Carbon Fibre Reinforced Plastics in high-end road vehicles

What is Carbon Fibre Reinforced Plastics (CFRP)?

Carbon-fiber-reinforced polymer

Carbon fiber–reinforced polymer, **carbon fiber–reinforced plastic** or **carbon fiber–reinforced thermoplastic** (**CFRP**, **CRP**, **CFRTP** or often simply **carbon fiber**, or even **carbon**), is an extremely strong and light fiber-reinforced polymer which contains carbon fibers.
CFRPs can be expensive to produce but are commonly used wherever high strength-to-weight ratio and rigidity are required, such as aerospace, automotive and civil engineering, sports goods and an increasing number of other consumer and technical applications.
The binding polymer is often a thermoset resin such as epoxy, but other thermoset or thermoplastic polymers, such as polyester, vinyl ester or nylon, are sometimes used. The composite may contain other fibers, such as aramid e.g. Kevlar, Twaron, aluminium, Ultra-high-molecular-weight polyethylene (UHMWPE) or glass fibers, as well as carbon fiber. The properties of the final CFRP product can also be affected by the type of additives introduced to the binding matrix (the resin). The most frequent additive is silica, but other additives such as rubber and carbon nanotubes can be used. The material is also referred to as *graphite-reinforced polymer* or *graphite fiber-reinforced polymer* (*GFRP* is less common, as it clashes with glass-(fiber)-reinforced polymer). In product advertisements, it is sometimes referred to simply as *graphite fiber* for short.

http://en.wikipedia.org/wiki/Carbon-fiber-reinforced_polymer

Once only used in racing cars for motor sport such as Formula One, it can now be found in the new BMW i3 and i8 cars greatly reducing weight but keeping structural integrity.

http://www.bmw.com/com/en/newvehicles/i/i3/2013/showroom/safety.html

These vehicles are driven purely by electrical power allowing for high performance with minimal environmental impact.

Further information about these vehicles can be found on the Internet.

The concern here if any is the impact on the rescue of trapped occupants in the event of a crash, I know that in my area of the world these cars are selling so well that there is now a waiting list, so there will be a time that we can expect to deal with an extrication involving such a vehicle in the not to distant future.

http://www.bmw.com/com/en/newvehicles/i/i8/2014/showroom/images_and_videos.html#

For the rescuer the issue that stands out is not the fact that this is an electrically powered vehicle, as we have should a good understanding of the issues with hybrids and EV vehicles.

It is our ability to ascertain the make and model of the vehicle and to highlight that it is indeed a vehicle comprising of an Aluminium chassis with the main monocoque body made from CFRP's

The BMW i3:

The passenger compartment of the BMW i3, the so-called Life module, is completely made of carbon (also known as 'carbon fiber reinforced plastic' or CFRP) – an especially light and high-strength material that provides outstanding protection for vehicle passengers in the event of an emergency.
http://www.bmw.com/com/en/newvehicles/i/i3/2013/showroom/safety.html#carbon

http://www.bmw.com/_common/shared/newvehicles/i/i8/2013/showroom/drive_efficiency/lightweigth.jpg

As you can see the construction is minimal to keep weight as low as possible, but with a very strong passenger compartment to offer maximum safety and strength.

In a rescue situation the process remains the same, the issues we as rescuers will have to overcome is how we create space, what is the best method to cut this material and what safety issues does it create for the rescuer?

Generally the CFRP will remain rigid with little deformation, it takes a huge amount of energy to fracture the framework, where this is to be the case the structure will relocate with ease.

At these early stages it is difficult to surmise the problems we may or may not encounter during a vehicle crash situation.

In these diagrams, courtesy of www.boronextrication.com you can see that the vehicles still have side impact protection built into the side doors, which offer extra protection and energy absorbance by redirecting the impact energy through the vehicle putting less stress on the CFRP components.

The aluminium chassis will absorb a lot of the crash energy and divert the energy through the structure lessening the stresses that the CFRP may be subjected to.

The rescue equipment inventory carried by most will be able to deal with this material with relative ease.

As you can see the Scissor door opening can be a surprise if you are not expecting it, having looked into them I cannot see any real issues in dealing with this type of configuration, as popping the door of its hinges is very similar to current techniques. (a demo video will be available at some time)

Space creation techniques may well be minimal due to the strength and rigidity of the CFRP structure, however never say never, with the current methods of casualty removal with suspected spinal injuries and the need to remove the roof, this is perhaps something we need to know, although training for such an event is perhaps years away due to the availability of these vehicles to train on.

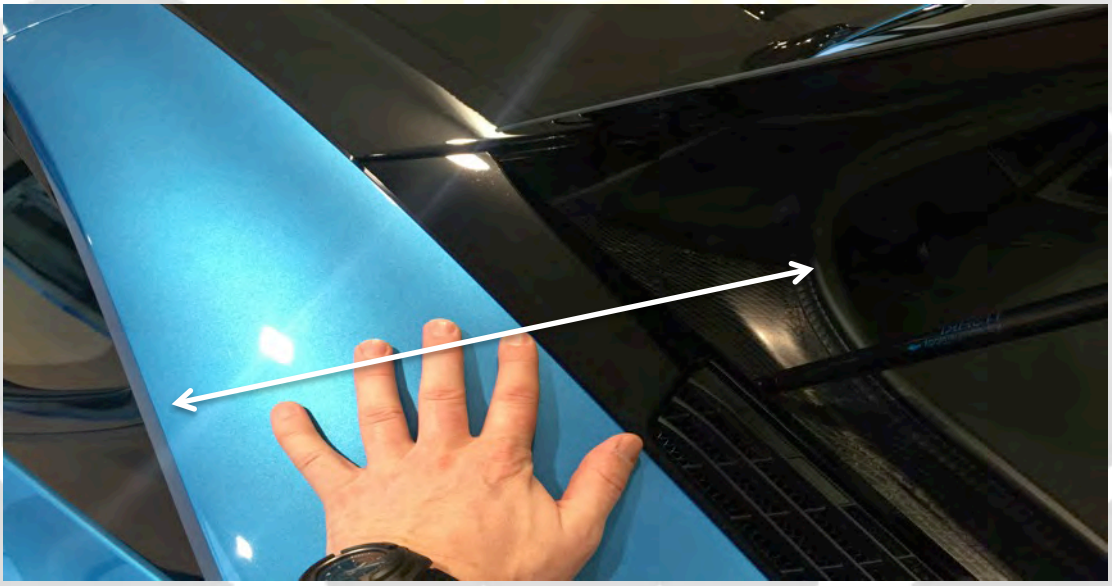
Some areas for thought are tool purchase points and the use of additional supports such as sill supports in well-placed locations to carry out standard applications.

The CFRP isn't so forgiving as the metals we are used to dealing with, it needs to be treated with caution and understanding. If you are to cut this material with hydraulic cutters, the best method is to approach the cut with a slower more controlled cutter speed, the main issue with CFRP is that is will fail with catastrophic results if cut at speed, the cuts need to be made slowly for the energy to be absorbed and dispersed whilst the cut is being made.

Reciprocating saws can cut such materials with ease but will produce a lot of carbon fibre strands and dust particles, so full PPE including eye, face and respiratory protection must be worn, by respiratory we mean a suitable dust mask etc.

When using hydraulics the same protection should be used to protect against CFRP particles becoming airborne. If using hydraulics to cut or spread etc, generally the material if damaged will move with little resistance, but if its still intact and maintains its rigidity it may have to be cut, spread or relocated slowly in a controlled manner, if you try to carry out these tasks at speed and as already mentioned it will cause the material to fail with huge force and momentum with the potential to cause injury.

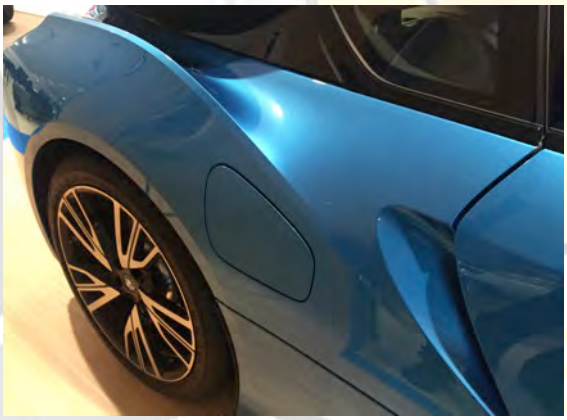
The construction of the vehicles are very solid and as you can see in the diagram of the i8 I have used my hand as a reference for size, this c-pillar is a large structure and cutting through it would create a lot of dust, fibre strands.

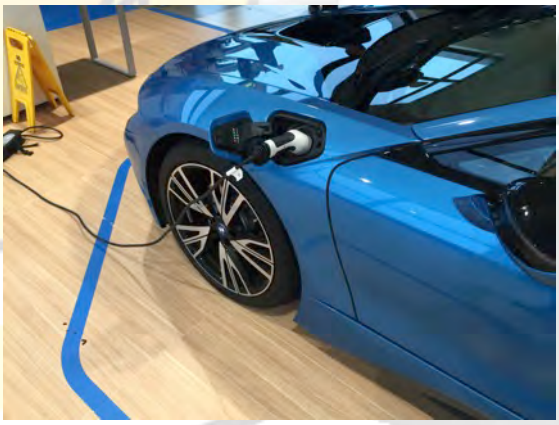


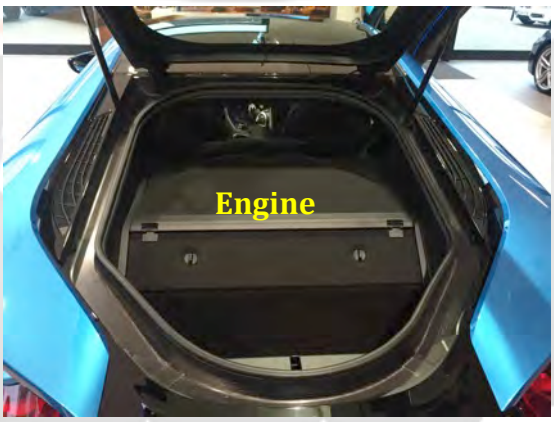
The doors themselves on the i8 open in what they call a scissor direction. There are two hinges fitted in the A-post, which are accessible for cutting and spreading, the only issue would be good manual handling as the angle of tool operation would be fairly awkward. A very large gas strut backs up the hinges, which enables the door to open upwards easily and remain open.

One thing to note is how the door opens, on the outside there is a door opening lever as normal, from the inside the door is opened by an electronic switch, however should the electrical power be lost this door opening button will no longer work, there is a manual opening lever on the upper part of the door body on the inside so that the doors can be opened if power is lost, something a rescuer might need to be aware of if trying to open either door from inside.

The BMW i8 is a hybrid running off electrical power and petrol, in these diagrams you can see the electrical plug in charger and the petrol-filling cap, on the i8 the engine is in the rear as seen here;







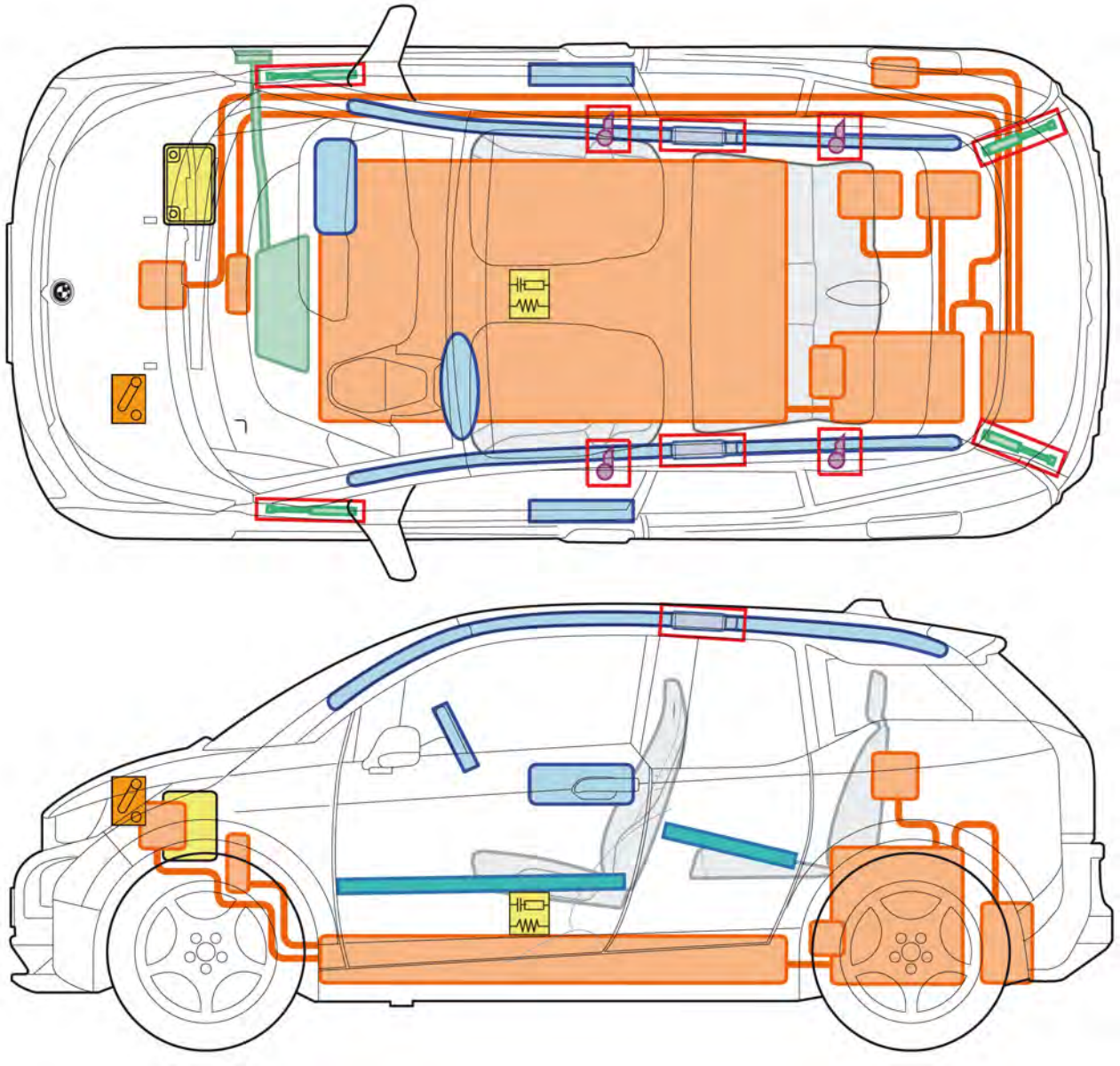
The BMW i3 does not come as a hybrid and is purely electrical with the option of a range extender, this is a small engine similar to that of a lawn mower, this just runs to charge the battery to extend the range of the vehicle, which is an optional extra.

Some additional pictures of the interior, as you can see they are very similar to most hybrids allowing early recognition and shut down buttons (Power Button)

As always please send in any experiences or feedback to rtc.rescue@gmail.com

i3

(from 11/2013)



Legend

Airbag	Body reinforcement	Airbag control unit	High-voltage emergency separation point
Gas generator	Gas-filled shock absorber	12 V battery	
Belt tensioner	Fuel tank	High-voltage components	

This overview shows the maximum possible vehicle equipment.

Issue 09/2013

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	**Danger to life!** Do not touch high-voltage components! **Special features:** High-voltage system with direct current voltage up to 1000 volts!

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Secure vehicle to prevent it rolling.

Press "P" button.

Pull the switch for the electrical Automatic Hold brake up.

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	**Airbag activated** The high-voltage system is automatically deactivated (de-energised) if an accident is experienced that triggers the airbags.

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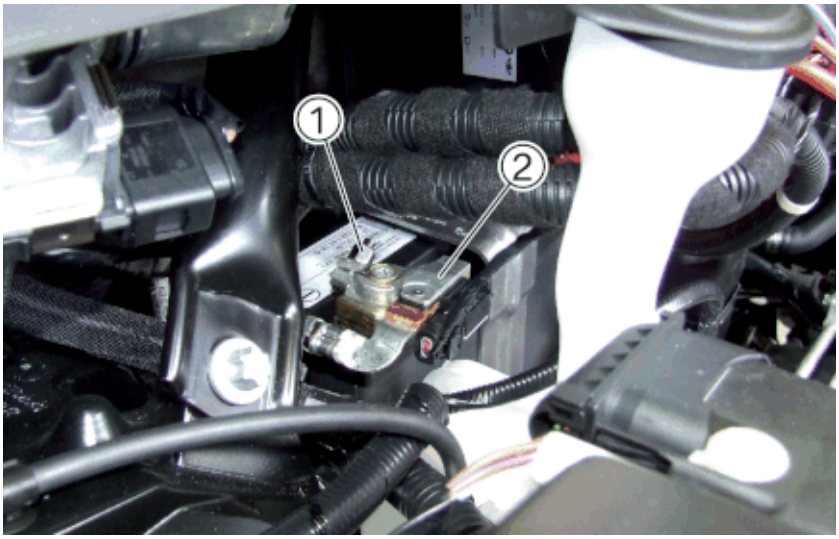
Deactivate the electric motor and high-voltage system (switch to de-energised) – airbag not activated.

(START-STOP and 12 V battery accessible)

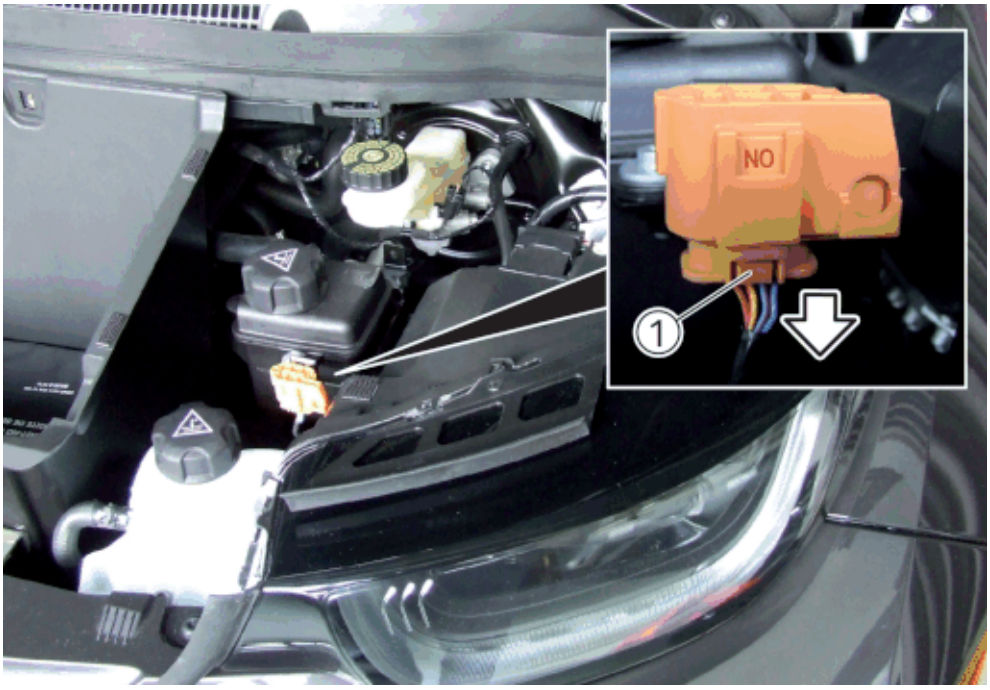
1. Press the START-STOP button, the system switches off.

Open the engine compartment lid and remove the cover (1).



Slacken the nut (1) and pull off the battery earth lead (2) in the upwards direction.

Remove the cover (1).



Unlock connector for high-voltage emergency separation point (1) and pull apart in direction of arrow.

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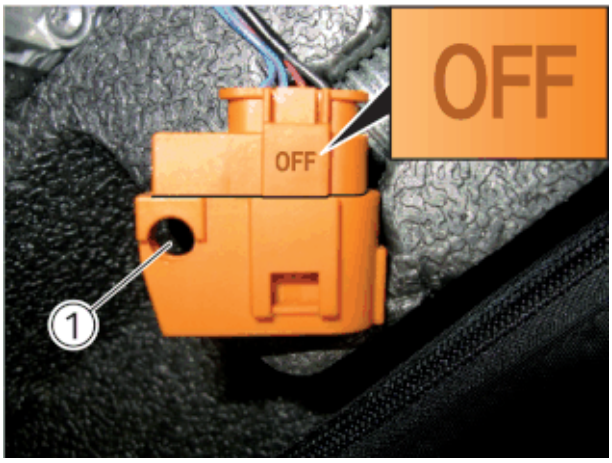

The high-voltage system is deactivated when bore hole (1) is completely free and the word "OFF" can be seen on the connector.

For example, you can install a padlock through the open bore hole (1) to prevent unintended activation of the high-voltage system!

Note: The plug connection cannot be fully disconnected.

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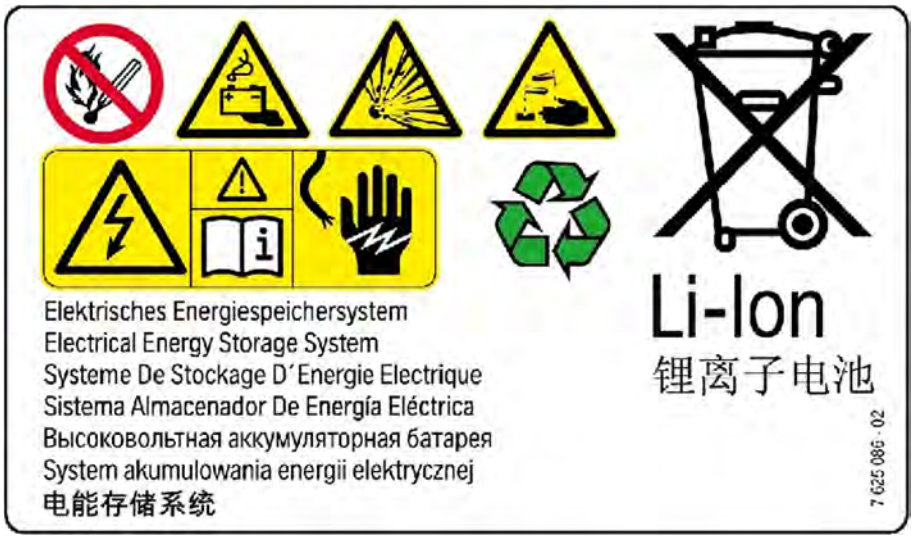
The high-voltage battery is located on the vehicle underbody.

Identification of high-voltage battery:	

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Identification of the remaining high-voltage components:	

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Identification of the high-voltage cable (1) (insulation / orange coating).

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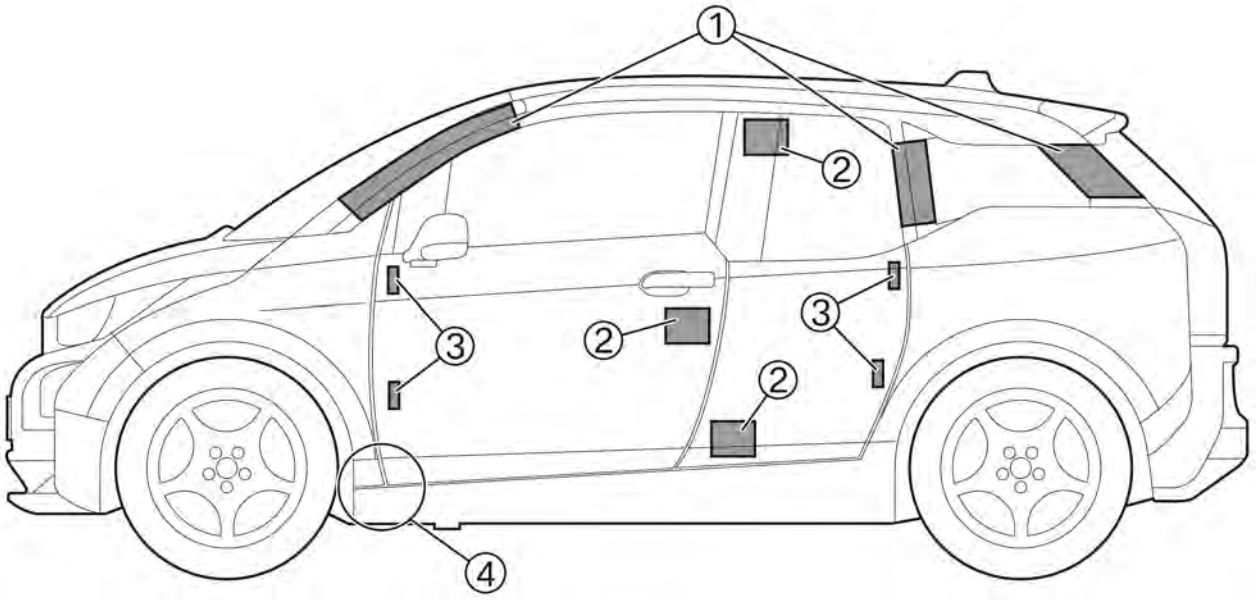
Opening the vehicle

These notes apply exclusively to trained emergency service personnel. Knowledge of the function and operating principle of the safety systems and vehicle characteristics is also needed.



1. The areas mark the zones at which the roof can be cut off.

   Modern heavy duty cutting equipment is mandatory for cutting the body; older hydraulic cutting tools could be overloaded.

   The heavy duty cutting equipment must be properly used by trained and qualified personnel.
2. Door locks
3. Door hinges
4. Release step area

Important information

Further information is given in the expert guide that is an element of the rescue manual. The information for the rescue personnel must be complied with.