment can be based on the amount of fire smoke, gases, the possibility of ventilation, as well as whether the smoke divers must work in the room or there is a review in connection with the delivery of material.
In connection with efforts in, for example, parking facilities, there will typically be a long penetration path, which should be taken into account.

For the individual smoke diver, the total intervention time should be estimated at 1 hour. After this, there should be washing and replacement of all the insert ring8.

In the open, the intervention time will be comparable to a 'normal' intervention - however, with the premise that a full intervention mask is used, including a respirator, and that stay in the plume of smoke or seeping gases as far as possible is minimized.

Exposure to fire smoke should be minimized When working in small or closed rooms, special care must be taken to minimize exposure to harmful substances. Especially for fires in electric cars, there is a risk of leakage of gases from the high-voltage battery, which can happen without ignition occurring. This risk is handled at the same time as the risk of the fire smoke itself.

If the electric car is inside a building or parking facility, this can possibly be achieved with the help of an overpressure fan, and that the crew stays as far as possible under the flue gas layer and with protective water mist, which ensures additional protection against exposure to fire smoke and extinguishing water.

After the end of the intervention, the mouthpiece and the equipment used are handled as contaminated, which means that no other actions can be taken until the mouthpiece has been removed.

Cleaning of equipment and personnel It must be assumed as a starting point that the smoke divers, especially in closed spaces, have been exposed to fire smoke, possibly corrosive and health-damaging extinguishing water and various substances (fluorine compounds) on surfaces.
Normal good practice for handling contaminated (contaminated) material and 'clean firefighter' is followed according to own operational procedure.
An SOP for smoke diving in an environment with fire smoke and leaking gases from the electric car's high-voltage battery can be usefully drawn up.

In addition to the smoke diving itself, there should be a focus on personal hygiene, as HF gas and flue acid can be absorbed through the skin. Therefore, thorough washing should be carried out as soon as possible after efforts.

All emergency clothing should be removed after the end of the operation, including undergarments, with minimal contact with the skin, e.g. by using walking gloves and suitable respiratory protection.
Mouth ring is considered contaminated.

A procedure should also be drawn up for cleaning the equipment, as it is also con
it would be tamed

In case of exposure to fire smoke
In practice, valid measurements of the presence or occurrence of dangerous substances will be difficult. Since there is currently no if there is exact knowledge of the toxicity of the real concentrations during an intervention, work should be based on a precautionary principle with the least possible exposure of the individual employee.

Symptoms of poisoning with e.g
HF gas or hydrofluoric acid can cause coughing, difficulty breathing and pain in the airways when inhaled, where contact with the skin is described as a burn throbbing pain and caustic ulcers. Pain can be delayed up to 24 hours.

In case of signs of or suspicion of poisoning, rapid personal cleaning should be started. Knowledge can be sought in the Emergency Management Agency's 'Far equal substances' app. The health authorities should be contacted for guidance and any need for hospitalization for observation.

This also applies to any injured persons and other actors in the effort who have been exposed to fire smoke etc.

Action card – Question guide for the call centre, AMK and first vehicle

Input from the scene of the accident to Vagtcentral and AMK plays an important role in contributing to the identification of whether an electric car is involved in a traffic accident and in passing this information on to the first vehicle at the scene of the accident.

The role of the alarm center can be a significant cover-up of the question of whether an electric car is involved. This coverage is carried out by the alarm operator at the time of notification. When sending the correct reason code, make a choice: Electric car or non-electric car. Coverage will be a quick assessment of electric car / non-electric car and fire / non-fire.

The alarm center can choose to connect the healthcare visitor to the call (conference call). After this, the following questions can be asked by the healthcare visitor at AMK. If the alarm operator judges that it makes sense to listen in, the operator does this. More information can be sent to the rescue services in the form of dispatch 2 (additional information).

QUESTIONS REGARDING INJURED	
ARE THERE INJURIES IN THE VEHICLE? **YES** - How many? - Where are they located in the vehicle? - Are they immediately stuck?	ARE THERE INJURIES OUTSIDE THE VEHICLE? **YES** - How many? - Where are they located?
IF YES, WHAT IS THE CONDITION OF THE INJURED? - Do they have visible damage? - Unconscious; Conscious? - Not contactable; Contactable? - Unstable on ABC; stable on ABC? - Can the injured get out themselves the vehicle? ÿ **YES** – consider it if to the risk of fire in the vehicle	**ATTENTION** - All contact with defective/exposed cables and wires should be avoided - If you start removing the damaged parts, there may be a risk of voltage in the car's body due to deformation of the battery pack - If the car's airbags are deployed, the cables from the battery pack will be de-energized, and possibly first aid or emergency evacuation can be started if the injured person is threatened at ABC
DO INJURIES RECEIVE FHJ IN THE DRIVING CLOTHING? **YES** - How many receive FHJ? - How many does FHJ provide to injured people? - Can the injured get out of the car the clothes? - Are the injured trapped?	DO INJURIES RECEIVE FHJ OUTSIDE THE VEHICLE? **YES** - How many receive FHJ? - How many does FHJ provide to injured people? - If you provide FHJ at a safe distance to drive the clothes? - Have they been injured inside the vehicle or outside (hit)?
DO INJURIES RECEIVE FHJ IN THE VEHICLE? **NO** - Is there a reason why FHJ is not provided?	DO INJURIES OUTSIDE THE VEHICLE RECEIVE FHJ? **NO** - Is there a reason why FHJ is not provided?

IS THERE FIRE, SMOKE OR GAS EVOLUTION IN/FROM THE ELECTRIC CAR?

-Is there visible smoke or flames from driving the clothes?
- Is there a hissing sound from the vehicle?
  Is there a jet-like flame from approx. 1 – 2 from the bottom section of the vehicle?
- What color is the smoke?
  White dense smoke – speed of the smoke?
- Smells or sounds from the vehicle?
  Small banging noises/noises from the vehicle all the time etc. sometimes?

-Is there a fire in other/several cars?
- Is the car located close to a building?
- How many are electric cars?

Especially for hydrogen cars:
- Noise/ from hydrogen tank (hissing)
- Leakage of gas from the hydrogen tank (https://kemikalieberedskab.dk/)

WHAT TYPE OF VEHICLE IS IT ABOUT?

Check the registration number on the website motorregister.skat.dk

Visible characteristics electric car: -Electric car logo: Tesla; ID3; ID4 etc.
- Electric car: EV; BEV; PEV; ZEV;
  Drive E; Zero emission; I-on; Electrical; Ie - Charging socket, but no fuel cap - No exhaust pipe -
No cooling grille - No engine noise

Visible characteristics hybrid car:
-Hybrid car: PHEV; HEAVY; MHEV and others
- Charging socket and/or tank cover

Visible characteristics hydrogen car:
- Hydrogen logo e.g. Hydrogen

QUESTIONS ABOUT THE VEHICLE

WHERE DID THE TRAFFIC ACCIDENT OCCUR?
- Motorway - country road - urban / residential road - gravel road; in water? (lake, harbor, stream, etc.)?
-Is the vehicle a nuisance to the flow of traffic on the road, path, etc.?
- Is it on the road? Which track;
  inner, outer, middle or emergency tracks; off the roadway; lies on the side of the road; opposite lane?
- Does it stand on all 4 wheels – lying on its side – upside down – opposite direction of travel lane?

IS IT ABOUT AN ELECTRIC CAR – ONE OR MORE VEHICLES INVOLVED?
- How many vehicles?
- How many electric cars are involved?
- Keeps the vehicle alone or together with other vehicles?
- Does the vehicle pull into the vehicle in front?
- Has the vehicle been hit from behind?
- Holds the vehicle together like an accordion shock?

Visible damage to the electric car
- Damage to the front or rear
- Damage to the left or right side
- Exposed or damaged orange cables from the vehicle
- Are the airbags deployed

Visible damage to the battery pack
- Holds the vehicle in the guardrail
- Is there leakage of liquids from the battery pack
- Deformation of the battery pack
- Battery pack exposed

HOW FAST WAS THE CAR DRIVING AT THE ACCIDENT? (BEST RATING)
- Above or below 70 km/h?

Action card – Brand i elbil
– Persons in danger in electric cars/nearby

Used in accidents, fire in an electric car, where there is a need for extrication or other danger to people's life or mobility.

FIRE IN ELECTRIC CAR BATTERY - PERSONS IN DANGER IN CAR/NEARBY	
Persons at risk	**Offensive effort**
Need for release	**Offensive effort**

TACTICAL PRIORITIES
FOR
Risk assessment
Disconnect the power supply if the car is waiting for charging (possibly by connecting to the supply cabinet for the charging station)
If this is not possible, the fire should be considered as a fire in high voltage installation
Implement blocking and marking/signs with danger of high voltage to the charging station)
Ensure that there is no high voltage in the body of the electric car
Place chocks at the wheels to the charging station)
Disconnect the electric car's main switch if this is possible
Disconnect the car's 12 V battery to the charging station)
UNDER
offensive tactics. Turn off or cool the electric car battery with superior beam and carry out rescue
For personal rescue - see the thematic booklet on rescue
After personal rescue, the subsequent action card is used: Fire in an electric car's battery - no one in danger
AFTER
After personal rescue, the following action card is used: Fire in an electric car's battery - no one in danger

Action card – Brand i el′

- No people in danger

FIRE IN ELECTRIC CAR BATTERY - NO PERSONS IN DANGER		
Possibility of fire spread	Offensive effort	Defensive effort
No possibility of fire spreading		Defensive effort
Critical infrastructure	Offensive effort	Defensive effort
Danger to citizens (smoke generation)	Offensive effort	Defensive effort

TACTICAL PRIORITIES
FOR
Risk assessment
Disconnect the power supply if the car is waiting for charging (possibly by contacting the supply cabinet for the charging station)
If this is not possible, the fire should be considered as a fire in a high-voltage installation
Put in place barriers and markings/signs with the risk of high voltage
Ensure that there is no high voltage in the body of the electric car
Place chocks at the wheels
Disconnect the electric car's main switch if this is possible
Disconnect the car's 12 V battery
UNDER
Offensive tactics Turn off or cool the high-voltage battery. Place any the electric car in a fire-extinguishing container
offensive tactics If necessary, use water mist to cool the surroundings and wash down dangerous substances from the fire smoke with large amounts of water mist with as small droplets as possible
Defensive tactics Let the high voltage battery burn out. This may take more than 120 minutes
defensive tactics If necessary, use water mist to cool the surroundings and wash down dangerous substances from the fire smoke with large amounts of water mist with as small droplets as possible
defensive tactics If necessary, use a fan to control the smoke plume
AFTER
Blocking and signage will be maintained for as long as possible
When the battery has cooled sufficiently, it is checked that the battery's temperature is stable or falling for a minimum of 60 minutes - to below 80C. Use thermal camera
Transport the vehicle to a suitable storage location and place it at least 5 meters from other combustible material, including buildings
Inform the recipient that it is an electric car or a hybrid/plug-in hybrid car
Pass on the assessment to the police, transporter, whether there is damage to the electric car or the battery

Action card – Fire in an electric car – Building/closed structure Used in the event of a fire in an electric car which is located in a building or a closed structure, e.g. a P-cellar, where there is not necessarily the possibility of good ventilation.

FIRE IN ELECTRIC CAR – BUILDING/CLOSED CONSTRUCTION	
Possibility of fire spread	**Offensive effort**
Danger to citizens (smoke generation)	**Offensive effort**

TACTICAL PRIORITIES

FOR

- Create effective venting of flue gases from emergency room entry routes
- Make sure that the flue gases are not vented to areas where people are exposed to them
- Block off any access routes to the room, thus preventing access to persons without correct emergency clothing
- Push forward towards the fire so that all contact with smoke is minimised
- Disconnect the power supply if the car is waiting for charging (possibly by contacting the supply cabinet for the charging station)
- If this is not possible, the fire should be considered as a fire in a high-voltage installation
- Put in place barriers and markings/signs with the risk of high voltage
- Ensure that there is no high voltage in the body of the electric car
- Place chocks at the wheels
- Disconnect the electric car's main switch if this is possible
- Disconnect the car's 12 V battery

UNDER

- Offensive tactics
  Turn off or cool the battery. Place any the electric car in a fire-extinguishing container
- offensive tactics
  Use water mist to cool surroundings and wash down dangerous substances from the fire smoke with large amounts of water mist with as small droplets as possible
- offensive tactics
  Use a fan to control the smoke plume
- Pay attention to discharge and possible collection of extinguishing water
- defensive tactics
  The electric car is brought out into the open
- defensive tactics
  The action card is then used: Fire in electric car battery - no one in danger

AFTER

- When the battery has cooled sufficiently, it is checked that the battery's temperature is stable or falling for a minimum of 60 minutes - to below 80C. Use thermal camera
- After personal rescue, the subsequent action card is used:
  Fire in electric car battery – no one in danger 68

Action card – Brand i elbil
- No battery

Used in the event of a fire in an electric car where the fire has not yet spread to the high-voltage battery, but there is a risk that this could happen.

FIRE IN ELECTRIC CAR - NOT BATTERY	
Possibility of fire spread	**Offensive effort**
No possibility of fire spreading	**Offensive effort**

TACTICAL PRIORITIES
FOR
Risk assessment
Disconnect the power supply if the car is waiting for charging (possibly by contacting the supply cabinet for the charging station)
If this is not possible, the fire should be considered as a fire in a high-voltage installation
Put in place barriers and markings/signs with the risk of high voltage
Ensure that there is no high voltage in the body of the electric car
Place chocks at the wheels
Disconnect the electric car's main switch if this is possible
Disconnect the car's 12 V battery
UNDER
Offensive tactics. Put out the fire in the electric car
Ensure that the temperature from the fire has not affected the electric car's battery
Check that the battery temperature is stable and below 80oC Use thermal camera
AFTER
Check that the battery temperature is stable below 80oC. Use thermal camera
After personal rescue, the subsequent action card is used: Fire in an electric car's battery - no one in danger

Action card - Police

This action card provides a number of attention points for proper handling of electric cars until the arrival of the emergency services.

In the event of a traffic accident with electric cars, there is a significantly greater risk of possible high voltage in the bodywork, a sudden fire in the battery and leaking gases.

Particular attention is paid to the following:

- •All types of high-energy accident (the electric car is deformed).
- •Visible electrical cables – orange (dangerous electrical voltage).
- •Sparks, smoke, steam from the battery (indication of fire). • Leakage of liquids and/or noise from the battery.

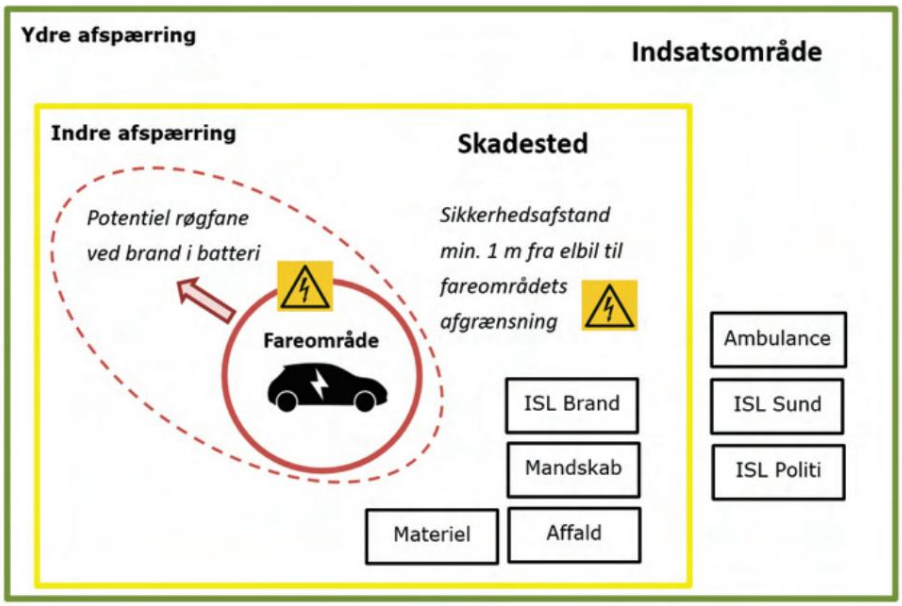
On the Emergency Management Agency's app 'Dangerous substances' there is information about the dangerousness of substances, safety distance, health risk etc.

In principle, electric cars should not be touched without proper PPE. If one or more of the above points are present, the first patrol car should weigh the risks of working in or near the electric vehicle against the proper personal protective equipment (PPE) that is available.

Staying in the plume of smoke or when gases and liquid seep from the battery is associated with the risk of poisoning. On the Emergency Management Agency's app 'Dangerous substances' there is information about dangerous substances, safety distance, health risk, e

The first patrol car can be helpful in securing the scene of the accident. This includes blocking off, removing people around the electric car and in any smoke plume. We work based on the below principle for building up damage place.

There is a risk of high voltage when contacting cables/ wires or live parts.



The structure of the scene in the event of a traffic accident with the need to free trapped persons or risk of fire.

Illustration: The National Emergency Management Agency

QR code for video with 'thermal runaway' during reading on sweeper blade.

PATROL CAR ARRIVES AT THE SCENE OF THE INJURY AS THE FIRST CAR	
Insurance of the place of damage	- Stopping traffic - Blocking off the site of damage - Securing own personnel and persons against any plume of smoke
Overview	- Fire / no fire in the vehicle? - Persons in danger / not in danger? In or out of vehicle? - Person – Unstable on ABC, Unconscious? ÿ Need to withdraw ÿ Emergency move? - Person – stable on ABC, Conscious? ÿ No need to remove casualties
Fire/risk of fire	-Fire: flames or smoke (black) - Risk of fire: sounds; odors; white smoke (degassing from battery) - Avoid staying in the smoke plume or gases (all without PPE)
Type of vehicle (electric car/plug-in/hybrid electric car)	- Confirmed/ not confirmed electric car? - Location at the scene of the accident – on/off the road, in the water, etc. - Location on the roof, on the side, etc.
Damage to the electric car ÿ risk of shock	- Exposed or damaged cables? - Deformations in bodywork, battery? - Triggered airbags = live cables. The battery pack cannot be de-energized
Handling casualties? - Only if it is possible	and safe: -Need for emergency evacuation of the injured from the vehicle? - FJH of injured persons outside the vehicle? - FJH of injured persons in vehicle ÿ without contact with electric car?
Disclosure of information to ISL BRAND, ISL SUND	- Actions cf.: - Securing the scene of the accident - Overview of the injured ÿ Handling? - Type of vehicle (electric car/ hybrid) - Fire/risk of fire - Damage to the electric car

POSSIBLY. ADDITIONAL INFORMATION

- What type of vehicle is it - registration number? Electric car, plug-in/hybrid electric car?
- Are there injured people in the vehicle? Are they stuck?
- Have we removed the injured and bystanders to a safe distance from the scene of the accident?
- Have people been exposed to smoke (crew, injured, other people)?
- What location is the vehicle (on the road, in a ditch, in water, upside down, etc.)
- Is there visible smoke or outgassing from the vehicle?
- Sounds; Smoke development; Unnatural smells or liquid leaking from the battery?
- Danger of voltage at the vehicle - danger of high voltage, exposed, broken cables?

For more details on observations at the scene of the accident, see Action card – Question guide for the call centre, AMK and first vehicle'

Action card - Health preparedness

There may be situations where the ambulance arrives first at the scene of the accident. This action card provides a number of attention points for proper rescue handling
the effort with electric cars until the arrival of the rescue services.

In the event of a traffic accident with electric cars, there is a significantly greater risk that the crew may be injured due to possible high voltage in the bodywork, a sudden fire in the battery and leaking gases.

Based on this and a risk assessment carried out by the first vehicle on the scene, the emergency services should be called if it is not happened on the report, if the following is visible to the crew:

- •All types of high-energy accident (the electric car is deformed).
- •Visible electrical cables – orange (dangerous electrical voltage).
- •Sparks, smoke, steam from the battery (indication of fire). • Leakage

of fluids and/or noise from the battery.

In principle, electric cars should not be touched without proper PPE. If one or more of the above points are present, the first vehicle/ambulance should weigh the risks of working in or near the electric vehicle against the correct personal protective equipment (PPE) that is available.

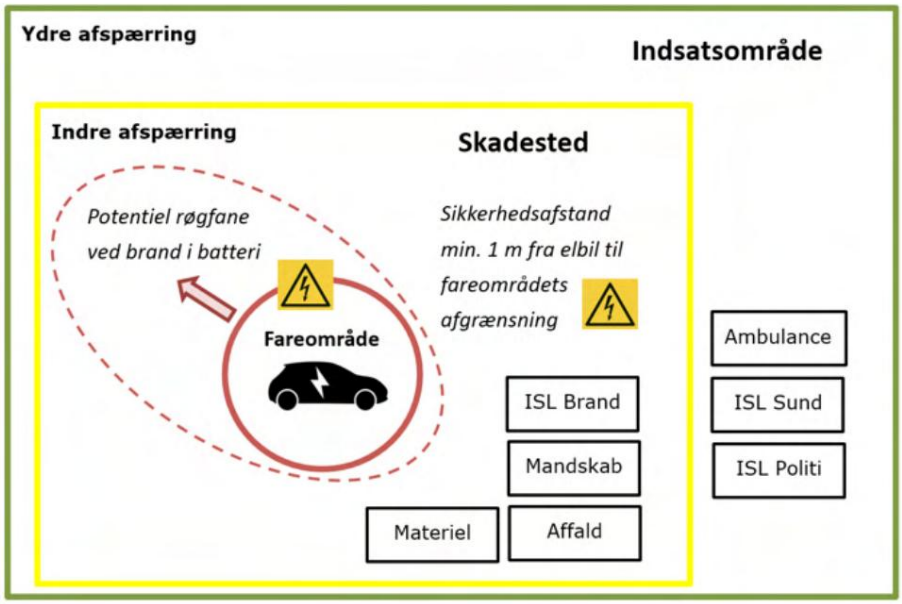
Subject	Personal protective equipment (PPE)
Main	Suitable home - EN 50365:2003
Eyes	Suitable visor / glasses - EN 166:2002
Body	Emergency suit (typical enough) - EN 61482-1 and 2
Feet/Body	ESD approved footwear – EN 15090:2012, type F2A
Hands	Suitable gloves EN 60903:2004

Staying in the plume of smoke or when gases and liquid seep from the battery is associated with the risk of poisoning. On the Emergency Management Agency's app 'Dangerous substances' there is information about dangerous substances, safety distance, heat radiation, etc.

The first vehicle can be helpful in securing the scene of damage. It includes blocking, removal of people around the electric car and in any smoke plume. We work based on the principle below for building up the damage site.

There is a risk of high voltage when contacting cables/ wires or live parts.

The Emergency Management Agency's app 'Dangerous substances' provides information on the dangerousness of substances, safety distance, health risk, etc.



The structure of the scene in the event of a traffic accident with the need to free trapped persons or risk of fire. Illustration: The National Emergency Management Agency

THE EMERGENCY SERVICE ARRIVES AT THE SCENE OF THE INJURY AS THE FIRST CAR (AMBULANCE, AMBULANCE, AMBULANCE)	
Insurance of the place of damage	- Stopping traffic - Blocking off the scene of the accident - Securing your own crew and people against possible plume of smoke
Overview	- Fire / no fire in the vehicle? - Persons in danger / not in danger? In or out of vehicle? - Stable on ABC / Unstable on ABC - Person trapped/ Not trapped ÿ Need for emergency relocation YES ÿ Possible and justifiable?
Fire/risk of fire	-Fire: flames or smoke (black) - Risk of fire: sounds; odors; white smoke (degassing from battery) - Avoid staying in the smoke plume or gases (all without PPE)
Type of vehicle (electric car/plug-in/hybrid electric car)	- Confirmed/ not confirmed electric car? - Location at the scene of the accident – on/off the road, in the water, etc. - Location on the roof, on the side, etc.

Damage to the electric car ÿ risk of shock	Visible damage? -Is there one or more vehicles? – Electric cars? - Damage to the front or rear - Damage to the left or right side - Exposed or damaged orange cables from the vehicle - ATTENTION risk of high voltage in contact with cables/wires or live parts - Deformations in bodywork, battery? - Triggered airbags = live cables. The battery pack cannot be de-energized - Does the vehicle hold in the guard rail? - Speed above or below 70 km/h?
Handling casualties? - Only if it is possible and safe:	-Need for emergency evacuation of the injured from the vehicle? - FJH of injured persons outside the vehicle? - FJH of injured persons in vehicle ÿ without contact with electric car? Attention - All contact with defective/exposed cables and wires should be avoided. - If you start removing the injured, there may be a risk of tension in the vehicle's bodywork due to deformation. - If the car's airbags are deployed, the cables from the battery pack will be de-energized, and extraction can begin if the injured person is threatened at ABC. - Insulating rubber mats and special protective equipment (PPE) should be used to protect personnel who must work in and around the electric car. Therefore, the emergency services should be called. - A safety distance of min. 1 m from the electric car, cf. EN 50110-1, where direct contact with conductive parts is defined as 'work under voltage' and work within 30 cm of conductive parts is defined as 'work near voltage'.
Disclosure of information to ISL BRAND, ISL POLICE	- Actions cf.: - Securing the scene of the accident - Overview of the injured ÿ Handling? - Type of vehicle (electric car/ hybrid). - Fire/risk of fire. - The electric car's damage.

POSSIBLY. ADDITIONAL INFORMATION

- What type of vehicle is it - registration number? Electric car, plug-in/hybrid electric car?
- Are there injured people in the vehicle? Are they stuck?
- Have we removed the injured and bystanders to a safe distance from the scene of the accident?
- Have people been exposed to smoke (crew, injured, other people)?
- What location is the vehicle (on the road, in a ditch, in water, upside down, etc.)
- Is there visible smoke or outgassing from the vehicle?
- Sounds; Smoke development; Unnatural smells or liquid leaking from the battery?
- Danger of voltage at the vehicle - danger of high voltage, exposed, broken cables?

For more details on observations at the scene of the accident, see Action card – Question guide for the call centre, AMK and first vehicle'

Action card - Settlement of the scene of damage

After the emergency services have invested in an electric car, it is important that one is given relevant instructions to the transporter who has to transport the electric car away, if it is on the way or to the police when the scene of the accident is released.

SETTLEMENT OF THE SITE OF DAMAGE	
Clean up the scene	- Marking of the danger area with signage against high voltage – this is maintained when the damage site is released (min. 1 m) - The scene of the accident/the electric car is handed over to the police or transporter, if this is present at the scene of the accident, when the incident leader assesses that there is no longer a possibility of 'ther mal runaway' - If work earthing has been carried out, it should be ensured that the electrical installer or equivalent expert, will be able to dismantle grounding when the damage site is released.
Instructions for carrier	The carrier should have the following information: - It is an electric car/hybrid car. - Brief information on the rescue services' efforts: fire extinguishing, release (damage to cables). - Assessment of the condition of the car's high-voltage battery, purchase ling of the main switch, voltage. - The risk of 'thermal runaway' during transport to the workshop and what the transporter should do if this happens. - That the electric car should be placed min. 5 m away from buildings and other flammable material.

Examples of danger signs

Action card - Away transport of electric car

After carrying out a rescue operation in an electric car, it is important that a relevant one is given instructions to the transporter who has to transport the electric car away or to the police, if the place of damage is handed over to them.

Removal of electric car	
The carrier is informed of the following before the electric car is loaded	- This is an electric car/hybrid car. - Explain about the efforts of the rescue services. - Explain about the state of the car's battery and the possible danger of high voltage.
The transporter should pay attention when loading the electric car	- That the electric car can be loaded, transported and unloaded in a safe and sound manner, including the use of personal protective equipment (PPE) by the transporter. - That there is tension in the body as a starting point a security guard present. - That there are no unnecessary turns in the car while it is loaded can be seen on the sweeper blade. - That it is observed for possible heat development or 'thermal runaway' in the battery while the car is being loaded. - Noises, smoke or unnatural smells from the battery. - Liquid leaking from the battery.
The transporter should pay attention to the following when transporting the electric car	To call 112 and provide relevant information if: - Fire/'thermal runaway' occurs in the battery. - Heat development in the battery. *Or significant changes in relation to:* - Sounds from the battery. - Smoke generation from the battery.
The transporter should be aware of the following when the electric car is unloaded at the final destination	- The electric car should not be placed in a building/under cover and. - The electric car should be placed at a suitable distance from surrounding buildings, roofs and other flammable storage, so that fire cannot spread here. - The electric car should be clearly marked with a barrier and sign with 'Danger - high voltage'. To call 112 and provide relevant information if there is: - Fire/'thermal runaway' in the battery. - Heat development in the battery. - Liquid leaking from the battery. *Or significant changes in relation to:* - Sounds from the battery. - Smoke generation from the battery. - Unnatural odors from the battery.

Citations and references

1 https://www.euroncap.com/en/press-media/press-releases/euro-ncap-improves-tertiary safety-by-introducing-a-mobile-app-for-first-responders-in-europe/

2 Euro ncap rescue sheet, free app, https://www.euroncap.com/en/about-euro-ncap/timeline/ euro-ncap-launches-euro-rescue-free-downloadable-rescue-information-for-first-respon ders/

3 Electric car batteries: What you need to know (firerescue1.com), https://www.firerescue1. com/firefighter-training/articles/what-firefighters-need-to-know-about-electric-car-batteries omiDv8vd87oZ9ZKs/

4 Industriens Branchearbejdsmiljøråd, 2016, Electric and hybrid cars. Safety during repair and maintenance, https://www.bfa-i.dk/media/aazlwuvr/el-og-hybridbiler.pdf

5 https://risefr.com/media/publikasjoner/upload/2017/a17-20096-03-01-fullskala-brannfor sok-av-elbil.pdf]

6 SP Fire Research A/S, 20/02 2017, A17 20096:03-01

7 https://www.ntsb.gov/safety/safety-studies/Documents/SR2001.pdf]

8 NFPA Bulletin, september 2017

9 Informational video Pre-hospital skills when responding to fires in lithium-ion batteries, https://youtu.be/vaspu8f_X_w

[10] Gaseous HF in case of fire in confined spaces - risks of skin absorption during interventions, MSB 2021

11 LBK no. 26 of 10/01/2019, Promulgation of the Act on safety in electrical installations, electrical installations and electrical equipment (elsikherdsloven), https:// www.retsinformation.dk/eli/lta/2019/26

[12] The Swedish Safety Agency, https://www.sik.dk/erhverv/elinstallationer-og-elanlaeg/vejledninger/ elinstallationer/l-aus-arbejde-under-spaending/arbejde-paa-elektriske-installationer, accessed 25-01-22

13 Dansk Standard, "DS/EN IEC 60900:2018 Live work - Hand tools for use up to 1000 V ac and 1500 V dc," Dansk Standard, 2018

14 International Organization for Standardization, ”ISO 7010:2019 Graphical symbols — Safety col-ours and safety signs — Registered safety signs,” ISO, 2019

15 FDM: How does an electric car work? https://fdm.dk/alt-om-biler/elbil-hybridbil/alt-om-livet with-an-electric car/how-an-electric-car-works, accessed 01-25-22

[16] The Swedish Safety Agency: Charging of electric cars https://www.sik.dk/erhverv/elinstallationer-og-- elanlaeg/vejledninger/elinstallationer/elbiler/opladden-el-biler, accessed 13-06-22

17 Handling of traffic-damaged electric cars, SKAD – auto damage industry, https://www.skad.dk/images/Bilteknik/SKAD_guideline_skadede_el-hybridbiler_V1_2019.pdf

On the National Emergency Management Agency's website www.brs.dk you can find information on other publications, e.g

Laws and rules

Guidelines and instructions

Learning materials

Opinions and judgments

Historical material

Graphic setup:
Graphic artist Pernille Gaarden, Publikationselementet, Korsør

The National Emergency Management Agency

Datavej 16

3460 Birkerød

Phone: +45 71 85 20 00

Email: brs@brs.dk

www.brs.dk

EAN: 5798000201705

CVR: 52990319