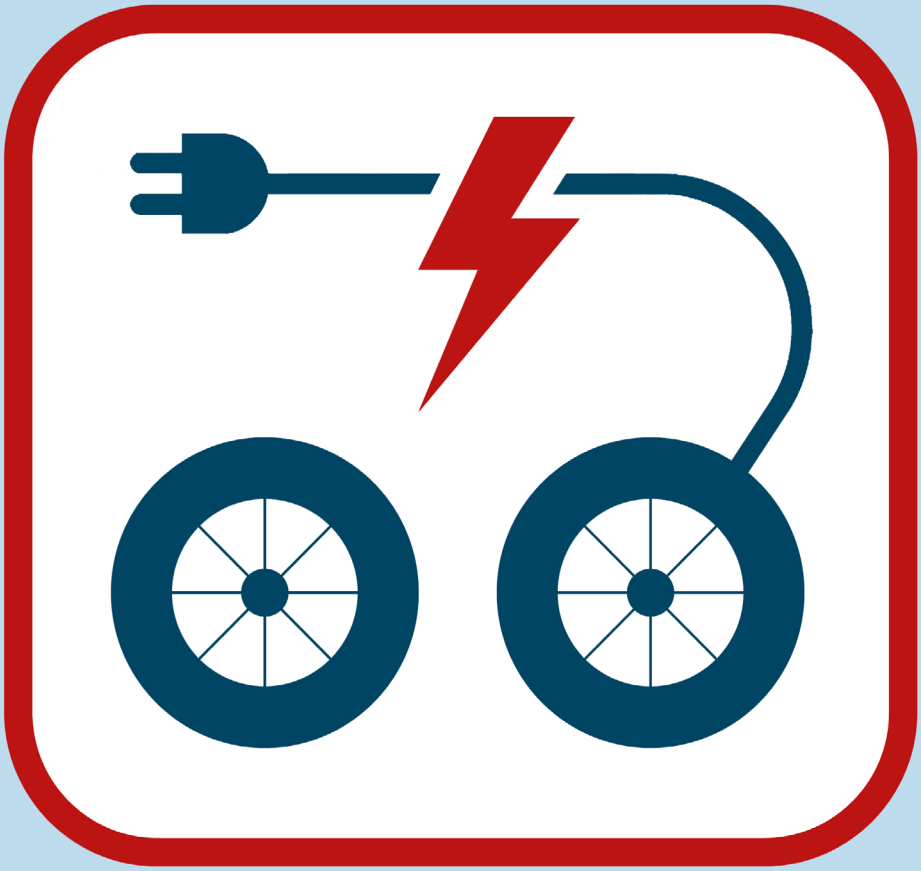
Nederlands Instituut Publieke Veiligheid

# Incidents involving alternative fuel vehicles

## Annual report 2021



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# Summary

Some Dutch fire service regions and the Netherlands Institute for Public Safety (NIPV) expressed the need to take stock of the number and types of incidents involving AFVs. This request and a project which had already been started by the Twente Fire Service formed the basis for the national 'Database incidenten alternatief aangedreven voertuigen' project or 'Database of incidents involving alternative fuel vehicles' project in English. This database contains incident information gathered by both the regional Fire Research Teams and the NIPV. This report is based on this database and gives quantitative information on the incidents which occurred in the period from 1 January 2021 to 31 December 2021.

The following questions are answered in this research:
1. How many incidents involving alternative fuel vehicles occurred in 2021?
2. What were the characteristics *accidents* involving alternative fuel vehicles in 2021?
3. What were the characteristics of *fires* involving alternative fuel vehicles in 2021?

The fire service attended a total of 221 incidents involving AFVs in 2021. These 221 incidents comprised 159 accidents and 62 fires. The majority of vehicles involved were passenger cars; 54.7% of these vehicles were battery electric vehicles, and 38.7% were (plug-in) hybrid vehicles. In 67 incidents, there were one or more casualties, 5 of whom died.

The 159 *accidents* involved 168 alternative fuel vehicles in total. About half of these were battery electric vehicles, and approx. 40% were (plug-in) hybrid vehicles. There was one case where the fuel contributed to the accident when the vehicle's battery pack caught fire after the collision. There was not a single accident where the battery pack was damaged so badly that there was an electrocution hazard. The Crash Recovery System was used to gather information in 63.5% of the incidents. A thermal imaging camera was used 46 times to check whether the battery pack was involved in the incident. There were two accidents where the vehicle was placed in an immersion container to remove it from the scene of the accident.

In total, 62 *fires* involved 77 alternative fuel vehicles. Of these, 61% were battery electric vehicles and about one third were (plug-in) hybrid vehicles. Most fires took place in built-up areas, but none of them was in a multi-storey car park. 71 vehicles with battery packs were involved in fires and in 50.7% of these cases the battery was involved in the fire. In one of the 7 vehicles with an gas tank, the tank started to blow off, igniting the (hydrogen) gas. The fire service used breathing apparatus when fighting 53 fires. The CRS was used 51 times to obtain information about the vehicles involved. Thermal imaging cameras were used 28 times to determine whether the battery pack was involved in the fire. There were 23 incidents where the vehicle was parked at a charging point; the batteries of 17 of these vehicles were involved in the fire. The vehicles were immersed in immersion containers in 11 fires.

# Contents

# Foreword

We proudly present the first annual report on *Incidents involving alternative fuel vehicles*. Our first half-yearly report received great acclaim both nationally and internationally. This praise concerned the ‘near-to-real time dashboard’, the monthly case studies focusing on an incident with an alternative fuel vehicle, the infographic and of course the actual report.

We are now presenting the first annual report: an important milestone. The fire service attended a total of 221 incidents involving AFVs in 2021, comprising 159 accidents and 62 fires. The data on these fires and accidents has provided valuable information, e.g. on the situations in which they occurred and the resources and equipment employed by the fire service.

This report and the other products illustrate how research works: many parties jointly gathering the pieces of the puzzle (i.e.: data), followed by analysing and presenting them. Our colleague Tom Hessels and professorship trainee Maarten Huisman were the tireless forces behind the products referred to above. The fire research teams of the Dutch safety regions entered the data in a questionnaire and shared it with us. Bureau VIA, responsible for managing the STAR (smart traffic accident reporting) data, shared lists of incidents involving alternative fuel vehicles with us. And our own NIPV Business intelligence team contributed to ensuring a clear, up-to-date and attractive presentation of the data on our website.

The safety working group of the National Charging Infrastructure Agenda (part of the Netherlands Enterprise Agency (RVO)) contributed resources and knowledge to the questionnaire and to the database design. Furthermore, resources to expand our work were made available from the ‘*proeftuinen brandonderzoek*’ (‘fire research labs) of the Netherlands Fire Service.

Such a method, where several parties and experts are connected together is also characteristic of the way in which the energy transition works and how data relating to the energy transition should be collected: many parties are cogs in that massive transition and the trick is to correctly match up those parties or cogs to create a well-oiled machine.

I would like to express my heartfelt thanks to all these institutions and persons. None of the products referred to above would have been realised without you.

Nils Rosmuller
Professor of Energy and Transport Safety

# Introduction

## Background

$CO_2$ emissions must be reduced in the Netherlands. As agreed in the Dutch Climate Agreement (*Klimaatakkoord*, 2019), the Clean Air Agreement (*Schone Lucht Akkoord*, 2020) and other policies and agreements, efforts are therefore being made to make mobility less environmentally harmful as well. In order to achieve this, an ever greater proportion of the Dutch vehicle fleet will have to be sustainably fuelled vehicles. By 'sustainably fuelled' we mean sources of energy which are less harmful to the environment than fossil fuels such as diesel, petrol and LPG. Such sustainably fuelled vehicles are referred to as alternative fuel vehicles (AFVs). The number of alternative fuel vehicles, such as electric vehicles, as well as fuel cell electric vehicles, or CNG or LNG powered vehicles has actually increased significantly in recent years and will continue to increase. All other things being equal, the number of incidents[1] in which these alternative fuel vehicles are involved will increase as well.

Some fire service regions and the Netherlands Institute for Public Safety (NIPV) had long expressed the need to get a better idea of the number and type of incidents involving AFVs, and particularly to account for such incidents. As a result of this need, the Oost 5 district ran a project during the period from 1 June to 31 December 2020 where a questionnaire was used to gather data on these incidents. This regional need was felt more broadly and led to a national initiative to account for incidents and the handling of incidents involving AFVs.

Aspects of this interpretation are information about practical experiences of and approaches employed by the fire service, information about the circumstances surrounding an incident, and an understanding of the risks encountered by first responders. This enables supplementary knowledge of both risk management and incident response to be gathered which can be used for recommendations, or to improve recommendations, about such topics. The national need and the Twente initiative resulted in the Dutch national project for the 'Database of incidents involving alternative fuel vehicles' being set up. This project was carried out in close collaboration between the Vakgroep Brandonderzoek (Fire Research Group) of the Netherlands Fire Service and NIPV's Energy and Transport Safety professorship.

## Database

The 'Database of incidents involving alternative fuel vehicles' contains incident information gathered by both the regional Fire Research Teams (FRT) and the NIPV. First, fire researchers from the several regions and NIPV researchers enter this information into the fire researchers' questionnaire. The data from the completed questionnaires is then compiled in the above database. Some key figures from this database are presented 'near to real time' in a live dashboard of key figures.nipv.nl. The present report is a summary product, based on

[1] We have defined incidents as fires, accidents and other reported events (e.g. a leaking fuel tank) in connection with which the fire service is called in to fight the incident or create a safe situation.

the data from this database. This report quantifies the data on incidents in the period from 1 January 2021 to 31 December 2021.

## Purpose and result

The objective of this report is to present and, where possible, visually present the data on incidents involving alternative fuel vehicles in the Netherlands in the period from 1 January 2021 to 31 December 2021. This sketches a picture of the number and nature of incidents involving AFVs in the Netherlands to which the fire service responded and deepens our understanding of the nature and extent of these incidents; for example the possible cause or the number of times that a charging point, hydrogen tank or battery was involved in an incident. The data is not compared to any data on conventionally fuelled vehicles (petrol, diesel, LPG).

## Study questions

The following main questions and corresponding subquestions were formulated for this research:

4. How many incidents involving alternative fuel vehicles occurred in 2021?
    a. What was the nature of these incidents?
    b. What where the characteristics of the vehicles involved in the incidents?
    c. Which types of alternative fuel vehicles were involved in these incidents?
    d. How many casualties did incidents involving alternative fuel vehicles claim?
5. What were the characteristics of the *accidents* involving alternative fuel vehicles in 2021?
    a. What were the characteristics of the locations where these accidents occurred?
    b. What was the role that the alternative fuel technology played in these accidents?
    c. What was the response to these incidents?
6. What were the characteristics of *fires* involving alternative fuel vehicles in 2021?
    a. What were the characteristics of the locations where these fires occurred?
    b. What was the role that the alternative fuel system played in these fires?
    c. How were these incidents fought?
    d. What was the involvement of charging infrastructure, if any?

## Scope

This annual report presents the data of incidents in the period from 1 January 2021 to 31 December 2021.

The scope of incidents included in the database is as follows:

> **Fuel**: this research considers the following fuels as indicators of an AFV being involved:
  – battery electric vehicle (BEV)
  – (plug-in) hybrid vehicle (P)HEV
  – fuel cell electric vehicle (FCEV)
  – Compressed Natural Gas (CNG),
  – Liquefied Natural Gas (LNG)
  – LNG or CNG in combination with petrol or diesel.

  Any purely conventional fuel vehicles, such as purely petrol, diesel and/or LPG, are not part of the scope of this research.

> **Vehicle category**: in line with the definition given by the Netherlands Vehicle Authority in the mobility chain, a vehicle has four or more wheels. The research also considers motorbikes, trikes, microcars[2] and boats. These latter four categories were added because of the relatively large battery capacity in the battery packs of these means of transport. Electric scooters, hoverboards, e-steps, e-bikes and similar vehicles are beyond the scope of this research due to their low battery capacity and the fact that they have fewer than four wheels.

> **Presence of the fire service**: only incidents which were physically attended by the fire service have been included. The reason for this is that we would like to know how the fire service took account of the special nature of an AFV in its action. Therefore, any incidents which were not physically attended by the fire service have not been included.

## Structure of this report

The first chapter presents the data collection method. Chapter two presents general information about the vehicles and incidents. The third chapter focuses specifically on characteristics of accidents involving AFVs and the fourth chapter zooms in on vehicle fires involving AFVs. Chapter five contains the conclusion. The final chapter reflects on the results.

[2] A microcar is a motorised vehicle with a limited maximum speed and with more than two wheels.

# 1 Research method

## 1.1 Questionnaire

The questionnaire used in order to collect data was based on an existing questionnaire which had been prepared by the Twente Fire Service. This was used as part of a pilot study into incidents involving AFVs in the Oost 5 district during the second half of 2020. In late 2020, specialists from the Twente Fire Service, the Brabant-Zuidoost Safety Region, the Safety Working Group of the National Charging Infrastructure Agenda and the then IFV (now NIPV) provided input to revise this questionnaire. The project team used their input to draft the current questionnaire. This questionnaire provides a structured and consistent approach to collecting information on incidents involving AFVs. The NIPV entered the questionnaire into LiveReports, a digital questionnaire system. Fire researchers from the safety regions and the NIPV then tested the questionnaire, after which it was improved where necessary. The questionnaire can be found in Annex 1: Questionnaire.

## 1.2 Identifying incidents

Three approaches were taken in order to identify incidents involving AFVs.

> The first approach involved monitoring media coverage. Both social media and news reports were monitored by the NIPV in order to identify fires and/or accidents involving AFVs, using Obi4Wan to scan media messages. The search terms used for Obi4Wan are listed in Annex 2: Obi4Wan search terms.
> The second approach concerns contacts in the safety regions notifying the NIPV researchers, or giving them tips, about incidents involving AFVs.
> The third approach is linking the data from the Dutch GMS (Geïntegreerd Meldkamer Systeem (integrated control room system)) to data from the STAR (Smart Traffic Accident Reporting) database of the VIA traffic-specific ICT agency. VIA has been commissioned by the Dutch police and the Verbond van Verzekeraars (Dutch Association of Insurers) to record all traffic accidents in the Netherlands. This makes it possible to find out where and when traffic accidents involving AFVs attended by the fire service occurred.

## 1.3 Data collection method

The questionnaire in LiveReports can be used by the fire research teams (FRTs) of the safety regions and by NIPV researchers. The FRTs can either opt to physically investigate the AFV involved by themselves and to fill in the questionnaire afterwards, or to contact the commanding officer, the officer in charge (OIC) or the hazardous materials advisor (HMA) to retrieve information about the incident and use this to fill in the questionnaire.

Where a regional FRT did not have sufficient capacity to retrieve the incident information, the NIPV, in conjunction with the regional FRT, retrieved the incident information from the commanding officer, the officer in charge or the hazmat advisor involved. Subsequently, the

NIPV researcher used this information to fill in the questionnaire, thus entering it into the database.

## 1.4 Criterion for including an incident in the database

The criterion for including an incident in the database is that the fire service must have been physically present at the scene. Whether or not the fire service was active is not relevant in this context. This criterion was chosen because the notion of 'being active' is hard to define. This enables a discussion to be held about whether the consultation which takes place between the fire service and its chain partners immediately after the fire service arrives at the scene should be considered as the fire service being active.

Any fire service turnout which is cancelled while en route to the incident is not included in the database because the fire service was not physically present at the scene.

## 1.5 Vehicle involvement

We have defined incidents as fires, accidents and other reported events (e.g. a leaking fuel tank) in connection with which the fire service is called in to fight the incident or create a safe situation.

### 1.5.1 In an accident

The criteria for determining whether a vehicle was or was not involved in an accident are: the vehicle caused the incident, and/or the vehicle sustained damage.

### 1.5.2 In a fire

The criterion applied in the event of fire is that the vehicle contributed to the fire. An AFV which only sustained damage due to a fire, e.g. because another vehicle was on fire or because of a fire in a charging point, without the AFV having actually been on fire has not been included in the data collection since such an incident does not concern an AFV on fire. The same applies if the cargo in a vehicle was on fire: the incident is not included in the database. An example of this is the burning load of a refuse truck where the fire did not spread beyond the refuse.

Whenever it is doubtful whether an AFV was involved in an incident, the 'four-eyes principle' is applied. This means that two NIPV researchers ascertain whether the AFV was involved. If they are in doubt, they will ask the following question: did the fire service action initially target the AFV? If so, the incident 'counts' in the database; if not, it does not 'count'. The following two examples serve to illustrate an ambiguous situation:

> Example 1: A collision between a person and an electric bus where the fire service was called in to come and remove the person from under the bus *does* count. This is because the initial target of the fire service action was to rescue the person from under an AFV.
> Example 2: A collision occurred between an electric car and a motor scooter with the scooter driver ending up in a ditch; the fire service was called in to provide medical assistance to the scooter driver on site and, if necessary, lift him out of the ditch. Since

this was an incident where the target of the fire service action was not the AFV, the incident did *not* 'count'.

## 1.6 Data representation method

PowerBI was used to make the data from LiveReports available in an Excel file after which the NIPV analysed the data in R version 4.0.3 and presented it in tables and graphs.

## 1.7 Rationale

Although the greatest possible care was observed when collecting and processing the data presented in this report, it is possible that, in retrospect, conditions and data were found to be different from how they were interpreted at the moment when they were entered and when writing this report. The reason for this may be that long and thorough research revealed more information than was available at the moment when the initial conditions and data were entered.

It is also possible that some incidents occurred in the period under review which were not yet known to the NIPV. Wherever this report refers to incidents, this should be understood to mean: 'the incidents known to the NIPV research team during the defined period.'

# 2 General information

This chapter presents general incident and vehicle information. The combination of vehicle data per incident is also addressed. This chapter thus answers the first research question: *How many incidents involving alternative fuel vehicles occurred in 2021?* as well as the corresponding subquestions.

## 2.1 Incident data

As stated above, we have defined incidents as fires, accidents and other reported events (e.g. a leaking fuel tank) in connection with which the fire service is called in to fight the incident or create a safe situation.

### 2.1.1 Type of incident

As far as the NIPV has been able to ascertain, there were 221 incidents involving AFVs which were attended by the fire service in 2021. These incidents can be broken down into 159 accidents (71.9%) and 62 fires (28.1%)[3]. One accident also led to a fire (0.45%). See figure 2.1 below.

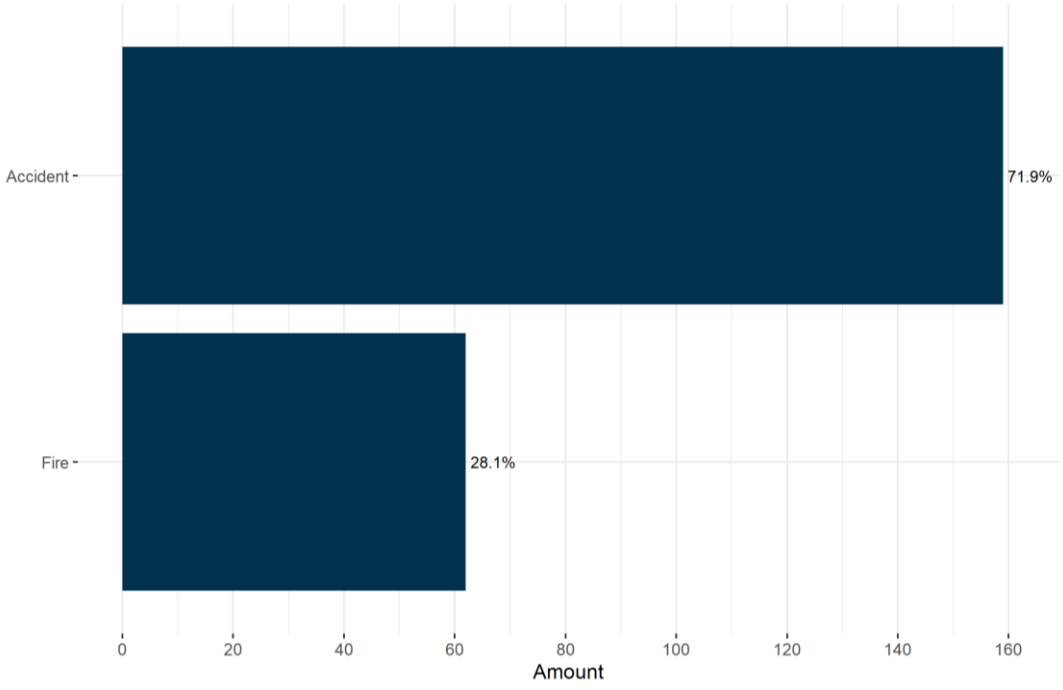



**Figure 2.1 Type of incident**

[3] *Involvement of a vehicle in an accident*: The criteria for determining whether a vehicle was or was not involved in an accident are: the vehicle caused the incident, and/or the vehicle sustained damage.
*Involvement of a vehicle in a fire*: The criterion applied in the event of fire is that the vehicle contributed to the fire. An AFV which only sustained damage due to a fire, e.g. because another vehicle was on fire or because of a fire in a charging point, without the AFV having actually been on fire is not included in the data collection

The monthly breakdown of the fires and accidents was as shown in figure 2.2 on the next page.

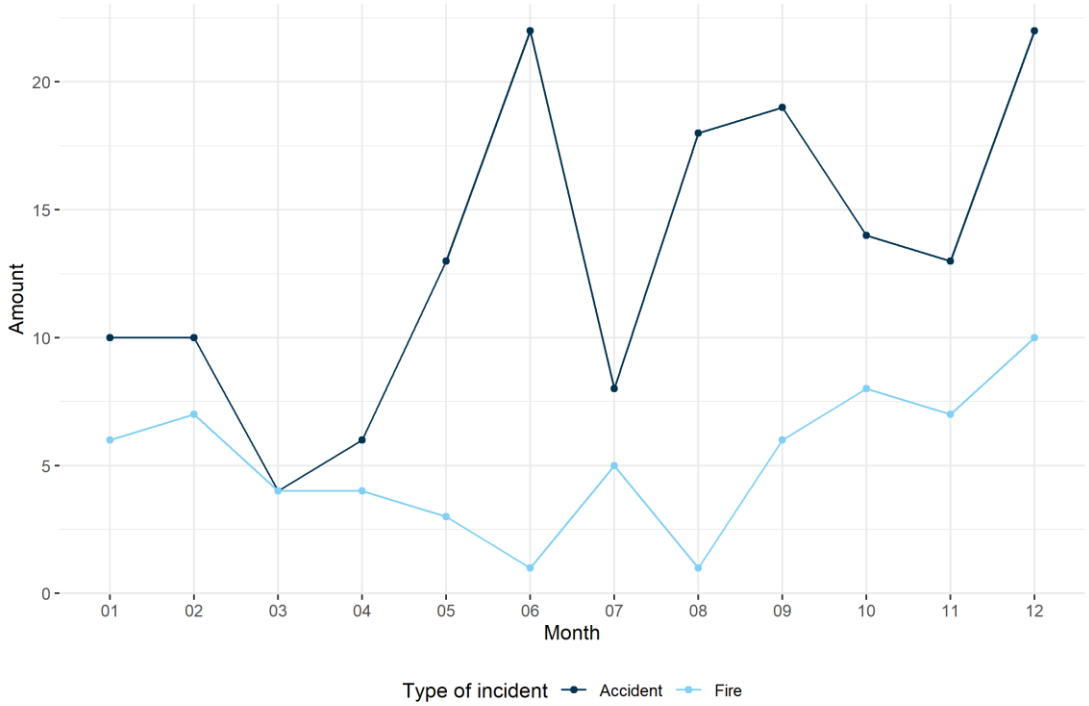



**Figure 2.2 Breakdown of the incidents over the months of the year**

### 2.1.2 Geographical spread

The breakdown of *incidents* over the 25 safety regions was as shown in figure 2.3. The darker the colour, the more incidents occurred in the region in question.

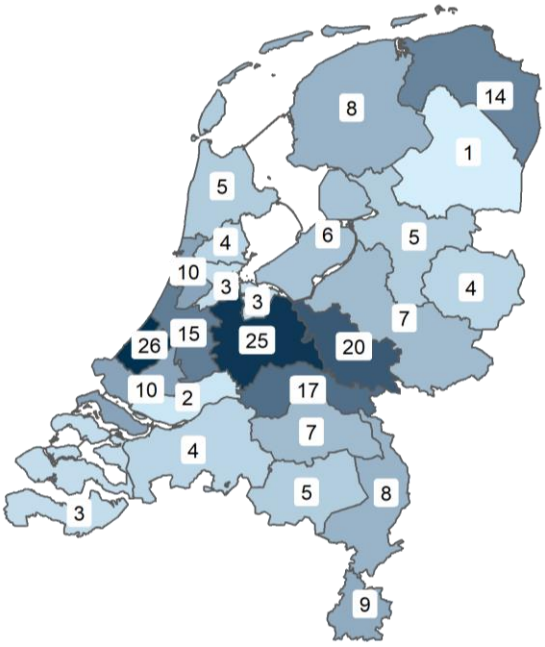



**Figure 2.3 Incidents involving AFVs in the individual safety regions in 2021**

The breakdown of *fires* over the safety regions was as shown in figure 2.4.

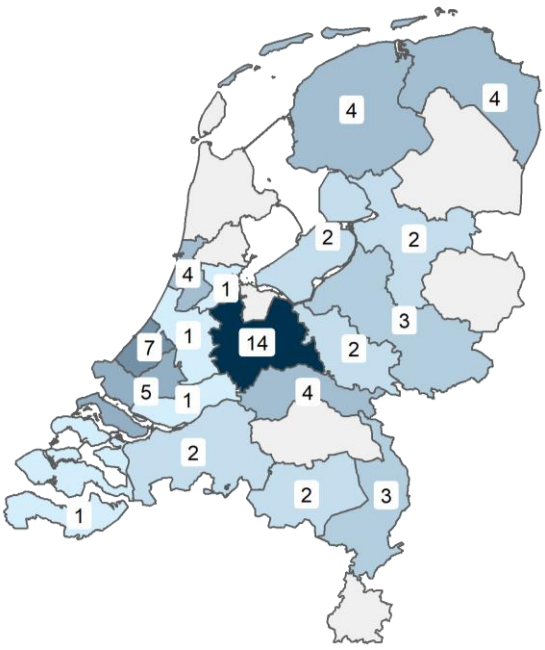



**Figure 2.4 Fires involving AFVs in the individual safety regions in 2021**

The breakdown of *accidents* over the safety regions was as shown in figure 2.5

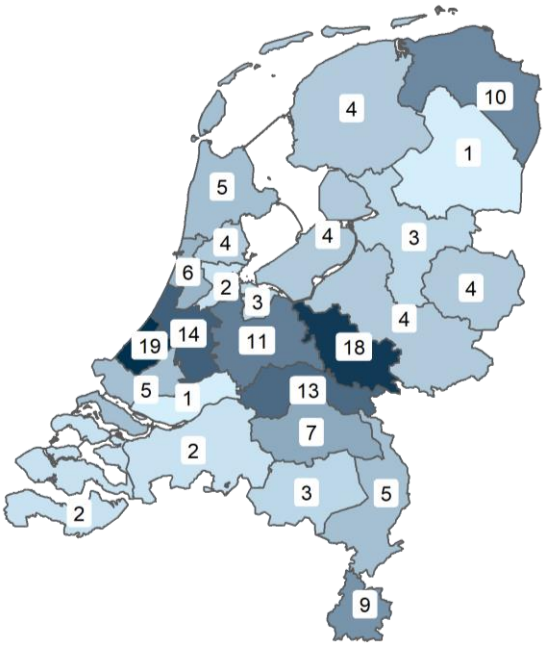



**Figure 2.5 Accidents involving AFVs in the individual safety regions in 2021**

### 2.1.3 Incidents broken down by types of road

Where incidents occurred with vehicles that were in motion, it was recorded whether they took place in a built-up area, outside the built-up area or on a motorway or highway (types of road). The breakdown of the 167 incidents for which this information is known over these four types of road is shown in table 2.1 below. The type of road is unknown for 54 incidents.

**Table 2.1 Types of road in incidents**

| Type of road | Number of incidents | Of which fires | Of which accidents |
|---|---|---|---|
| In a built-up area | 68 | 9 | 59 |
| Outside the built-up area | 46 | 2 | 44 |
| Motorway/highway | 51 | 3 | 48 |
| Other | 2 | 0 | 2 |
| **Total** | **167** | **14** | **153** |

The two accidents in the 'other' category occurred in a multi-storey car park.

### 2.1.4 In motion versus not in motion

Of the 243 vehicles involved in an incident, 166 were in motion.[4] The vehicle involved was stationary in 70 cases. For seven vehicles, it is not known whether the vehicle was in motion or was stationary.

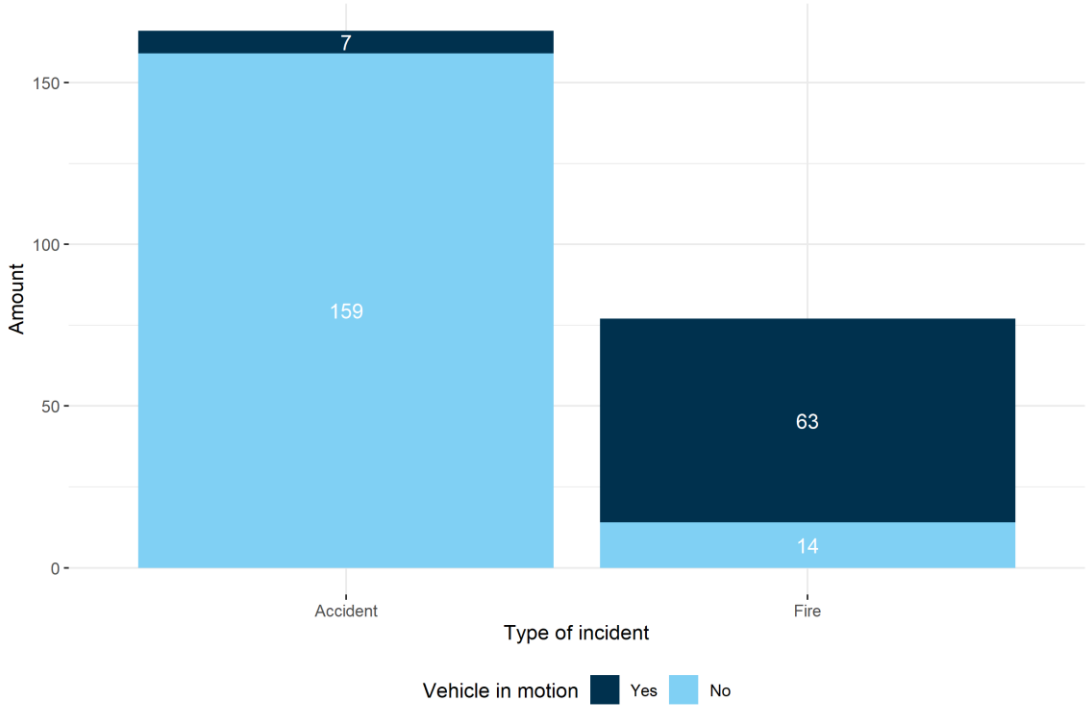



**Figure 2.6 Number of incidents involving vehicles in motion and stationary vehicles**

[4] In motion here means: the vehicle was travelling on a public road.

## 2.2 Vehicle characteristics

This section focuses on the characteristics of the 243 vehicles involved in the incidents. There were:

> 214 incidents where one AFV was involved
> five incidents where two AFVs were involved
> one incident where three AFVs were involved
> one incident where 16 AFVs were involved.

The sections below start by indicating the vehicle technology / fuel type of the AFV, followed by the type of vehicle, the vehicle technology / fuel type for each type of vehicle, the brand of vehicle involved and finally the vehicle technology / fuel types for the different brands of vehicle.

### 2.2.1 Vehicle technology / fuel

The 243 vehicles involved were of the vehicle technology / fuel types as indicated in figure 2.7.

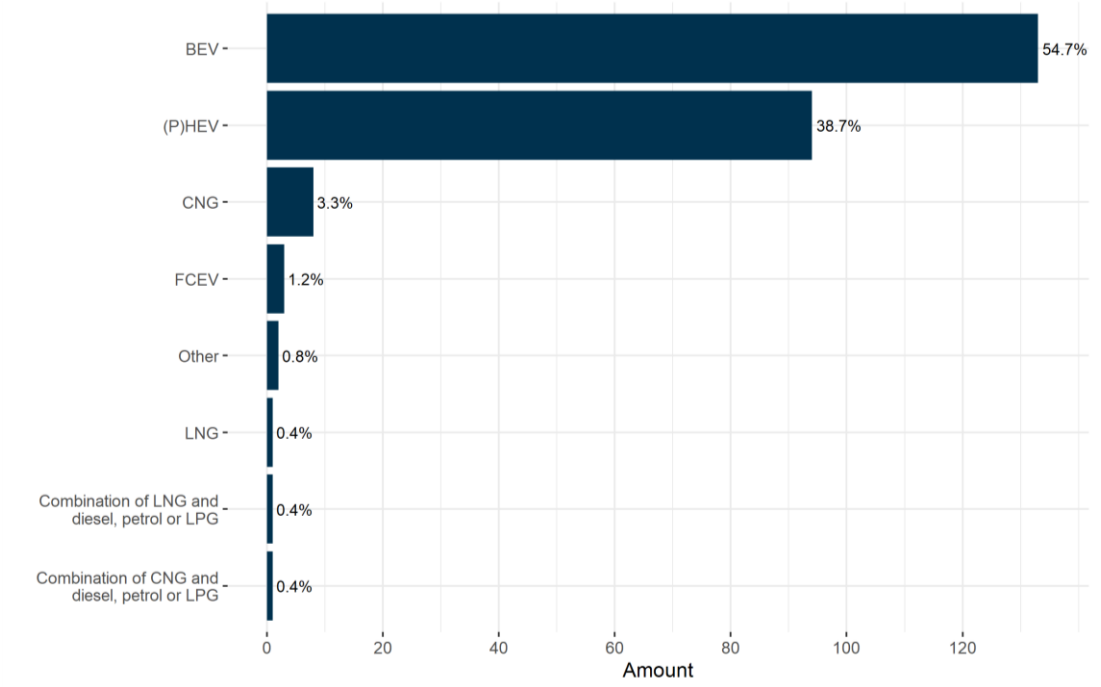



**Figure 2.7 Incidents (%) broken down by vehicle technology / fuel types of the AFVs**

### 2.2.2 Type of vehicle

The 243 vehicles involved were the vehicle types listed in figure 2.8.

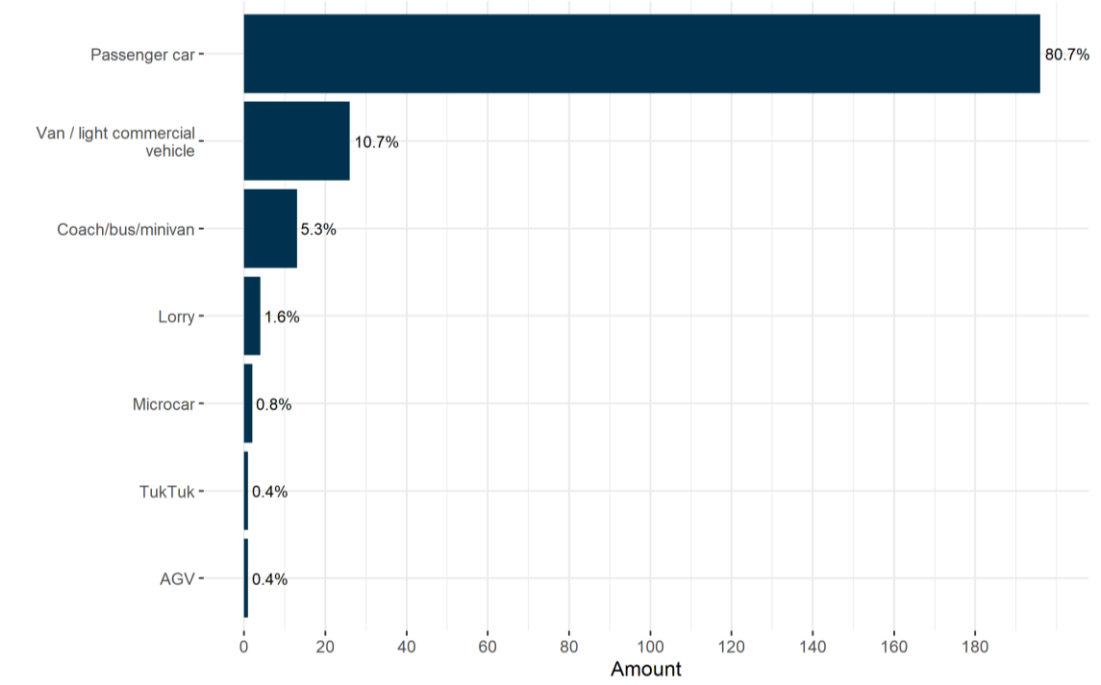
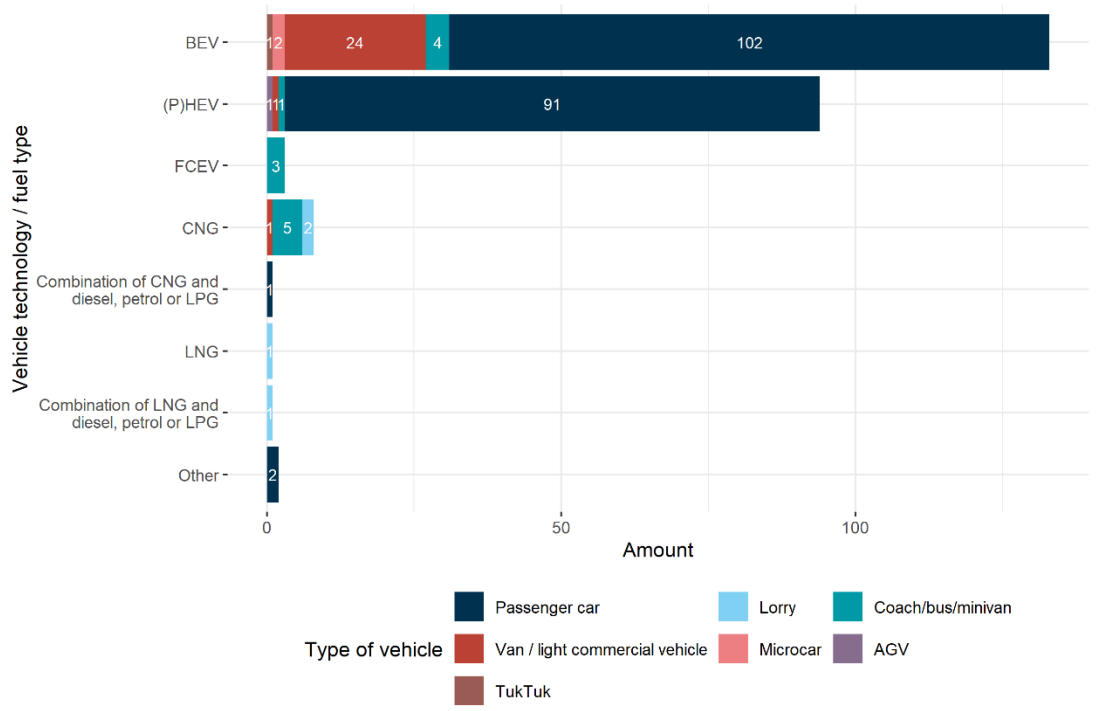



**Figure 2.8 Incidents (%) broken down by types of vehicle**

### 2.2.3 Types of vehicle broken down by vehicle technology / fuel types

Figure 2.9 below indicates the types of vehicle involved in the incidents for each vehicle technology / fuel type.




AGV is an acronym for Automated Guided Vehicle

**Figure 2.9 Incidents broken down by types of vehicle broken down by vehicle technology / fuel type**

### 2.2.4 Brand of vehicle

The 243 vehicles were the brand listed in figure 2.10 below.

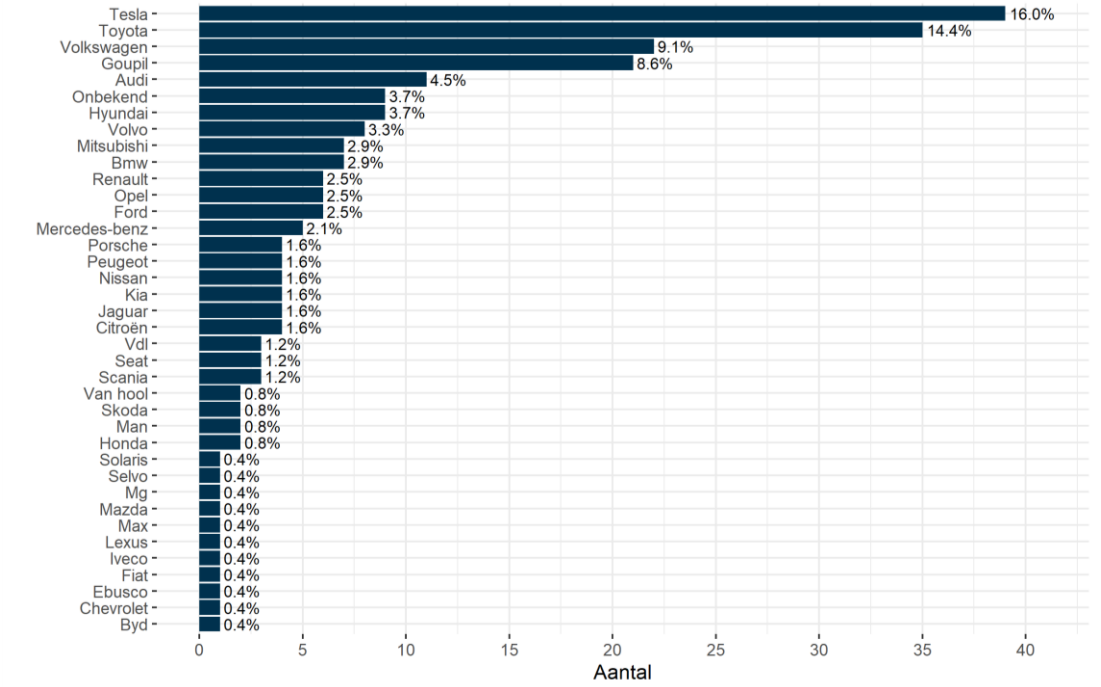



**Figure 2.10 Incidents broken down by brand of AFV**

There were some incidents where the commanding officer or OIC involved could tell the NIPV that an AFV was involved, but they did not remember the brand of the vehicle. These AFVs are shown in the 'Unknown' category.

### 2.2.5 Types and brands of vehicle

Table 2.2 below shows the incidents broken down by type of vehicle and brands as provided by the commanding officer, OICs, fire researchers and HMAs.

**Table 2.2 Incidents broken down by type and brand of vehicle**

| Type of vehicle | Make | Number of incidents |
|---|---|---|
| Coach/bus/minivan | BYD | 1 |
| Coach/bus/minivan | Ebusco | 1 |
| Coach/bus/minivan | Fiat | 1 |
| Coach/bus/minivan | MAN | 2 |
| Coach/bus/minivan | Mercedes-Benz | 2 |
| Coach/bus/minivan | Solaris | 1 |
| Coach/bus/minivan | Van Hool | 2 |
| Coach/bus/minivan | Vdl | 1 |

| | | |
|---|---|---|
| Coach/bus/minivan | Volvo | 1 |
| Automated Guided Vehicle | VDL | 1 |
| Van / light commercial vehicle | Goupil | 21 |
| Van / light commercial vehicle | Iveco | 1 |
| Van / light commercial vehicle | Mercedes-Benz | 1 |
| Van / light commercial vehicle | Peugeot | 1 |
| Van / light commercial vehicle | Renault | 1 |
| Van / light commercial vehicle | Toyota | 1 |
| Microcar | Max | 1 |
| Microcar | Selvo | 1 |
| Passenger car | Audi | 11 |
| Passenger car | BMW | 7 |
| Passenger car | Chevrolet | 1 |
| Passenger car | Citroën | 4 |
| Passenger car | Ford | 6 |
| Passenger car | Honda | 2 |
| Passenger car | Hyundai | 9 |
| Passenger car | Jaguar | 4 |
| Passenger car | Kia | 4 |
| Passenger car | Lexus | 1 |
| Passenger car | Mazda | 1 |
| Passenger car | Mercedes-Benz | 2 |
| Passenger car | MG | 1 |
| Passenger car | Mitsubishi | 7 |
| Passenger car | Nissan | 4 |
| Passenger car | Unknown | 7 |
| Passenger car | Opel | 6 |

| | | |
|---|---|---|
| Passenger car | Peugeot | 3 |
| Passenger car | Porsche | 4 |
| Passenger car | Renault | 5 |
| Passenger car | Seat | 3 |
| Passenger car | Skoda | 2 |
| Passenger car | Tesla | 39 |
| Passenger car | Toyota | 34 |
| Passenger car | Volkswagen | 22 |
| Passenger car | Volvo | 7 |
| TukTuk | Unknown | 1 |
| Lorry | Unknown | 1 |
| Lorry | Scania | 3 |

### 2.2.6 Vehicle technology / fuel types broken down by brand of vehicle

Table 2.3 below shows the numbers of incidents broken down by vehicle technology / fuel types and brands of vehicle.

**Table 2.3 Numbers of incidents broken down by vehicle technology / fuel types and brands of vehicle**

| Vehicle technology / fuel type | Brand | Number of incidents |
|---|---|---|
| (Plug-in) hybrid vehicle (P)HEV | Audi | 3 |
| (Plug-in) hybrid vehicle (P)HEV | BMW | 4 |
| (Plug-in) hybrid vehicle (P)HEV | BYD | 1 |
| (Plug-in) hybrid vehicle (P)HEV | Chevrolet | 1 |
| (Plug-in) hybrid vehicle (P)HEV | Citroën | 2 |
| (Plug-in) hybrid vehicle (P)HEV | Ford | 4 |
| (Plug-in) hybrid vehicle (P)HEV | Honda | 2 |
| (Plug-in) hybrid vehicle (P)HEV | Hyundai | 2 |
| (Plug-in) hybrid vehicle (P)HEV | Iveco | 1 |
| (Plug-in) hybrid vehicle (P)HEV | Kia | 3 |

| | | |
|---|---|---|
| (Plug-in) hybrid vehicle (P)HEV | Lexus | 1 |
| (Plug-in) hybrid vehicle (P)HEV | Mazda | 1 |
| (Plug-in) hybrid vehicle (P)HEV | Mercedes-Benz | 2 |
| (Plug-in) hybrid vehicle (P)HEV | MG | 1 |
| (Plug-in) hybrid vehicle (P)HEV | Mitsubishi | 6 |
| (Plug-in) hybrid vehicle (P)HEV | Unknown | 2 |
| (Plug-in) hybrid vehicle (P)HEV | Opel | 1 |
| (Plug-in) hybrid vehicle (P)HEV | Peugeot | 3 |
| (Plug-in) hybrid vehicle (P)HEV | Porsche | 2 |
| (Plug-in) hybrid vehicle (P)HEV | Renault | 1 |
| (Plug-in) hybrid vehicle (P)HEV | Seat | 3 |
| (Plug-in) hybrid vehicle (P)HEV | Toyota | 31 |
| (Plug-in) hybrid vehicle (P)HEV | VDL | 1 |
| (Plug-in) hybrid vehicle (P)HEV | Volkswagen | 13 |
| (Plug-in) hybrid vehicle (P)HEV | Volvo | 3 |
| CNG | Fiat | 1 |
| CNG | MAN | 2 |
| CNG | Mercedes-Benz | 3 |
| CNG | Scania | 2 |
| Combination of CNG and diesel, petrol or LPG | Volvo | 1 |
| LNG | Scania | 1 |
| Combination of LNG and diesel, petrol or LPG | Unknown | 1 |
| Unknown | Unknown | 2 |
| Battery electric vehicle (BEV) | Audi | 9 |
| Battery electric vehicle (BEV) | BMW | 3 |
| Battery electric vehicle (BEV) | Citroën | 2 |
| Battery electric vehicle (BEV) | Ebusco | 1 |

| | | |
|---|---|---|
| Battery electric vehicle (BEV) | Ford | 2 |
| Battery electric vehicle (BEV) | Goupil | 21 |
| Battery electric vehicle (BEV) | Hyundai | 7 |
| Battery electric vehicle (BEV) | Jaguar | 4 |
| Battery electric vehicle (BEV) | Kia | 1 |
| Battery electric vehicle (BEV) | Max | 1 |
| Battery electric vehicle (BEV) | Mitsubishi | 1 |
| Battery electric vehicle (BEV) | Nissan | 4 |
| Battery electric vehicle (BEV) | Unknown | 4 |
| Battery electric vehicle (BEV) | Opel | 5 |
| Battery electric vehicle (BEV) | Peugeot | 1 |
| Battery electric vehicle (BEV) | Porsche | 2 |
| Battery electric vehicle (BEV) | Renault | 5 |
| Battery electric vehicle (BEV) | Selvo | 1 |
| Battery electric vehicle (BEV) | Skoda | 2 |
| Battery electric vehicle (BEV) | Tesla | 39 |
| Battery electric vehicle (BEV) | Toyota | 4 |
| Battery electric vehicle (BEV) | VDL | 2 |
| Battery electric vehicle (BEV) | Volkswagen | 9 |
| Battery electric vehicle (BEV) | Volvo | 4 |
| Fuel cell electric vehicle (FCEV) | Van Hool | 2 |
| Fuel cell electric vehicle (FCEV) | Solaris | 1 |

## 2.3 Incident data broken down by vehicle characteristics

This section looks in more detail at the characteristics (fuel, type) of vehicles, broken down into fires and accidents. How often a specific vehicle technology / fuel type was involved in a fire or accident is shown first. Next, the number of fires and accidents broken down by types of vehicle is presented, and finally the accidents and fires broken down by make of vehicle.

### 2.3.1 Nature of the incident broken down by vehicle technology / fuel types

Table 2.4 shows how the fires and accidents can be allocated to the different vehicle technology / fuel types.

**Table 2.4 Nature of incidents broken down by vehicle technology / fuel types**

| Fuel | Fire | Accident | Total |
|---|---|---|---|
| (Plug-in) hybrid vehicle (P)HEV | 23 | 71 | 94 |
| CNG | 5 | 3 | 8 |
| Combination of CNG and diesel, petrol or LPG | 0 | 1 | 1 |
| LNG | 1 | 0 | 1 |
| Combination of LNG and diesel, petrol or LPG | 0 | 1 | 1 |
| Unknown | 0 | 2 | 2 |
| Battery electric vehicle (BEV) | 47 | 86 | 133 |
| Fuel cell electric vehicle (FCEV) | 1 | 2 | 3 |

### 2.3.2 Nature of the incident per type of vehicle

Table 2.5 shows how the incidents can be allocated to the different types of vehicle for the 243 vehicles involved in incidents.

**Table 2.5 Nature of incident broken down by type of vehicle**

| Type of vehicle | Fire | Accident | Total |
|---|---|---|---|
| Coach/bus/minivan | 6 | 7 | 13 |
| Automated Guided Vehicle | 1 | 0 | 1 |
| Van / light commercial vehicle | 21 | 5 | 26 |
| Microcar | 1 | 1 | 2 |
| Passenger car | 45 | 151 | 196 |
| TukTuk | 1 | 0 | 1 |
| Lorry | 3 | 1 | 4 |

### 2.3.3 Nature of incidents broken down by brand of vehicle

Table 2.6 on the next two pages show the spread of the incidents over the different brands of vehicle.

**Table 2.6 Nature of incidents broken down by brand of vehicle**

| Brand | Fire | Accident | Total |
|---|---|---|---|
| Audi | 3 | 8 | 11 |
| BMW | 4 | 3 | 7 |
| BYD | 1 | 0 | 1 |
| Chevrolet | 0 | 1 | 1 |
| Citroën | 2 | 2 | 4 |
| Ebusco | 0 | 1 | 1 |
| Fiat | 1 | 0 | 1 |
| Ford | 1 | 5 | 6 |
| Goupil | 20 | 1 | 21 |
| Honda | 2 | 0 | 2 |
| Hyundai | 0 | 9 | 9 |
| Iveco | 0 | 1 | 1 |
| Jaguar | 1 | 3 | 4 |
| Kia | 1 | 3 | 4 |
| Lexus | 0 | 1 | 1 |
| MAN | 1 | 1 | 2 |
| Max | 1 | 0 | 1 |
| Mazda | 0 | 1 | 1 |
| Mercedes-Benz | 2 | 3 | 5 |
| MG | 0 | 1 | 1 |
| Mitsubishi | 3 | 4 | 7 |
| Nissan | 0 | 4 | 4 |
| Unknown | 0 | 9 | 9 |
| Opel | 4 | 2 | 6 |

| | | | |
|---|---|---|---|
| Peugeot | 3 | 1 | 4 |
| Porsche | 1 | 3 | 4 |
| Renault | 1 | 5 | 6 |
| Scania | 3 | 0 | 3 |
| Seat | 0 | 3 | 3 |
| Selvo | 0 | 1 | 1 |
| Skoda | 0 | 2 | 2 |
| Solaris | 1 | 0 | 1 |
| Tesla | 6 | 33 | 39 |
| Toyota | 5 | 30 | 35 |
| Van Hool | 0 | 2 | 2 |
| VDL | 2 | 1 | 3 |
| Volkswagen | 7 | 15 | 22 |
| Volvo | 1 | 7 | 8 |

## 2.4 Casualties

As far as the NIPV was able to find out, a total of 67 of all 221 incidents involving AFVs claimed one or several casualties or fatalities. A casualty is a person who was in the AFV and who was taken to hospital as a result of the incident. In total, 91 casualties were injured in a total of 63 accidents. The nature of the injuries is unknown. Four accidents resulted in fatalities: five people lost their lives.

No fire service personnel sustained any injuries in, or while attending, the incidents.

## 2.5 Answer to research question 1

This section answers the first research question and the corresponding subquestions.

*Research question 1: How many incidents involving alternative fuel vehicles occurred in 2021?*
The fire service attended a total of 221 incidents involving AFVs in 2021.

*Subquestion 1a: What was the nature of these incidents?*
These 221 incidents were 159 accidents and 62 fires. One accident also caused a fire to break out.

*Subquestion 1b: What where the characteristics of the vehicles involved in the incidents?*
Most vehicles involved were passenger cars (80.7%). Vans and light commercial vehicles accounted for 10.7% of the vehicles involved, and coaches and buses accounted for 5.3%. Lorries (1.6%), microcars (0.8%), one TukTuk (0.4%) and one automated guided vehicle (0.4%) were the other vehicles involved.

*Subquestion 1c: Which types of alternative fuel vehicles were involved in these incidents?*
54.7% of the vehicles were battery electric vehicles, followed by 38.7% (plug-in) hybrid vehicles. The aggregate of the other alternative fuels accounts for 5.8%. In 0.8% of the cases it was known that an AFV was involved, but the vehicle technology / fuel type was unknown.

*Subquestion 1d: How many casualties did incidents involving alternative fuel vehicles claim?*
A total of 67 of all 221 incidents involving AFVs claimed one or several casualties. In total, 91 casualties were injured in a total of 63 accidents. Four accidents resulted in fatalities: five people lost their lives.

# 3 Characteristics of accidents involving AFVs

This chapter presents the data concerning the accidents (not fires; they are presented in chapter 4) involving alternative fuel vehicles. This serves to answer the second research question: *What were the characteristics of the accidents involving alternative fuel vehicles in 2021?*

The chapter starts with a presentation of the vehicle characteristics (fuel, type of vehicle) of the AFVs involved. It then goes on to discuss the location characteristics of the accidents, followed by a discussion of the role the alternative fuel played in the accidents. The fourth section addresses the incident response, and the last section looks into how the AFVs were recovered after the accidents.

## 3.1 Vehicle characteristics

In 2021, a total of 166 alternative fuel vehicles were involved in 159 accidents.

### 3.1.1 Fuel

The 166 vehicles involved in accidents were of the vehicle technology / fuel types indicated in figure 3.1

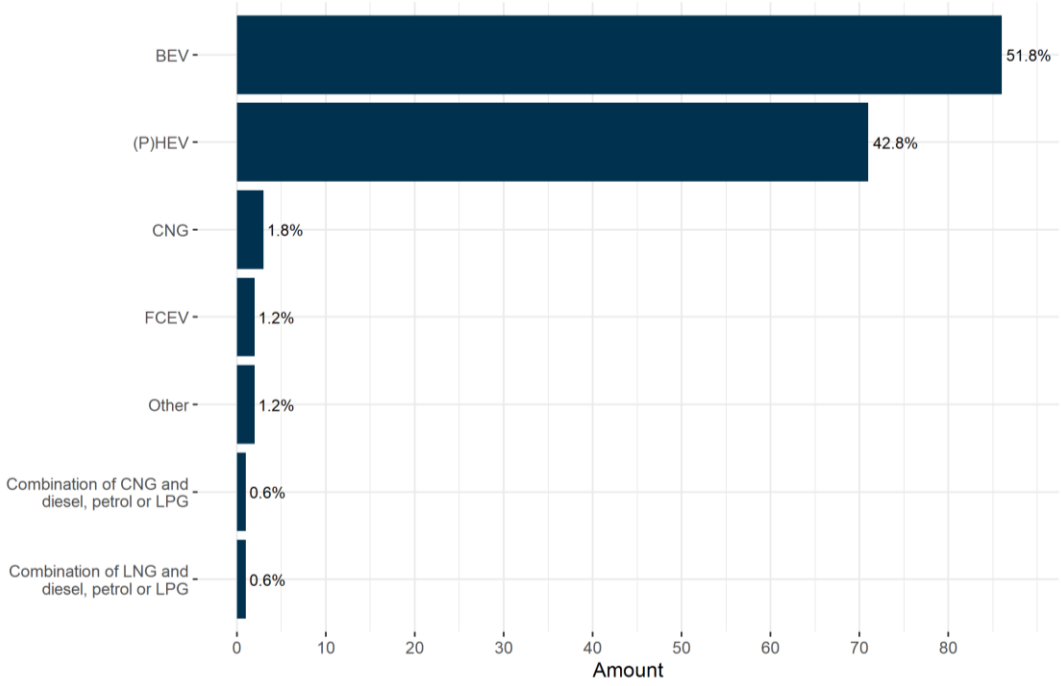



**Figure 3.1 Accidents (%) broken down by vehicle technology / fuel types of the AFVs**

### 3.1.2 Type of vehicle

The 166 vehicles involved in accidents were the vehicle types listed in figure 3.2

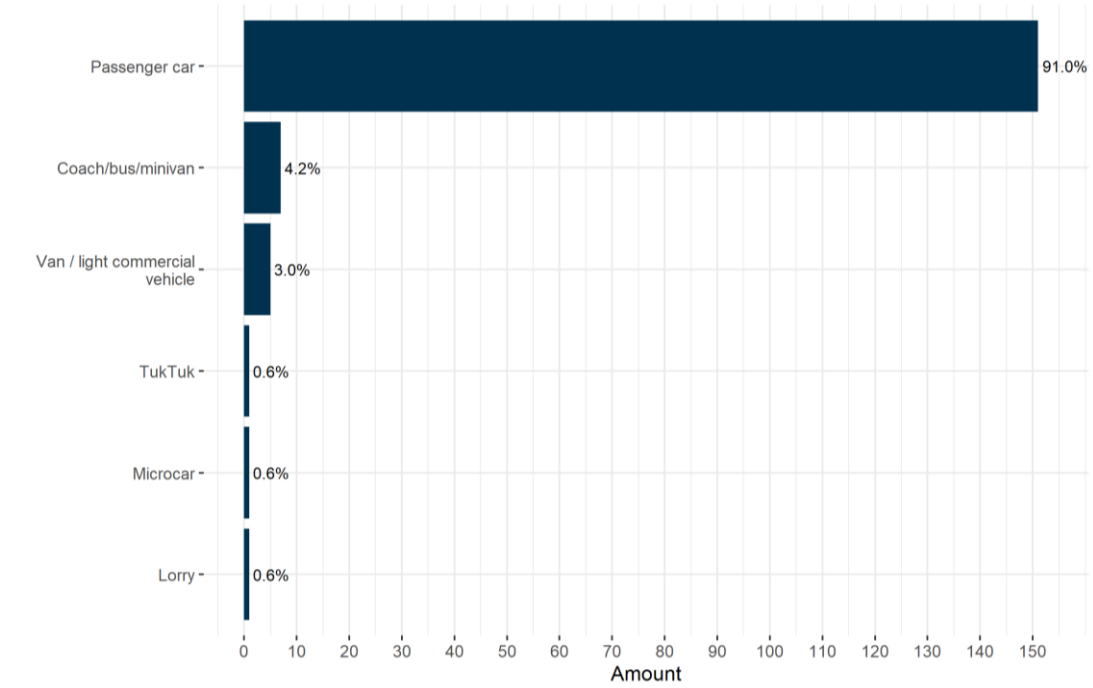



**Figure 3.2 Accidents (%) broken down by type of vehicle**

### 3.1.3 Types of vehicle broken down by vehicle technology / fuel types

Figure 3.3 below indicates the types of vehicle involved in the accidents for each vehicle technology / fuel type.

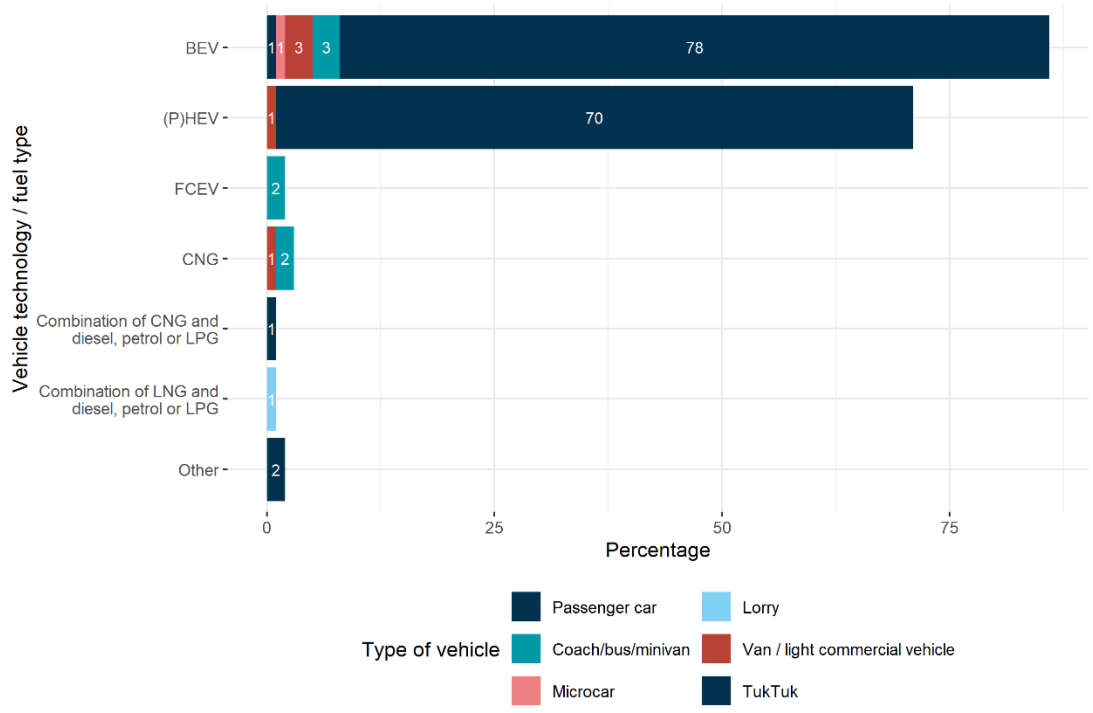



**Figure 3.3 Accidents broken down by types of vehicle broken down by vehicle technology / fuel types**

## 3.2 Location

The accidents involving AFVs occurred in the locations shown in figure 3.4. The locations are only known if the vehicle in question was in motion during the accident.

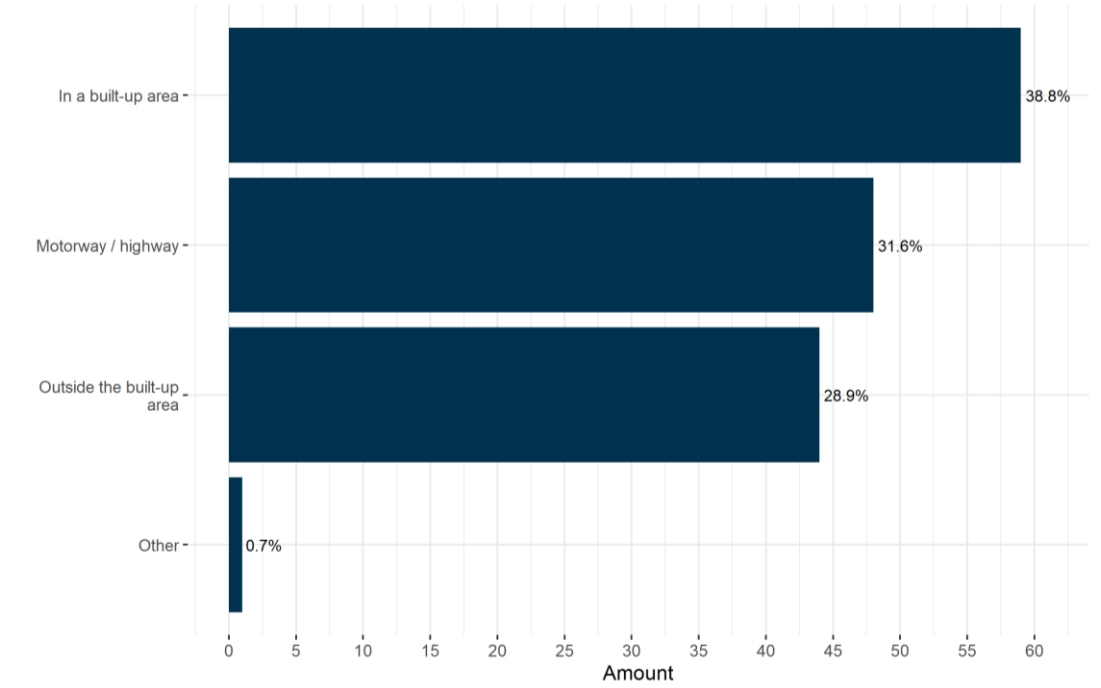



**Figure 3.4 Accident locations**

Two traffic accidents involving electric vehicles occurred in multi-storey car parks and have been classified as ‘other’.

## 3.3 Influence of the vehicle technology / fuel type on the course of the incident

One of the 159 accidents resulted in fire breaking out. This caused the battery to become involved in the fire, leading to a state of ‘thermal runaway’[5]. The thermal runaway occurred before the fire service arrived.

As far as could be ascertained, the battery pack was not damaged in any accident to such an extent that this led to a risk of electrocution.

### 3.3.1 Establishing the involvement of the vehicle technology / fuel type

Where AFVs were involved in accidents, the fire service used several methods to try to establish the involvement of the vehicle technology / fuel type. This is shown in the left-hand column of table 3.1 on the next page. The right-hand column shows the number of times a certain method was used.

[5] A thermal runaway is a failure mechanism which leads to auto-heating in a battery or battery cell and which can result in fire.

**Table 3.1 Method of establishing the involvement of the different vehicle technology / fuel types**

| Method of establishing involvement | Number of times this has been applied |
|---|---|
| No signals observed | 120 |
| Smoke observed | 2 |
| Visually | 82 |
| Heat generation observed | 1 |
| Thermal imaging camera | 46 |

## 3.4 Incident response

A fire broke out in one out of a total of 159 accidents involving an AFV; the battery was involved in the fire.

### 3.4.1 Use of personal protective equipment

Table 3.2 shows which personal protective equipment was used by fire service personnel when dealing with accidents involving AFVs and how often this equipment was used.

**Table 3.2 Personal protective equipment**

| Personal protective equipment | Quantity |
|---|---|
| 1000v gloves | 18 |
| Breathing apparatus | 17 |
| FFP3 face mask | 2 |

### 3.4.2 Deployment of fire service potential (personnel and equipment)

The following fire service potential was deployed at the 159 accidents involving AFVs[6] (see table 3.3 on the next page).

[6] The total number of fire service potential/equipment called out was taken into account, without distinguishing between whether these units were deployed at the AFV or elsewhere.

**Table 3.3 Potential deployed**

| Potential deployed | Frequency (number of times) |
|---|---|
| 1 fire appliance | 140 |
| 2 fire appliances | 8 |
| 3 fire appliances | 1 |
| Hazardous Materials Advisor | 3 |
| Fire service motorbike | 6 |
| Fire Service First Responder | 1 |
| Accident unit | 40 |
| Officer in Charge | 83 |
| Rescue tender | 1 |
| Rapid Intervention Vehicle | 1 |
| Water / Foam tender | 1 |
| Diving unit | 1 |

### 3.4.3 Extinguishing agent or refrigerant used

The fire service carried out an extinguishing or cooling action in one accident involving AFVs. Low pressure was used here.

### 3.4.4 Sources of information

Table 3.4 below shows which sources of information were used by fire service personnel when dealing with accidents involving AFVs and how often each source was used.

**Table 3.4 Sources of information**

| Sources of information | Frequency (number of times) |
|---|---|
| Vehicle recovery operator's advice | 1 |
| Colleague with specific knowledge | 15 |
| CRS | 101 |
| External expert | 5 |
| SOP (Standard Operating Procedure) | 1 |
| LiveOp | 4 |
| Unknown | 8 |

### 3.4.5 Side of approach

Table 3.5 shows from which sides AFVs were approached by fire service personnel after the accidents and how often they were approached from the side in question.

**Table 3.5 Side of approach**

| Side of approach | Frequency (number of times) |
|---|---|
| Unknown | 93 |
| At a 45-degree angle | 20 |
| From the front | 18 |
| From the side | 35 |

## 3.5 Vehicle recovery

An analysis of the data shows that most vehicles were transferred to the police or were removed by a vehicle recovery service in accordance with regular practice. As far as could be ascertained, there were two cases where the vehicle involved was placed in an immersion container[7], nowadays commonly referred to as a salvage container, to remove it.

There were six cases where the fire service advised parking the vehicle at an “ample distance” from other vehicles and/or buildings. There was one case where the vehicle manufacturer was contacted to find out whether their remote reading of the on-board computer had shown an increased temperature in the battery pack. This was not the case.

In one case, the vehicle recovery operator asked the fire service personnel to ‘pull’ the service plug, otherwise the operator would not transport the vehicle. ‘Pulling’ the service plug means removing the plug from the battery pack to deactivate the high-voltage system.

## 3.6 Answer to research question 2

This section answers the second research question and the corresponding subquestions.

*Research question 2: What were the characteristics of the accidents involving alternative fuel vehicles in 2021?*

The 159 accidents involved 168 alternative fuel vehicles in total. Of these, 51.8% were battery electric vehicles, and 42.8% were (plug-in) hybrid vehicles. Another 1.8% were CNG fuelled and 0.6% were fuelled by CNG in combination with another fuel. 1.2% of the vehicles

[7] ‘‘The immersion container is a liquid-tight container in which a passenger vehicle or other object can be placed. The container needs to be transported to the scene of the incident, e.g. on the loading platform of a tow truck or using a hook loader vehicle. Immersion containers are used in the Netherlands to immerse lithium-ion batteries which are, or have been, on fire and which are or may be unstable in water for a longer period of time in order to stop the actual or imminent thermal runaway process. In the Netherlands, immersion containers are used by vehicle recovery companies.’’ Source: IFV, 2020.

were fuel cell electric vehicles and 0.6% were fuelled by LNG combined with another fuel. The vehicle technology / fuel type of 1.2% of the vehicles was not known.

*Subquestion 2a: What were the characteristics of the locations where these fires occurred?*
38.8% of all accidents happened within built-up areas. 28.9% of the accidents happened outside built-up areas. 31.6% of the accidents occurred on a motorway or highway. Two accidents, 0.7%, occurred in multi-storey car parks.

*Subquestion 2b: What was the role that the alternative fuel system played in these accidents?*
There was one case where the fuel contributed to the accident and the battery pack of the vehicle in question caught fire after the collision. There was not a single accident where the battery pack was damaged so badly that there was an electrocution hazard.

*Subquestion 2c: What was the response to these incidents? '*
The fire service used 1000V gloves as PPE in 18 cases when responding to an accident. The fire service personnel wore breathing apparatus in 17 cases. The Crash Recovery System was used to gather information in a majority (63.5%) of the incidents. There were 15 cases where a colleague had the specific knowledge needed to respond to the incident. Help was sought from an external expert in five cases. A thermal imaging camera was used 46 times to check whether the battery pack was involved in the incident. There were two accidents where the vehicle was placed in an immersion container to remove it from the scene of the accident. There were another six cases where parking the vehicle at an ample distance from other vehicles and/or buildings was advised.

# 4 Characteristics of fires involving AFVs

This chapter presents the data concerning the *fires* (not *accidents*; they were addressed in chapter 3) involving alternative fuel vehicles. This answers research question 3: *What were the characteristics of fires involving alternative fuel vehicles in 2021?*

The chapter starts with a presentation of the vehicle characteristics (fuel, type of vehicle) of the AFVs involved in fires. It then goes on to discuss the location characteristics of the fires, followed by a discussion of the role which the alternative fuel played in the fires. The fourth section addresses the incident response to the fires and the last section looks into how the vehicles involved in the fires were recovered.

## 4.1 Vehicle characteristics

In 2021, 77 alternative fuel vehicles were involved in a total of 62 fires.

### 4.1.1 Fuel

The 77 vehicles involved in fires were of the vehicle technology / fuel types indicated in figure 4.1.

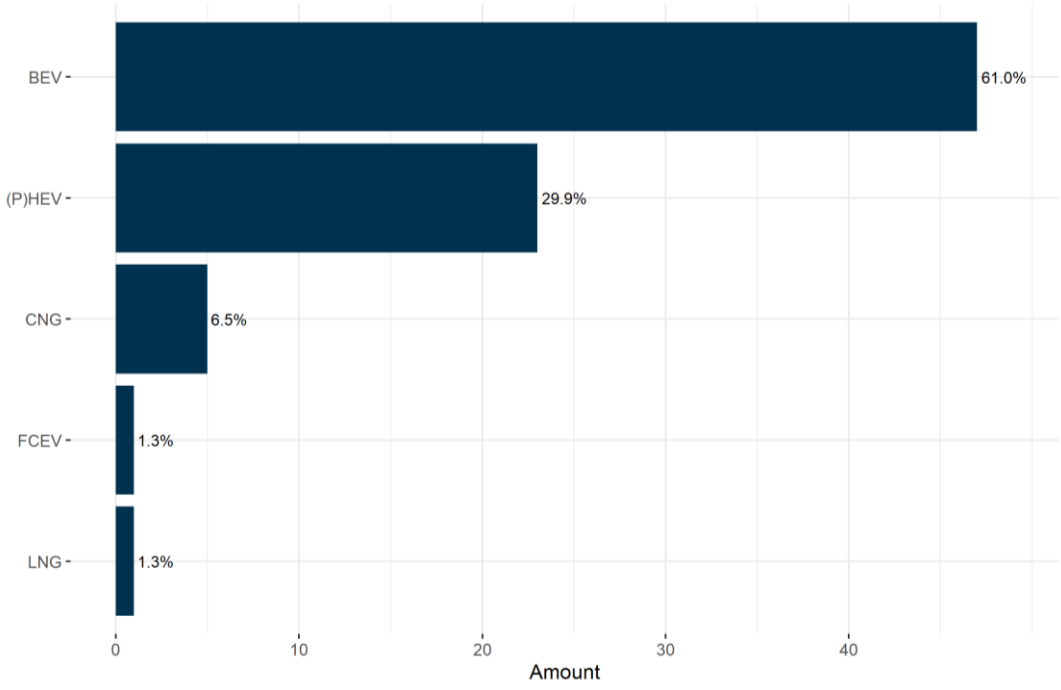



**Figure 4.1 Fires (%) broken down by vehicle technology / fuel types of the AFVs**

### 4.1.2 Type of vehicle

The 77 vehicles involved in fires were of the following types (see figure 4.2).

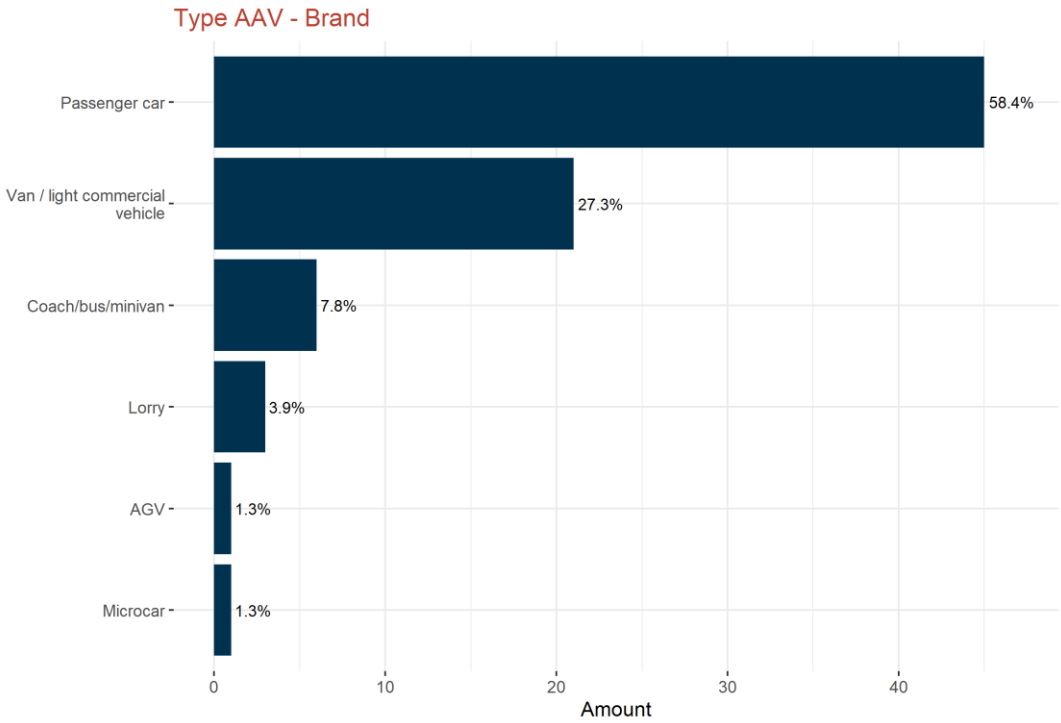



**Figure 4.2 Fires (%) broken down by type of vehicle**

### 4.1.3 Types of vehicle broken down by vehicle technology / fuel types

Figure 4.3 below indicates the types of vehicle involved in the fires for each vehicle technology / fuel type.

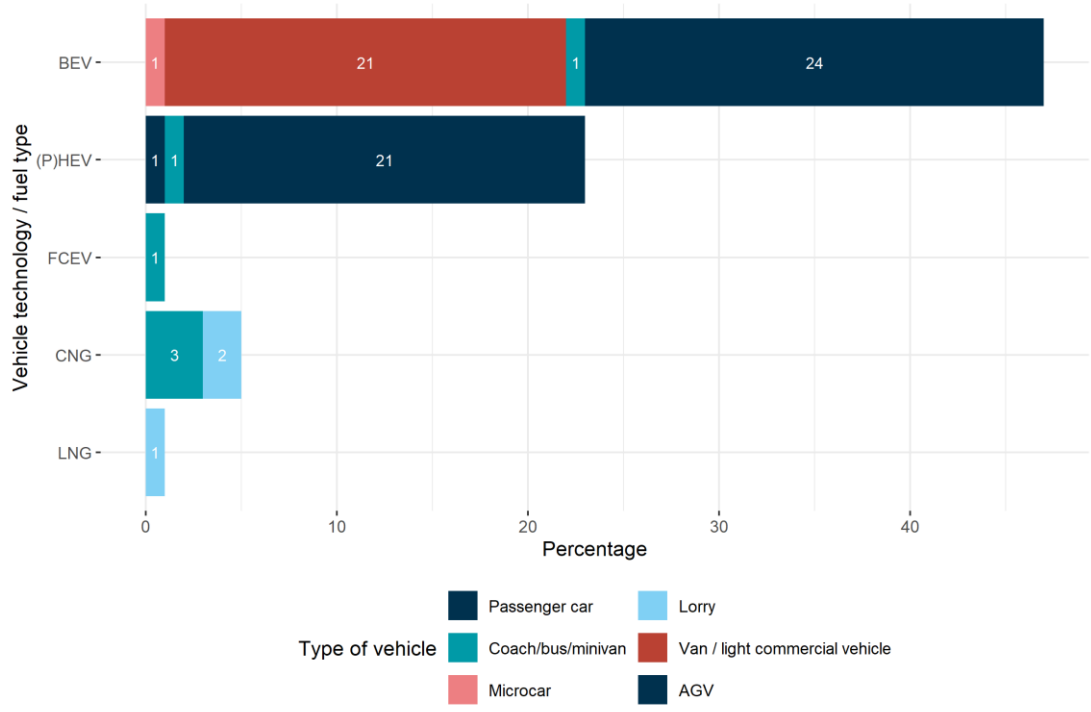



**Figure 4.3 Fires broken down by type of vehicle broken down by vehicle technology / fuel types.**

## 4.2 Location

The fires involving AFVs occurred in the locations shown in figure 4.4. The locations are only known if the vehicle in question was in motion.

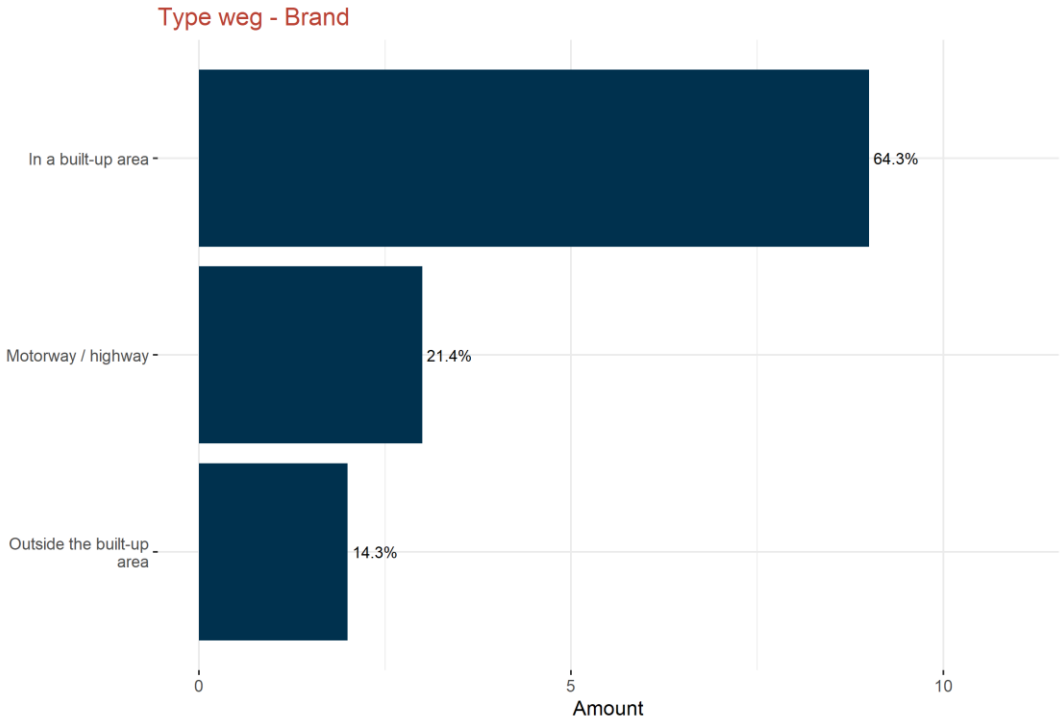



**Figure 4.4 Locations of the fires**

## 4.3 Role played by the vehicle technology / fuel type

### 4.3.1 Battery pack

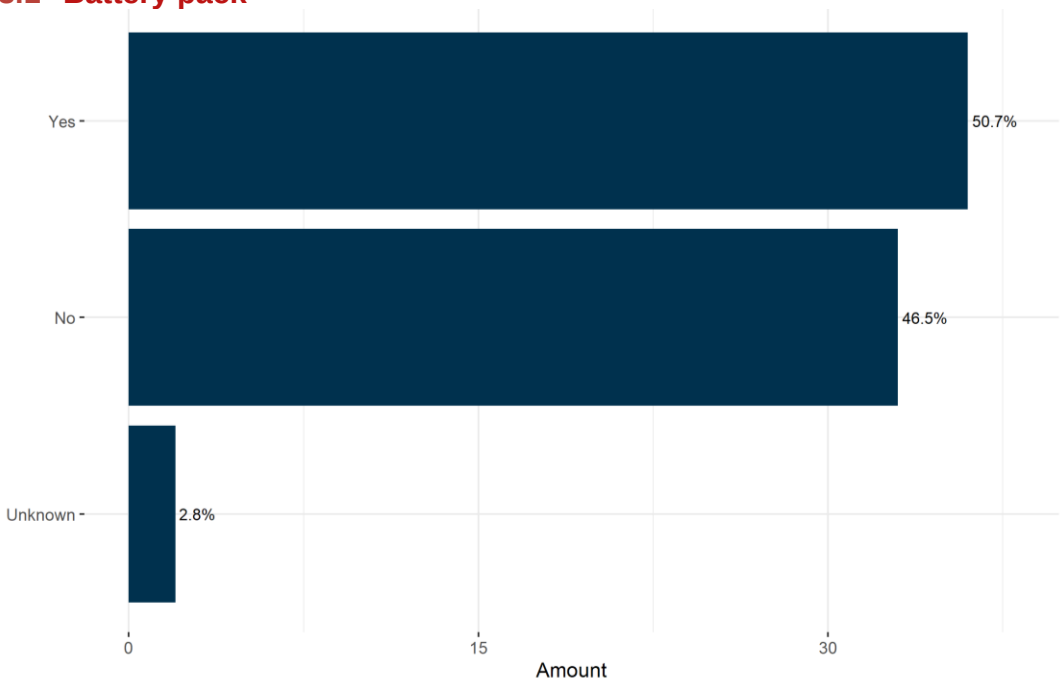



**Figure 4.5 Battery pack on fire**

In 50.7% of the 71 fires involving an AFV with a battery pack for propulsion, the vehicle battery was on fire. In the other cases, the battery was not on fire, and did not directly contribute to the incident. There are two incidents where it was not known whether the batteries were involved.

### 4.3.2 Thermal runaway

Thermal runaway occurred in 33 of the 36 incidents where the battery was on fire. This thermal runaway occurred at the following times in relation to the presence of the fire service (table 4.1).

**Table 4.1 Time of the thermal runaway**

| Time of thermal runaway | Quantity |
|---|---|
| Prior to the arrival of the fire service | 10 |
| While the fire service was present | 21 |
| Unknown | 3 |

### 4.3.3 Cause of the involvement of the battery in the fire

There were 36 incidents where a battery was involved in the fire. The probable causes are shown below.

> There was a fire in a shed containing 16 vehicles; all 16 vehicles were affected by the fire. This caused the batteries to catch fire as well. The cause of this fire is not known.
> There were four cases of arson in which the battery caught fire as well.
> The battery became overheated once while a vehicle was being towed.
> Two incidents of failure in a battery pack led to fire.
> One incident of a technical defect while charging led to fire.
> There were five incidents with technical failures elsewhere in the vehicle after which the battery got involved in the fire.
> There were seven cases whose cause is not known.

### 4.3.4 Establishing the involvement of the vehicle technology / fuel type

Where AFVs were involved in fires, the fire service used the methods listed in table 4.2 to try to establish the involvement of the vehicle technology / fuel type.

**Table 4.2 Method of establishing the involvement of the different vehicle technologies / fuel types**

| Established by means of | Frequency (number of times) |
|---|---|
| Fuming | 5 |
| No signals observed | 30 |
| Boiling | 2 |
| Smoking | 14 |
| Hissing | 5 |
| Visually | 27 |
| Heat development | 7 |
| Thermal imaging camera | 28 |

### 4.3.5 Charging infrastructure

The following was established for the 62 vehicles involved which may have been parked at a charging point (if the vehicle was parked and it was involved in the fire and it was an electric, hybrid or fuel cell electric vehicle):

> the vehicles were on a charging point in 23 cases
> the vehicles were *not* parked at a charging point in 31 cases.

There were eight cases where it was unknown whether the vehicle was parked at a charging point.

The batteries of 17 of the 23 vehicles which were parked at a charging point were involved[8] in the fire. In six of these cases, the vehicle's battery was not involved in the fire. The fire researchers think that at least one of these 17 fires was probably caused by the battery pack. The cause of another fire may have been a technical defect while charging. The causes of the other incidents are not known. There was also one incident where a fire started within one minute of being disconnected from the vehicle from the charger.

### 4.3.6 Gas tank

Seven fires involved vehicles with gas tanks; only one of these gas tanks blew off. This caused the hydrogen gas to ignite in the garage where the vehicle was parked, triggering a jet fire. The cause of the fire in this vehicle is not known yet.

## 4.4 Incident response

### 4.4.1 Use of personal protective equipment

Table 4.3 below shows which personal protective equipment was used by fire service personnel when dealing with fires involving AFVs and how often this equipment was used.

[8] Involved in the fire does not mean that the fire started while charging.

### Table 4.3 Personal protective equipment

| Personal protective equipment | Quantity |
|---|---|
| 1000v gloves | 10 |
| Breathing apparatus | 53 |
| FFP3 face mask | 10 |

## 4.4.2 Deployment of potential

The following fire service potential was deployed at the 62 fires involving AFVs[9] (see table 4.4 on the next page).

### Table 4.4 Potential deployed

| Potential deployed | Frequency (number of times) |
|---|---|
| 1 fire appliance | 52 |
| 2 fire appliances | 7 |
| 3 fire appliances | 1 |
| 4 fire appliances | 1 |
| Hazardous Materials Advisor | 5 |
| Accident unit | 1 |
| Officer in Charge | 15 |
| Rescue tender | 2 |
| Rapid Intervention Vehicle | 1 |
| Water / Foam tender | 8 |

## 4.4.3 Extinguishing agent or refrigerant used

The fire service carried out 40 extinguishing or cooling actions in fires involving AFVs. The table below shows how often each extinguishing agent and/or refrigerant was used.

### Table 4.5 Extinguishing agent

| Extinguishing agent | Frequency (number of times) |
|---|---|
| Covering | 1 |

[9] The total number of fire service potential/equipment called out was taken into account, without establishing whether these units were deployed at the AFV or elsewhere.

| | |
|---|---|
| High Pressure | 17 |
| Low Pressure | 13 |
| Medium Pressure | 2 |
| Unknown | 2 |
| Foam | 7 |

### 4.4.4 Sources of information

Table 4.6 on the next page shows which sources of information were used by fire service personnel when dealing with fires involving AFVs and how often each source was used.

**Table 4.6 Sources of information**

| **Source of information** | Frequency (number of times) |
|---|---|
| Colleague with specific knowledge | 7 |
| CRS | 51 |
| External expert | 3 |
| SOP (Standard Operating Procedure) | 6 |
| LiveOp | 3 |
| Unknown | 4 |

### 4.4.5 Side of approach

Table 4.7 below shows from which sides AFVs were approached by fire service personnel during a fire and how often they were approached from the side in question.

**Table 4.7 Side of approach**

| **Side of approach** | **Frequency (number of times)** |
|---|---|
| Unknown | 29 |
| At a 45-degree angle | 19 |
| From the front | 8 |
| From the side | 13 |

## 4.5 Vehicle recovery

As far as has been ascertained, immersion containers were used 20 times in order to remove a vehicle involved in a fire:

> In eleven cases, the vehicle was removed and then immersed in water in the container.
> In seven cases, the vehicle was transported in the immersion container, but it is not certain that the vehicle was immersed.
> There were two cases where the vehicle was placed in the container as a preventative measure, but the container was not filled with water.

In the other cases, the vehicle was removed in accordance with regular recovery protocols, it was transferred to the police or it is not known how the vehicle was recovered.

## 4.6 Answer to research question 3

This section answers the third research question and the corresponding subquestions.

*Research question 3:* What were the characteristics of fires involving alternative fuel vehicles in 2021?
In total, 62 fires involved 77 alternative fuel vehicles. 61% of these vehicles were battery electric vehicles. Hybrid or plug-in hybrid vehicles were involved in 29.9% of the fires; CNG vehicles in 6.5%, fuel cell electric vehicles in 1.3% and LNG vehicles in 1.3%.

*Subquestion 3a: What were the characteristics of the locations where these fires occurred?*
Most fires took place in built-up areas (64.3%). 21.4% occurred on a motorway or highway and 14.3% of the fires took place outside built-up areas. Not a single fire involving an alternative fuel vehicle occurred in a multi-storey car park.

*Subquestion 3b: What was the role that the alternative fuel system played in these fires?*
71 vehicles with battery packs were involved in fires and in 50.7% of these cases the battery was involved in the fire. The battery was not involved in 46.5% of these fires. In two cases, it is is still unclear whether or not the batteries were involved in the fire (2.8%). Seven vehicles with gas tanks were involved in fires. In one case (14.3%) the gas tank blew off due to the fire, causing the hydrogen gas to ignite.

*Subquestion 3c: What was the response to these incidents?*
The fire service used breathing apparatus in 53 cases when fighting fires involving AFVs. 1000V gloves were used as well in ten cases. The CRS was used in 51 cases to provide information about the vehicles involved. Help was sought from an external expert in three cases and a colleague with specific knowledge was consulted in seven cases. Thermal imaging cameras were also used 28 times to determine whether the battery pack was involved in the fire.

A high pressure system was used 17 times to fight the fire. Low pressure was used 13 times, medium pressure twice and foam seven times. The vehicles were immersed in immersion containers in 11 fires. Seven vehicles were transported in the immersion container, but it is not certain whether they were actually immersed. There were two cases where the vehicle was transported in the immersion container, but did not need to be immersed.

*Subquestion 3d: What was the involvement of charging infrastructure, if any?*
In 23 fires involving AFVs the vehicle was parked at a charging point. In 17 of these cases, the vehicle's battery was involved in the fire. There were six cases where the vehicle was parked at a charging point, but the battery was not involved in the fire. The probable cause of one fire was a technical failure while charging.

# 5 Conclusions

The fire service attended a total of 221 incidents involving AFVs in 2021, comprising 159 accidents and 62 fires.

## Accidents

The 159 accidents involved 168 alternative fuel vehicles in total. Of these, 51.8% were battery electric vehicles, and 42.8% were (plug-in) hybrid vehicles. There was one case where the battery contributed to the accident when the battery pack caught fire after the collision. As far as could be ascertained, the battery pack was not damaged in any accident to such an extent that this led to a risk of electrocution.

The fire service used 1000V gloves, breathing apparatus, vehicle information from the available information systems and thermal imaging cameras to respond to accidents. There were two cases where the vehicle was removed in an immersion container after the accident.

## Fires

In total, 62 fires involved 77 alternative fuel vehicles. 61% of these vehicles were battery electric vehicles. A (plug-in) hybrid vehicle was involved in 29.9% of the fires. Not a single fire involving an alternative fuel vehicle occurred in a multi-storey car park.

71 vehicles with battery packs were involved in fires and in 50.7% of these cases the battery was involved in the fire. The vehicles were parked at a charging point in 23 cases. In 17 of these cases, the vehicle’s battery was involved in the fire.

The fire service used 1000V gloves, breathing apparatus, vehicle information from the available information systems and thermal imaging cameras to fight the fires. No uniform fire attack took place either as regards the method of approach or the cooling capacity (extinguishing agent) used. The data is not conclusive as to the cause of this.

The vehicles were immersed in immersion containers in 11 fires. Seven vehicles were only transported in an immersion container.

# 6 Reflection

This research has led to a breakthrough by making numeric information available about incidents involving alternative fuel vehicles. It provides quantitative information about the occurrence of accidents and fires involving alternative fuel vehicles, the locations of the accidents and fires, how the fire service responded and which equipment was deployed.

But figures are meaningless without further context. If, for example, the fire involving 16 PicNic vehicles, 13 of which were charging, were removed from the data set, the figures for fires involving alternative fuel vehicles would change substantially. And furthermore, if a situation hardly every occurred in 2021 (e.g. fires involving AFVs in multi-storey car parks), it does not mean that this incident scenario is not relevant enough to be taken into consideration. The figures discussed here only reflect a specific year and the sample is too small to enable any trends to be identified. Fighting fires inside multi-storey car parks remains a tricky business and fires involving electric vehicles take a different course than fires involving fossil-fuelled vehicles. And what's more, only 4% of the Dutch vehicle fleet is electric. Any scenarios that do not or only rarely occur now could become more common in the future as the vehicle fleet grows.

This awareness of the context also applies to the figures we collected. The figures show that fires involving an AFV occurred relatively often (i.e. 23 out of 62 relevant fires) when the vehicle was at a charging point. Attention to charging safety, the advice to use mode 3 or mode 4 charging and increased risk awareness may lead to a decrease in the share of fires involving AAVs at a charging point.

## Accident response

The figures also show that there was only one incident where the battery contributed to the accident (because a fire started and the battery became involved) and that there was not a single accident where the battery pack was damaged so badly that this gave rise to a risk of electrocution. This is useful information for the fire service as regards the possible hazard involved in such accidents. Based on these figures, the fire and electrocution hazards are relatively minor.

## Firefighting

The figures show that the battery was involved in fifty percent of all fires. This means that firefighters will have to take into account that it will take a long time to handle the fire (extinguishing, cooling and removal of the vehicle, possibly using an immersion container), and that the vehicle recovery operator should pay attention to contaminated cooling water.

# Annex 1: Questionnaire

The questionnaire used in this research is presented below. Question dependencies have been removed from this questionnaire to make it easier to read.

## Position

1 **Your position during the accident**

*Options (not mandatory)*

- ☐ OIC
- ☐ Commanding Officer
- ☐ FRT
- ☐ HMA
- ☐ Other

*Other position, i.e.*

## Vehicle

2 **What type of incident happened?**

*Multiple response*

- ☐ Fire
- ☐ Accident

3 **Was the vehicle in motion?**

- ☐ Yes
- ☐ No

4 **Was the vehicle in a multi-storey car park?**

- ☐ No
- ☐ Yes, an open structure above ground
- ☐ Yes, a closed structure above ground
- ☐ Yes, an underground car park

5 **On parking storey:**

e.g. -1 or +3

6 **Where was/were the vehicle(s)?**

*Options*

- ☐ In a built-up area
- ☐ Outside the built-up area
- ☐ Motorway / highway
- ☐ Other

*Other*

## Vehicle data

7 **How many AFVs were involved in the incident?**

*Options*

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4 or more → end of this questionnaire; you will be contacted by phone

8 **Is the AFV's registration number known?**

*Options*

- ☐ Yes: *Enter the registration number*
- ☐ No

9 **Which type of AFV was involved in the incident?**

*Options*

- ☐ Passenger car
- ☐ Bus/minivan
- ☐ Coach
- ☐ Van / light commercial vehicle
- ☐ Lorry
- ☐ Agricultural vehicle
- ☐ Bicycle
- ☐ Motor scooter
- ☐ Microcar
- ☐ Ship
- ☐ E-scooter
- ☐ Other

*Other*

10 **What is the AFV make?**

*Options (dropdown list)*

- ☐ Audi
- ☐ BMW
- ☐ Citroën
- ☐ Fiat
- ☐ Ford
- ☐ Hyundai
- ☐ Jaguar
- ☐ Kia
- ☐ Mazda
- ☐ Mercedes-Benz
- ☐ MG
- ☐ Mini
- ☐ Mitsubishi
- ☐ Nissan
- ☐ Opel
- ☐ Peugeot
- ☐ Porsche

- ☐ Renault
- ☐ Seat
- ☐ Skoda
- ☐ Smart
- ☐ Tesla
- ☐ Toyota
- ☐ Volkswagen
- ☐ Other

*Other*

11 **What is the AFV model?**

*Text*

*Enter your answer*

12 **What was the AFV fuel or vehicle technology?**

*Multiple choice*

- ☐ Battery electric vehicle (BEV)
- ☐ (Plug-in) hybrid vehicle (P)HEV
- ☐ Fuel cell electric
- ☐ CNG
- ☐ Combination of CNG and diesel, petrol or LPG
- ☐ LNG
- ☐ Combination of LNG and diesel, petrol or LPG
- ☐ Other

*Other*

## Battery

13 **Was the vehicle connected to a charging point (only hybrid or battery electric)?**

*Options*

- ☐ Yes
- ☐ No
- ☐ Unknown

14 **Was the battery pack on fire?**

*Options*

- ☐ Yes
- ☐ No
- ☐ Unknown

15 **Did the fire start in the battery pack?**

*Options*

- ☐ Yes
- ☐ No
- ☐ Unknown

16 **Did thermal runaway take place and if so, when?**

*Options*

- ☐ No

- ☐ Prior to our arrival
- ☐ During our arrival
- ☐ During our presence
- ☐ After we left (if known)
- ☐ Other

*Other*

17 **Was the AFV's battery pack stable?**

*Options*

- ☐ Yes
- ☐ No
- ☐ Other

*Other*

18 **How was it established whether the battery pack was stable or unstable?**

*Multiple choice*

- ☐ No signs
- ☐ Fuming
- ☐ Boiling
- ☐ Smoking
- ☐ Hissing
- ☐ Thermal imaging camera
- ☐ Heat development
- ☐ Visually
- ☐ Other

*Other*

19 **Was the vehicle's battery pack stabilised / made safe?**

*Options*

- ☐ Yes, how?
- ☐ No

*Explanation of how*

## Gas tank

20 **Was it known in good time that this vehicle had a gas tank?**

- ☐ Yes
- ☐ No

21 **Did the tank blow off during the incident?**

- ☐ Yes
- ☐ No

22 **In which direction did the tank blow off?**

- ☐ To the rear
- ☐ Downwards
- ☐ Sideways

- ☐ Upwards
- ☐ Forwards

23 **Did the tank contents catch fire?**
- ☐ Yes
- ☐ No

24 **Report of tank blow-off**
*Long answer*

*Enter your answer*

## Fire intervention

25 **Were the contents of the first fire appliance sufficient for extinguishing/cooling?**
- ☐ Yes
- ☐ No

26 **Which actions were taken in connection with the incident?**
*Multiple choice*
- ☐ The action concerned expelling gases
- ☐ The first response circuit was cut
- ☐ The 12 V battery was disconnected

27 **Were the AFV or any parts of the AFV extinguished/cooled?**
*Options*
- ☐ Yes
- ☐ No

28 **How were the AFV or its parts extinguished/cooled?**
*Multiple choice*
- ☐ Covering
- ☐ HP
- ☐ LP
- ☐ MP
- ☐ O-bundles
- ☐ Immersion (by a vehicle recovery operator)
- ☐ Other

*Other*

## Safety / assessment

29 **Which supplementary PPE and/or actions were used/implemented as part of the deployment/response**
*Multiple-choice options*
- ☐ Breathing apparatus
- ☐ Rubber mat
- ☐ Earthing the vehicle

- ☐ Measuring the vehicle
- ☐ 1000V gloves
- ☐ FFP3 face mask
- ☐ Other

*Other*

30 **Which type of information source/provision contributed to an effective deployment/response?**

*Multiple-choice options*

- ☐ Dutch CRS / MOI
- ☐ LiveOp
- ☐ QR code
- ☐ Rescue Sheet
- ☐ *Handelingsperspectief* (Protocol of possible actions) / *ARO* (Cards with areas of attention for repressive action)
- ☐ Colleague with specific knowledge
- ☐ None
- ☐ Other

*Other*

31 **From which direction / side was the vehicle approached?**

*Multiple choice*

- ☐ From the front
- ☐ From the side
- ☐ At a 45-degree angle
- ☐ Unknown

32 **Why was it approached from this side/direction?**

*Long answer*

*Enter your answer*

33 **Did the weather affect the way in which you carried out your action?**

- ☐ No
- ☐ Yes

*Explanation if yes Text (max. 100 words)*

## Deployment

34 **Which units were deployed during the incident?**

*Multiple choice*

- ☐ 1x fire appliance
- ☐ 2x fire appliance
- ☐ 3x fire appliance
- ☐ HMA
- ☐ Rescue tender
- ☐ Accident unit

- ☐ OIC
- ☐ Water / Foam tender
- ☐ Other

*Other*

## Own personnel

35 **Were any of your own personnel injured (even if they were not taken to hospital)?**

*Options*

- ☐ Yes
- ☐ No

## Casualties / injuries

36 **Did this incident claim any casualties in the AFV? (A casualty is someone who was taken to hospital or died.)**

*Options*

- ☐ Yes
- ☐ Yes, a fatal casualty
- ☐ No

37 **How many casualties did this incident claim?**

*Numeric quantity*

*The value must be a number*

## Other questions

38 **Which agreements were made with the vehicle recovery operator when handing the incident?**

*Long answer*

*Enter your answer*

39 **What was the probable cause of the incident?**

*Long answer (max. 100 words)*

*Enter your answer*

40 **What caused the fire?**

*Long answer (max. 100 words)*

*Enter your answer* >

# Annex 2: Obi4Wan search terms

("gevaarlijke stof" OR
accu* OR
lithium* OR
batterij* OR
batterij OR
battery* OR
gastank* OR
waterstof* OR
H2 OR
lng OR
cng OR
"elektrische auto" OR
"elektrische auto's" OR
“elektrische voertuigen” OR
“elektrisch voertuig” OR
“elektrische bus” OR
“elektrische vracht*” OR
“cng vracht*” OR
“lng vracht*” OR
“elektrische bestel*” OR
Tesla OR
Hybri* OR
Laadp* OR
Runaway OR
Garage OR
Bus) AND
(incident OR
ongeluk OR
ongeval OR
brand OR
bots* OR
aanrijding OR
knald* OR
crash* OR
beschadigd OR
explosie OR
brandweer OR
veiligheidsregio OR
hulpdienst* OR
hulpverlen* OR
lekkage OR
Dompel* OR
Salvagecontainer)