Summary of previous activities and results of the ALBERO project

current status: 14th April, 2020

Activities

Date	Event
22.08.2018	Meeting at the ferry terminal of company Scandlines at Rostock port
01./02.10.2018	Kick-Off Meeting for the project ALBERO at Warnemünde
08./09.10.2018	Kick-Off Event "Civil Security - Transport Infrastructures" at Frankfurt/Main
04.12.2018	Inspection voyage with hybrid ferry "Berlin" of shipping company Scandlines
15.01.2019	Joint Workshop with SUVEREN project at Berlin (similar topic for the protection of underground garages)
26./27.03.2019	Inspection voyage and test trial with ferry "Peter Pan" of shipping company TT-Line
09./10.04.2019	Project Meeting at Rheinbach (Hochschule Bonn-Rhein-Sieg)
06.-10.05.2019	Fire experiments with Li-Ion-Batteries at Trauen
22.05.2019	Workshop “Car Position Concept” at Hamburg
07./08.10.2019	Project Meeting at Hamburg
26./27.11.2019	Inspection voyage and test trials with ferries "Stena Britannica“ and „Stena Hollandica" of shipping company Stena Line
25./26.02.2020	Milestone Meeting at Stuttgart

Also on different dates:

- Interviews with representatives of the shipping companies Scandlines, TT-Line and Stena Line, visits to the harbor grounds at Rostock and at Travemünde
- Interview with the responsible department at the Ministry of Energy, Infrastructure and Digitalization Schwerin
- Interview with Verification Authority North Rostock
- Interview with Technical Monitoring Rostock GmbH
- Interviews with various car dealers offering electric vehicles
- Interview with sales manager and head of development of the company Mennekes (manufacturer of charging stations and plugs) at Kirchhundem
- Interview with CEO of Company Ellermann - Producer of container systems for extinguishing electric cars after accidents
- Interview with ÖPNV Schwerin about the planned purchase of electric buses
- Participation on Maritime Safety Conference Bremerhaven
- Interview with Port Operating Company Lübeck
- Meeting with the German Insurance Association at Berlin
- Participation on 47th Evening of Technology „Future hydrogen technologies - an opportunity for the region“ at Stralsund

Results

Following below is a rough summary of the previous insights. These insights are provided in the most understandable form and therefore may not always be presented in a scientifically correct form.

Vehicle stock (circa) currently in Baltic Sea states (as of 2018)

country	authorized cars in total	electric cars absolutely/%	plug-in cars absolutely/%	CNG cars absolutely/%	LPG cars absolutely/%
Norway	3 Mio	160.000 / 6%	90.000 / 3%	< 1000 /< 0,2%	< 5000 / < 1%
Sweden	5 Mio	20.000 / < 1%	60.000 / 1,5%	50.000 / 1,2%	< 5000 / < 1%
Danmark	3 Mio	10.000 / < 1%	< 5000 / < 1%	< 1000 / < 0,2%	< 5000 / < 1%
Finland	4 Mio	< 5000 / < 1%	10.000 / 1 %	< 1000 / < 0,2%	< 5000 / < 1%
Latvia	< 1 Mio	< 5000 / < 1%	< 5000 / < 1%	< 1000/ < 0,2%	15000 / 8%
Estonia	< 1 Mio	< 5000 / < 1%	< 5000 / < 1%	< 1000 / < 0,2%	< 5000 / < 1%
Lithuania	1,5 Mio	< 5000 / < 1%	< 5000 / < 1%	< 1000 / < 0,2%	100.000 / 6%
Poland	23 Mio	< 5000 / < 1%	< 5000 / < 1%	5.000 / < 0,2%	3.000.000 / 14%
Germany	45 Mio	100.000 / < 1%	100.000 /<1%	70.000 / 0,2 %	470.000 / 1 %

electric cars are meant as purely battery-powered vehicles + plug-in hybrid

Forecast vehicle development for Germany

year	battery-powered vehicle	plug-in hybrid	natural gas (CNG/ LNG)	liquefied gas (LPG)
2030	925.000	3.980.000	430.000	565.000
2040	3.065.000	10.515.000	535.000	530.000

Labelling of alternatively powered vehicles (AOV)

There is no single European regulation for the labelling of AOV.

For holders of electrically powered vehicles registered in Germany, the holder may apply for an E-mark (E as last letter on the license plate), but this is not mandatory. Gas-powered vehicles are not recognizable in Germany via the license plate.

In Norway, alternatively powered vehicles have special letter combinations (which otherwise indicate the registration area) on the license plate: Electric vehicles: EL, EK or EV, Hydrogen: HY, Gas vehicles GA

Austria: Electric vehicles have license plates with green instead of black letters.

France, Belgium and Denmark have environmental stickers in different colors. However, some of them are also vehicles that are powered by gasoline but running in a special clean mode.

1. Dangers due to alternatively powered vehicles

All in all, there is still an insufficient number of data to produce meaningful statistics on the accident behavior of alternatively powered vehicles. However, an impending statement is that such vehicles do not more frequently get damaged than conventional gasoline or diesel vehicles, but in the event of an accident, there may be special dangers to which there is no sufficient preparation yet.

Gas-powered vehicles

In the case of overheating, the tanks of gas vehicles are designed in such a way that the gas is blown out of the tank intermittently or completely. What can be a good solution ashore to protect against a bursting of the tank that may be a special source of danger at a (closed) vehicle deck of a ro-ro ferry. There may be fires and explosions. Gas fires can, if environment permits, burn off in a controlled manner or be extinguished with the extinguishing agents for gas fires known to date. The main problem appears then at the car deck to get access to a vehicle - a problem that applies to all other vehicles too.

Electric cars

According to an extensive study carried out within the ALBERO project, electric vehicles do not show a higher fire risk, obviously the risk of fire is even lower than for conventionally powered vehicles. Nevertheless – if there occurs a fire at an electric car, the risks are different. First of all the fire will last for a longer time, because extinguishing is difficult and re-ignition occurs even after ours. During the fire single Li-Ion cells can be ejected from the vehicle battery at high speed and fly around. For all these reasons the risk of fire spreading to neighboring vehicles is higher. In addition, particularly corrosive and toxic fluorine-containing gases can be released during the fire. At the moment a lot of water is considered as a means of choice - especially for cooling and thus to control the fire. The use of much water on a ship is only possible if sufficient drainage can be guaranteed at the same time. As a rule, seawater is used on board for extinguishing or cooling. Depending on the salinity, however, this may possibly have an unfavorable effect on the course of the fire, since seawater can act as an electrolyte and possibly short circuits in a battery pack are promoted.

The occurrence probability of an accident concerning an alternatively powered vehicle can be estimated as follows:

cause	**car park / underground garage**	**ferry**	**occurrence probability onboard a ferry**
leakage	damage upon entry	damage at ascend	equal
ignition	no ex-protection	ex-protected areas	lower
temperature increase	low, sun exposure	Heat input by technical equipment	higher
overfilled fuel tank	possibly petrol station next to parking garage	driving distance between refueling and loading	lower
fire incursion	extinguishing system not always available	sprinkler system	lower
rear-end collision/ power impact	driver at fault	rough seas	higher

Possible impacts on passengers and on ship in the event of an accident with an alternatively powered vehicle

Impact on passengers

- Due to the high requirements that car decks onboard of ro-ro-ferries have to meet the effects of an accident with an alternatively powered vehicle are locally limited for the passengers.
- Passengers are most at risk when on car deck (before and after passage).
- Before and after passage, there are sufficient personnel on the car decks to coordinate loading and unloading. This personnel can quickly identify problems and react accordingly. Appropriate education and regular training are necessary to fulfil these tasks.

Impact on crew

While fire fighting there is a higher risk for the crew because

- alternatively powered vehicles are not always recognizable from the outside,
- batteries can heat up by fire as a thermal runaway occurs,
- gas tanks can blow off suddenly due to heating or burst if the safety valve fails.

The risk can be minimized by the crew by

- giving an early alert,
- education und regular training,
- having an information where and what type of an alternatively powered vehicle is on board.

Impact on ship

Onboard the reference ships there are no car decks with a maximum height of 2.5 m, but only decks designed for cars and trucks with a ceiling height of approx. 4.6 m. The water spray system is dimensioned accordingly for the expected fire load of trucks:

- ceiling height up to 2.5 m ---> 5 l / m² min (car deck)
- ceiling height between 2.5 m and 6.5 m---> 10 l / m² min (reference ships)
- ceiling height between 6.5 m and 9 m ---> 15 l / m² min

The disability to manoeuvre or a blackout are not expected on the reference ships:

- Due to the purpose of use ro-ro cargo holds are type A separated (fire resistant).
- Depending on the category to which the adjoining rooms are belonging, separation areas are required to be on type

  A0 e.g. service spaces (low risk),
  A15 e.g. stairways,
  A30 e.g. service spaces (high risk) und
  A60 e.g. machinery spaces of category A.
- Electrical cables are not routed through the cargo holds, thus ensuring the power supply of the steering gear in case of fire.

2. Behaviour of lithium-ion batteries in emergency situations

Fire experiments

The ALBERO consortium performed fire tests with Li-Ion batteries. Within this tests E-bike batteries were heated slowly and the effects to the battery and the gas development was observed and measured. In all cases there was a strong release of smoke and gases, especially of H2. In some cases there was an ignition of the gases and a fire. Nevertheless it could also be observed that despite the strong development of smoke an ignition will not take place necessarily, possibly because of the addition of flame retardants to the electrolyte within the Li-Ion cells. Therefore, a fire within a closed batterie is very unlikely. The hazard starts when the thermal runaway reaction caused by a battery failure leads to the bursting of the complete battery module and oxygen can come in contact with the free gases. A research for scientific results regarding the starting of a thermal runaway in a battery resulted in the finding, that a thermal runaway of a Lithium-Ion -Battery can start from temperatures at around 80°C. Within the ALBERO fire experiments these values were confirmed. So detection systems using temperature detection should have appropriate alarm settings.

The composition of the gases depends on the specific cell chemistry of lithium-ion batteries, but the main constituents are carbon dioxide, carbon monoxide, hydrogen and short-chain hydrocarbons. In addition, there are, in small but not harmless quantities, various organic and fluororganic compounds as well as inorganic phosphorus and fluorine compounds.

The amount of released gases and also the composition of the gas mixture depends on the charge level of the batteries. At a higher state of charge, the volume of released gas increases.

Summarized overview about the consequences of a damage

<table>
<tr><th>cause of failure</th><th>measures against the occurrence of a damage</th><th>measures to limit the consequences of a damage</th><th>consequences of a damage</th></tr>
<tr><td>overheating due to a fault in the charging process</td><td>monitor surface temperature and stop charging process</td><td rowspan="4">extinguishing system with optimized cooling

structural separation

smoke extraction

escape and rescue routes and boats

press-prepared concept and publication of the measures</td><td rowspan="4">destruction of many vehicles on the decks

destruction of the ferry

personal injury

image damage</td></tr>
<tr><td>self-ignition after prejudicial damage (accident)</td><td rowspan="2">monitor surface temperature and cool manually (with water)</td></tr>
<tr><td>failure within vehicle electronical system</td></tr>
<tr><td>fire of a vehicle nearby</td><td>fire detection and extinguishing (e.g. by sprinkler system)</td></tr>
</table>

3. Development of safety measures

Recording of the safety technologies currently available onboard the Baltic Sea ferries

Based on the recordings during the ferry passages, the evaluation of the project partner reports and interviews the results are as follows:

For the project-relevant area, i.e. the car decks, there are

- cameras, with monitors at the bridge
- punctiform smoke detectors, punctiform fire heat detectors, with connection to the BMA and display of alarm positions on the bridge
- sprinkler heads (with glass tubes)
- spray water systems, manually releasable

A sufficiently location-resolving detection technology that can, for example, locate gas leaks or detect a thermal runaway of an electric car battery is currently not available.

Measurement campaigns

During inspection and test runs onboard the ships of the associated partners the following measurement results could be determined:

- heterogeneous picture of air flows on the different decks and different ferries
- longitudinal and transverse flows at floor level depending on the ventilation regime
- possible installation location sensors are side walls and the ceiling
- heterogeneous picture of flows at ceiling height often downwards, resulting in
    - that sensors should be installed as low as possible
    - that electrical cars should be placed as close as possible to sensor nodes or smoke aspiration systems

Exemplary measurement results, with active ventilation, vehicles with running engines:

hydrogen	natural:	0.5 ppm
	on board:	fluctuating up to approx. 3 ppm
methane	natural:	2.0 ppm
	on board:	no indications of fluctuations
VOC	0.0 up to 2 ppm (PID, partly due to cargo, no indications of increased concentrations)	
NOx	disturbance of MOx and EC (hydrogen) during the process of loading and unloading	

Determination of detection possibilities

option of detection	fixed detector next to each vehicle	detector on drone, drives independently under all vehicles	detector on rail/rope, moves laterally along all vehicles
monitoring area	1 vehicle	full deck	one row of vehicles
reliability	high	vulnerable	high
detection sensitivity	high	high	medium
costs	high	medium	medium
detection speed	fast	slow	medium
ex-zone suitability	yes, prepared	very laborious	yes

Development of a demonstrator

A first demonstrator was developed, consisting of a gas sensor and an IR sensor, which will be available in the second half of the project. With the help of this demonstrator it should be possible to reliably detect a gas leak, the overheating of a vehicle or the fire of an electric vehicle and manually release corresponding alarms at the bridge.

4. Determination of particularly suitable parking spaces on board

Advantages of designated parking spaces for alternatively powered vehicles

- simple identification of the vehicles
- crew training will be facilitated
- instruction of external rescue services will be facilitated e.g. fire brigade
- parking spaces can be better equipped to minimize potential hazards arising from the energy source
- the escape route concept can be optimized
- special extinguishing agents/systems as loose equipment or permanently installed, are immediately available and can be stocked up within an economically justifiable framework

In the event of a fire, it may be easier to seal off the affected area from adjacent parking spaces (using fire curtains or similar).

Development of a parking space concept for alternatively powered vehicles on board

In the course of the project, three possibilities for a parking space concept became apparent.

Definition of defined parking spaces

In this concept the most suitable parking spaces for the individual types of alternatively powered vehicles are precisely identified on each ship. The advantage is that fixed parking bays can be specifically equipped with detection, safety and extinguishing technology for the respective types of alternatively powered vehicles. The probability of early detection of a hazardous situation and the use of the most suitable measures are relatively high. This would require presorting in the port area. A disadvantage is that the number of parking spaces designated for the individual types of alternatively powered vehicles will only in rare exceptional cases correspond to the actual number of vehicles departing.

Definition of defined areas

In this concept only rough areas are defined where which types of alternatively powered vehicles are transported. For example, it is specified that gas-powered cars have to enter open roro spaces without making more concrete specifications about their location on this deck. This has the advantage that the designated areas can be equipped with adapted detection, safety and fire-fighting technology and the ship's command would know exactly that in this area a possible accident of an alternatively powered vehicle could be expected. Another disadvantage would be the need to pre-sort the vehicles in the port. The detection and fire-fighting technology would have to cover larger areas. Additionally it must be taken into account that other (conventional) vehicles may also be present in addition to alternatively powered vehicles. The project currently favors this variant and is developing a concept for appropriate software support during loading. The booking data with the information on the individual alternatively powered vehicles are to be used to make recommendations for a corresponding pre-sorting in the port as well as the stowage on board.

Flexible parking spaces with real-time location display

This concept is based on the assumption that the type of alternatively powered vehicle is not determined until the vehicle is driven onto the ramp or is positioned on board, e.g. by means of rapid recognition by the instructor, by scanning license plates and promptly requesting the license plate number from the Federal Motor Vehicle Office or by scanning the vehicle with various sensor and camera technology. With this parking space variant the detection systems must therefore either be installed everywhere or be mobile and, if necessary, depending on the loading pattern, move automatically to the respective vehicle type. With this concept, the hazard prevention and fire extinguishing systems would also be mobile, e.g. through the use of mobile partition walls or non-combustible tarpaulins on the car decks or the use of mobile water spraying devices on board. The advantage of this concept is that no pre-sorting seems necessary and the loading of the ship can be carried out quickly and as required and independently of the parking space. A disadvantage is that the rapid detection of an unmarked vehicle type is not yet technically feasible. Furthermore, mobile sensor technology is expensive.

5. Charging of electric cars during passage

Regulation for charging stations

For the construction of charging stations a regulation applies in Germany (Ladesäulenverordnung LSV). It only applies to publicly accessible charging points. Charging points are open to the public if the associated parking spot is either at a public place or on private land which nevertheless can be entered by an indefinite group of people. The extent to which the LSV applies to a ferry (under German flag), i.e. if the circle of users is an indeterminated group of people or not, has not yet been clearly clarified according to current knowledge of the ALBERO consortium. We stick to it. Starting on 1st April, 2019 installed charging points have to be calibrated if they sell the current according to the actually charged kWh. Without calibration the charging can only be offered via using a lump-sum or as an all-inclusive-price for instance for parking or transporting.

Selection of charging station for on-board-operation

The installation of a charging station is recommended for security reasons. Charging an electric vehicle is theoretically also possible simply by plugging it into a socket, which is otherwise e.g. used for the cooling units of refrigerated trucks (possibly with plug adapters). However, a charging station can communicate with the battery management system of the vehicle, which cannot be done by a simple power socket. The charging station may therefore recognize certain problems during the charging process and may interrupt it if necessary.

Whether a standard charging station or a fast charging station should be installed depends primarily on the amount of electricity still available on board. For this purpose, calculations for selected ferries have already taken place in the project. Vehicle batteries must always be charged with direct current. Standard charging stations supply the alternating current coming from the grid to the vehicle. The conversion into direct current takes place in the charging cable or in the vehicle. Fast charging stations convert the alternating current into direct current already in the charging station and deliver direct current to the vehicle. They need more electricity. How many and what kind of charging stations are possible, therefore, depends first on the overall energy balance of the particular ship and must be calculated exactly. Another, but subsequently criterion is the time available. For short crossings (less than 2 hours), fast-charging stations seem more appropriate than standard charging stations.

As of today, there is still no charging station that is suitable for the special conditions on a car deck. This concerns in particular with the following aspects:

- In contrast to the batteries, which must pass safety tests for movements, vibrations, impact, etc., there are no such test procedures for charging stations and plug connections between vehicle and charging station, as in shore operation, where the charging station is fixed. The location ship where charging station has to follow the ship movements and where the station is also exposed to vibrations has not been considered so far, there are no corresponding approval procedures.
- Electrical installations on closed car decks must be explosion-proof up to a certain height. The previously contacted charging station manufacturers do not offer explosion-proof charging stations.
- The current parameters on board (voltage, frequency) are often different from those on land. To what extent the charging station can cope with this is not really clear.

- The power grid on board is different compared to the typical ashore. This concerns in particular the layout of the zero conductor, hence a corresponding adjustment would be necessary for the charging station.