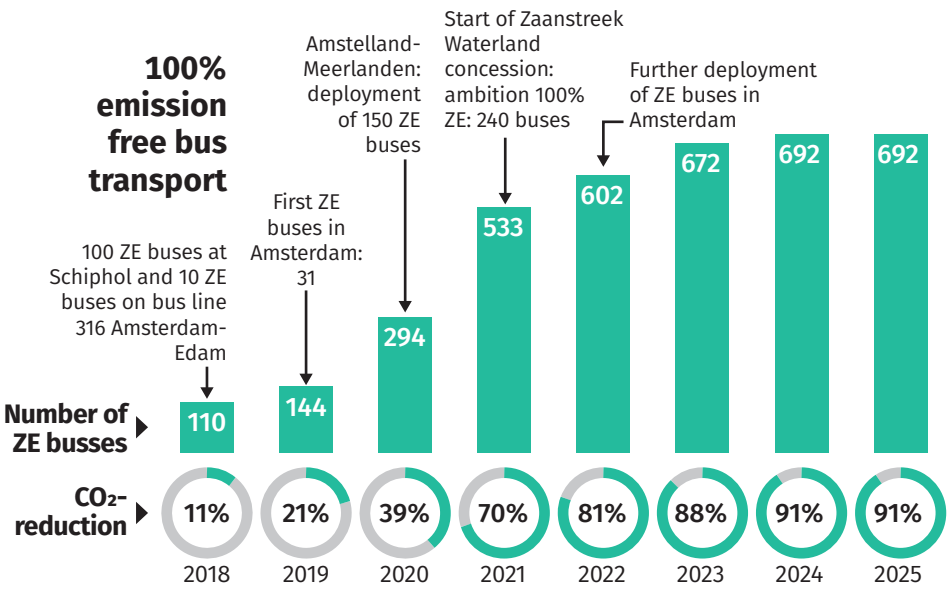
Vervoerregio Amsterdam

Factsheet Zero Emission Bus

Zero Emission Mobility Programme

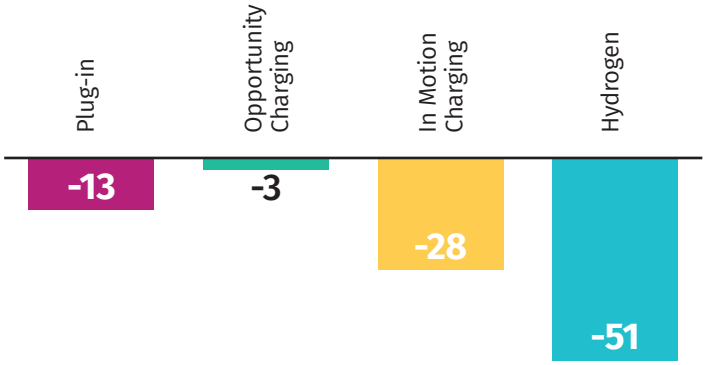
Ambition

The Transport Authority Amsterdam (Vervoerregio) aims for cleaner and quieter public transport for its residents and travellers. With the transition to zero emission public transportation we contribute to the global climate goals. That is why from 2025 all new buses in the Amsterdam Metropolitan Region will be emission free. In 2030 this applies to all buses. Additionally, in 2030 all buses will be charged with electricity derived from 100% renewable energy sources.



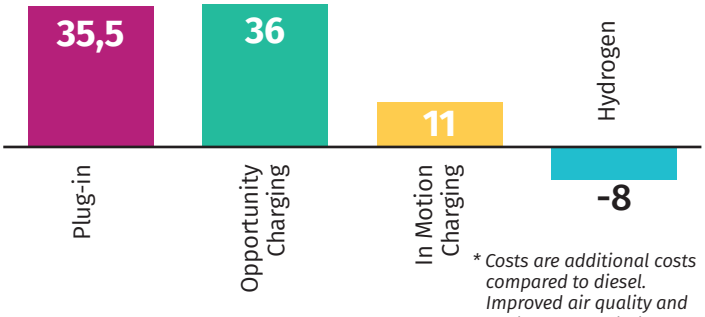
Zero Emission is more expensive than diesel...

Additional costs* of ZE technology in millions of euros per year



...yet it is socially viable

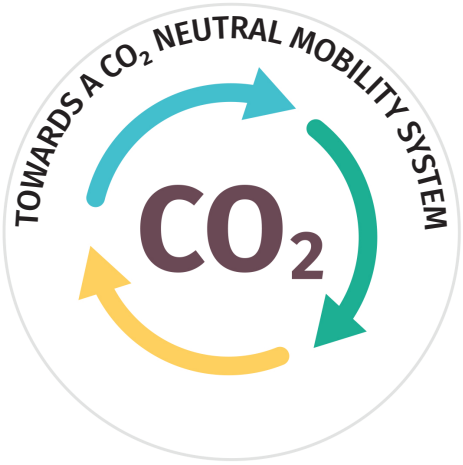
Societal benefits* in millions of euros per year



** Costs are additional costs compared to diesel. Improved air quality and avoided CO_2 emissions are examples of the benefits. In the figure they are expressed in euros.*

Preferred technology

For the coming years the Vervoerregio foresees that OC, IMC and plug-in are the most promising techniques. Together with our partners we will investigate per sub-network whether OC, IMC or plug-in is technically, financially and spatially the most feasible option, before making a definitive choice.



Power grid and the public space

Plug-in, OC and IMC have significant consequences for the power grid. A bus depot with 100 plug-in buses approximately consumes 15 megawatt hours in one night. On a yearly basis, this is comparable to the annual consumption of almost 3000 single-person households. Additionally, public space is required for the (fast) charging infrastructure of OC buses and for overhead lines for IMC buses.

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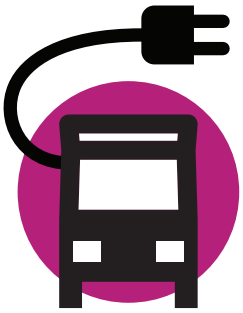
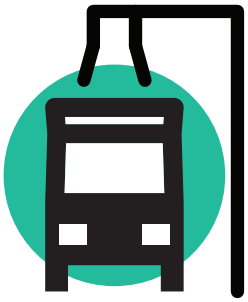
Key Zero-Emission technologies



PLUG-IN BUS

- **Can be used up to 250 km/day (increasing), more with range extender**
- **Slow-charging overnight or fast-charging during the day at the depot**
- **Loss of passenger capacity due to large battery**



OPPORTUNITY CHARGING BUS (INTERMEDIATE STATIONARY CHARGING: ENERGY TOP UPS DURING OPERATION, OC)

- **Fit fast-charging in the timetable**
- **1 minute of charging provides 7 km range (with 450 kW charger)**
- **Smaller battery but more expensive charging infrastructure**
- **Fast-charging devices are required mostly at the bus stops**

IN-MOTION CHARGING BUS (CHARGE WHILE DRIVING, IMC)

- **Requires overhead lines, but less than regular trolleybus due to a battery in the bus**
- **Flexible deployment in comparison with regular trolleybus**
- **15 minutes of charging results in 20 km autonomy without wire**

HYDROGEN BUS

- **Flexible deployment, probably rarely any restrictions on the driving range**
- **Producing, transporting and fuelling large quantities of hydrogen is a logistical challenge**

Other CO_2 reduction technologies

Diesel hybrid buses and using (green) gas as fuel are both options to reduce CO_2 emissions.
Both techniques significantly reduce CO_2 emissions, but are not 100% emission free.

Did you know that..?

.. Europe's largest number of electric buses are in service in the AmsterdamMetropolitan Region?

.. State of Charge (SOC) indicates how full the battery is?

.. bus drivers do a contest who can arrive at the terminal with the highest SOC?

.. in 15 minutes an OC bus charges as much power as one household uses in one month?

Existing policies

Global — *The Paris Agreement, 2015*

- **Keep the increase in global average temperature to well below 2°C above pre-industrial levels**

National — *Administrative Agreement on Zero Emission Bus, 2016*
Climate Act, 2018

- **In 2030: all regional public transport zero emission**
- **In 2050: 95% reduction of CO_2 emissions compared to 1990**

Regional — *Policy Framework Mobility Amsterdam Transport Authority*

- **In 2050: a CO_2 neutral mobility system**

Municipal — *Example: Zero Emission Public Transport Amsterdam*

- **In 2025: public transport zero emission in Amsterdam**

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Plug-in

- Can be used up to 250 km/day (increasing), more with range extender
- Slow-charging overnight or fast-charging during the day at the depot
- Loss of passenger capacity due to large battery

Spatial integration

Because plug-in buses are only charged overnight, this type of ZE bus is spatially well-suited. The spatial consequences of the required charging infrastructure are limited. Charging infrastructure must be realised only in the parking facility (depot). Additionally, extra space is required for the charging stations (which are usually located next to the vehicle when loading with a plug) and a transformer.

Technology

A plug-in bus is powered by an electric motor. The required electricity is stored in the battery of the bus. The bus is recharged once a day (this usually happens overnight). If the electricity is generated in a sustainable manner, the plug-in bus is 100% emission free.

Charging method

Plug-in buses are charged with a plug, just like electric cars. The output power is usually 30 kW and charging takes around 4 to 6 hours.

Application in public transport

The plug-in bus can replace diesel buses on routes up to 250 kilometres per day. Since plug-in buses have a large battery the bus cannot be loaded too heavily and fewer passengers can be transported. Plug-in buses are therefore particularly interesting for lines with a low frequency and that are not too busy.
The first deployment of plug-in buses in the Amsterdam Transport Authority will take place on lines 65 and 67 in the Zaanstreek concession.

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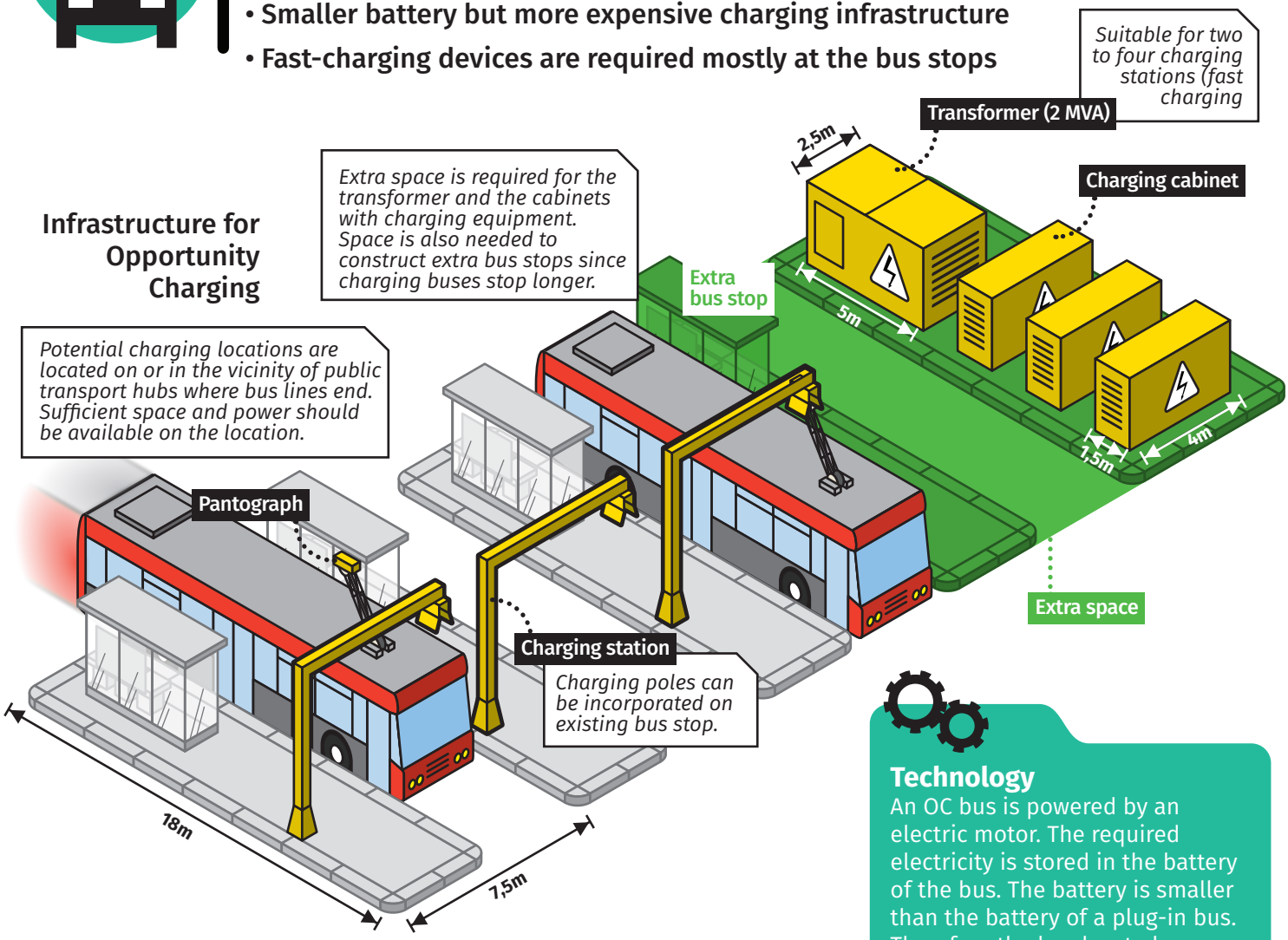
Opportunity Charging (OC)

- Intermediate stationary charging
- Fast-charging must fit in the timetable
- 1 minute of charging provides 7 km range (with 450 kW charger)
- Smaller battery but more expensive charging infrastructure
- Fast-charging devices are required mostly at the bus stops

Infrastructure for Opportunity Charging



Technology

An OC bus is powered by an electric motor. The required electricity is stored in the battery of the bus. The battery is smaller than the battery of a plug-in bus. Therefore the bus has to be recharged during the day. If the electricity is generated sustainably, the OC bus is 100% emission free.

Charging method

OC buses are charged by means of a pantograph. The pantograph can be mounted on the roof of the bus or on the charging station. Below high output powers (up to 600 kW) the buses are charged in about 15 minutes. Overnight the buses are recharged at the depot.

Application in public transport

OC buses are suitable for busy lines with a high-frequency timetable since fast charging can be optimally included in the schedule. Because of the charging time, more buses are needed in comparison with the other techniques.
100 OC buses are operating in the Amstelland-Meerlanden region on and around Schiphol Amsterdam Airport. OC buses also run on bus line 316 in Waterland.

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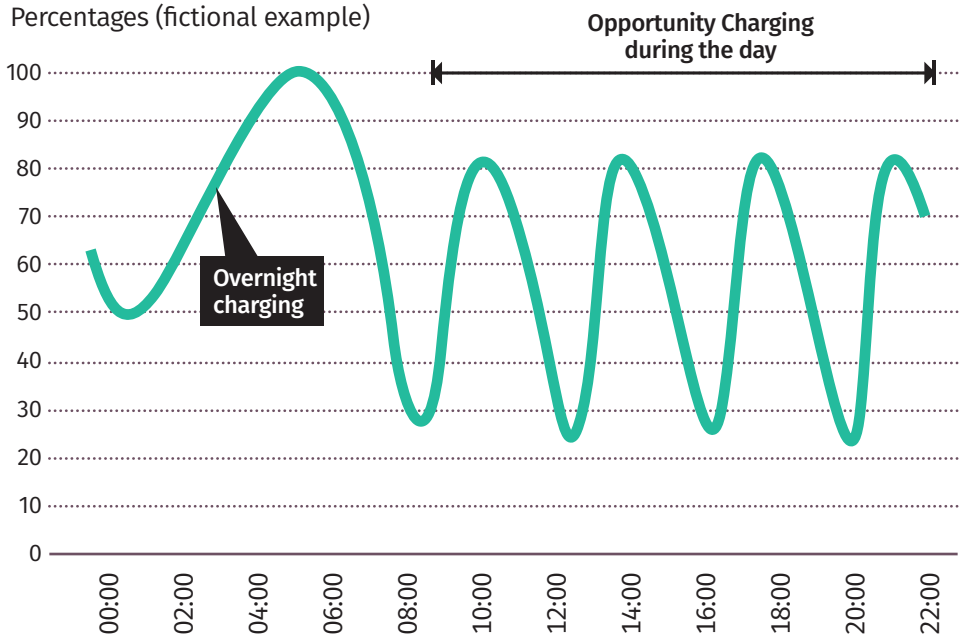
Opportunity Charging (OC)

State of charge of OC bus during the day

Percentages (fictional example)

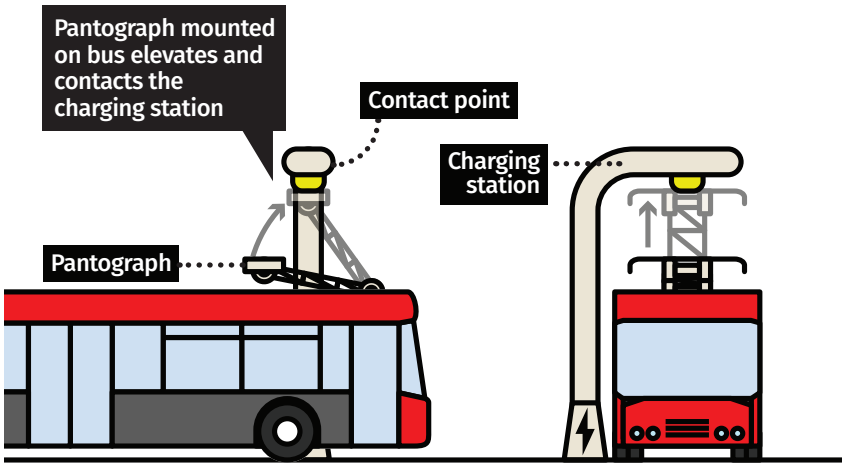


Spatial integration

OC buses have to be recharged a couple of times during the day. Fast-charging infrastructure has to be developed in the vicinity of, or on, terminals. As the charging duration is approximately 10-20 minutes, charging on the bus platform is not always desirable. In that case extra space is required to construct charging infrastructure.

OC buses also charge overnight in the depot. For this charging infrastructure has to be implemented. The charging stations are located above the buses and take up little extra space. Additional space is needed for the control technology and connection to the power grid.

Pantograph on bus (Opportunity Charging)



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In Motion Charging (IMC)

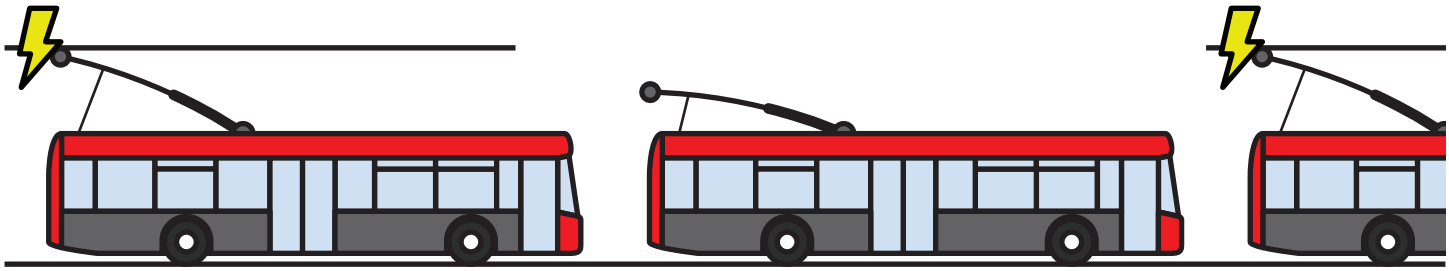
- Requires overhead lines, but less than a regular trolleybus due to a battery in the bus
- Provides more flexible deployment in comparison with a regular trolleybus
- 15 minutes of charging results in 20 km autonomy without wire

Spatial integration

IMC buses are recharged when driving. Because an IMC bus also has a battery it only has to drive connected to overhead lines on parts of the route. For this reason overhead lines are only required on sections of the trajectory.

IMC buses also charge overnight in the depot. This requires charging infrastructure.

IMC: charging on parts of the trajectory



Technology

An IMC bus is powered by an electric motor. The required electricity is stored in the battery of the bus or is taken directly from the overhead. The bus is recharged when driving. If the electricity is generated in a sustainable manner, the IMC bus is 100% emission free.

Charging method

With IMC buses a pantograph collects power through contact with an overhead line.
The power is used for driving and for recharging the battery in the bus. An IMC bus cannot make use of the overhead line of the tram.

Application in public transport

IMC buses are suitable for busy lines with a high frequency and a high average speed. The IMC bus requieres an overhead contact line on parts of the route. This depends on the duration and speed at which the bus travels on the routes with and without overhead lines. IMC buses can only slightly deviate from their route because the battery can quickly become discharged.

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Hydrogren (H_2)

- **Flexible deployment, probably rarely any restrictions on the driving range**
- **Producing, transporting and fuelling large quantities of hydrogen is a logistical challenge**

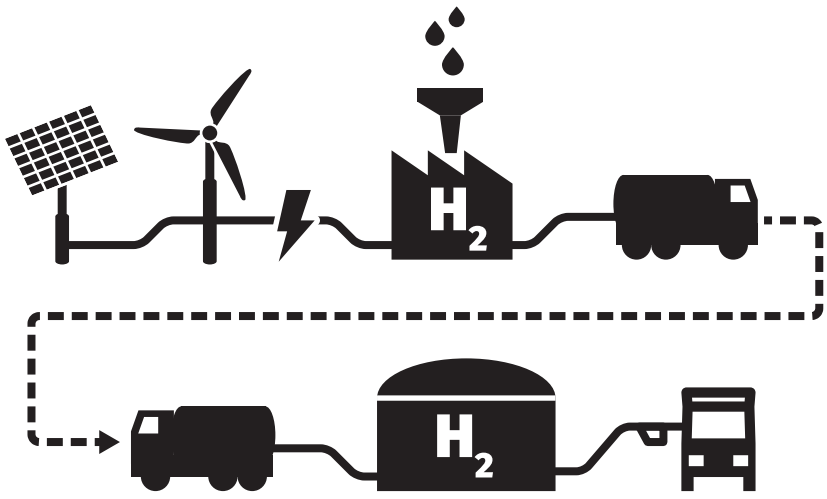
Is H_2 bus transport feasible?

Hydrogen technology involves high costs. Therefore it will not replace diesel in the short term.
A hydrogen bus does have advantages compared to an OC bus. No 'loading buses' are required and there is no need to construct charging infrastructure in the public space. Technological innovation in the field of hydrogen production, will make hydrogen driven buses a realistic alternative around 2030. The transition from diesel to zero emission has started too early for the hydrogen technology.

Spatial integration

Hydrogen buses refuel at a hydrogen refuelling station. These could be located at the bus terminal. There are strict safety regulations for the placement of a hydrogen station. Since the refuelling of multiple hydrogen buses simultaneously will take a few hours, more refuelling points are needed than for diesel buses.

Also for the production of H_2 extra space is required. Hydrogen can be transported either by road or via a pipeline to the refuelling station.



Technology

A hydrogen bus is powered by an electric motor. The required electricity is generated in a fuel cell. A fuel cell converts hydrogen gas and oxygen into electricity. If the hydrogen is produced sustainably, the hydrogen bus is 100% emission free.

Charging method

At a hydrogen refuelling station, hydrogen is pumped into the tanks of the bus under high pressure. During refuelling, the pressure of the hydrogen in the filling station decreases. The pressure must be increased again before another bus can be loaded. Loading one bus currently takes around 4 to 6 hours.

Application in public transport

Hydrogen buses can replace diesel buses one-to-one because sufficient fuel (hydrogen gas, H_2) can be taken to drive for a day. Experiments with use of H_2 buses will be performed in Groningen and Rotterdam in order to gain experience with the technique. In the Netherlands no lines currently operate entirely with H_2 buses.