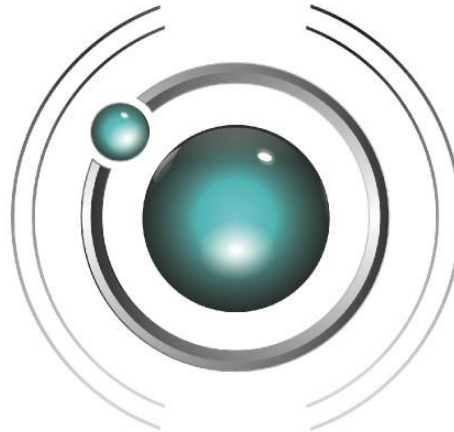


3<sup>rd</sup> Pilot Training Session, 06 -10 June 2016,  
ENSOSP, Aix-en-Provence, France



# HyResponse

Strategies and Intervention tactics -  
Vehicles incidents fuel comparison

Franck Verbecke, AREVA Energy Storage



# Content

1. Generalities about vehicles
2. LPG vehicles
3. CNG vehicles
4. Hybrid vehicles (HV) and electric vehicles (EV)
5. Fuel cell electric vehicles (FCEV)

# Key reference



# Generalities about vehicles

# Technical devices and influence on the emergency operations

## ● DIFFERENT TYPES OF ENERGY COMMONLY USED

### ● Storage

- Prior to any operation, Power Systems have to be neutralized
- Beware of any type of fire on EV or under pressured gas propelled vehicle in a closed area (parking lot, undergroundway...)
- Under pressure gas tanks have to be treated with care, in case of a possible tank rupture, but also if there is a simple gas leak or in case of a fire (overpressure / BLEVE).

### ● Power supply

- According to the type of vehicle, energy is delivered by high voltage cables (generally orange colored) or some other types of cables/canalizations.
- **No action is required on the orange cables or any other energy transportation devices (canalizations...).**



<http://youtu.be/3J4HUz18ZSQ>

# Technical devices and influence on the emergency operations

## ● ON BOARD SAFETY DEVICES

- Primary or active : before the impact -> ABS, ESP...
- Secondary or passive : during the impact e.g. Airbags, Pretension systems -> **Danger for emergency units**
- Tertiary : Facilitates the operations after the accident e.g. e-call -> No danger for emergency units

<http://youtu.be/O1SONXi2sEg>

## ● Airbags

- In order to prevent airbags inopportune action, it is forbidden to touch or damage the ECU (Electronic Control Unit).
- A double-deploying airbag system is never neutralized and may re-open again!
- The only way to neutralize an airbag is to install a protection device on it.
- **Avoid any operation next to an airbag! Stay away from the deploying zone.**



## ● Safety belt pretensioner

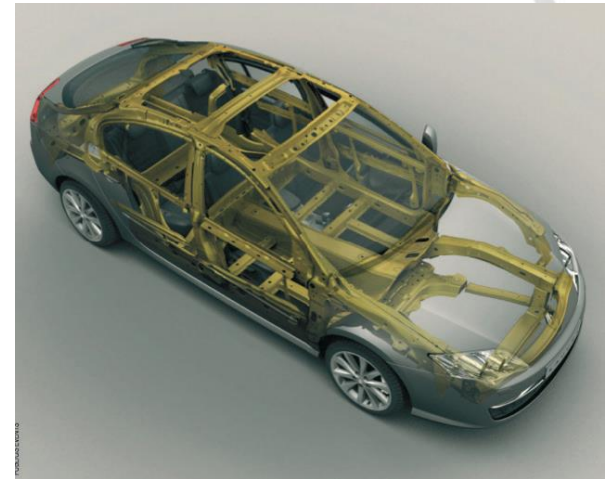
- Belt pretensioner is dedicated to maintain passengers bodies on the car sit. It is reducing the safety belt travel. The disposal has a pyrotechnic cartridge inside, initiated by an electronic system, in order to tense the safety belt.
- **It is forbidden to touch or damage safety belt pretensioner during the extrication operations.**



# Technical devices and influence on the emergency operations

## ● Stiffeners

- New vehicles with a “survival cell” built around the passengers
- Use of new generation materials having a greater resistance up to 7 or 10 times compared to a normal iron e.g. iron mixed with boron, called VHEL (Very High Elastic Limit) and EHEL (Extra High Elastic Limit),
- **With some types of iron, the extrication tools may be totally inefficient. Stiffeners and VHEL and EHEL irons can hardly be cut by the “jaws of life”, even powered by a high pressure group (700 b).**



Structural tube from  
a Saab in 1990



Structural tube from  
a Saab in 2000

# Technical devices and influence on the emergency operations

- **Crash bars**

- It is forbidden to stay in the deploying zone of the crash bars!

- **Reactive engine covers**

- Do not place anything on a damaged engine cover! Do not wedge the vehicle from the engine cover!

- **WINDOWS**

- Window glasses may cause serious injuries, such as deep cuts on any parts of the body, eye-injuries or lung injuries (by inhalation of some microscopic glass parts, during the extrication operations).
- Rescue teams and of course the victims have to be well protected. Furthermore, the tool's choice and the way to remove the windows have to be relevant, depending on the type of glass!

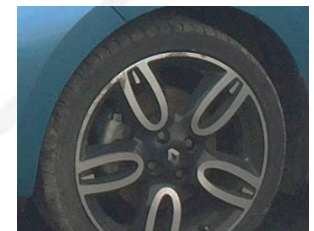
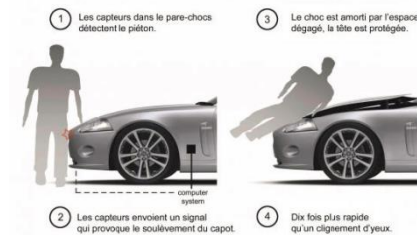
- **MISCELLANEOUS DEVICES**

- **Hydraulic jacks**

- Hydraulic jacks can be ejected in case of a car fire (missile effect), or generate an oil projection when involuntary cut. Individual protection, danger awareness and anticipation are essential.

- **Metal blen**

- Aluminum and magnesium are often used in engine blocks, crankcases, cooling radiators or alloy wheels.
- In case of a fire and when water is used for extinguishing operations, a violent reaction may occur (boiling metal projections). Individual protection, danger awareness and anticipation are essential.





# Technical devices and influence on the emergency operations

- **Automatic disconnection systems**

- During the impact, these systems are dedicated to the battery pack insulation, by disconnecting electric terminal.
- **This important point has to be considerate, as much as the other power supply items on board.**

- **Refrigerant gas**

- Some gas used in the air-conditioning systems can be highly toxic, when exposed to a fire.
- **Avoid any damages on the containers during the extrication operations!**

- **Start capacitors**

- Many constructors equip their cars with « **start and stop systems** ». These cars have start capacitors permanently kept in charge. When crashed, the start capacitors can allow a toxic gas to escape (acetonitrile).
- **Avoid any damages on start capacitors during extrication operations!**

- **Tires**

- **In case of a car fire (particularly a heavy-load or a bus), the tire blasting can be extremely dangerous for the emergency units (blast, projection, audition impact). Beware of « delayed tire blasts » that can happen after the extinguishing operations.**

- **Different kind of materials used in new generation cars**

- Using new types of materials, the constructors have considerably increased the calorific charge and the chemical products concentration under new generation vehicles
- **During a car fire, the thermal and toxic effects have to be considered!**



# Decision making tools for firemen

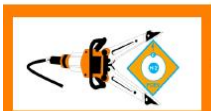
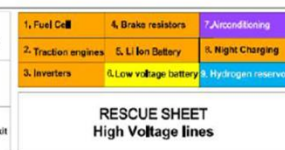
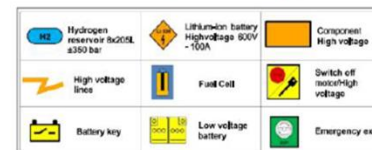
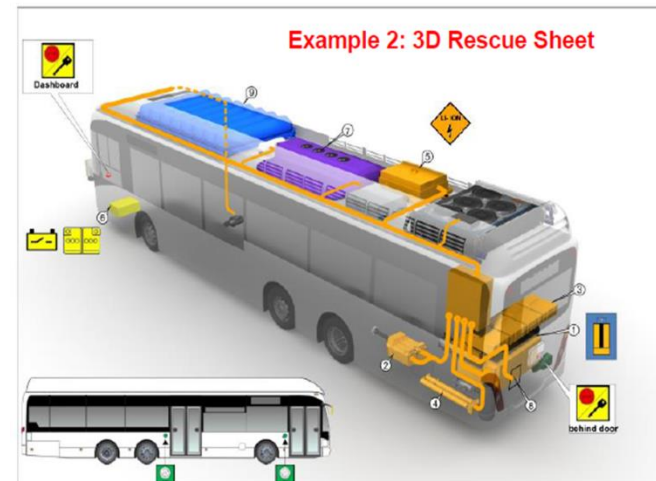
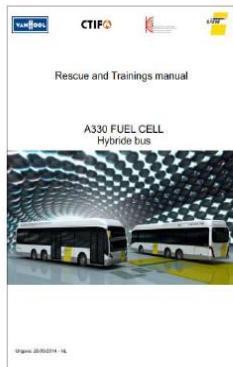
## RESCUE SHEETS

### ERG (EMERGENCY RESPONSE GUIDE)

Describes how to neutralize the energy

Describes how to extricate passengers safely

### A) Rescue and training manual vehicle



COMMISSION FOR EXTRICATION AND NEW TECHNOLOGY





## LPG vehicles



# LPG vehicles

- **LPG fuel: Liquefied Petroleum Gas**
- LPG is a mix of liquefied propane and butane. In winter, the mixes contain more propane, while in summer, they contain more butane.
- It can be found mainly on cars but also on trucks and buses.
- LPG vehicles are also called autogas or auto propane. Their engines are fueled by liquefied gas which is stored in a steel tank.
- Vehicles can use only LPG or they can use LPG and petroleum (bi-fuel vehicles). In this last case, LPG system has been added to the petroleum system.

LPG stored in a tank at 7,5 bars of pressure (70 to 80 liters)

20% unused volume in the tank



Transfer to the engine

In specific hoses



Evaporation

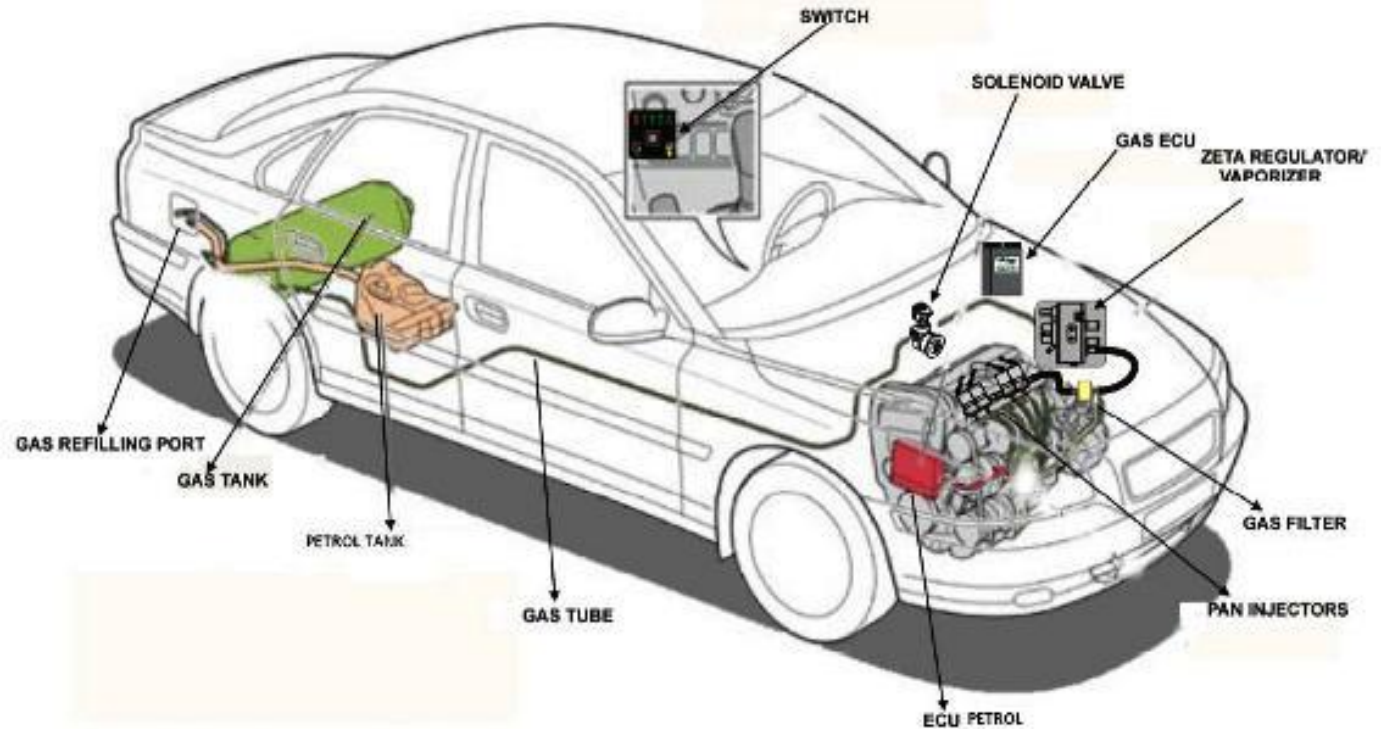
Liquid to gas



Combustion

Running engine

# Specific equipments





# Main safety features

## Safety components

### Electronically shut-off valve

closes the flow of gas to the engine if the engine stops for any reason

### Pressure relief valve

if tank's pressure is over 27 bars

### Fuse

Some tanks are equipped with fuse wire which melt at 110°C, releasing gas to the air

Car on its wheels  
**Regular** cycles Gas flare



Car on its roof  
**Continuous** cycle Liquid flare



# Specific phenomena



on-roof or on-side vehicle :

LPG is in liquid state. No changing in state ☐ no cooling of the tank



**Bleve can occur**

Lack of liquid in the tank :

Pressure increases but not enough to trigger the opening of the valve



**The tank can be torn\***

case of cylindrical tanks :

Top part of the collar has a lower resistance in case of high temperatures. It can tear up at this weak point before opening of the pressure relief valve.



**The tank can be torn\***

Insufficient flow in the relief valve :

Steel of the tank overheated and thus it is weakened.



**The tank can be torn\***

\*Same heat effects as BLEVE but no projection



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<http://youtu.be/fKm-ep3qPmw>

# Specific equipments and related hazards

If not burning  
flow



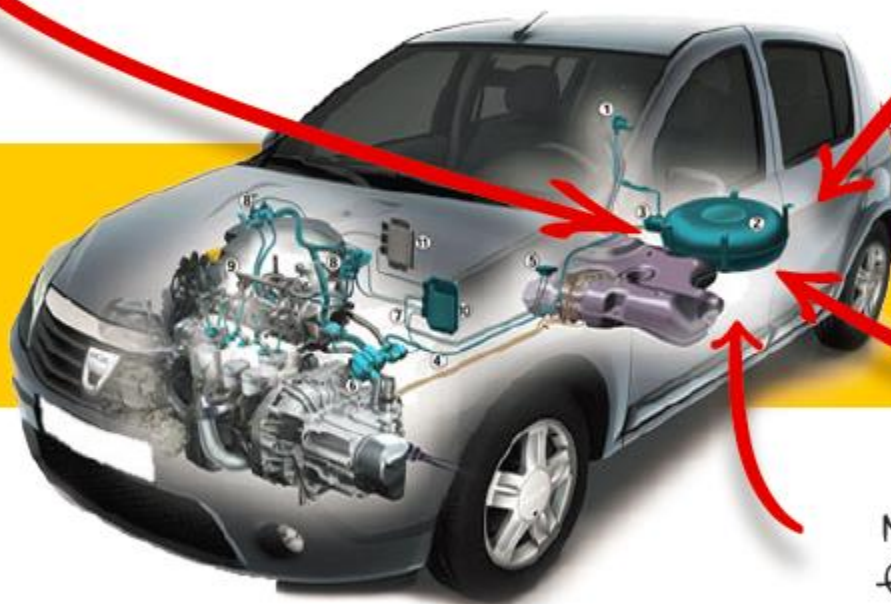
Flare



Tank explosion



NOT burning  
flow (inside)





## CNG vehicles



# CNG vehicles



# CNG vehicles

- A natural gas vehicle (NGV) uses compressed natural gas (CNG) or liquefied natural gas (LNG).
- Focus on CNG cars in which gas is stored at a 200b pressure in different kinds of tanks.
- NGV can be found in trucks, public transport and few hybrid cars. In France it remains pretty rare because of the lack of filling stations.

CNG is stored in a tank



Transfer to the engine  
In specific grey stainless steel pipes



Combustion  
Running engine



# Main safety features

## Safety components

### Electronically shut-off valve

which stops the flow of gas to the engine if the engine stops for any reason

### Manual valve



### Fuse

Fuse wire which melt at 110°C, which melt at 110°C;

Blowdown time : 2 to 3 min



12 Video 1 CNG bus fire.wmv

Current regulation allows having only one safety device on each tank.

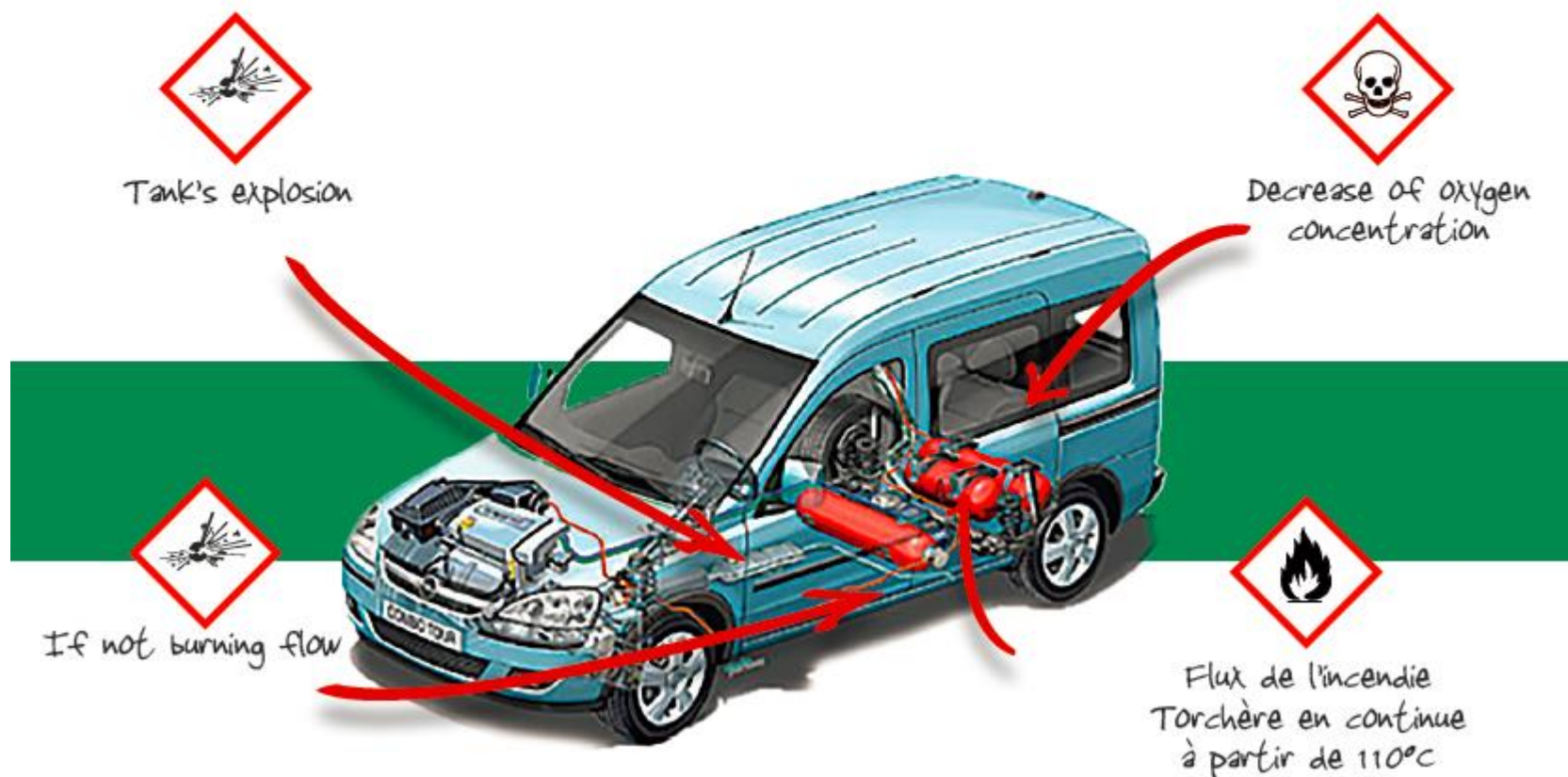
Thus, a fuse wire on an end of the tank will not work if temperature's increase occurs on the other end of the tank. This will induce a **pressure increase which can trigger an explosion.**

Accidents analyses and experimentations have shown that regulation should evolve in order **to improve NGV's tank safety.**



# Specific equipments and related hazards

Tonic	Heat	Explosion
		





Hybrid vehicles (HV) and electric vehicles (EV)



# Hybrid vehicles (HV) and electric vehicles (EV)

- EV or HV??

- EV : Exclusively propelled by an electric power system
- HV : Combination of a thermal engine and an electric power system

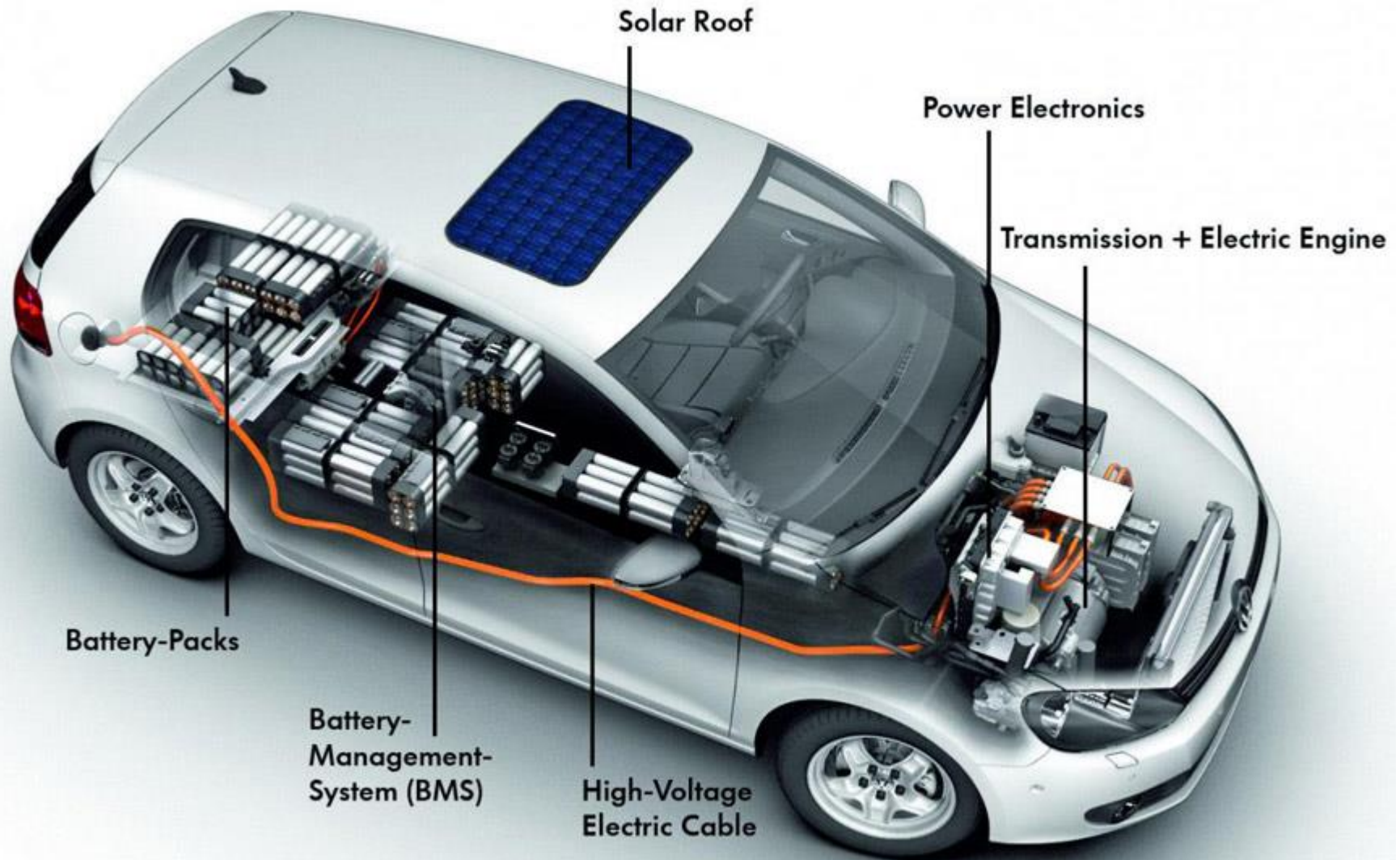
- How does a HV work?

- <https://www.youtube.com/watch?v=m2qvGJwTuBo>





# Specific equipments/hazards





# Main Safety features on HV and EV

- Constructors take provisions to ensure that **the integrity of the electric circuits on HV/EV** is at its higher level.
  - High voltage cables placed out of the usual cutting areas
  - Battery packs are located in protected places (between the two rear-wheels, for example, or in a central position) ;
  - Shock-proofed battery packs...
- Furthermore, some hybrid or electric vehicles can be equipped with **devices dedicated specially to disconnect batteries**:
  - Automatic systems (fuses, relay), in case of a violent shock or if temperature increases ;
  - Manual systems (Service plug)
    - At first, Service plug was dedicated to people working on cars (mechanics, coach builders...), in order **to disconnect temporarily the battery**.
    - They can be located in **different places, according to the model**, because there is no standard for Service plugs.



# EV specific phenomena

- High voltage battery pack **mainly is NiMH, Li-ion or LMP (Lithium Metal Polymer)**. Fire service operational procedures may change according to the technology used, in case of a car fire.

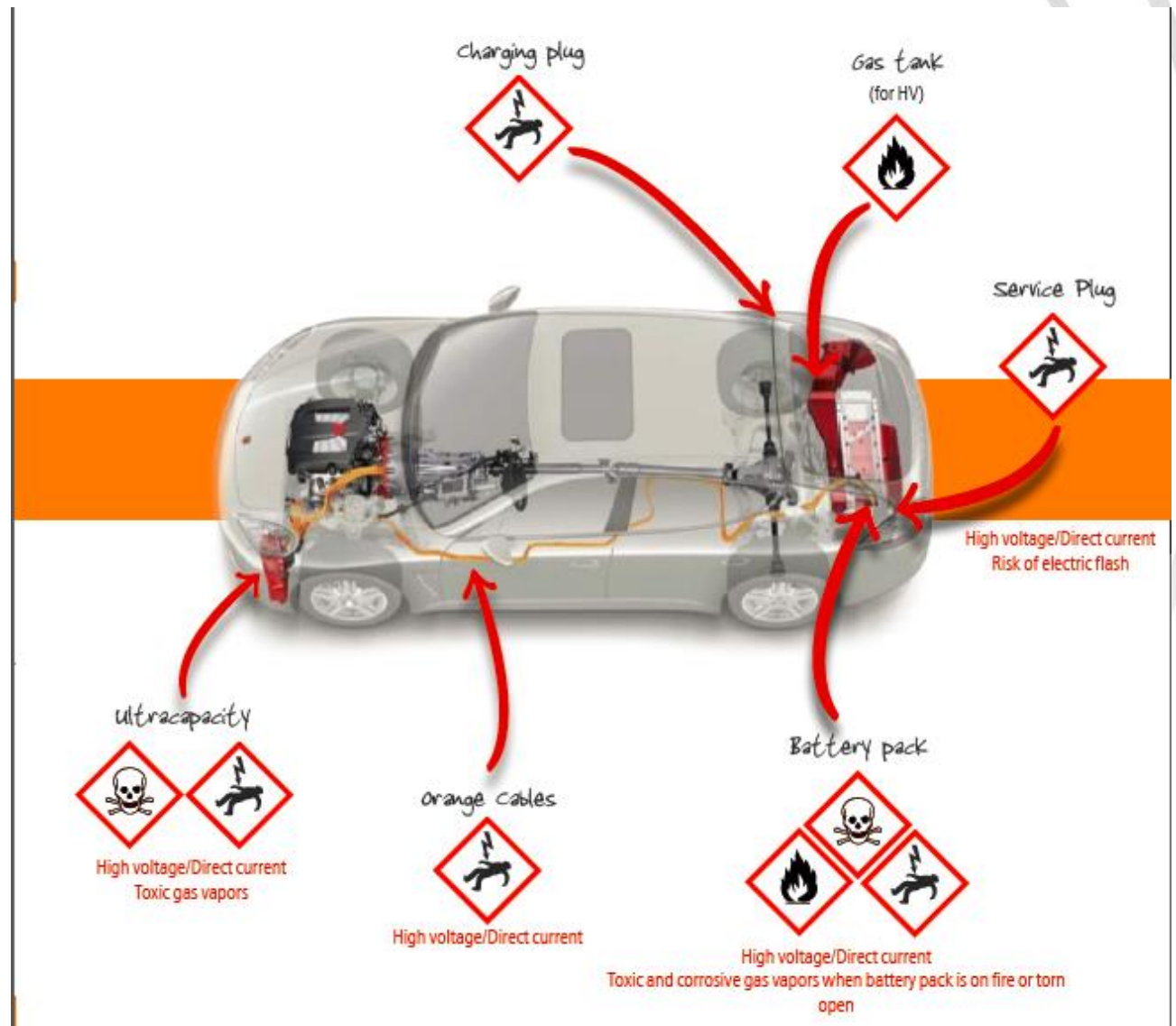


<http://youtu.be/0Ny9LBmOAls>

- Extinguishing operations may be difficult (Li-ion) or quite impossible (LMP). Environmental protection is required with a high priority.
- Some constructors (RENAULT) install thermal fuses or « fireman access» on battery packs, in order to help extinguishing operations, by introducing water directly into the batteries.
- Boiling metal projections may occur during the operations!
- Toxic gas may escape from the battery pack: HF, HCl....
- Battery pack weight changes normal balance of the vehicle (weight is concentrated on the back, for example). To be aware while Firemen trying to block the vehicle.



# Specific equipments and related hazards



Fuel cell electric vehicles (FCEV)

# FCV and FCEV vehicles

- A FCV is an electric vehicle
- It produces its own electricity which is supplied :
  - Directly to an electric engine (full power technology) or
  - To a battery to extend its duration and then to an electric motor (range extender technology)

H<sub>2</sub> stored in one or two tanks  
pressure of 350 to 700 bars

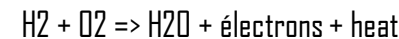


Transfer to the FC

Gas state



Chemical reaction



Use of electricity

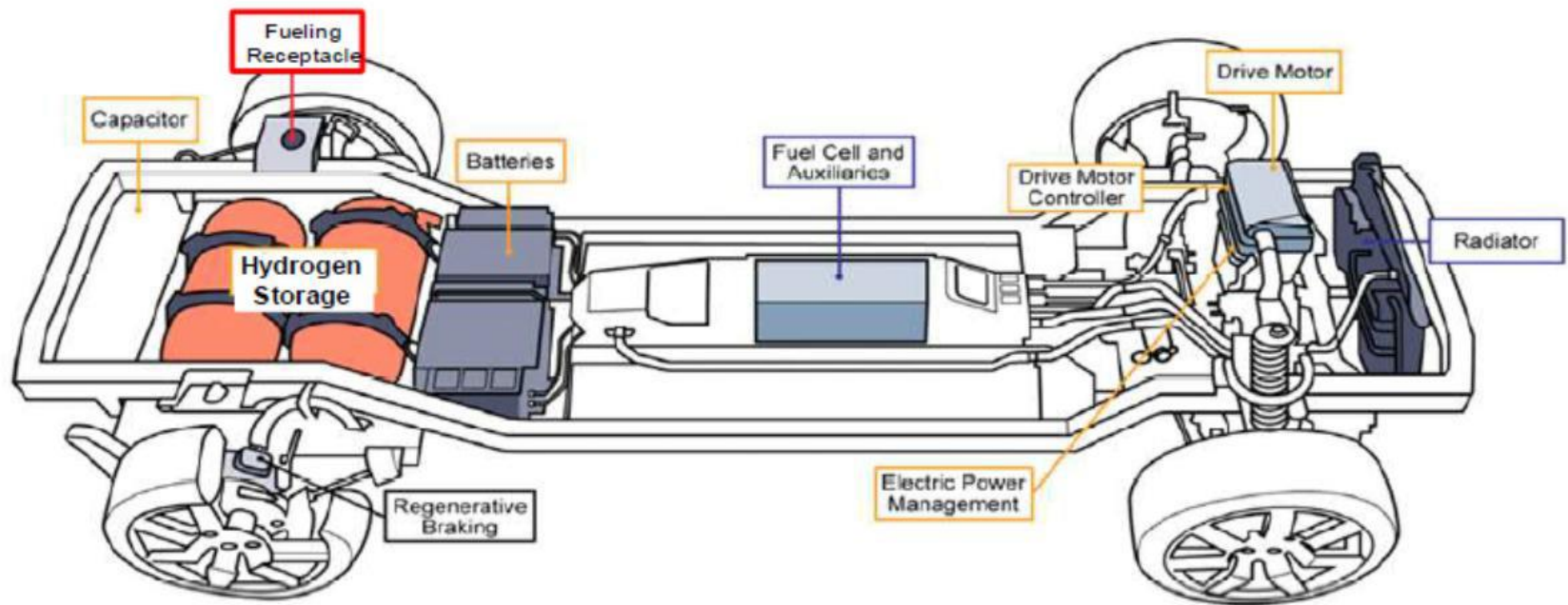
Electric motor

Use of electricity

Charge battery

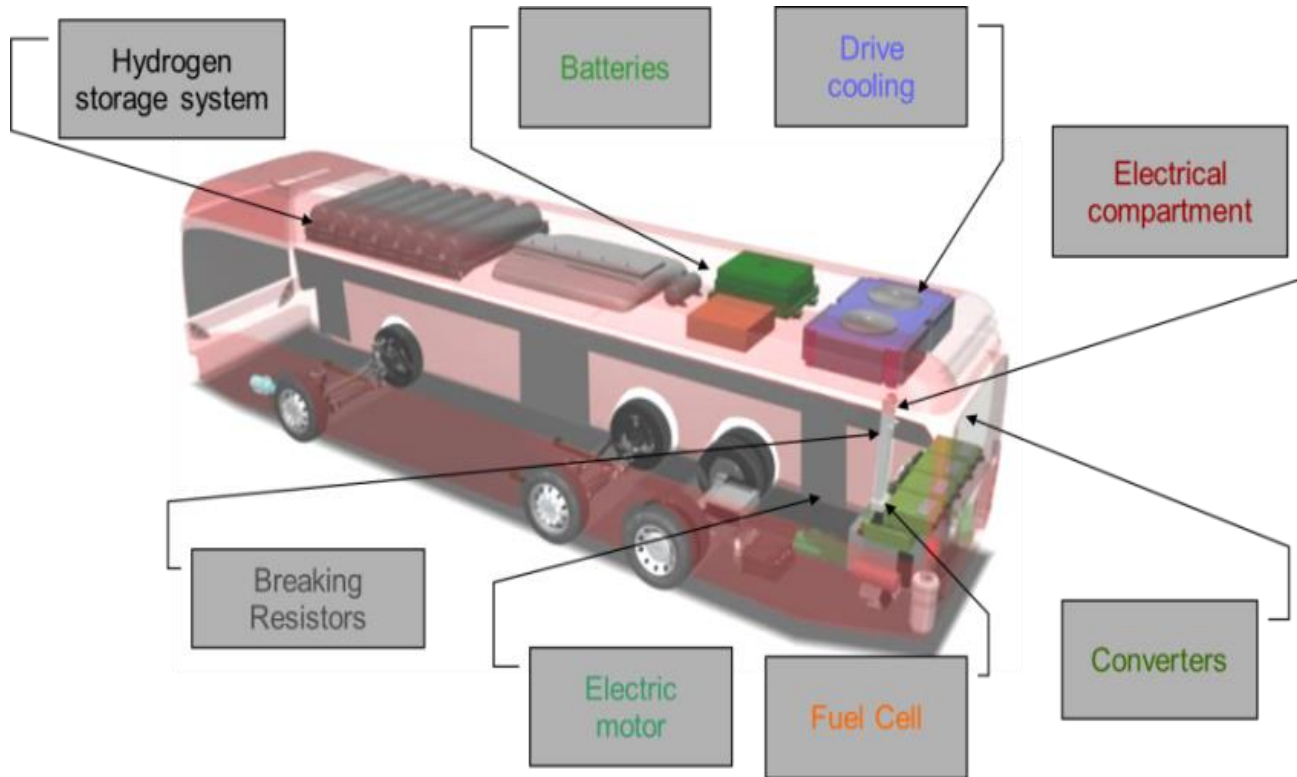


# Fuel cell car

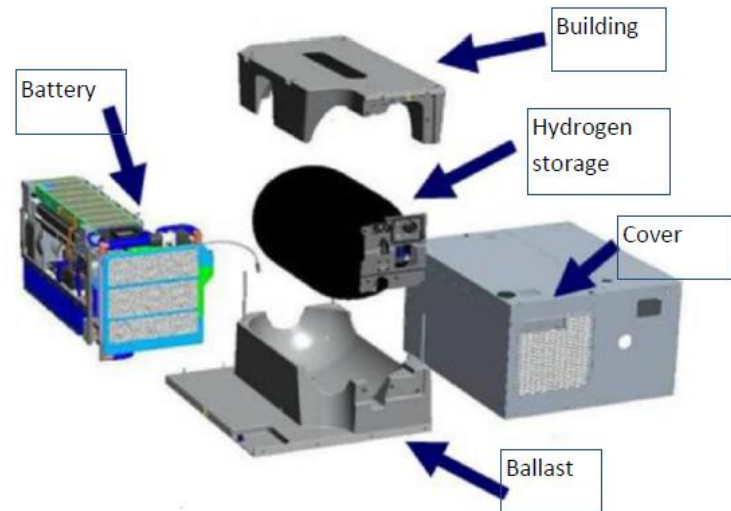




# Fuel cell bus



# FC Forklift





# Main safety features

## Composite tanks

Validation Tests	
<ul style="list-style-type: none"><li>•Hydrostatic Burst</li><li>•Extreme Temp. Pressure Cycle</li><li>•Ambient Temp. Pressure Cycle</li><li>•Chemical Exposure</li><li>•Bonfire</li><li>•Gunfire Penetration</li><li>•Flaw Tolerance</li><li>•Accelerated Stress</li></ul>	<ul style="list-style-type: none"><li>•Drop Test</li><li>•Permeation</li><li>•Hydrogen Cycle</li><li>•Softening Temperature</li><li>•Tensile Properties</li><li>•Resin Shear</li><li>•Hydrogen-Compatible Material</li><li>•Numerous Internal Tests</li></ul>



# Main safety features

## Safety components

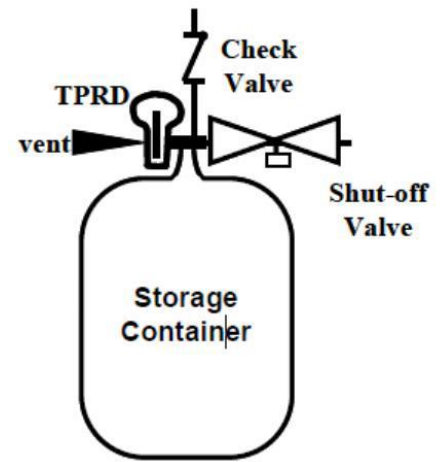
### Electronically shut-off valve

which stops the flow of gas to the engine if the engine stops for any reason

### Temperature activated Pressure Relief Devices (TPRD) in each tank.

In case of high temperature, a fusible metal plug melts open and hydrogen is rapidly released, which is an extremely audible event. 2-3min (car).

No harmonisation regarding the direction of the vent: upward (kangoo) or back of vehicle

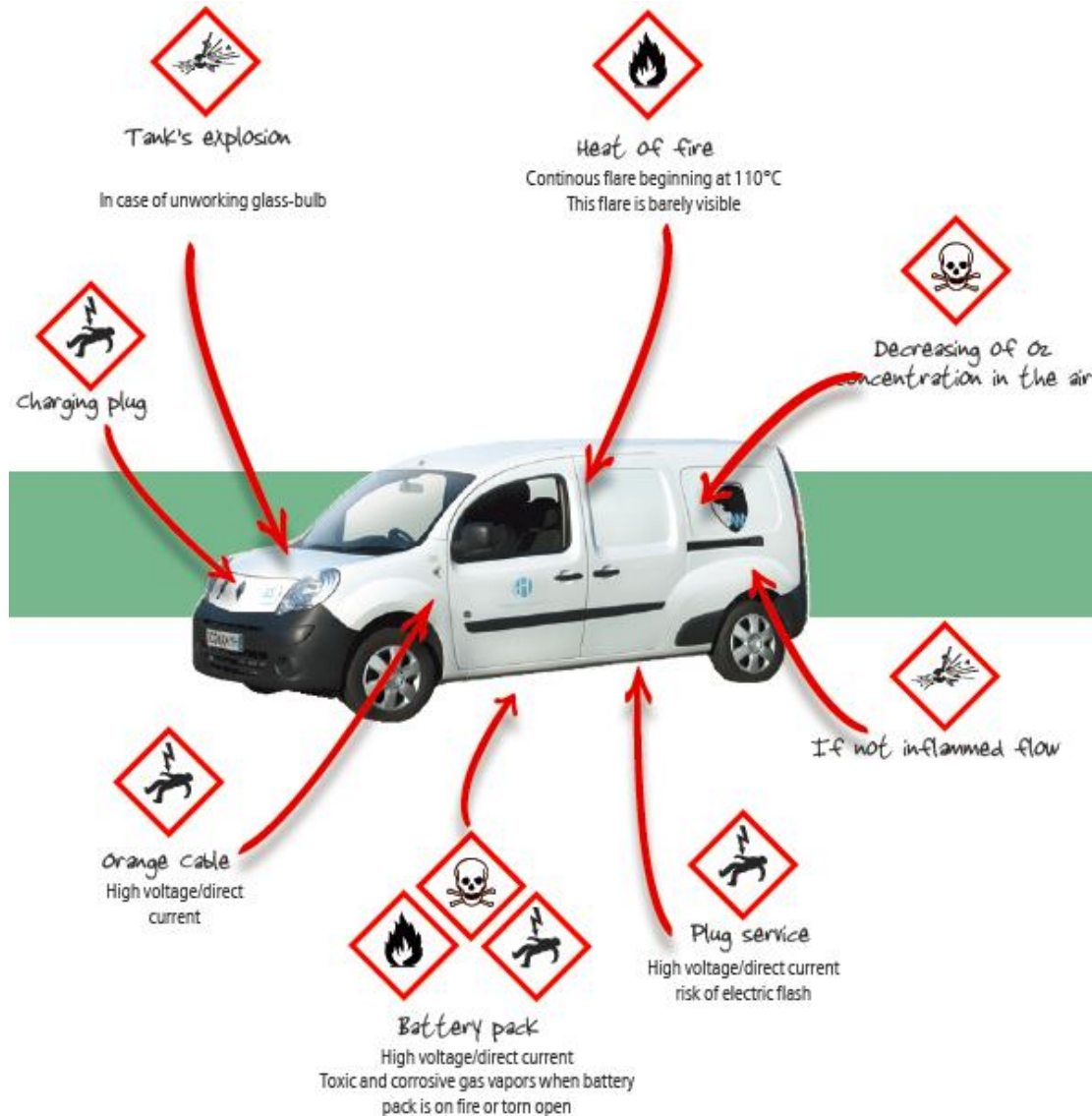


Type IV technology

# TPRD activation



# Specific equipments and related hazards





## Comparison of Alternative Energy Vehicle engulfed in a fire

# LPG/CNG and FC cars engulfed in a fire



HyResponse





# Thank you for your attention

<http://www.hyresponse.eu/>

HyResponse: Coordination and Support Action funded by Fuel Cells and Hydrogen Joint Undertaking and supported by the European Commission under the 7th Framework Program. Project reference: 325348.

