

EVS-GTR Protection against Water

**EVS-GTR 19th
China
2019.12**

1 Summary of whitepaper

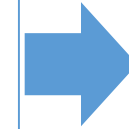
■ Summary of whitepaper according to EVS18-HACT0300



EVS18-HACT030
WhitepaperWater

Question 1 : Does field data support the concern on the safety failure in case of water immersion?

- **Answer 1:** Field data related to safety issues related to full immersion of EVs is considered limited and such conditions potentially wouldn't allow driving an EV.
- **Answer 2:** From field information from China, the risk of EV fire in case of immersion is not significant, the biggest risk in case of water immersion is water itself and the cases indicated in the presentation caused dangerous situation for vehicle occupants.
- **Answer 3:** Discussions on the appropriateness of fire and explosion in water immersion condition should be made first than field data.
- If the reason of fewer field data is the OEM requires the water immersion safety, it is necessary to figure out how many OEM requires the water immersion safety and what reasons.
- **Answer 4:** Water immersion cases for normal condition are already described in GTR No.20. The conditions where a vehicle cannot be driven (e.g. tsunami, severer flood, sink, etc.) is considered as abnormal situation which is out of our mandate.
- **Answer 5:** In China there are already two immersion-related failure found in market.
- IP67 is required by typical OEMs over the world and that is the reason why immersion failure case is rare now. It should be required by regulation rather than required by OEM because it is passenger safety related.
- **Answer 6:** Canada does not have data to support the need for a water immersion test.
- **Answer 7:** In the US, the safety concerns from submersion does not seem to be different for electric and conventional vehicles. The 2012 Hurricane Sandy Fiskar electric car fires were initiated at the 12 V battery when the vehicles were submerged in 5-8 feet of seawater. The vehicles burned without explosions. In the 2017 Hurricane Harvey, there were 101 EV submersion related claims of which 72 were total losses. There was no evidence of fire, electric shock etc. with these 101 vehicle submersions In the 2017 Hurricane Irma there were 42 weather related damage of EVs. These may all not be submersions. These may include trees falling on cars etc. Of the 42, 11 were total losses. Again there was no evidence of fires, loss in isolation, etc. in any of these cases.

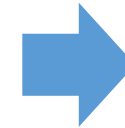


- **View 1:** EV fire in case of immersion is not significant.
- **View 2:** Discussions on the appropriateness of fire and explosion in water immersion condition should be made first than field data.
- **View 3:** Extreme conditions such as severer flood and sink are out of the scope of GTR.
- **View 4:** Yes. There are already some immersion-related failures found in market.

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Question 2 : Can failure cases be recreated in laboratory?

- **Answer 1:** Potentially yes (but it is a question if a relevant scenario can be found and selected).
- **Answer 2:** No.
- **Answer 3:** Yes. The DUT in which the event occurred was fire occurred or exploded until proper improvement was made.
- **Answer 4:** Yes.
- **Answer 5:** Potentially but we do not have representative cases to base it off of.
- **Answer 6:** Yes, but cannot have a generalized single test that would reproduce each of the failures.



- **View 1:** Yes.
- **View 2:** No.
- **View 3:** Potentially yes (but it is a question if a relevant scenario (representative cases) can be found and selected).

✓ Summary: **Failure cases can be recreated in laboratory in China and Korea.** Page 12&EVS18-E3WI-0100

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Question 3: Is battery pack designed as waterproof? If yes, how to guarantee the validity of pack design against water immersion.

- **Answer 1:** Packs are not necessarily waterproof (and potentially there are other benefits for non-water proof packs).
- **Answer 2:** Not necessarily water-proof.
- **Answer 3:** Even if there is no waterproof function, it is possible to secure safety in water immersion condition by only proper insulation design.
- **Answer 4:** No. Battery packs with air-cooling system loaded in passenger compartment are not water proof.
- **Answer 5:** If there is no fire or explosion of battery pack in salt water immersion, waterproof design may not be required.
- **Answer 6:** not necessarily and requiring it to be could be design restrictive
- **Answer 7:** Requiring battery packs to be absolutely leak proof may not be needed to ensure safety.



- **View 1:** Not necessarily.
- **View 2:** If not, additional safety design is necessary.

✓ Summary: **Either waterproof feature or extra design is required to guarantee the safety of battery pack.**

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Question 4: Safety risk of EV fire in case of flooding compared to that in other natural disaster?

- **Answer 1:** Exposing an EV to immersion is not recommended and is considered an abnormal use.
- **Answer 2:** flooding is abnormal situation which is not considered for the other safety regulations for conventional vehicles
- **Answer 3:** Flooding can affect the battery safety due to battery characteristics compared to other natural disasters.
- **Answer 4:** In case of flooding, it is not recommended to drive into such situation and driving vehicles under such circumstances would be considered as abnormal
- **Answer 5:** Although it is not recommended to drive in case of flooding, it can be found around the world. There will be specific risks for EVs in case of flooding due to high-voltage battery pack onboard. What's more, in scenario of flooding in underground parking EV could cause fire if it can't be protected against water, which would lead to the fire in the building.
- **Answer 6:** Flooding to the scale being discussed is beyond the scope of our regulatory regime. We do not set requirements for non-EV vehicles and the risks do not appear to be greater for EVs.
- **Answer 7:** Flooding such as that in Hurricanes Sandy and Harvey are catastrophic events and expecting electric vehicles to be safe in these conditions is going beyond what is expected of conventional fuel vehicles. Additionally, field data indicates that the vehicles simply burn and do not explode (similar to a conventional fuel vehicle fire that initiates due to shorting of the 12V battery).



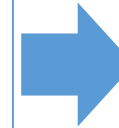
- **View 1:** Flooding is abnormal situation and not considered.
- **View 2:** Flooding can affect the EV safety due to battery characteristics compared to other natural disasters.

✓ **Summary: EV equipped with high-voltage and high-energy battery pack could lead to severe consequence compared with non-EV vehicle after being immersed.**

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Question 5: EV fire could possibly caused by 12V battery mounted on vehicle, not just by high-voltage battery pack.

- **Answer 1:** We agree.
- **Answer 2:** The vehicle fire will happen even for 12V systems. It is not reasonable to only focus on electric vehicles.
- **Answer 3:** The 12v battery can cause a fire also, but the amount of energy in a traction battery is huge that safety considerations are needed. What matters is not only the possibility of fire, but also the amount of energy released.
- **Answer 4:** Japan understand that 12V system is one of the main causes.
- **Answer 5:** Consequence of HV battery-related fire is much more severe than 12V system due to HV battery has much more energy released when firing, therefore significantly shortening the responding time for vehicle occupants.
- **Answer 6:** Correct, risks are similar for EV and non EV
- **Answer 7:** Investigation of the Fiskar fires in Hurricane Sandy showed that the fires were caused by shorting at the 12V battery.
- **Answer 8:** The issues in case of flooding exist also for 12V systems and will not be separated from HV systems. Also mentioned that people may use the vehicle after submerge without repair/check.



- **View 1:** The 12v battery can cause a fire as well
- **View 2:** The 12V battery can cause a fire as well, but consequence of HV battery-related fire is much more severe than 12V system due to HV battery has much more energy released when firing.

✓ **Summary: Due to characteristics of with high-voltage and high-energy battery, it could cause more severe consequence than 12V battery, therefore significantly shortening the responding time for vehicle occupants.**

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Question 6: The necessity of regulating safety protection against water immersion.

- **Answer 1:** Further evidence and justification would be required (also to demonstrate normal condition under which such risks could occur).
- **Answer 2:** The need of such requirements must be justified by the field data and the actual protection requirements (test or something else) should adequately reproduce the typical scenario.
- **Answer 3:** If OEM requires the water immersion safety to battery manufacturer, it is necessary to figure out how many OEM requires the water immersion safety and what reasons. The GTR is intended not only for the safety of passengers but also for safety around electric cars, so it is also necessary to consider the safety not only the vehicle driving situation but also the parked vehicle at water immersion. If a fire occurs in a flooded situation, it can not be evacuation from the vehicle and can hinder access to the rescue team.
- **Answer 4:** Further justification is needed.
- **Answer 5:** Proposed to add water immersion test of REESS after vibration test based on the reasons mentioned in EVS16-E3WI-0100. Water immersion test is already included in Chinese standard. Further research, discussion and final decision is needed.
- **Answer 6:** Evidence does not support the need for a EV specific water immersion test.
- **Answer 7:** Field data available does not justify the need for a water immersion test.



- **View 1:** Field data available does not justify the need for a water immersion test.
- **View 2:** Further justification is needed.
- **View 3:** Yes.

- ✓ **Summary: Based on summary of previous topics, for safety of personnel and vehicle, it is necessary to regulate safety protection. Also this additional regulation will not lead to massive extra cost because IP67 has been required by typical OEMs. page 10-19**

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Question 7: Is there any potential threat when after-treating immersed battery pack?

- **Answer 1:** Potentially yes (e.g. short circuits, reduction of isolation resistance, re-ignition of fire), but this is not considered normal use.
- **Answer 2:** Isolation resistance might be reduced, but vehicle system will detect such a failure and take necessary measures. Using flooded vehicle without taking proper maintenance will be clearly misuse case and vehicle should normally detect isolation failure as well.
- **Answer 3:** The water proof battery pack is alive even after the test. We remove the waterproof and then dip it again in brine to discharge the energy.
- **Answer 4:** Isolation failure and short circuit inside the battery pack may happen.
- **Answer 5:** If the pack is designed waterproof ,then it is fine for responders to treat battery pack without risk. However if there is any water ingress into the pack, then there is still potential risk of fire during after-treatment.
- **Answer 6:** Potentially but we do not have representative cases to base it off of.
- **Answer 7:** Need to better understand the health of the battery pack after any such incidence. Research is ongoing.
- **Answer 8:** For after treatment of EV, the responders should know that fire could happen after immersion

Question 8: China introduced the table summarizing the views presented so far.

- **Answer 1 :** If the group uses this matrix for further discussion, all should fill out the boxes.
- **Answer 2:** request to clarify the assumed conditions for such requirements.

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Question 9: Korea shared their experience by presenting two failure cases in the REESS immersion tests it conducted

- **Answer 1:** Question about what scenario is looked at. In the first example the fire in the water will release less smokes. Korea considers fire and explosion will have higher risks.
- **Answer 2:** In case of post immersion, isolation resistance monitoring system will disable the system operation. Complete flood is abnormal scenario and out of scope of vehicle regulation.
- **Answer 3:** Korea asks if there is an OEM that does not require the water immersion safety. Also, if it is one of natural for a fire or explosion during water immersion, why the OEM demand the water immersion safety to the battery manufacturer.
- **Answer 4:** Whole submersion of vehicle will not be a relevant scenario for this regulation.
- commented that the use of vehicle after immersion will be driver's responsibility.
- **Answer 5:** There will be two scenario; (a) drive through water which is not too deep where the water does not come into the cabin but battery pack may be fully or partly immersed, (b) treatment of the vehicle after immersion. Also China will investigate the difference between the ICE vehicles and EVs.
- **Answer 6:** These scenarios will not be the case to be considered for GTR as the risk is not EV specific and not normal in-use conditions.
- **Answer 7:** Vehicle submersion is a catastrophic event and requiring electric vehicles to maintain safety under these circumstances goes beyond that required for conventional fuel vehicles that may also catch fire in floods.

2 Accidents Found in Market

- New Accidents Found in Market



2019/08 Hangzhou China, EV caught fire because battery pack previously had significant water damage.

2 Accidents Found in Market

■ Former Accident Found in Market



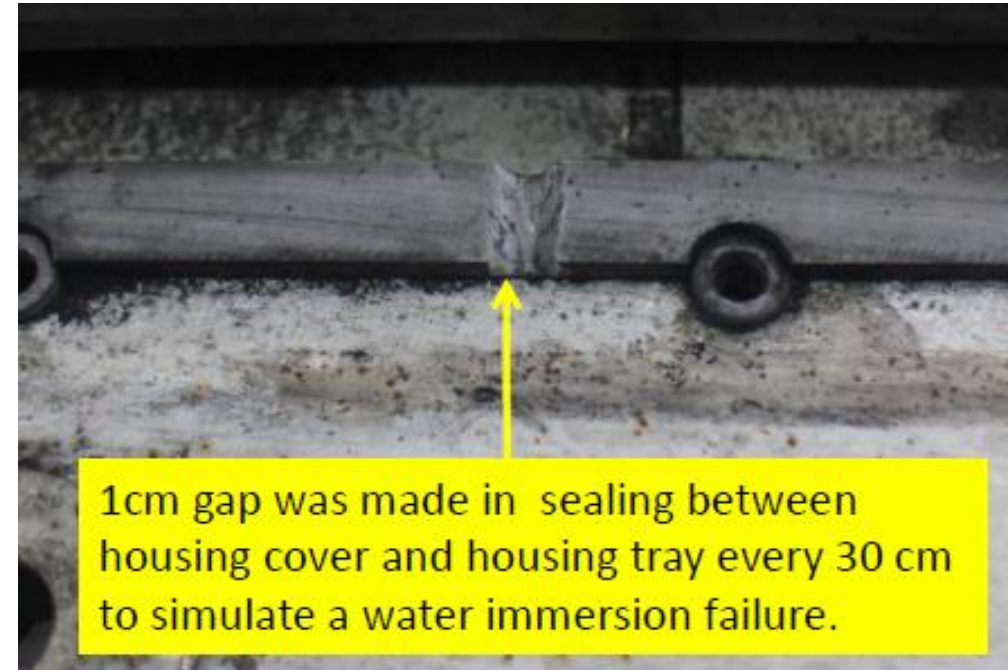
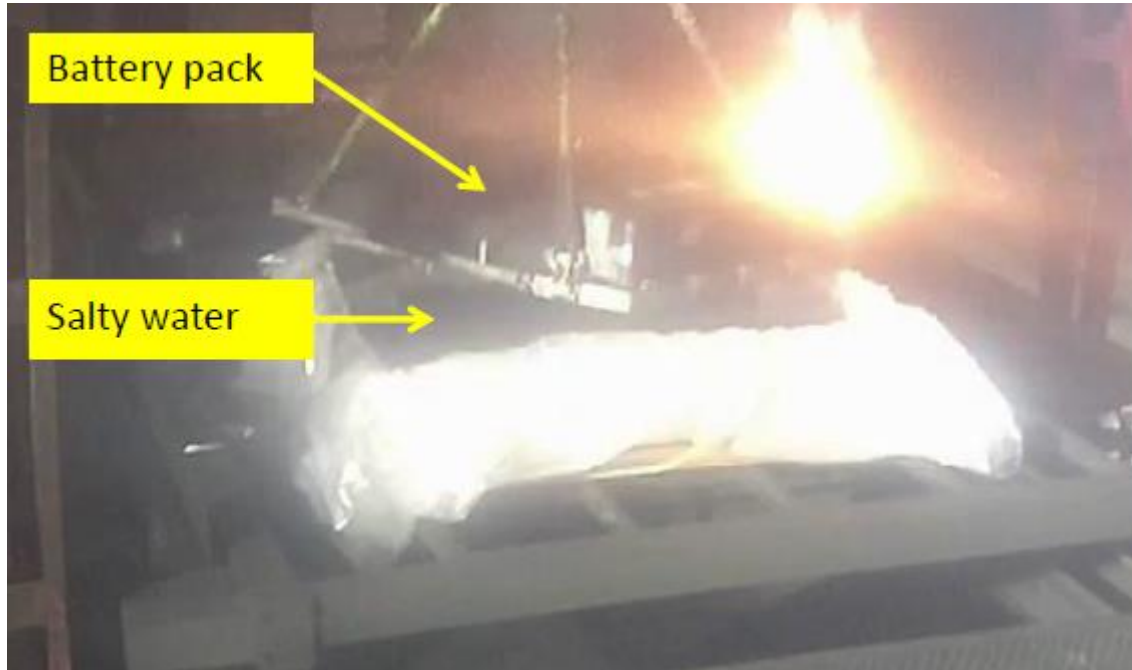
2016/07 Nanjing China, 2 parking (no charging)
EV-buses caught fire due to pack (IP54)
immersion in flooding water.



2018/09 Guangzhou China, EV caught fire
due to soaking in heavy rain*.

3 New Immersion Test Result

- Battery pack was immersed in salty water(3.5%) for 30min and catch fire after 21min rest.



4 Water Protection from OEMs

■ Case 1



IPX7长时间浸水试验

IPX7 temporary immersion in water

模拟车辆泡水后，电池包是否出现水侵入状况。

Test the air tightness of the battery pack after water immersion.

■ Reference: safety feature of battery from OEMs' website

<https://tiguan.svw-volkswagen.com/PHEV/>

■ Case 2

AUTOS • AUTO RECALL

Audi Recalls Its First Electric Car for Battery Fire Risk

By Gabrielle Coppola, Dana Hull, and Bloomberg June 10, 2019



Audi is recalling its first all-electric vehicle due to risk of battery fires.

JOHN KEEBLE—GETTY IMAGES

Volkswagen AG luxury brand Audi is recalling its first all-electric vehicle due to the risk of a battery fire.

The company issued a voluntary recall of approximately 540 E-Tron SUV models sold in the U.S. because of a risk that moisture can seep into the battery cell through a wiring harness glitch, spokesman Mark Dahncke said. The company isn't aware of any fires or injuries because of the flaw, which affects a total of 1,644 models, he said.

- Audi has announced a voluntary recall on the E-Tron, because of a risk for battery fires.
- Audi says that a wiring harness glitch in the affected models can cause moisture to seep into the individual battery cells, which could spark a fire.

<https://fortune.com/2019/06/10/audi-electric-car-recall/>

4 Water Protection from OEMs

■ Water Protection requirement from OEMs

No.	Requirement*
OEM1	The test shall be applied in accordance with [ISO 20653], Chapter 6 "Degrees of protection against water", second code element 7: "temporary immersion in water".
OEM2	The EES must comply with leak-tightness requirement IP67 (default: IP67) within the vehicle assembly.
OEM3	Requirement and testing of degree of protection (IP code) as per ISO 20653, High-voltage battery pack in installed condition fulfills the IPXXD/IP6K9K/IP6K7

■ Comments

- As IP67 is required by typical OEMs over the world, it won't cause too much cost if regulating safety protection against water immersion in EVS-GTR.
- Water immersion has been considered by many OEMs and battery pack is designed against this scenario. This is the reason why failure in market is rare.
- But if no mandatory requirement, safety risk still exist if some OEMs design not properly.

*Only key relevant information is listed here, because of confidential contracts with OEMs.

5 Usage scenario

■ Immersion vehicle in flooding events

Scenario 1: Driving during a flush water



■ Comments

Although it is not recommended to drive in case of flooding, it can be found around the world. There will be specific risks for EVs in case of flooding due to high-voltage battery pack onboard.

5 Usage scenario

■ Immersion vehicle in flooding events

Scenario 2: Vehicles parked in the underground parking garage



2019/4 Dallas USA



2018/12 Hochdorf Germany



2016/10 London UK

■ Comments

In this kind of scenario EV could cause fire if it can't be protected against water, which would lead to the fire in the building.

Considering this kind of severe consequence, this scenario has to be taken into consideration by regulation and EV must be designed accordingly to avoid it.

5 Usage scenario

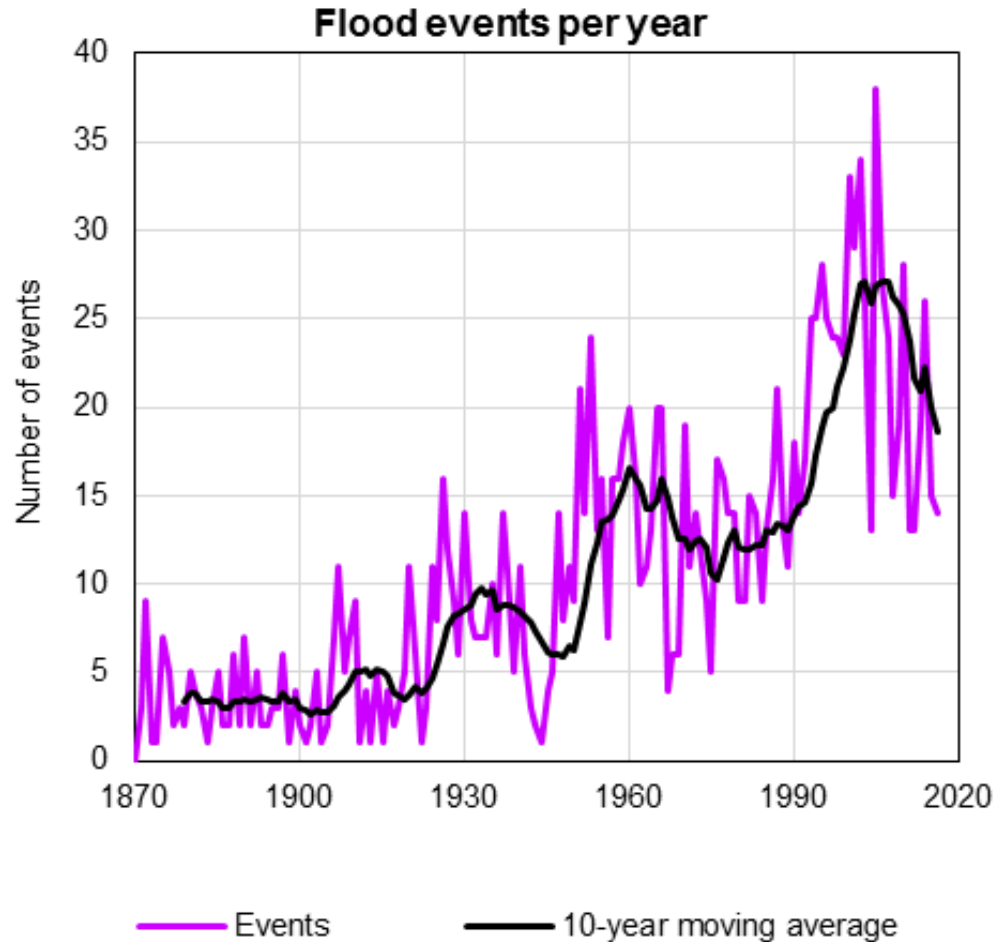
■ Numbers of Vehicles Damaged in Flood Events

	Date	Numbers of vehicles damaged
Hurricane Katrina	2005/08	approx. 300,000
Superstorm Sandy	2012/10	250,500
Louisiana floods	2016/08	approx. 100,000
Hurricane Harvey	2017/08	422,000

Data from National Insurance Crime Bureau (NICB).

5 Usage scenario

■ Flood Events in European Countries



■ Comments

Although it seems flood events are rare and irrelevant to most of the majority, **an increasing trend of flood events** can be found in European countries .

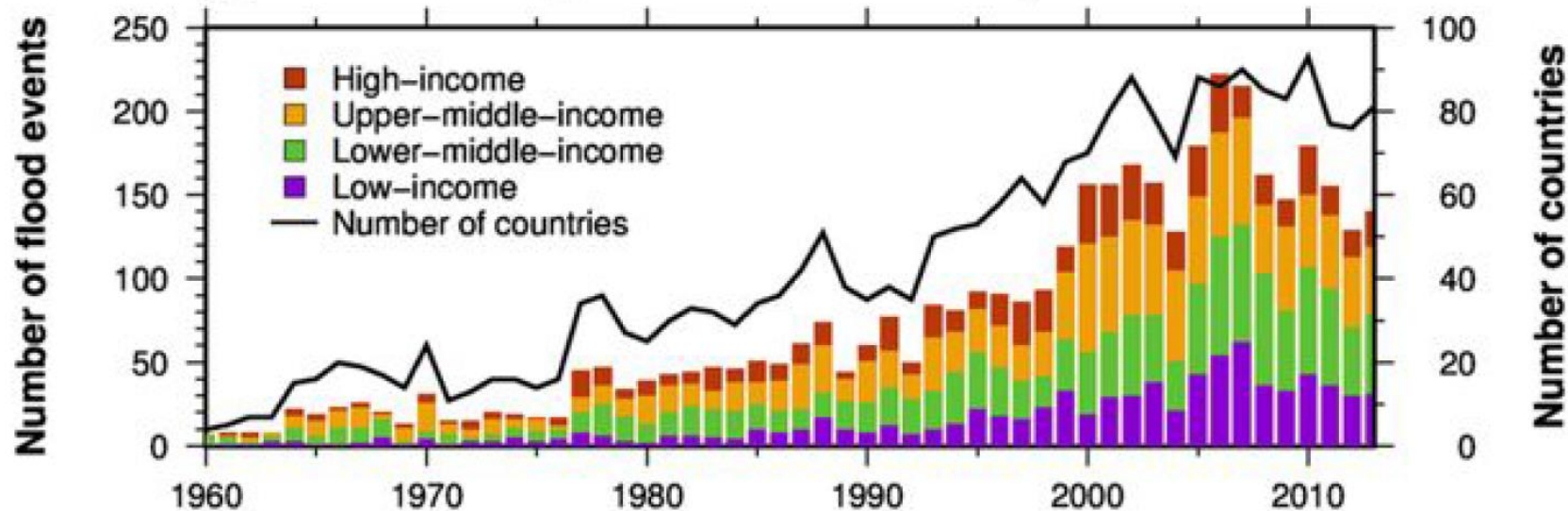
Annual number of flood events in European countries*

*Paprotny , D., T. et al. Trends in European flood risk over the past 150 years. arXiv. 2017 Oct 26; 1710.11044

5 Usage scenario

■ Flood Events Around the World

(a) Number of reported flood events by EM-DAT



(a) Number of flood events for each income level (bar) and number of countries in which a flood event was reported in the Emergency Events Database (EM-DAT) (solid line) from 1960 to 2013. The definition of income level was obtained from the World Bank (<http://data.worldbank.org/about/country-and-lending-groups>).*

■ Comments

Same increasing trend of flood events and affected countries can be found from the EM-DAT (Emergency Events Database) between 1960 and 2013 around the world.

Considering safety issue is critical to drivers and rescuers, **OEMs shall have obligation to consider the water immersion scenario in a safety perspective and design electric vehicles accordingly.**

*Tanoue, M., T. et al. Global-scale river flood vulnerability in the last 50 years. Scientific Reports. 2016 Oct 26;6:36021

<https://www.nature.com/articles/srep36021>

Thanks for your attention!