5 ELBAS – WP5: Conclusions and Recommendations

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Danish Institute of Fire and Security Technology
Jernholmen 12, 2650 Hvidovre, Denmark · Phone: +45 36 34 90 00 Fax: +45 36 34 90 01 ·
E-mail: dbi@brandogsikring.dk · Web: www.brandogsikring.dk, https://brandogsikring.dk/en/

5.1 Conclusions

This chapter summarizes the findings of the ELBAS project, giving the overall perspective of the problem of handling EV fires on board ferries, as gathered during this study. The reader is referred to the respective sections of the full report for comprehensive insights concerning these conclusions.

The overall conclusion of the ELBAS project is that EV fires on ferries are not to be feared more than any other fire at sea. They can typically be dealt with using the correct technology, education, and training of shipboard personnel, as well as with coordinated cooperation between the ship and with emergency services on land.

Extra attention should be paid to training of crew on ships carrying electric and other modern vehicles, through performing realistic drills involving vehicle deck fires, and including the appropriate protection and correct disrobing procedures post fire, to avoid harmful contamination from chemical exposure.

For portable firefighting tools to work, their operation must be included when developing vehicle stowage procedures for loading the vessel, in order to have any effect with the fire.

5.1.1 Results of the Live Fire Tests and Fire Simulations

The use of portable fire extinguishers alone is not as effective as the use of fixed, water based firefighting systems. Cooling is key and use of sprinkling with a water mist turned out to be highly effective. Not in fully extinguishing an EV fire, but for limit the spread of the fire, so that the shipboard firefighters can get to seat of the fire and continue extinguishing with traditional extinguishing methods, possibly combined with appropriate specialized tools.

ELBAS results have also demonstrated how fire simulation can give insights into how fire and smoke can spread within a ro-ro vehicle deck, and how current fire protection methods e.g., detection and suppression, perform given different simulated scenarios of an EV fire.

5.1.2 Active Use of Ventilation as part of a Fire Management Strategy

Keeping the ventilation system running (jet fans) may have positive effect for smoke control during a fire on the vehicle deck in certain scenarios and could be considered as part of the fire management strategy. Simulations using advanced fire modelling tools can be very useful to identify issues and behavior of fire and smoke, but the results of such simulations are dependent on the specific ship geometries and loading conditions modeled.

The results presented in this report are based on case studies of two of the ships included in the ELBAS project, and, therefore, any generalizations should be done with care. It is therefore recommendable to perform this type of study on more ships, to better quantify this, and inform owners and the shipboard officers and crew of the specificities of their ship.

5.1.3 Use of Fixed Sprinkler (Drencher or Water Mist) System Provides a Quick Response

Early sprinkler activation is the key to stopping the fire spread. While a drenched or water mist system will not necessarily target the battery directly of the EV, it will produce a spray once activated from its fixed position causing a cooling effect, both on the burning car itself and to the surroundings including nearby structural elements. As soon as the fixed system in the ELBAS tests was activated, a drop in temperature on the battery, smoke layer above the EV and the surrounding cars were observed, helping to contain the fire and prevent spread.

5.1.4 Large Thermal Fire Blanket Over Vehicle

The use of a large thermal fire blanket to enclose the car has shown to be effective, especially when combined with the other efforts of using both fixed firefighting installations supplemented with manual firefighting are combined. While use of a fire blanket alone did not put out the fires in the ELBAS tests, the fire blanket did an effective job in containing it, by removing oxygen and preventing fire spread.

It is also conceivable that cars surrounding the burning EV could be protected by fire blankets, to prevent the additional spread of fire. The fire blanket's main purpose is to limit the flame spread to adjacent vehicles or to the structural elements and provide enough time for the vessel to reach port and get external shore-side assistance.

However, use of a fire blanket requires space to wrap the burning EV correctly and a minimum of two persons in appropriate PPE, so this solution depends on how close the cars are stowed onto the vehicle deck. On a smaller ferry with few vehicles and crew, fire blankets could be a helpful tool as a supplement to the existing firefighting arrangement. Whereas in larger fires and/or tightly stowed vehicle decks which limits direct access to the fire, use of fire blankets may not be as effective given the restricted space available.

5.1.5 Battery Extinguishing Systems

Two methods for direct battery extinguishing were tested as part of the ELBAS project. Direct cooling of the battery is advantageous and extremely efficient when controlling a battery fire, and the battery pack was cooled down with a considerably lower water consumption compared to other water based extinguishing systems used in ELBAS series of experiments. However, these devices are not capable of putting out flames inside the passenger cabin or vehicle itself.

These devices are most appropriate when only the actual battery itself is the concern. It is therefore required that the flames outside the battery have been put out prior to using this device. This makes it much easier for the firefighters to attack the battery without the effects from external flames and smoke. The intended use of these devices is primarily to cool down the battery after the fire has been extinguished, and given the complexities of use, may be most appropriate for use by professional firefighters with proper training with battery and battery fires.

5.1.6 Portable Mist Curtain and Undercarriage Cooling

Several portable firefighting tools producing a local water mist curtain were tested as part of the ELBAS live fire experiments. This water curtain is to act as a barrier for flame spread and keeps the fire contained within the originally ignited vehicle.

Each of these devices must be connected to the water supply using a standard fire hose found onboard, before placing it near the burning vehicle. These systems provide local water cooling on either the sides of the burning vehicle and/or in a smaller array underneath the burning EV where the batteries are normally located. The intention is to create a water barrier around the EV, through which heat and flames cannot penetrate and spread.

The use of such portable mist cooling devices may assist in keeping an EV fire from growing and spreading, until the ship reaches port. However, these devices must be placed prior to the fire spreading, and depends on how close the cars are stowed on the vehicle deck, as it required sufficient clearance around the vehicles.

For all these portable firefighting tools to work, their operation must be included when developing vehicle stowage procedures for loading the vessel, in order to have any effect with the fire.

5.1.7 Combined Firefighting Methods

The combination of using the fixed firefighting installations supplemented with manual firefighting from the crew on board is the most common fire strategy for first response to an EV fire onboard. Early response and cooling are key for the fire not to spread or to develop further. These are critical measures to be taken onboard to protect the ship, it's passengers and crew while heading to the nearest port where emergency services can provide assistance.

It is known from research of actual events and experience from the ELBAS live fire testing that fire in an EV battery can flare up again after a period of time. Thus, achieving complete extinguishing of such EV fires may be too much to expect from shipboard firefighters, who may have only limited live fire experience for the statutory maritime fire courses required by STCW and the Flag State. Therefore, it is important to engage with available local shoreside firefighters in the planning for potential occurrence of an EV fire onboard.

5.1.8 Specialized Fire Training

Realistic firefighting training of maritime personnel is essential. In general, it is recommended based on the performance of the ELBAS project, for crew members to do more realistic fire drills and possibly training involving live fires using real cars in a set-up resembling a vehicle deck – to experience the difference between tackling a conventional car fire and EV fire, for instance.

Part of this specialized training should also include use of correct PPE, both for the shipboard firefighters and the crew with emergency duties as assistants, to avoid post fire contamination. Further, it should be encouraged to include a decontamination step in the post-fire clean-up procedure. Such training can also be done in cooperation with shore-based firefighters.

5.1.9 Joint Exercises and Drills with Shipboard and Shore-side Firefighters

All fires onboard ships present a challenge for the ship's crew, not least a fire on the vehicle deck. In the case of an EV fire onboard, an integral planning of a combined response with the assistance of shore-based fire fighters is highly recommended. Through working together with local emergency services and first responders, it is possible to transfer existing and develop knowledge of EV-specific firefighting from ashore over to the maritime sector.

Full scale joint exercises should be held regularly, between the ship and shore-side emergency response services, in order to identify potential opportunities for improved cooperation and coordinated response. Through interviews it was found that, in some cases shore-based fire fighters are not always fully aware of the specific firefight procedures, training and equipment existing onboard ships.

5.1.10 Need for a Regularly Updated Fire Risk Assessments

The requirement for assessment and management of risks is one of the fundamental Objectives of the ISM code (Part A, 1.2.2) Regular risk assessments shall be carried out to see how accidents, injuries or illnesses could be caused on the ship and what can be done to reduce the chances of them happening. Risk assessments should be reviewed annually, as well as whenever there are significant changes to either the ship or working activities onboard.

With the increase in transportation of new fuel vehicles, including EVs, updated Risk Assessments are required to identify these new risks, and new procedures developed to address them. These are also a focus point during port and flag state inspections, as well as by other inspection authorities, and need to be developed by the ship's master with the support of the crew, the shipping company and other relevant safety experts.

While the carriage of EVs is no more dangerous than the carriage of ICE vehicles, the dangers they pose are different and the consequences of a fire are potentially more severe. Stakeholders should ensure that those dangers are identified, discussed and mitigated appropriately and incorporated in new procedures addressing these risks.

5.1.11 Crew Size Impacts Available Response

Day ferries on shorter routes typically operate with fewer crew onboard than longer and overnight ferry routes. Therefore, they are often more reliant on the use of the fixed firefighting systems found onboard, as they may not have sufficient manning or equipment to preform effective manual firefighting operations, or use specialized firefighting tools. It is therefore of even greater importance for such ferry operators to engage in a dialog with and include available shore-side emergency services, in the response plans for a possible EV fire onboard.

5.2 Recommendations

This section summarizes the recommendations of the ELBAS project from each of the WPs as gathered during the study. The reader is referred to the respective sections of the report for comprehensive insights concerning these recommendations.

5.2.1 WP1 Human Factors - Recommendations

The recommendations and conclusions presented below are based on the field work performed onboard the three ferry types and presented in this report. Therefore, any generalizations should be done with care.

The challenge of fighting fires in EVs and modern vehicles is a socio-technical problem that requires broad solutions beyond what can be delivered through technical solutions. It is recommended that the individual is taken into consideration when evaluating how to best fight EV fires. Early detection is key to getting to fighting the fire before irreversible damage has been caused. Detection systems including suitable CCTV can help provide early detection. The ability to operate the ship's firefighting systems from the bridge can help with an early response to EV fires. Any time spent identifying the source of the fire and taking the proper steps to mitigate the situation will influence the outcome of the firefighting.

Extra attention should be paid to training and education of personnel on ships carrying electric and other modern vehicles. Regular exercises developed by the individual operator will allow the crew to experience vehicle fires first-hand and are recommended to prepare them for what to expect in a real fire event. This also gives the crew the ability to try correct disrobing procedures to avoid harmful contamination from chemical exposure. At the end of such a live fire exercise, the personnel should be instructed in how to handle the vehicle to prevent reignition which is occasionally seen in EVs.

Decisions in relation to use of the ventilation system are currently taken according to procedure or individual assessments on the bridge. An overview of predicted effects of smoke movement and ventilation behavior in case of a fire would be a good tool to aid in this decision-making process. This overview can be provided through a risk assessment of the individual ships with appropriate simulations.

5.2.2 WP2 Technological Aspects – Recommendations

The recommendations and conclusions presented below are based on the two case studies presented in this report. Any generalizations should be made with care. There is a need to perform this type of study more often, to better quantify and inform owners and the crew of the specificities of their ship. Results presented in this section are based on the detailed analysis outlined in greater detail in section 6 (**ELBAS Appendix - WP2: Technological Aspects - Fire Scenarios and Technologies**).

Within the world of Fire Safety Engineering (FSE), there are specifically design computational tools that allow FSEs to run fire scenarios and investigate the potential risks, consequences and life and property safety. The use of these tools is common practice in the design of buildings. However, this type of fire and life safety analysis seems to have found little traction in the maritime industry, even though these tools, typically implementing a form of computational fluid dynamics (CFD) simulating smoke and fire development, would be applicable to e.g., ships just as much as they are used for buildings.

Keeping the ventilation system on (jet fans) may have positive effect for smoke control during a fire, especially on a high-speed ferry’s higher car deck (tier 2). On the closed vehicle deck, ventilation during the fire may be dangerous and may lead to a fire spreading after 10 minutes. The advantage of using fire simulation tools is that large potential fire scenarios can be investigated without having to perform full scale tests. It is recommended to perform CFD simulations for each specific loading case and ship arrangement, as the results will depend on both the vessel’s and the specific vehicle deck’s geometries.

Detection time for a slow growing EV fire often observed in large-scale tests can be longer (double, compared to a fast-growing fire), thus development and testing of alternative early detection methods is recommended. In tests, the detection times may be influenced (longer) when the ignition car is placed in vicinity of ventilation outlets. Thus, considering the specific placement of EVs could be helpful.

In low season, cars should be distributed along all decks, to minimize the risk of fire spreading to adjoining cars. A larger gap between two cars means that the flame spread might take longer allowing more time for the crew to muster and gear up before fighting the fire. The time the crew has before the fire spreads to neighboring vehicles may vary between 2 to 6 minutes depending on the specific ship type and location of fire, according to tested scenarios.

Exposed and uninsulated aluminum structures on the high-speed craft can reach critical temperatures from 5 to 18 minutes after the fire starts, depending on the fire location and time for activation of the sprinklers. This can result in a structural failure or that a car falls on another deck if no cooling action is taken and the fire is allowed to burn. Protection of structures that can be exposed to fire is recommended.

Early sprinkler activation is the key to stopping the fire spread. Simple and clear procedures should be developed for this purpose. In cases where drencher zones are not following the flood control door zones (often found on older ro-ro passenger ships due to water-on-deck stability concerns), the decision on the systems activation should be supported by information on sequence of the detection activation combined with visual inspection, to determine the correct zone of the fire.

5.2.3 WP3: Live Fire Testing - Recommendations

The recommendations and conclusions presented are based on the nine large-scale live fire tests performed during the ELBAS project and presented in this report. All generalizations should be made with care.

Large-scale fires tests performed using a similar set-up with a similar methodology for triggering Thermal Runaway (TR) within the battery pack resulted in different fires. This showed the unpredictable nature of an EV fire and the wide range of the total spectrum of how the conditions might escalate during such a fire. These variations should be considered in designing safety systems for EV fires and when modelling EV fire scenarios.

Flame spread was one of the focus areas given the tight stowage arrangements usually seen on vehicle decks on board ro-ro vessels. Flame spread among vehicles depends on parameters such as the flame length and radiation from the flames which can be unpredictable during an EV fire as mentioned earlier. Flame spread was observed at various times during the fire, ranging from a few minutes up to 10-min, after the fire was detected via the smoke detectors. In other cases, flame spread did not occur.

Both direct and indirect cooling methods were evaluated within the experimental set-up. The usability of larger portable firefighting devices proved to be challenging due to the limited space around the stowed vehicles. The smoke layer descended to eye levels, which also posed additional challenges on locating the fire seat and maneuvering and managing the devices. These challenges were in particular, observed when hammering in the extinguishing lance into the battery pack and when maneuvering larger firefighting devices.

Providing direct cooling on the battery pack was the most efficient way of cooling the battery pack down below TR with a lower water consumption. Cooling around the burning EV prevented flame spread to adjacent vehicles. However, the time of activation is key, to ensure these methods achieve their goals.

Water consumption was lower for direct cooling methods compared to indirect methods. Lower water consumption used for shipboard firefighting is always desirable, due to stability considerations. Water efficient direct cooling on the battery pack, and containing the fire with a non-water-based techniques are both examples of limiting the water consumption. Both direct and indirect cooling methods have their pros and cons but combining these methods showed to be effective during the ELBAS experiments.

Smoke detectors installed on the ceiling were able to respond with short detection times after smoke could be visibly observed. Selective detection systems for hydrogen fluoride also generated alarms, however the location of the detection system impacted their effectiveness.

5.2.4 WP4: Fire Drills and Training - Recommendations

The recommendations and conclusions presented are primarily based on observations made during the fire drills performed onboard and the live fire training with actual cars conducted during the ELBAS project, and which are presented in this report. All generalizations should be made with care.

Onboard fire drills provide the opportunity to test response times, checking of readiness of firefighting equipment, and the functioning of fire systems. However, such drills may only be of limited value to prepare for a real-life situation of an EV fire onboard. It is important to perform as realistic training exercises as possible, as this helps to reveal any issues in how specialized firefighting equipment is used and gives the crew confidence in their skills and in the firefighting procedures. The intention of advanced training on firefighter tactics for EVs is to shorten the time for fire crew response and improved overall preparedness.

The following recommendations are made for fire drills and training related to onboard EV fires:

- Training for fire fighters and their assistants, in correct use of **PPE and decontamination** post fire,
- Perform specific training on the effective use of **CCTV** as a fire detection and verification of a fire, thus potentially improving response timing to the fire,
- Proactively use of a **Smoke Management Strategy**, including active use of ventilation, as part of the decision support tools based on CFD fire simulations,
- **Sprinkler/drencher/water-mist system** – general training on the effectiveness and strategy of using the system during a fire incident – theory related to toxicity, stability, sprinkler zones, etc. Better understanding of the benefits of using water to dilute toxic smoke and gases.
- **Realistic fire training** – FF training using a simulated vehicle deck set-up with real cars, realistic firefighting training of maritime personnel is essential. Crew members should be provided with more realistic training or realistic drills – to experience differences between conventional car fires and EV fires, for instance.
- **Effective drills** should incorporate socio-technical elements, in order to effectively manage a fire onboard.
- **Debrief** – Expand post fire drill debrief, to include facts surrounding battery fire, toxic gasses, and smoke movement.
- Perform **joint exercises**, involving both shipboard and shore-side firefighters - It is recommended to work together with local emergency services, first responders, and national authorities to exchange and develop existing knowledge of EV-specific firefighting from ashore over to the maritime sector.

This specialized training will often go above and beyond the statutory requirements, as prescribed in SOLAS, STCW, etc.

5.3 Misconceptions and Myths

In addition to testing specific technologies and techniques, the many tests performed in ELBAS help to confirm or disprove some of the misconceptions and myths associated with fires in EVs onboard ships. For example:

5.3.1 Risk of Electrocution due to use of Sea Water as Extinguishing Medium

"*It is more dangerous to put out an electric car fire on board a ferry than on land, because the crew stands on a metal deck and use salty sea water for extinguishing*."

From all the tests conducted during ELBAS, there was nothing to suggest that use of sea water makes the onboard firefighting work more dangerous. In addition, no reported cases have been sighted providing any evidence to support the theory that there exists an increased risk of electrocution via the water stream.

5.3.2 Increased Heat Under an EV

"*There is a greater risk onboard High-Speed Craft of damage to the aluminum deck below a burning EV, due to the high heat generated by an EV battery fire. "*

Since the battery pack is typically located at the bottom of an EV, there has been concern that a fire might even melt the decks of aluminum ferry. While this may be the case if the EV is left unattended and burns in the same location for several hours straight, the ELBAS tests indicated that the heat impact from the bottom of the car is not so severe, that it would damage or even melt the vehicle deck.

When the burnt EV was removed, there was little evidence of the fire on the steel plates representing the vehicle deck.

5.3.3 Are EV Fires Manageable?

"*It is not possible to control an EV battery fire.*"

While the carriage of EVs is no more inherently dangerous than the carriage of ICE vehicles, the fire risks they pose are different and the consequences potentially more severe if not addressed adequately. From the new knowledge and experience gained in ELBAS, through the 9 live fire tests involving an EV traction battery, it can be concluded that, EV fires can be managed with the proper procedures, equipment, and training.

5.4 Dissemination Activities

The ELBAS project has attracted an enormous amount of interest, starting from even before the project began and continuing throughout the period in which it was conducted. This interest has been from both Danish and international stakeholders, emphasizing the importance and relevance of this challenge.

Given the topic's relevance and high level of interest in ELBAS, dissemination activities have taken place throughout the project. This has included presentation at workshops, seminars, and conferences, taking place in both maritime and fire safety forums. Additionally, a number of articles have been published with focus on the ELBAS research, both in relevant Danish and international media.

5.4.1 Table of ELBAS Activities

Key dissemination activities are listed in the table below. This list is not all inclusive, and includes presentations on ELBAS activities at conferences, workshops, and seminars.

Table 5.1: List of ELBAS Publicity Activity

Activity	Presentation Title	Conference or Workshop	Date
Danish Shipping - Ferry Group	**Fires on vehicle decks** *(Brand på vogndæk)*	Workshop	2022/03/09
IDA Maritim/STSF - Danish Engineering Society/ Danish	**Electric Vehicle Fire Safety at Sea** - ELBAS, LASH FIRE	Conference	2022/04/04

Society of Naval Architecture and Marine Engineering			
MarNav - Marstal School of Navigation	ELBAS presentation at FIREFIGHTING of EVs ONBOARD FERRIES (*Brandslukning i elbiler på færger*) – Course and Workshop	Workshop	2022/05/17
DBI – The Danish institute of Fire & Security Technology	**EV Firefighting tactics and fire behavior** at Professional development day for Danish police and insurance companies	Workshop	2022/09/15
RESC – Rescue & Safety Center, Korsør, Denmark	Fires and accidents with electrical vehicles – Emergency Services East & Slagelse Municipality Fire and Rescue (*Brande og uheld med el-biler - Beredskab Øst & Slagelse Brand og Redning*)	Workshop	2022/10/05
CFIS 2022 – Conference on Fire Safety at Sea, EMSA	**Electric Vehicle Fire Safety at Sea (ELBAS)** – 2022 LASH FIRE public conference, Lisbon, PT	Conference	2022/10/11
Society of Danish small island ferry operators – annual meeting (*Årsmøde i Småøernes Færgeselskaber*)	Presentation of **EV Fires onboard ferry vehicle decks** – Esbjerg, Denmark	Conference	2022/11/09
UK-AFI (IAAI Chapter 67) Annual Training Conference	Presentation of ELBAS work - ***Findings from full scale fire tests involving electric vehicles***	Conference	2023/01/31

5.4.2 List of Articles Exposing the ELBAS Project

The ELBAS project has experienced a broad and industry wide (global focus) interest, throughout the duration of the research project, and has been the featured topic in both Danish and international journals and publications.

The following is a list of published articles featuring exposés of the ELBAS Project:

- Brand & Sikring – 3.2021 - ***Færger skal sikres mod BRAND I ELBILER*** (pg.54-56)
- SØFART – Nr. 32 - 4. oktober 2021 – ***Det er urealistisk at slukke en batteri-brand i en elbil om bord på en færge*** (pg.16-17)
- Brand & Sikring – 2.2022 - ***Brandtest giver ny viden om batteribrande i elbiler på færger*** (pg.13-17)
- SHIPPAXInfo – April 2022 issue ***The Lithium Ion Challenge*** (pg.19-22)
- UK FPA's journal, Fire & Risk Management – October 2022 issue ***High seas e-car risk*** (pg.54-56)
- Online Article Postings:
    - CFPA website – July 2022, New knowledge about battery fires in electric cars on ferries:- https://cfpa-e.eu/new-knowledge-about-battery-fires-in-electric-cars-on-ferries/
    - Nautilus International website - 4 August 2022, Electric vehicle study addresses ferry fire fears: https://www.nautilusint.org/en/news-insight/telegraph/electric-vehicle-study-addresses-ferry-fire-fears/
    - CEPREVEN (ES) website – 26 August 2022, Detección y extinción de incendios de baterías de coches eléctricos en las cubiertas de vehículos de los transbordadores : -

https://www.cepreven.com/deteccion-y-extincion-de-incendios-de-baterias-de-coches-electricos-en-las-cubiertas-de-vehiculos-de-los-transbordadores-924

5.5 Further Research Recommendations

The following section focuses on recommendations on areas for further research through future work.

Human and organizational factors and their respective roles in EV fire incidents.

Interview more and a wider range of stakeholders – this is already ongoing and should continue after the end of the ELBAS project but should also be a feature of any future projects. The recommendation here would be to broaden the scope and include topics such as alternative fuel and other modern vehicles.

Future work and collaboration with selected industry partners, including ship-owners – this is also ongoing and will continue after the project. This will help with a greater understanding of the problem, getting more concrete with certain issues and solutions with selected partners.

Fire Modeling and Smoke Development Simulations

It is recommended to perform simulations for each specific loading case and ship arrangement, as the results will depend on both the vessel's and the specific vehicle deck's geometries. No two ships are entirely the same and certain loading conditions may influence risk of fire development and spread. Fire simulations can help identify situations where ventilation can be beneficial for smoke control.

Additional topics for further work

- Use of ventilation as an active firefighting strategy for smoke control
- Use of ship systems to assist with firefighting tactics, including CCTV, communications, compartment openings, movement of personnel and guests,
- Improved detection capabilities onboard vehicle decks,
- Improvements to water-based lithium-ion battery (LIB) firefighting systems
- Material identification and response capabilities onboard ships
    - Materials: plastics, alloys, refrigerants, electric mobility devices, etc.
- Post LIB fire management procedures,
- Fire Safety related to other types of alternative fuel vehicles carried onboard.
- Toxic gas exposure risks to Firefighters
- Specialized Training Course Content, including:
    - In-depth live fire training for ship personnel
    - In-depth live fire training for shoreside personnel
    - In-depth live fire joint training seminar with both ship and shoreside personnel
- Investigation into effectiveness of on-board safety drills (use of debrief and meetings to disseminate latest information and lessons learned, cabin searches - child vs adult in cabin)

5.6 Going Forward

The overall conclusion of the ELBAS project is that EV fires on ferries are not to be feared more than any other fire at sea. They can typically be dealt with using the correct technology, education, and training of shipboard personnel, as well as with coordinated cooperation between the ship and with emergency services on land.

The following conclusions regarding EV Fires can be drawn based on analysis of all data from the respective tests used for validation of the CFD simulations developed to simulate fire spread on board:

Firstly, the battery pack in a new EV is significantly more firesafe than in an old one. When short-circuiting the battery cells in a Renault Fluence, the entire battery burned. When ignited a newer Tesla Model 3, only that specific battery cell bank burned.

Secondly, the positive message is that fires in EV on board ferries are manageable and are not something we should necessarily fear more than any other type of fire. All the fires in the ELBAS tests could be extinguished safely, so with the right firefighting technologies on board, the right training of the crew and a well-coordinated cooperation with the emergency services on land, EVs should not pose an increased safety problem in ferry traffic.

Given the many companies across the Blue Denmark who have important roles to play in the battery safety value chain, DBI believe there exists a great potential here in Denmark, to impact and improve EV fire safety and the ships which carry them in operation all around the world.

DBI continues to work and collaborate with industry partners, including ship-owners, manufacturers of equipment, maritime training facilities, ship designers and consultants, on the important issues related to EV fires at sea, fire safety related to Power-to-X and other alternative fuels. This effort is ongoing and will continue after the ELBAS project.

DBI sees the ELBAS project as just the beginning, and that ELBAS confirms the need for further research into these important fire safety topics.