STEP AHEAD

for students

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STEP AHEAD II

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Automotive Innovation & Teacher training Academy
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Autonomous cars

The aim of the lesson:

Students will be able to recognize 5 levels of autonomous cars and describe them with their own words.

ANNEX 1

Autonomous cars - Introduction

If you're interested in the future of transport, you'll probably have heard of the autonomous vehicle levels already. Simply put, they're a set of guidelines determined by the Society of Automotive Engineers (SAE) to describe the differing levels of autonomy in driverless cars. There are currently five-ish levels in total - we'll explain why that's happened in a bit - with Level 1 being the most basic and Level 5 being the most advanced. It's pretty straightforward. What is now called Level 1 has been around for a few years now, and Level 2 is commonplace too. We're on the cusp of Level 3 and the next big thing - proper hands-off driving for long periods of time - is called Level 4 and, ultimately Level 5. For the last few years, car brands have begun to pick up and use the autonomous level terminology – the latest Audi A8's Level 3 autonomous was heavily used during its promotion – but what the levels are, or what they actually mean isn't widely publicized. To make things easier, we've explained every level of driverless tech, as well as who's in control, what features they include, and when they'll be on our roads.

Level 1 autonomous cars: a single aspect is automated

The SAE, the Society of Automotive Engineers, has created a lexicon of autonomy. Level 1, the most basic type, is where one element of the driving process is taken over in isolation, using data from sensors and cameras, but the driver is very much still in charge. This started in the late 1990s at Mercedes-Benz, with its pioneering radar-managed cruise control, while Honda introduced lane-keep assist on the 2008 Legend. These were the first steps towards removing the driver's duties behind the wheel.

- **When? The first steps in 1990s/00s**
- **Includes: Lane-keep assist, auto cruise control**
- **Who's driving? Driver *is* still in control**

Level 2 driverless cars: chips control two or more elements

Level 2 autonomy is where we're at today: computers take over multiple functions from the driver – and are intelligent enough to weave speed and steering systems together using multiple data sources. Mercedes says it's been doing this for four years. The latest Mercedes S-Class is Level 2-point-something. It takes over directional, throttle and brake functions for one of the most advanced cruise control systems yet seen – using detailed sat-nav data to brake automatically for corners ahead, keeping a set distance from the car in front and setting off again when jams clear, with the driver idle.

- **When? Current state of the art**
- **Includes: Lane-change mode, self-parking features etc**
- **Who's driving? Human hands-on at all times**

Level 2+ autonomous cars: somewhere in between

Nested in between Level 2 and Level 3, Level 2+ is more where most car makers hope to be by the end of this year. It's a level that's been coined by Nvidia, and although not quite the driverless Level 3 below, it's a little more than Level 2. With Level 2+ the driver is still alert and in control, but the vehicle is also well aware of its surroundings – and make adjustments if necessary. As well as the outside, the car is more aware of the driver too, and will monitor things like tiredness.

- **When? End of the year**
- **Includes: Driver monitoring, and more complex tasks**
- **Who's driving? Still human, but the car is aware of what's going on**

Level 3 autonomous cars: the car can boss safety-critical functions

Highly automated vehicles are not far off. The SAE calls Level 3 'conditional automation' – a specific – mode which lets all aspects of driving be done for you, but crucially the driver must be on hand to respond to a request to intervene. Audi calls its new A8 a Level 3 ready autonomous car – meaning the car has the potential to drive itself in certain circumstances, where it will assume control of all safety-critical functions. How? By refining maps, radar and sensors and fusing this environmental data with ever-wiser and faster processors and logic. Today's assumption of a two-second comms lag will soon look very slow.

- **When? The next big thing: 2020**
- **Includes: Next-gen sensors, algorithms, new laws**
- **Who's driving? Driver still on standby, but can be hands-off for periods of time**

Level 4 driverless cars: fully autonomous in controlled areas

Early next decade cars will fully drive themselves in geofenced metropolitan areas, as HD mapping, more timely data, car-to-car comms and off-site call centres (to deal with unusual hazards) improve accuracy. 'You won't really need the driver in Level 4,' says Merc's autonomous guru Christoph von Hugo. 'The likelihood is you will just be renting the car, rather than owning it. You won't take this car on vacation to Florida but you'll take it on an urban journey around New York, say. It is easier to have ultra-detailed mapping for carefully defined areas.' Twenty car makers say they'll sell autonomous cars in the US by 2022.

- **When? Due early to middle of next decade**
- **Includes: Driverless cars, shared pods**
- **Who's driving? Genuine hands-off driving**

Level 5 driverless cars: fully autonomous, anywhere. Driver optional...

The difference between Level 4 and 5 is simple: the last step towards full automation doesn't require the car to be in the so-called 'operational design domain'. Rather than working in a carefully managed (usually urban) environment with lots of dedicated lane markings or infrastructure, it'll be able to self-drive anywhere. How? Because the frequency and volume of data, and the sophistication of the computers crunching it, will mean the cars are sentient. It's a brave new world – and one that Google's Waymo car is gunning for, leapfrogging traditional manufacturers' efforts. The disruption will be huge: analysts HIS forecast 21 million autonomous vehicles globally by 2035**.**

- **When? Not long after Level 4, mid next decade**
- **Includes: Far-roaming robo taxis**
- **Who's driving? Steering wheel optional**

Sources used:

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NOTES:

Biofuels

The aim of the lesson:
Let students recognize the basic differences between fossil fuels and biofuels and their impact on the environment.

ANNEX 1

fossil fuels +	fossil fuels -	biofuels +	biofuels -

NOTES:

The opinions presented in this document are the views of the STEP AHEAD II project partnership and do not have to express the opinions of the EU.

Biofuels

The aim of the lesson:
Let students recognize the basic differences between fossil fuels and biofuels and their impact on the environment.

ANNEX 2

Source:
https://www.nationalgeographic.com/environment/global-warming/biofuel/
Promising but sometimes controversial, alternative fuels offer a path away from their fossil-based counterparts.

BY CHRISTINA NUNEZ

Group 1

Biofuels, explained

Biofuels have been around longer than cars have, but cheap gasoline and diesel have long kept them on the fringe. Spikes in oil prices, and now global efforts to stave off the worst effects of climate change, have lent new urgency to the search for clean, renewable fuels. Our road travel, flights, and shipping account for nearly a quarter of the world's greenhouse gas emissions, and transportation today remains heavily dependent on fossil fuels. The idea behind biofuel is to replace traditional fuels with those made from plant material or other feedstocks that are renewable.
But the concept of using farmland to produce fuel instead of food comes with its own challenges, and solutions that rely on waste or other feedstocks haven't yet been able to compete on price and scale with conventional fuels. Global biofuel output needs to triple by 2030 in order to meet the International Energy Agency's targets for sustainable growth.

Biofuel types and uses

There are various ways of making biofuels, but they generally use chemical reactions, fermentation, and heat to break down the starches, sugars, and other molecules in plants. The resulting products are then refined to produce a fuel that cars or other vehicles can use.
Much of the gasoline in the United States contains one of the most common biofuels: ethanol. Made by fermenting the sugars from plants such as corn or sugarcane, ethanol

contains oxygen that helps a car's engine burn fuel more efficiently, reducing air pollution. In the U.S., where most ethanol is derived from corn, fuel is typically 90 percent gasoline and 10 percent ethanol. In Brazil—the second-largest ethanol producer behind the U.S.—fuel contains up to 27 percent ethanol, with sugarcane as the main feedstock.

Alternatives to diesel fuel include biodiesel and renewable diesel. Biodiesel, derived from fats such as vegetable oil, animal fat, and recycled cooking grease, can be blended with petroleum-based diesel. Some buses, trucks, and military vehicles in the U.S. run on fuel blends with up to 20 percent biodiesel, but pure biodiesel can be compromised by cold weather and may cause problems in older vehicles. Renewable diesel, a chemically different product that can be derived from fats or plant-based waste, is considered a "drop-in" fuel that does not need to be blended with conventional diesel. Other types of plant-based fuel have been created for aviation and shipping. More than 150,000 flights have used biofuel, but the amount of aviation biofuel produced in 2018 accounted for less than 0.1 percent of total consumption. In shipping, too, adoption of biofuel is at levels far below the 2030 targets set by the International Energy Agency. Renewable natural gas, or biomethane, is another fuel that potentially could be used not only for t transportation but also heat and electricity generation. Gas can be captured from landfills, livestock operations, wastewater, or other sources. This captured biogas then must be refined further to remove water, carbon dioxide, and other elements so that it meets the standard needed to fuel natural-gas-powered vehicles.

Group 2

What is biofuel?

Biofuels are fuels produced from renewable organic materials. These fuels can be used for a range of reasons but in recent years they have played a growing role in transportation — including providing an alternative fuel for cars. There are two main types of biofuel used in cars: bioethanol and biodiesel. Bioethanol is an alcohol made from corn and sugarcane, whereas biodiesel is made using vegetable oils and animal fats. Both offer alternatives to non-renewable crude-oil derived fuels like petrol and diesel.

Is biofuel good for the environment?

Biofuels are seen as a good medium-term solution to traditional fuels as we move towards a world where electric vehicles are the norm. They are made from more sustainable energy sources than either petrol or diesel.
Bioethanol is classed as carbon-neutral, as any carbon dioxide released during production is removed from the atmosphere by the crops themselves. Biodiesel recycles otherwise unusable waste products, such as animal fats and cooking oil.
When used, biofuels produce significantly fewer pollutant emissions and toxins than fossil fuels. Bioenergy Australia estimates that biodiesel could cut emissions by over 85% compared to diesel, while bioethanol could reduce emissions by around 50%.

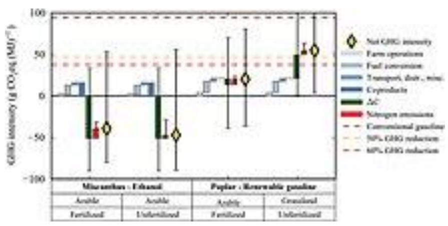
However, it is important to note that the scale of these environmental benefits is dependent on how the specific biofuels are actually produced and used.

Group 3

A biofuel is a fuel that is produced through contemporary processes from biomass, rather than a fuel produced by the very slow geological processes involved in the formation of fossil fuels, such as oil. Since biomass technically can be used as a fuel directly (e.g. wood logs), some people use the terms biomass and biofuel interchangeably. More often than not however, the word biomass simply denotes the biological raw material the fuel is made of, or some form of thermally/chemically altered solid end product, like torrefied pellets or briquettes. The word biofuel is usually reserved for liquid or gaseous fuels, used for transportation.
The EIA (U.S. Energy Information Administration) follow this naming practice.[1]
If the biomass used in the production of biofuel can regrow quickly, the fuel is generally considered to be a form of renewable energy.

Biofuel logo

Biofuels can be produced from plants (i.e. energy crops), or from agricultural, commercial, domestic, and/or industrial wastes (if the waste has a biological origin).[2] Renewable biofuels generally involve contemporary carbon fixation, such as those that occur in plants or microalgae through the process of photosynthesis.
Some argue that biofuel can be carbon-neutral because all biomass crops sequester carbon to a certain extent – basically all crops move CO2 from above-ground circulation to below-ground storage in the roots and the surrounding soil. For instance, McCalmont et al. found below-ground carbon accumulation ranging from 0.42 to 3.8 tonnes per hectare per year for soils below Miscanthus x giganteus energy crops,[3] with a mean accumulation rate of 1.84 tonne (0.74 tonnes per acre per year), [4] or 20% of total harvested carbon per year. [5]



GHG / CO2 / carbon negativity for Miscanthus x giganteus production pathways.
Relationship between above-ground yield (diagonal lines), soil organic carbon (X axis), and soil's potential for successful/unsuccessful carbon sequestration (Y axis). Basically, the higher the yield, the more land is usable as a GHG mitigation tool (including relatively carbon rich land.) However, the simple proposal that biofuel is carbon-neutral almost by definition has been superseded by the more nuanced proposal that for a particular biofuel project to be carbon neutral, the total carbon sequestered by the energy crop's root system must compensate for all the above-ground emissions (related to this particular biofuel project). This includes any emissions caused by direct or indirect land use change. Many first generation biofuel projects are not carbon neutral given these demands. Some have even higher total GHG emissions than some fossil based alternatives.[6][7][8]
Some are carbon neutral or even negative, though, especially perennial crops. The amount of carbon sequestrated and the amount of GHG (greenhouse gases) emitted will determine if the total GHG life cycle cost of a biofuel project is positive, neutral or negative. A carbon negative life cycle is possible if the total below-ground carbon accumulation more than compensates for the total life-cycle GHG emissions above ground. In other words, to achieve carbon neutrality yields should be high and emissions should be low.
High-yielding energy crops are thus prime candidates for carbon neutrality. The graphic on the right displays two CO2 negative Miscanthus x giganteus production pathways, represented in gram CO2-equivalents per megajoule. The yellow diamonds represent mean values. [9]
Further, successful sequestration is dependent on planting sites, as the best soils for sequestration are those that are currently low in carbon. The varied results displayed in the graph highlights this fact. [10] For the UK, successful sequestration is expected for arable land over most of England and Wales, with unsuccessful sequestration expected in parts of Scotland, due to already carbon rich soils (existing woodland) plus lower yields. Soils already rich in carbon includes peatland and mature forest. Grassland can also be carbon rich, however Milner et al. argues that the most successful carbon sequestration in the UK takes place below improved grasslands. [11] The bottom graphic displays the estimated yield necessary to compensate for related lifecycle GHG-emissions.
The higher the yield, the more likely CO2 negativity becomes.
The two most common types of biofuel are bioethanol and biodiesel.

NOTES:

CAN Bus

The aim of the lesson:
Understanding CAN bus working principles in automotive industry and learn basic diagnostic of CAN.

ANNEX 1

CAN NETWORK

What is it
A Controller Area Network (CAN bus) is a robust vehicle bus standard designed to allow microcontrollers and devices to communicate with each other in applications without a host computer. It is a message-based protocol, designed originally for multiplex electrical wiring within automobiles to save on copper, but is also used in many other contexts.

Applications

- Passenger vehicles, trucks, buses (gasoline vehicles and electric vehicles)
- Electronic equipment for aviation and navigation
- Industrial automation and mechanical control
- Elevators, escalators
- Building automation
- Medical instruments and equipment

The modern automobile may have as many as 70 electronic control units (ECU) for various subsystems.[7] Typically the biggest processor is the engine control unit. Others are used for transmission, airbags, antilock braking/ABS, cruise control, electric power steering, audio systems, power windows, doors, mirror adjustment, battery and recharging systems for hybrid/electric cars, etc. Some of these form independent subsystems, but communications among others are essential. A subsystem may need to control actuators or receive feedback from sensors. The CAN standard was devised to fill this need. One key advantage is that interconnection between different vehicle systems can allow a wide range of safety, economy and convenience features to be implemented using software alone - functionality which would add cost and complexity if such features were "hard wired" using traditional automotive electrics.

Examples include:

- **Auto start/stop:** Various sensor inputs from around the vehicle (speed sensors, steering angle, air conditioning on/off, engine temperature) are collated via the CAN bus to determine whether the engine can be shut down when stationary for improved fuel economy and emissions.
- **Electric park brakes**: The "hill hold" functionality takes input from the vehicle's tilt sensor (also used by the burglar alarm) and the road speed sensors (also used by the ABS, engine control and traction control) via the CAN bus to determine if the vehicle is stopped on an incline. Similarly, inputs from seat belt sensors (part of the airbag controls) are fed from the CAN bus to determine if the seat belts are fastened, so that the parking brake will automatically release upon moving off.
- **Parking assist** systems: when the driver engages reverse gear, the transmission control unit can send a signal via the CAN bus to activate both the parking sensor system and the door control module for the passenger side door mirror to tilt downward to show the position of the curb. The CAN bus also takes inputs from the rain sensor to trigger the rear windscreen wiper when reversing.
- Auto **lane assist**/**collision avoidance** systems: The inputs from the parking sensors are also used by the CAN bus to feed outside proximity data to driver assist systems such as Lane Departure warning, and more recently, these signals travel through the CAN bus to actuate brake by wire in active collision avoidance systems.
- **Auto brake wiping**: Input is taken from the rain sensor (used primarily for the automatic windscreen wipers) via the CAN bus to the ABS module to initiate an imperceptible application of the brakes whilst driving to clear moisture from the brake rotors. Some high performance Audi and BMW models incorporate this feature.
- **Sensors** can be placed at the most suitable place, and its data used by several ECU. For example, outdoor temperature sensors (traditionally placed in the front) can be placed in the outside mirrors, avoiding heating by the engine, and data used by both the engine, the climate control and the driver display.

CAN is a multi-master serial bus standard for connecting **Electronic Control Units [ECUs]** also known as **nodes**. Two or more nodes are required on the CAN network to communicate. The complexity of the node can range from a simple I/O device up to an embedded computer with a CAN interface and sophisticated software. The node may also be a gateway allowing a general purpose computer (such as a laptop) to communicate over a USB or Ethernet port to the devices on a CAN network.

All nodes are connected to each other through a two wire bus. The wires are a twisted pair with a 120 Ω (nominal) characteristic impedance.

ISO 11898-2, also called high speed CAN (512 Kbps), uses a linear bus terminated at each end with 120 Ω resistors. High speed CAN signaling drives the CAN high wire towards 5 V and the CAN low wire towards 0 V when transmitting a dominant (0), and does not drive either wire when transmitting a recessive (1). Designating "0" as dominant gives the nodes with the lower ID numbers priority on the bus. The dominant differential voltage is a nominal 2 V. The termination resistor passively returns the two wires to a nominal differential voltage of 0 V. The dominant common mode voltage must be within 1.5 to 3.5 V of common and the recessive common mode voltage must be within +/-12 of common.

ISO 11898-3, also called low speed or fault tolerant CAN (128 Kbps), uses a linear bus, star bus or multiple star buses connected by a linear bus and is terminated at each node by a fraction of the overall termination resistance. The overall termination resistance should be about 100 Ω, but not less than 100 Ω. Low speed/Fault tolerant CAN signaling drives the CAN high wire towards 5 V and the CAN low wire towards 0 V when transmitting a dominant (0), and does not drive either wire when transmitting a recessive (1). The dominant differential voltage must be greater than 2.3 V (with a 5 V Vcc) and the recessive differential voltage must be less than 0.6 V The termination resistors passively return the CAN low wire to RTH where RTH is a minimum of 4.7 V (Vcc - 0.3 V where Vcc is 5 V nominal) and the CAN high wire to RTL where RTL is a maximum of 0.3 V. Both wires must be able to handle -27 to 40 V without damage.

With both high speed and low speed CAN, the speed of the transition is faster when a recessive to dominant transition occurs since the CAN wires are being actively driven. The speed of the dominant to recessive transition depends primarily on the length of the CAN network and the capacitance of the wire used.

High speed CAN is usually used in automotive and industrial applications where the bus runs from one end of the environment to the other. Fault tolerant CAN is often used where groups of nodes need to be connected together.

The specifications require the bus be kept within a minimum and maximum common mode bus voltage, but do not define how to keep the bus within this range.

The CAN bus must be terminated. The termination resistors are needed to suppress reflections as well as return the bus to its recessive or idle state.

High speed CAN uses a 120 Ω resistor at each end of a linear bus. Low speed CAN uses resistors at each node. Other types of terminations may be used such as the Terminating Bias Circuit defined in ISO11783 [9]

A terminating bias circuit provides power and ground in addition to the CAN signaling on a four-wire cable. This provides automatic electrical bias and termination at each end of each bus segment. An ISO11783 network is designed for hot plug-in and removal of bus segments and ECUs.

CAN data transmission uses a lossless bitwise arbitration method of contention resolution. This arbitration method requires all nodes on the CAN network to be synchronized to sample every bit on the CAN network at the same time. This is why some call CAN synchronous. Unfortunately the term synchronous is imprecise since the data is transmitted without a clock signal in an asynchronous format.

The CAN specifications use the terms **"dominant"** bits and **"recessive"** bits where dominant is a logical 0 (actively driven to a voltage by the transmitter) and recessive is a logical 1 (passively returned to a voltage by a resistor). The idle state is represented by the recessive level (Logical 1). If one node transmits a dominant bit and another node transmits a recessive bit then there is a collision and the dominant bit "wins". This means there is no delay to the higher-priority message, and the node transmitting the lower priority message automatically attempts to re-transmit six bit clocks after the end of the dominant message. This makes CAN very suitable as a real time prioritized communications system.

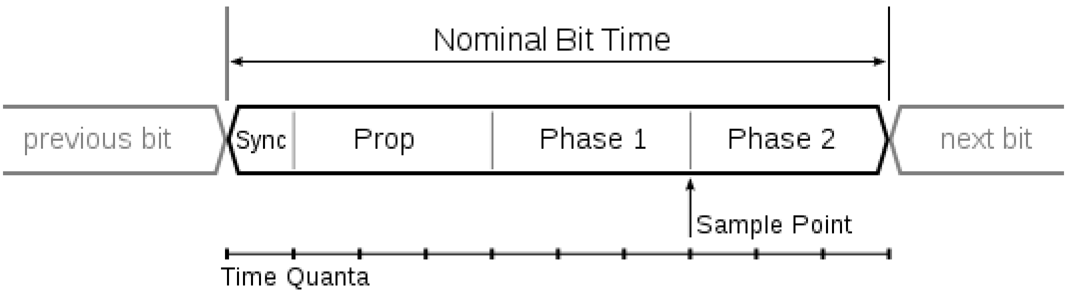
The exact voltages for a logical 0 or 1 depend on the physical layer used, but the basic principle of CAN requires that each node listens to the data on the CAN network including the transmitting node(s) itself (themselves). If a logical 1 is transmitted by all transmitting nodes at the same time, then a logical 1 is seen by all of the nodes, including both the transmitting node(s) and receiving node(s). If a logical 0 is transmitted by all transmitting node(s) at the same time, then a logical 0 is seen by all nodes. If a logical 0 is being transmitted by one or more nodes, and a logical 1 is being transmitted by one or more nodes, then a logical 0 is seen by all nodes including the node(s) transmitting the logical 1. When a node transmits a logical 1 but sees a logical 0, it realizes that there is a contention and it quits transmitting. By using this process, any node that transmits a logical 1 when another node transmits a logical 0 "drops out" or loses the arbitration. A node that loses arbitration re-queues its message for later transmission and the CAN frame bit-stream continues without error until only one node is left transmitting. This means that the node that transmits the first 1 loses arbitration. Since the 11 (or 29 for CAN 2.0B) bit identifier is transmitted by all nodes at the start of the CAN frame, the node with the lowest identifier transmits more zeros at the start of the frame, and that is the node that wins the arbitration or has the highest priority.

For example, consider an 11-bit ID CAN network, with two nodes with IDs of 15 (binary representation, 00000001111) and 16 (binary representation, 00000010000). If these two nodes transmit at the same time, each will first transmit the start bit then transmit the first six zeros of their ID with no arbitration decision being made.

All nodes on the CAN network must operate at the same nominal bit rate, but noise, phase shifts, oscillator tolerance and oscillator drift mean that the actual bit rate may not be the same as the nominal bit rate. Since a separate clock signal is not used, a means of synchronizing the nodes is necessary. Synchronization is important during arbitration since the nodes in arbitration must be able to see both their transmitted data and the other nodes' transmitted data at the same time. Synchronization is also important to ensure that variations in oscillator timing between nodes do not cause errors.

Synchronization starts with a hard synchronization on the first recessive to dominant transition after a period of bus idle (the start bit). Resynchronization occurs on every recessive to dominant transition during the frame. The CAN controller expects the transition to occur at a multiple of the nominal bit time. If the transition does not occur at the exact time the controller expects it, the controller adjusts the nominal bit time accordingly.

The adjustment is accomplished by dividing each bit into a number of time slices called quanta, and assigning some number of quanta to each of the four segments within the bit: synchronization, propagation, phase segment 1 and phase segment 2.



An example CAN bit timing with 10 time quanta per bit.

The number of quanta the bit is divided into can vary by controller, and the number of quanta assigned to each segment can be varied depending on bit rate and network conditions.

A transition that occurs before or after it is expected causes the controller to calculate the time difference and lengthen phase segment 1 or shorten phase segment 2 by this time. This effectively adjusts the timing of the receiver to the transmitter to synchronize them. This resynchronization process is done continuously at every recessive to dominant transition to ensure the transmitter and receiver stay in sync. Continuously resynchronizing reduces errors induced by noise, and allows a receiving node that was synchronized to a node which lost arbitration to resynchronize to the node which won arbitration.

A CAN network can be configured to work with two different message (or "frame") formats: the standard or base frame format (described in CAN 2.0 A and CAN 2.0 B), and the extended frame format (only described by CAN 2.0 B). The only difference between the two formats is that the "CAN base frame" supports a length of 11 bits for the identifier, and the "CAN extended frame" supports a length of 29 bits for the identifier, made up of the 11-bit identifier ("base identifier") and an 18-bit extension ("identifier extension"). The distinction between CAN base frame format and CAN extended frame format is made by using the IDE bit, which is transmitted as dominant in case of an 11-bit frame, and transmitted as recessive in case of a 29-bit frame. CAN controllers that support extended frame format messages are also able to send and receive messages in CAN base frame format. All frames begin with a start-of-frame (SOF) bit that denotes the start of the frame transmission.

CAN has four frame types:

- **Data frame:** a frame containing node data for transmission
- **Remote frame:** a frame requesting the transmission of a specific identifier
- **Error frame:** a frame transmitted by any node detecting an error
- **Overload frame:** a frame to inject a delay between data or remote frame

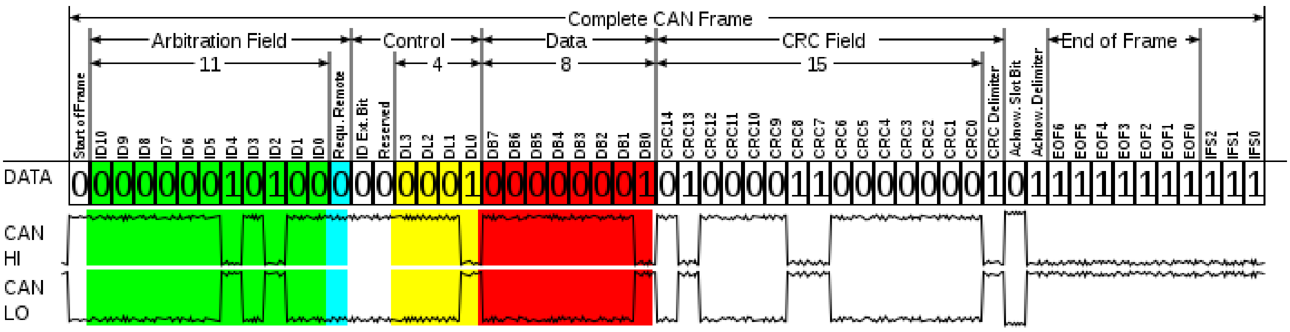
Data frame

The data frame is the only frame for actual data transmission. There are two message formats:

- Base frame format: with 11 identifier bits
- Extended frame format: with 29 identifier bits

The CAN standard requires the implementation must accept the base frame format and may accept the extended frame format, but must tolerate the extended frame format.

Base frame format



The frame format is as follows: The bit values are described for CAN-LO signal.

Field name	**Length (bits)**	**Purpose**
Start-of-frame	1	Denotes the start of frame transmission
Denotes the start of frame transmission	11	A (unique) identifier which also represents the message priority
Remote transmission request (RTR) (blue)	1	Must be dominant (0) for data frames and recessive (1) for remote request frames (see Remote Frame, below)
Identifier extension bit (IDE)	1	Must be dominant (0) for base frame format with 11-bit identifiers
Reserved bit (r0)	1	Reserved bit. Must be dominant (0), but accepted as either dominant or recessive.
Data length code (DLC) (yellow)	4	Number of bytes of data (0–8 bytes)[a]
Data field (red)	0–64 (0-8 bytes)	Data to be transmitted (length in bytes dictated by DLC field)
CRC	15	Cyclic redundancy check
CRC delimiter	1	Must be recessive (1)
ACK slot	1	Transmitter sends recessive (1) and any receiver can assert a dominant (0)
ACK delimiter	1	Must be recessive (1)
End-of-frame (EOF)	7	Must be recessive (1)

1. It is physically possible for a value between 9–15 to be transmitted in the 4-bit DLC, although the data is still limited to eight bytes. Certain controllers allow the transmission or reception of a DLC greater than eight, but the actual data length is always limited to eight bytes.

Extended frame format

The frame format is as follows:

Field name	**Length (bits)**	**Purpose**
Start-of-frame	1	Denotes the start of frame transmission
Identifier A (green)	11	First part of the (unique) identifier which also represents the message priority
Substitute remote request (SRR)	1	Must be recessive (1)

Identifier extension bit (IDE)	1	Must be recessive (1) for extended frame format with 29-bit identifiers
Identifier B (green)	18	Second part of the (unique) identifier which also represents the message priority
Remote transmission request (RTR) (blue)	1	Must be dominant (0) for data frames and recessive (1) for remote request frames (see Remote Frame, below)
Reserved bits (r1, r0)	2	Reserved bits which must be set dominant (0), but accepted as either dominant or recessive
Data length code (DLC) (yellow)	4	Number of bytes of data (0–8 bytes)[a]
Data field (red)	0–64 (0-8 bytes)	Data to be transmitted (length dictated by DLC field)
CRC	15	Cyclic redundancy check
CRC delimiter	1	Must be recessive (1)
ACK slot	1	Transmitter sends recessive (1) and any receiver can assert a dominant (0)
ACK delimiter	1	Must be recessive (1)
End-of-frame (EOF)	7	Must be recessive (1)

1. It is physically possible for a value between 9–15 to be transmitted in the 4-bit DLC, although the data is still limited to eight bytes. Certain controllers allow the transmission or reception of a DLC greater than eight, but the actual data length is always limited to eight bytes.

The two identifier fields (A & B) combine to form a 29-bit identifier.

Remote frame

- Generally data transmission is performed on an autonomous basis with the data source node (e.g., a sensor) sending out a Data Frame. It is also possible, however, for a destination node to request the data from the source by sending a Remote Frame.
- There are two differences between a Data Frame and a Remote Frame. Firstly the RTR-bit is transmitted as a dominant bit in the Data Frame and secondly in the Remote Frame there is no Data Field. The DLC field indicates the data length of the requested message (not the transmitted one)

i.e.,

RTR = 0 ; **DOMINANT** in data frame
RTR = 1 ; **RECESSIVE** in remote frame

In the event of a Data Frame and a Remote Frame with the same identifier being transmitted at the same time, the Data Frame wins arbitration due to the dominant RTR bit following the identifier.

Error frame

The error frame consists of two different fields:

- The first field is given by the superposition of ERROR FLAGS (6–12 dominant/recessive bits) contributed from different stations.
- The following second field is the ERROR DELIMITER (8 recessive bits).

There are two types of error flags:

Active Error Flag

six dominant bits – Transmitted by a node detecting an error on the network that is in error state "error active".

Passive Error Flag

six recessive bits – Transmitted by a node detecting an active error frame on the network that is in error state "error passive".

There are two error counters in CAN:

1. **Transmit error counter** (TEC)
2. **Receive error counter (**REC)

- When TEC or REC is greater than 127 and lesser than 255, a Passive Error frame will be transmitted on the bus.
- When TEC and REC is lesser than 128, an Active Error frame will be transmitted on the bus.
- When TEC is greater than 255, then the node enters into Bus Off state, where no frames will be transmitted.

Overload frame

The overload frame contains the two - bit fields Overload Flag and Overload Delimiter. There are two kinds of overload conditions that can lead to the transmission of an overload flag:

1. The internal conditions of a receiver, which requires a delay of the next data frame or remote frame.
2. Detection of a dominant bit during intermission.

The start of an overload frame due to case 1 is only allowed to be started at the first bit time of an expected intermission, whereas overload frames due to case 2 start one bit after detecting the dominant bit. Overload Flag consists of six dominant bits. The overall form corresponds to that of the active error flag. The overload flag's form destroys the fixed form of the intermission field. As a consequence, all other stations also detect an overload condition and on their part start transmission of an overload flag. Overload Delimiter consists of eight recessive bits. The overload delimiter is of the same form as the error delimiter.

Links to videos:

- https://www.youtube.com/watch?v=FqLDpHsxvf8
- https://www.youtube.com/watch?v=Gi7mxVmzLkM
- https://www.youtube.com/watch?v=YrJn2AyWVBc
- https://www.youtube.com/watch?v=dwU5aEbsgLM
- https://www.snapon.com/Diagnostics/US/KB/CAN-Bus-Diagnostics.htm

Links to material:

- http://download.ni.com/pub/devzone/tut/can_tutorial.pdf
- http://www.ni.com/en-us/innovations/white-papers/06/controller-area-network--can--overview.html
- https://www.csselectronics.com/screen/page/simple-intro-to-can-bus/language/en
- https://www.aa1car.com/library/can_systems.htm
- http://www.esd-electronics-usa.com/CAN-Bus-Troubleshooting-Guide.html
- https://pmmonline.co.uk/technical/can-bus-fault-finding-tips-and-hints-part-1/
- http://pmmonline.co.uk/technical/can-bus-fault-finding-tips-and-hints-part-2/
- https://www.consulab.com/files/canBusHandout.pdf

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Electric Cars - Traction batteries

The aim of the lesson:
Introduction to electric cars contribution to environmental issues, considering it from its production point of view, and also the electric energy consumption for consecutive battery charging.

APPENDIX 1

Introduction

In electric cars, the traction electric motor transforms the electric alternating power into mechanical power to propel the vehicle. This process also happens the other way around. Reverse gear is done by the reversal of the original engine working direction.

In electric cars we can observe some pieces using high voltage (HV), low voltage (LV), direct current voltage (DC) and alternating current (AC)

Traction battery

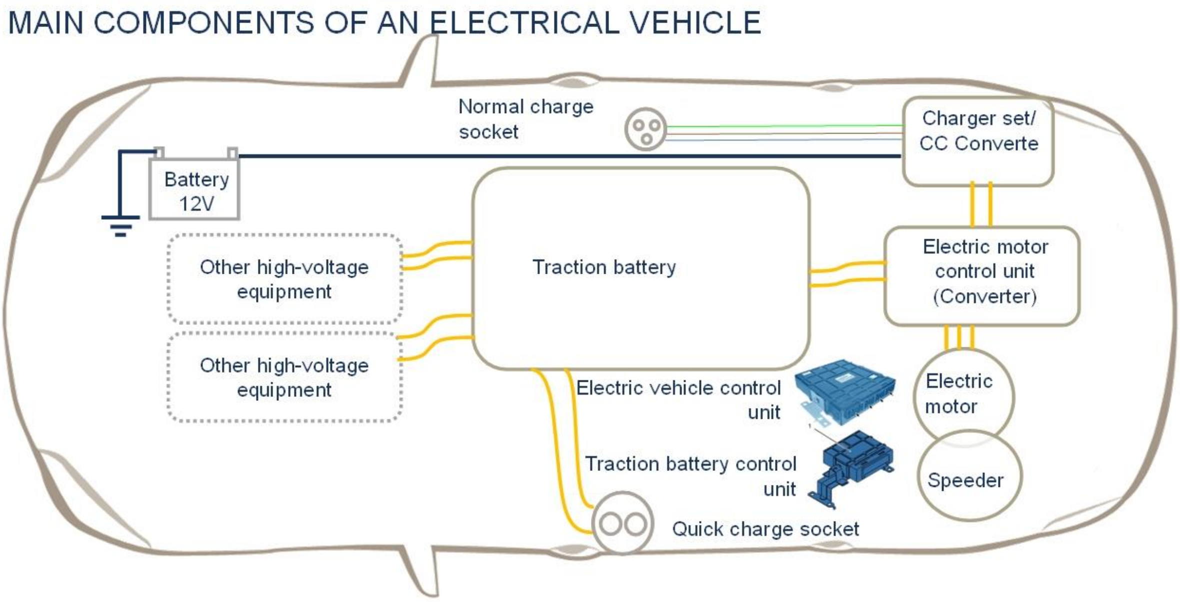
The electric power required to move a car is provided by the traction battery, although within the car we can find other type of conventional batteries for accessories.

Traction batteries use direct current voltage and the technology used to produce it, in electric vehicles, is Ion-Lithium. This technology allows to charge batteries at any moment, without waiting for complete charge and discharge cycles to be finished.

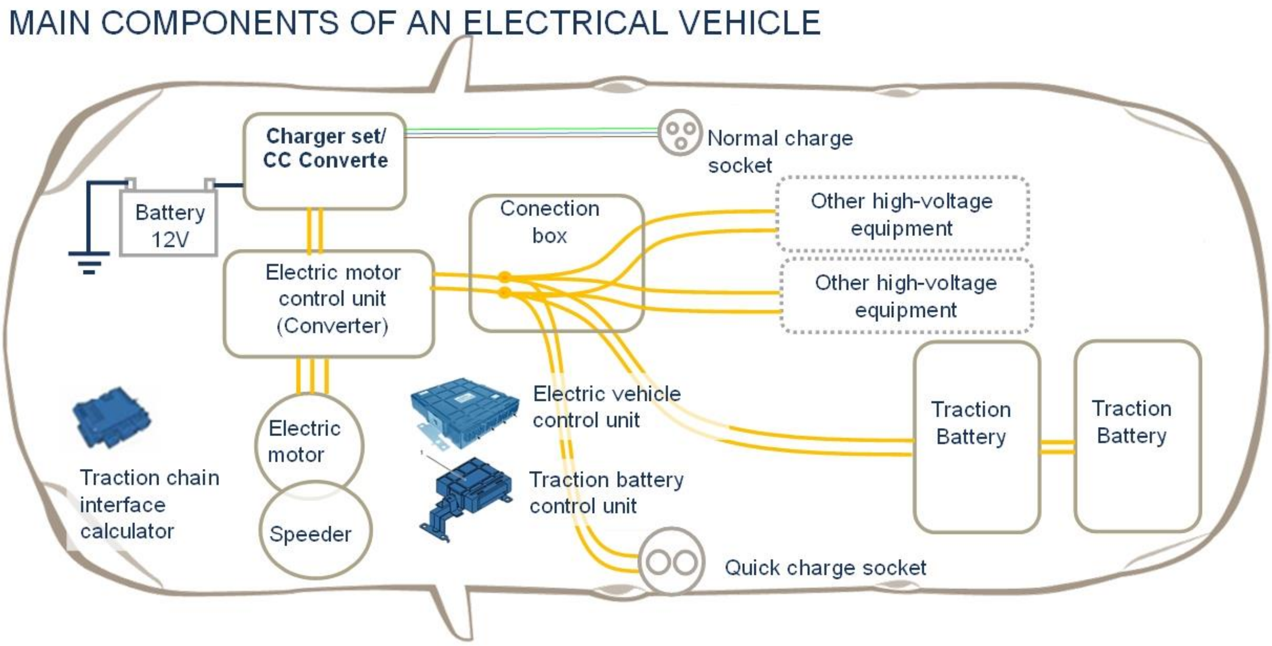
Image by http://www.aficionadosalamecanica.com/coche-electrico_bateria.htm for teaching use only, no commercial use allowed.

The efficiency of any car using an electric engine reaches 90%, meanwhile those cars using combustion engines just reach 18%.

In the following image you can observe different constitutive elements of an electric car with rear wheels traction.



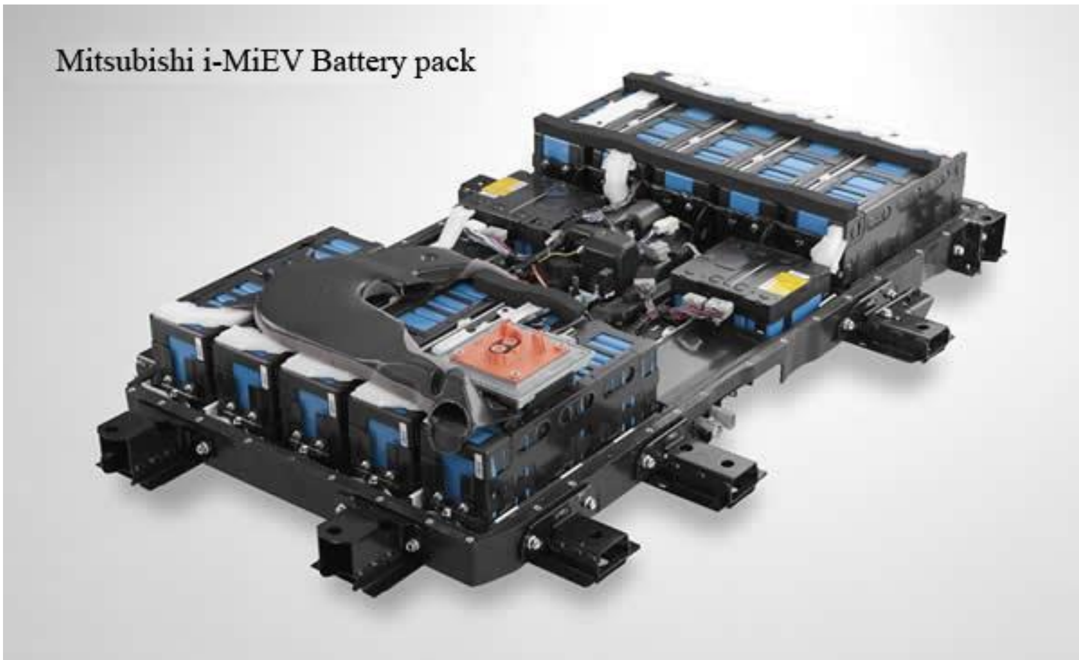
On the following plan you can see something similar for front wheels traction.



Traction Batteries

The following show the three main types of batteries we can find in nowadays electric vehicles. (also in hybrid and plug-in hybrid cars)

Ion Lithium battery



Battery used by Mitsubishi I-MiEV
http://www.aficionadosalamecanica.com/coche-electrico_bateria.htm

This type of battery technology is used in most electric cars we can find in the market today and also in part of plug - in hybrid cars. The battery fits within the available space we find below the seats.

The battery consists of cells. Each Ion Lithium cell provides a voltage of 3.7 nominal Volts. 50 Ah. 88 of these cells are placed in series. Those cells are gathered in 6 units modules connected in series, in such a way that each of those modules has about 147 V and 50 Ah. The total voltage provided is 330 volts with a charging capacity of 16Kwh.

Lithium - metal - Polymer battery (LMP)

It is a dry battery with a long operating life. They are batteries on continuous discharging, the car should be plugged during parking.

Nickel metal hydride battery (Ni-MH)

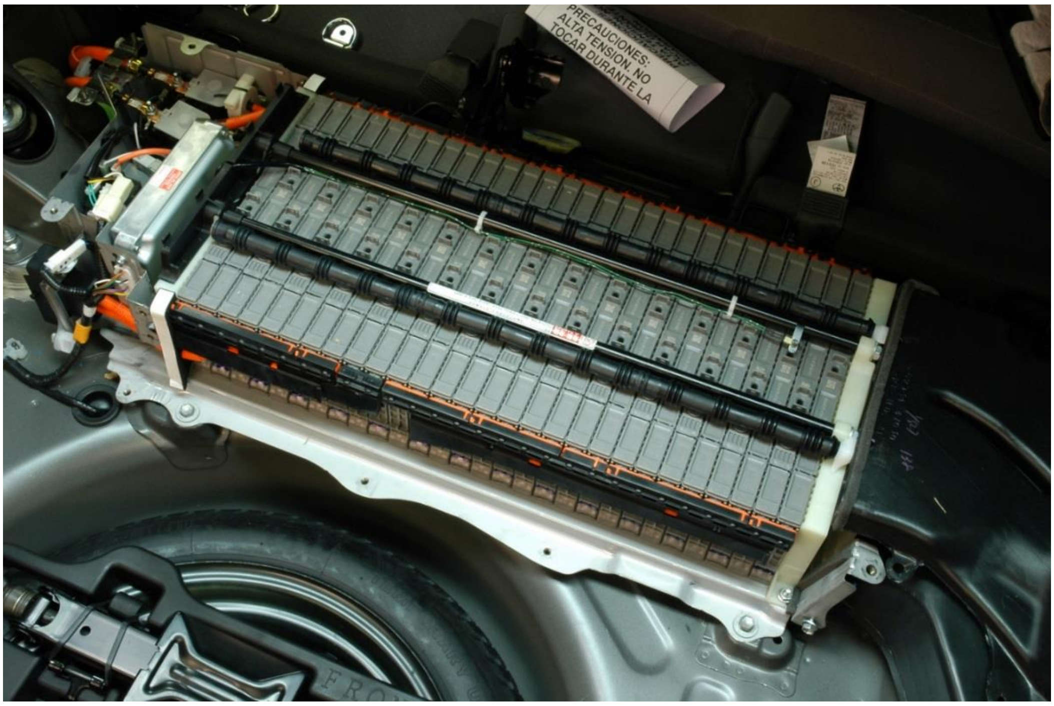
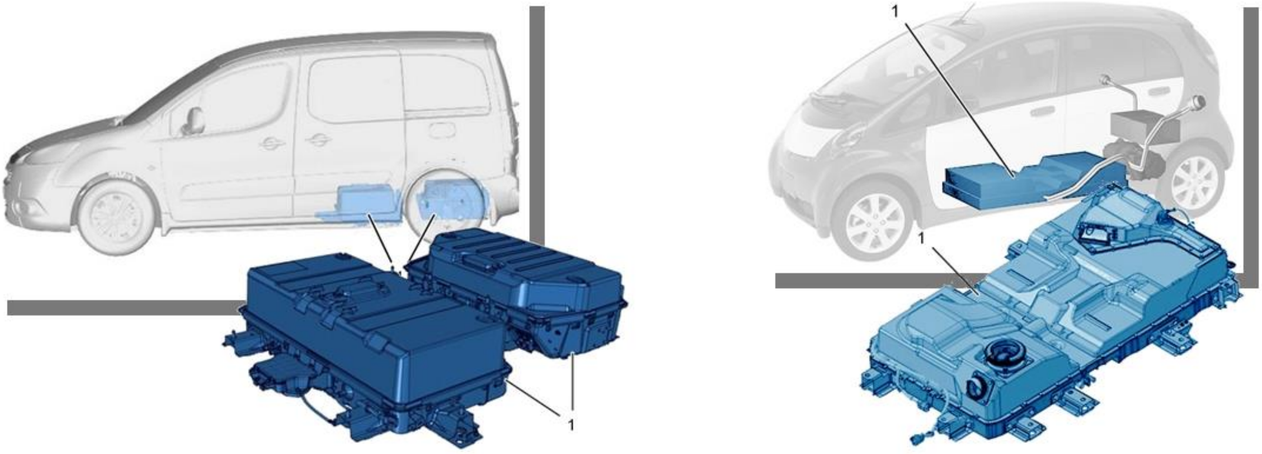


Image courtesy of CEIP Virgen del Camino in Navarra (España) from the project Step Ahead

They are placed on a great number of hybrid vehicles. These batteries have a longer duration and they are safer than those of Ion-Lithium, as they are not using flammable liquids, so they are less likely to burn in case of over-heating or battery overcharging. The cooling systems and the electronic control are less complex.

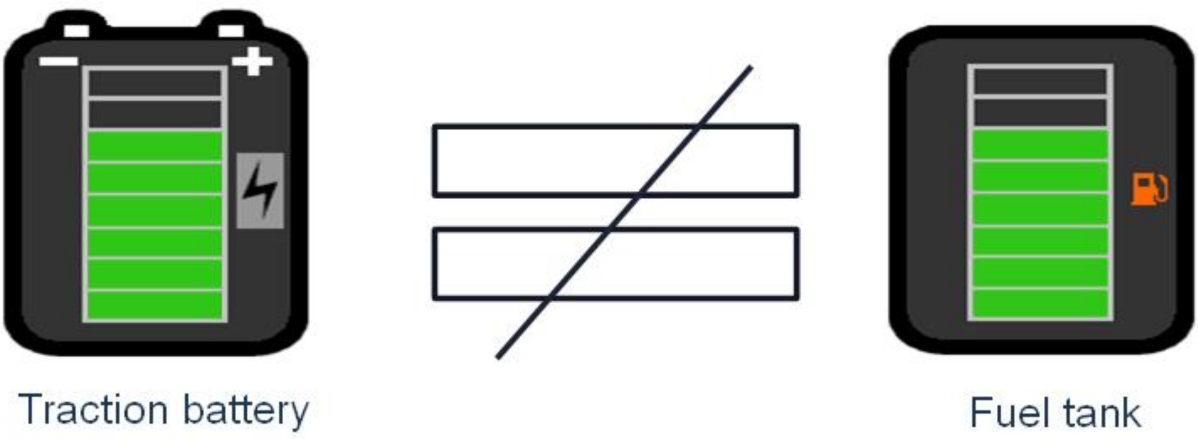
Ion-Lithium batteries position in vehicles



Traction batteries cannot be open at the garage. It is forbidden because of safety reasons.

Battery charge status

The charge markers only show the charge status of the traction battery but not its health status (capacity, range). In contrast to a combustion engine vehicle, a completely full battery (traction battery reaching 100 of its charging status) will not mean the same vehicle range.

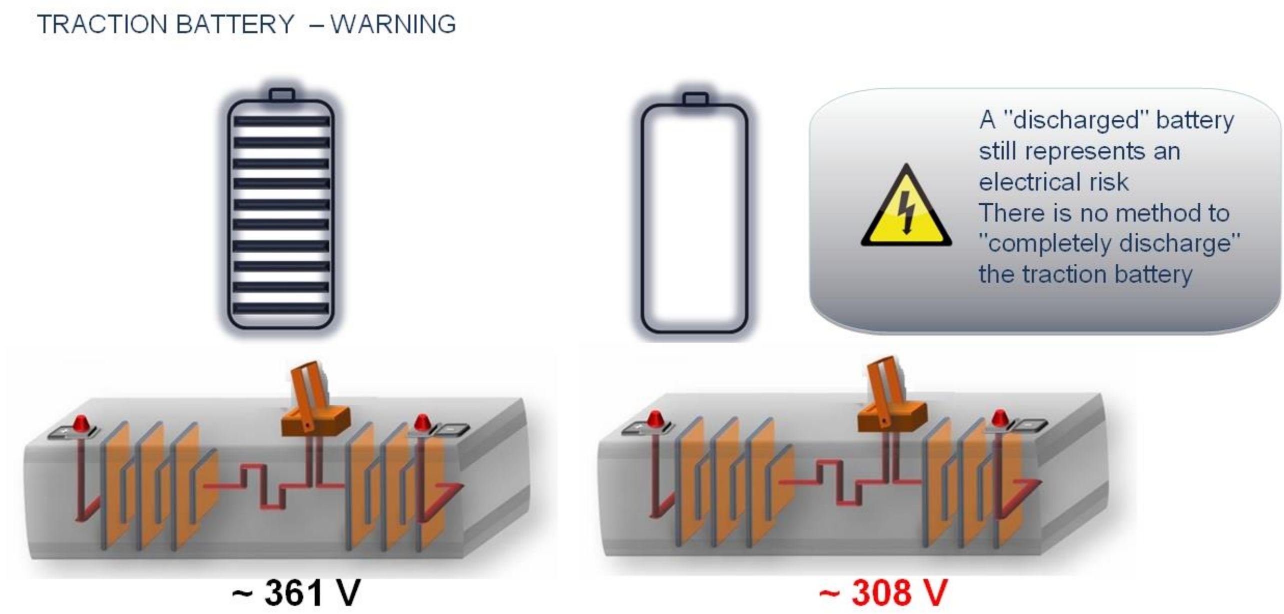


Inappropriate use of a battery (for example, when there is no balance of cells) will result in a degradation of its charging capacity. A specific number of parameters cause battery damage:

The age of the battery and/or its inactivity: the older the battery, the lower its capacity to store energy.

The battery temperature (and indirectly, environmental temperature): higher temperatures, speed battery ageing. An environmental temperature too low, prevent strong charging and discharging currents, and the vehicle performance is limited.

By "updating the charge capacity of a traction battery" we need to know the real evolution of the battery capacity, to avoid some misinformation about the car range.



As we have previously explained, batteries consist of a number of cells, that is, small batteries connected to each other to get high voltage and be able to provide high amperage as well. These small batteries imply some kind of maladjustment during charging and discharging processes, so it can became a problem causing lack of efficiency or even danger as a consequence of their battery overcharging in some of them. Then, it is very important the balancing process of those cells in a battery, to lengthen their life and also to avoid any unnecessary risks.

In the following video you can see how to do an active balancing of battery cells. The video doesn't have a voice-over explaining the process but it is very informative, though. Images are enough.

Watch video by AutarcTech GmbH (https://www.youtube.com/channel/UC_N4LbiSJfb-oDiHFkyFfqA) at: https://www.youtube.com/watch?v=jzRRivm-Osk

The real capacity of a battery is important to calculate the vehicle range. The traction battery calculator establishes a theoretical model showing the evolution of its capacity (ageing).

Eventually and according to the vehicle use, the real capacity of the battery evolves in a different way from the one foreseen by the theoretical model.

It is important to correct the value assignments according to the real capacity of the battery in order to obtain the real percentage of range and charge level.

An updating process of the real capacity of the traction battery must be done (depending on the car):
- During the new vehicle preparation for delivery to the customer.
- During regular inspections (have a look at the maintenance check-list)

To optimize the battery charging process these patterns should be considered:

- A full charge should be carried out every other week.
- To make sure it is a full charge, normal procedure must be followed (at a home electricity network) without being interrupted till the process is automatically finished. That moment will be indicated by the charge light which going out at the car control panel.
- In addition, every three months this recharging process must be done for the main battery, from a slightly below or equal to three segments charging level
- This same procedure must be done every three months if the car is going to be immobilized for a long time, checking in advance that the accessories battery is not discharged or unplugged.

APPENDIX 2

Video Transcription:

https://www.youtube.com/watch?v=17xh_VRrnMU

0:00
Do electric cars really help the environment? President Obama thinks so.
0:05
So does Leonardo DiCaprio. And many others.
0:08
The argument goes like this:
0:10
Regular cars run on gasoline, a fossil fuel that pumps CO2 straight out of the tailpipe
0:15
and into the atmosphere. Electric cars run on electricity. They don’t burn any gasoline at all.
0:21
No gas; no CO2. In fact, electric cars are often advertised as creating “zero emissions.”
0:29
But do they really? Let’s take a closer look.
0:33
First, there’s the energy needed to produce the car. More than a third of the lifetime
0:38
carbon-dioxide emissions from an electric car comes from the energy used make the car
0:43
itself, especially the battery. The mining of lithium, for instance, is not a green activity.
0:50
When an electric car rolls off the production line, it’s already been responsible for
0:54
more than 25,000 pounds of carbon-dioxide emission. The amount for making a conventional car:
1:01

just 16,000 pounds.
1:03
But that’s not the end of the CO2 emissions. Because while it’s true that electric cars
1:09
don’t run on gasoline, they do run on electricity, which, in the US is often produced by another
1:15
fossil fuel -- coal. As green venture capitalist Vinod Khosla likes to point out,
1:21
"Electric cars are coal-powered cars."
1:25
The most popular electric car, the Nissan Leaf, over a 90,000-mile lifetime will emit
1:31
31 metric tons of CO2, based on emissions from its production, its electricity consumption
1:37
at average U.S. fuel mix and its ultimate scrapping.
1:41
A comparable Mercedes CDI A160 over a similar lifetime will emit just 3 tons more across
1:48
its production, diesel consumption and ultimate scrapping. The results are similar for a top-line
1:54
Tesla, the king of electric cars. It emits about 44 tons, which is only 5 tons less
2:01
than a similar Audi A7 Quattro.
2:04
So throughout the full life of an electric car, it will emit just three to five tons less CO2.
2:12
In Europe, on its European Trading System, it currently costs $7 to cut one ton of CO2.
2:19
So the entire climate benefit of an electric car is about $35. Yet the U.S. federal
2:26
government essentially provides electric car buyers with a subsidy of up to $7,500.
2:32
Paying $7,500 for something you could get for $35 is a very poor deal. And that doesn’t
2:40
include the billions more in federal and state grants, loans and tax write-offs that go directly
2:46
to battery and electric-car makers.
2:48
The other main benefit from electric cars is supposed to be lower pollution.
2:53
But remember Vinod Khosla’s observation "Electric cars are coal-powered cars."
2:59
Yes, it might be powered by coal, proponents will say, but unlike the regular car,
3:04
coal plant emissions are far away from the city centers where most people live and where damage
3:09
from air pollution is greatest. However, new research in Proceedings of the National Academy
3:15

of Sciences found that while gasoline cars pollute closer to home, coal-fired power actually
3:22
pollutes more -- a lot more. How much more?
3:25
Well, the researchers estimate that if the U.S. has 10% more gasoline cars in 2020, 870
3:33
more people will die each year from the additional air pollution. If the U.S. has 10% more electric
3:39
vehicles powered on the average U.S. electricity mix, 1,617 more people will die every year
3:46
from the extra pollution. Twice as many.
3:50
But of course electricity from renewables like solar and wind creates energy for electric
3:55
cars without CO2. Won't the perceived rapid ramp-up of these renewables make future electric
4:01
cars much cleaner? Unfortunately, this is mostly wishful thinking. Today, the U.S. gets
4:08
14% of its electric power from renewables. In 25 years, Obama's Energy Information
4:14
Administration estimates that number will have gone up just 3 percentage points to 17%.
4:21
Meanwhile, those fossil fuels that generate 65% of U.S. electricity today will still generate
4:28
about 64% of it in 2040.
4:32
While electric-car owners may cruise around feeling virtuous, the reality is that the
4:37
electric car cuts almost no CO2, costs taxpayers a fortune, and, surprisingly, generates more
4:44
air pollution than traditional gasoline cars.
4:47
I'm Bjørn Lomborg, president of the Copenhagen Consensus Center.

NOTE: *Images and some other artwork are used with permission by the authors of the presentation in Ribadeo (Galicia- Spain) 2019 about electric vehicles by PSA for its didactic use, non-profit, belonging to the project Erasmus + "Step Ahead". The rest of the images sources are shown on the caption and they are licensed for this didactic, non-profit use.*

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Full hybrids

The aim of the lesson: Make a difference between various hybrid systems in automotive technology and turn focus on Full Hybrid System

ANNEX 1

Micro Hybrid & Hybrid Vehicles Explained
Source: https://www.yuasa.co.uk/info/technical/micro-hybrid-hybrid-vehicles-explained/

Stop/Start Technologies & Functionality (Micro hybrid 1)

Initially a manual system now becoming fully automatic, switches off the engine when the vehicle is stationary. The engine is restarted automatically by releasing the brake and depressing the accelerator pedal or clutch pedal dependent on transmission type. Initial Stop/Start systems could be manually switched off, but on next generation vehicles this option is disabled
Increases the number engine starts the battery has to deliver as well as supporting all of the electrical loads on the vehicle whilst the engine is stopped and the vehicle charging system is not operating
Requires new electronic methods of monitoring the battery status including State of Charge (SOC) and State of Health (SOH). As the number of Stop/Start cycles required are increased, the vehicle must be able to determine if the engine can restart when the vehicle comes to rest and the engine is switched off

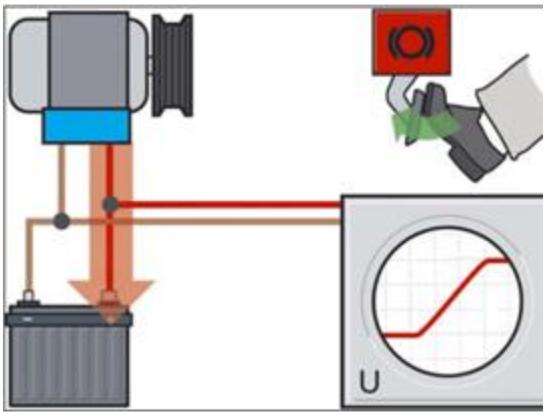
Initial Stop/Start systems would function if the ambient temperature was below 3°C whereas the latest systems are projected to operate at -10°C. This reduction in system operating temperature increases the demand on the battery to supply minimum voltages to the electronic circuits and control modules on the vehicle when cranking the engine
Various vehicle manufacturers state that, on their standard European drive cycles a typical fuel saving of up to 8% can be achieved by the installation of a Stop/Start system. This in current terms of electronics technology means a relatively low cost solution to reduce exhaust emissions.

New technologies such as the Enhanced Flooded Battery (EFB) and AGM (Absorbed Glass Mat) battery have been developed to achieve the new higher duty cycle requirements placed on the battery by particular OEM vehicle manufacturers
The introduction of Stop/Start technology has resulted in a new band of battery failure modes not previously experienced by vehicle manufacturers. This is based on evidence collected from a recent time dependent driving experiment. The experiment featured a journey across London which produced 87 Stop/Start cycles which when compared with a comparable timed motorway journey produced zero Stop/Start events as the feature was not activated

https://www.youtube.com/watch?v=XGFpffGtQ2A
https://www.youtube.com/watch?v=ddw0iC7R5ic
https://www.youtube.com/watch?v=YC--MLNIbik - how to relaplace battery

Charge Management & Regenerative Braking (Micro hybrid 2)
Charge Management
It is likely that vehicle owners would not be aware of the installation of this technology as its operation is seamless, unlike Stop/Start which is clearly detectable as the engine stops if all system operating conditions are fulfilled when the vehicle comes to rest
When the alternator is running it can typically consume up to 10% of the power produced by the engine. The charge management system effectively switches off the charging system by disconnecting the alternators drive from the engine. This increases the loads placed on the battery but significantly improves the fuel economy of the vehicle
The major fuel economy benefits of a charge management system are achieved on longer distance journeys. The use of this system shows that one technology alone is not the solution to every drive cycle but is important as part of an overall package of emission reduction and economy initiatives
The life expectations of the battery are greatly increased as it is supporting all of the electrical loads on the vehicle when the charge management system is operating
The introduction of charge management systems has resulted in the development of new battery technologies and designs with increased performance. These include EFB and AGM battery types which have a significantly better cyclic life and improved operation in low states of charge.

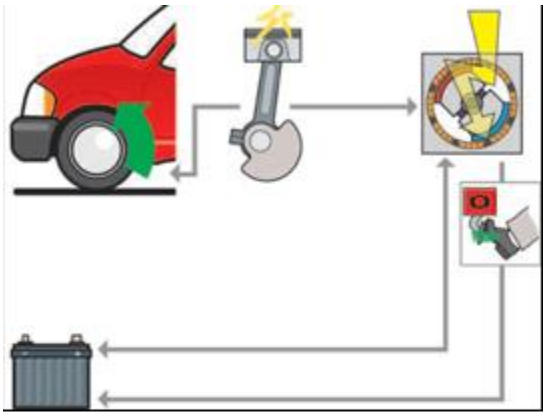
Regenerative Braking



Regenerative Braking systems recover the energy normally converted into and lost as heat during vehicle braking. When available the recovered energy is fed back into the charging system to recharge the battery

A conventional technology battery is very inefficient when utilized in a regenerative braking system. This type of battery is only able to reuse approximately 5 to 15% of the recovered energy due to its relatively high internal resistance. New battery technology developments such as EFB and AGM with reduced internal resistances provide more efficient use of the recovered energy.

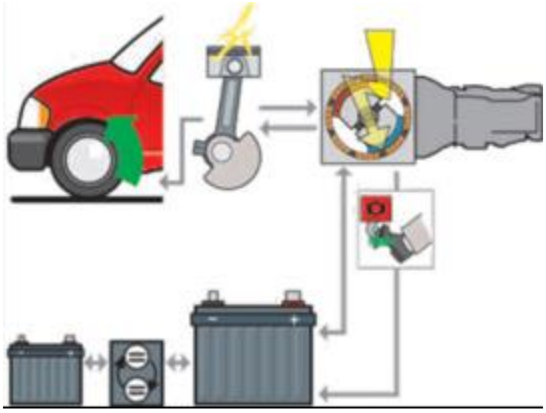
Starter/Generator (Micro hybrid 3)



Starter/generator technology replaces the conventional alternator and starter motor with a combined starter/generator unit installed between the engine and the transmission. The vehicle features both Stop/Start and regenerative braking systems that operate in the same way as for Micro hybrid 1 and 2 vehicles but utilises the starter generator for both start/stop and regenerative braking functions.

An AGM battery is therefore installed on the vehicle to support the stop/start and regenerative braking systems

Passive Boost (Mild hybrid)

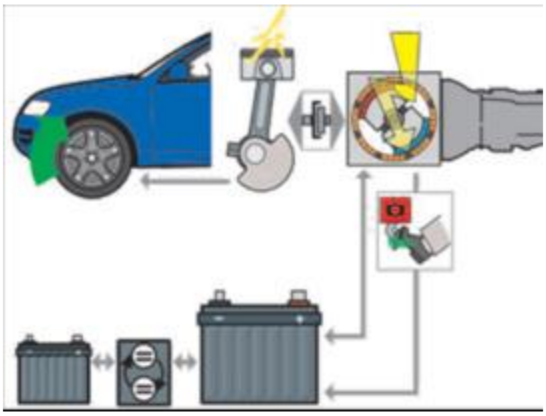


Future new technologies being introduced to the next generation of vehicles include a solution known as “Passive boost”. Passive Boost is a simpler more cost effective system related to the Kinetic Energy Recovery System (KERS) recently introduced into the Formula 1 race series

Passive boost technology replaces the conventional alternator and starter motor with a combined starter/generator unit installed between the engine and the transmission. The passive boost function reverses the generator polarity to convert the generator into a motor and utilise a high voltage battery to assist with the acceleration of the vehicle. The starter generator is only used to supplement the power produced by the internal combustion engine therefore the vehicle is not capable of full electric drive

An AGM battery is therefore only installed on the vehicle to support the electrically operated ancillary components only

Full hybrid



The full hybrid vehicle features a higher power starter generator and an additional clutch between the internal combustion engine and transmission. This allows the decoupling of the engine and starter generator.

The internal combustion engine features both stop start and regenerative braking functions, however this system only utilises the internal combustion engine when required which allows the vehicle to be driven on electric power only

An AGM battery is therefore only installed on the vehicle to support the electrically operated ancillary components only

These new requirements clearly expect significantly more from the battery and the technology has to be improved to match the further increase in demands.

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Full hybrids

The aim of the lesson: Make a difference between various hybrid systems in automotive technology and turn focus on Full Hybrid System

ANNEX 2

Micro-Hybrid	MHEV	HEV	PHEV

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Full hybrids

The aim of the lesson: Make a difference between various hybrid systems in automotive technology and turn focus on Full Hybrid System

ANNEX 3

Combustion engine		Micro-Hybrid		MHEV		HEV		PHEV	
+	-	+	-	+	-	+	-	+	-

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GPS monitoring, telematics

The aim of the lesson:

Let students get basic knowledge about what Telematics systems are, how do they work in general, technologies used, advantages of modern Telematics Systems

ANNEX 1

I KNOW	I WANT TO KNOW	I LEARNT

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GPS monitoring, telematics

The aim of the lesson:

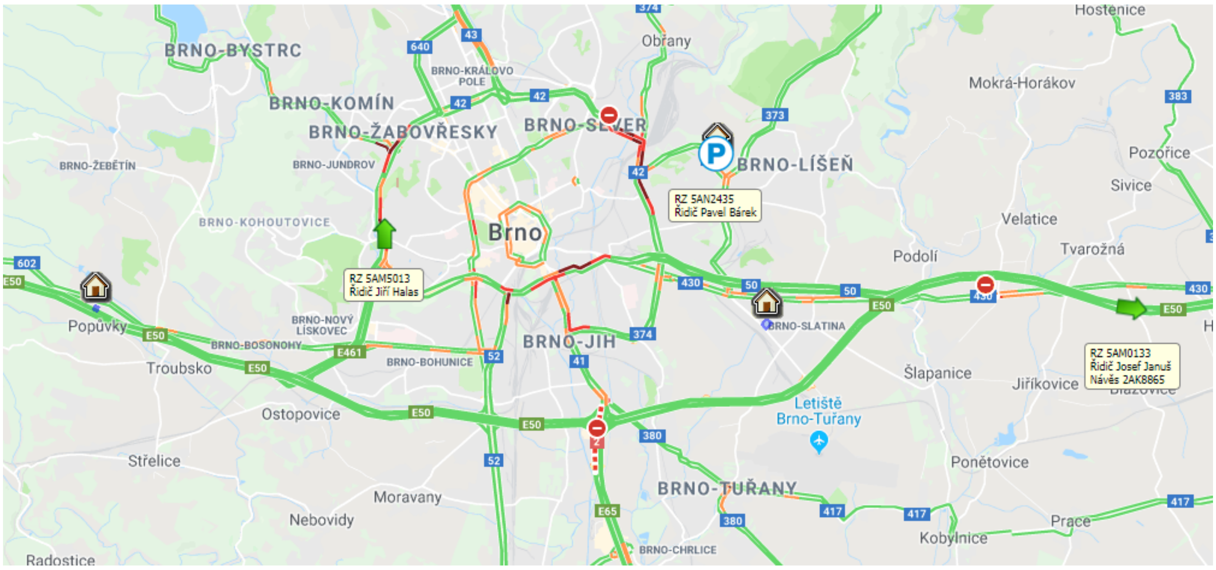
Let students get basic knowledge about what Telematics systems are, how do they work in general, technologies used, advantages of modern Telematics System

ANNEX 2

Distribution, work planning

Fleet telematics offers several tools to improve company's distribution and make it more efficient. If we took closer look to specific tools at the layer of dispatcher work environment, we are for example talking about:

- Possibilty to find nearest vehicle to concrete GPS coordinates while being able to choose vehicle which is currently not contained with other work
- Setting automaticly generated notifications about (not) reaching defined area (including possibilty of setting up conditions of weekday, concrete day time), and to send these notifications automaticaly based on on-line GPS positioning to end customer (this functionality is often used in case of „in time" transports)
- Google maps „Traffic" – which is feature showing real time traffic condition based on automatic location data collection by Google. Based on these informations dispatcher is able to react to it in advance, and change route plan – or inform end customer there will v probably be some delay.



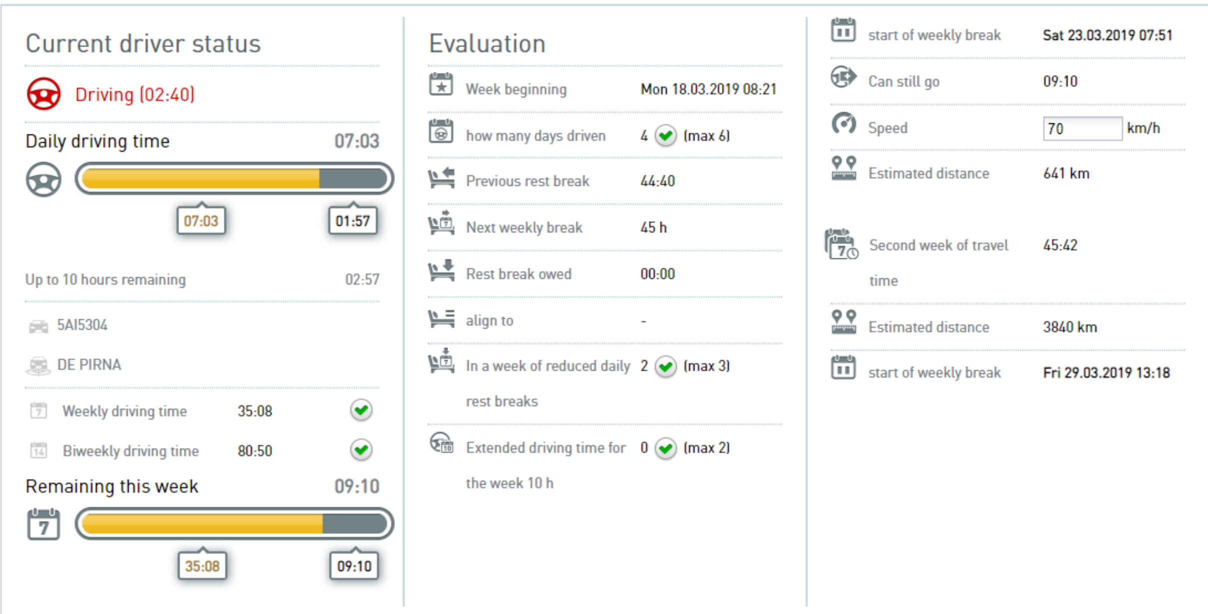
Traffic situation on-line, user defined areas, distinction of vehicles parked/in ride.

- Having awareness about driver's performance's by tachograph (regulation (EC) 561/2006) which leads to effecint transport planning
- Ability to do detailed planing of transportation – defining loading and unloading places, including exact instructions for driver like time windows, ammounts of gods, gods codes, detailed route planing etc. Within this in detail planned transportation it's possible to be automaticaly notified about leaving defined corridos (route plan), notifing not fulfilling time windows etc..
- Connecting GPS monitoring with optimalization software which (based on vehicles real movements and details filled at customers – load/unload points) can suggest routing optimalizations
- Controlling of fulfilling cold chain conditions

Tachograph

A digital tachograph is a device fitted to a vehicle that digitally records its speed and distance, together with the driver's activity selected from a choice of modes.
In Europe, drivers are legally required to accurately record their activities, retain the records, and produce them on demand to transport authorities who are charged with enforcing regulations governing driver's working hours. Regulation (EC) 561/2006 of the European Parliament and of the Council defines driver`s hours.

Thanks to reading that data from digital tachograph, telematics allows dispatchers not only to see exactly who is driving (has its tachograph card in tachograph slot) and therefore know drivers name, but also to view and control fulfilment of driver's working hours on-line during transportations, and this functionality also gives them overview of driver's working hours across the company which helps to make work planning more efficient.



UP - On-line status of driver`s working hours regarding do (EC) 561/2006

RIGHT - Regulation (EC) 561/2006 - Short list of rules

Daily driving time	**max. 9** hours (possible increase **2x** weekly to **10** hour) between two rests
Weekly driving time	max. **56**
Total driving time for two consecutive weeks	max. **90** hour
Break in the proceedings	no greater than **4,5** length of rest at least **45 minutes**. Can only be divided into **2** sections: **first 15** min and **second 30** mins
Normal daily rest	at least **11 hours within 24 hours from the end of the previous rest period**
The division of the normal daily rest period	during an extension of at least 12 hours can only be divided into **2 segments : the first stretch of 3 hours > 9 hours .**
Reduced daily rest period	Max. **3x can be shortened to 9 hours . between two weekly rest periods, without compensation**
Normal weekly rest	at least **45 hours .**
Short weekly rest period	at least **24 hours . with equalization by the end of the 3rd week following. (condition: previous weekly rest period must be normal = min.45 hrs)**
Start of weekly rest	At the latest after the lapse of six 24-hour periods from the end of the previous weekly rest.

Also the employer must control driver's compliance with the directive (EC) 561/2006 by downloading and evaluating raw data's from digital tachograph, which is demanded by law. It usually requires technician worker to get physically into each vehicle with Company card (company card are used by operators to retrieve data regarding their employees from the tachograph memory) and initiate data download manually.

Telematics allows companies to do this automatically and remotely. While using this solution from telematics systems like Webdispecink, company card is put in card reader connected to server which is initiating downloads continuously based on timer which is set up in vehicle units.

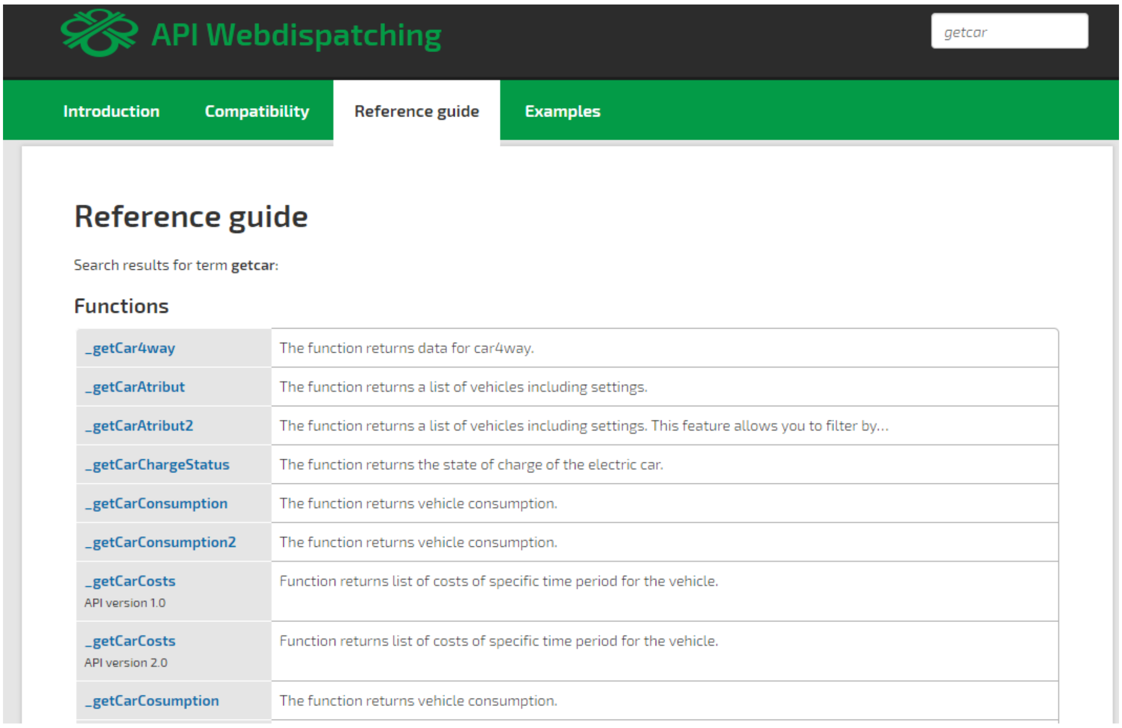
This function saves a lot of time for technician employees which had to physically visit each vehicle time to time.

API – Application programming interface

Is a set of various functions (web services) which makes telematics system able to communicate with other programs and systems.

One way of use is that it allows transportation company to provide information about vehicle position during transportation on-line to logistics companies or transport customer. This data sharing is more and more required by transport customers across the Europe. Today it is often a must-have-feature while making transportations for Europe`s leading logistics companies like DHL, Gefco, Gatehouse etc. Those companies usually have their own monitoring platform where they merge positioning information from various GPS monitoring providers)

With this type of connection, all transport stakeholders have the necessary information without having to get the information directly from the person (dispatcher)



API Webdispatching

getcar

Introduction | Compatibility | Reference guide | Examples

Reference guide

Search results for term **getcar**:

Functions

_getCar4way	The function returns data for car4way.
_getCarAtribut	The function returns a list of vehicles including settings.
_getCarAtribut2	The function returns a list of vehicles including settings. This feature allows you to filter by...
_getCarChargeStatus	The function returns the state of charge of the electric car.
_getCarConsumption	The function returns vehicle consumption.
_getCarConsumption2	The function returns vehicle consumption.
_getCarCosts API version 1.0	Function returns list of costs of specific time period for the vehicle.
_getCarCosts API version 2.0	Function returns list of costs of specific time period for the vehicle.
_getCarCosumption	The function returns vehicle consumption.

Example from Webdispecink API reference guide

Another and not less important use of API is to link it up with ERP – company information software.

Based on this connection it is possible to

- Generate traffic records, driver's working time report
- Border crossings to calculate travel compensations
- Record of fuel – cost of fuel, consumption
- Dispatcher communication with vehicle crew
- Sources for navigaiton, informations about i.e. loading/unloading

Main benefits are:

- Reduciton of data duplication
- Considerable time savings when processing the information
- Incerased accuracy of information
- Incerased effeciency of SW utilization

Vehicle management – Tasks

Tasks – a very helpful tool which allows telematics users to define tasks for vehicles, drivers or trailers. Based on time or odometer state conditions set, systems - like Webdispecink - are able to automatically generate notifications for upcoming service tasks.

Vehicle / Driver / Semi-trailer		expected date	Name	Check Date	Check km	Check mh	Window	Email	State	last fulfilled
2E7 2206	vehicle	19.12.2018 (93 days)	Technická Kontrola	19.12.2018 (93 days)	-	-	✓	✗	Repeated actions	19.12.2016
2E7 2206	vehicle	19.12.2018 (93 days)	EMISE	19.12.2018 (93 days)	-	-	✓	✗	Repeated actions	19.12.2016
3E5 6683	vehicle	27.12.2018 (85 days)	Servisní prohlídka + olej	27.12.2018 (85 days)	352235 (2517)	-	✓	✗	Repeated actions	27.12.2017
5E7 9474	vehicle	13.03.2019 (9 days)	Servisní prohlídka + olej	09.08.2019 (-140 days)	124537 (2042)	-	✓	✗	Repeated actions	09.08.2018
5E8 7163	vehicle	20.03.2019 (2 days)	Servisní prohlídka + olej	09.08.2019 (-140 days)	112875 (180)	-	✓	✓	Repeated actions	09.08.2018
5E5 3761	vehicle	25.03.2019 (-3 days)	STK + EMISE	25.03.2019 (-3 days)	-	-	✓	✗	Repeated actions	
5E5 3748	vehicle	29.03.2019 (-7 days)	Servisní prohlídka + olej	22.06.2019 (-92 days)	151830 (-868)	-	✓	✗	Repeated actions	22.06.2018
5E7 9464	vehicle	06.04.2019 (-15 days)	Servisní prohlídka + olej	31.08.2019 (-162 days)	118421 (-3162)	-	✓	✗	Repeated actions	31.08.2018
6E2 4257	vehicle	08.04.2019 (-17 days)	Servisní prohlídka + olej	30.08.2019 (-161 days)	25000 (-3196)	-	✓	✓	Repeated actions	

Example of Tasks set.

Information about vehicle

RM:	[redacted] 3176 Ford Transit Custom 9 míst OP00000301 [redacted] Lelystadt
Driver:	Nicolae [redacted].
Location:	OP301_Stavba
km:	28513,00
Fuel:	57,40 l
Parking	172 min
Time:	10:07:38
Tasks:	Servisní prohlídka + olej: -21days -1487km

Information about upcoming tasks is visible for all Webdispecink users, which helps to efficiently plan service schedule across the company – dispatchers are able to account with an upcoming task while planning work (transportations) for vehicles/drivers.

Basis for diets - travel expenses compensations

Employees (Drivers) traveling more than 5 hours away from place of work are entitled to get travel expenses compensations in form of diets.

The calculation is set on defined rates for each country (in various currencies) and time spent. These rates are being actualized each year.

	Duration of business trip			Code	Country	Amount	Currency	Pocket money	Valid from	inserted	inserted by
	...			DE	DE - Germany				01.01.2019	Show	
	1,00	-	12,00	DE	Germany	15,00	EUR	6,00	01.01.2019	07.02.2019	admin
	12,00	-	18,00	DE	Germany	30,00	EUR	12,00	01.01.2019	07.02.2019	admin
	18,00	-	24,00	DE	Germany	45,00	EUR	18,00	01.01.2019	07.02.2019	admin

Compensation allowance rates

Without Webdispecink travel expenses compensations are made out of traffic record's which are mostly handwritten by drivers. Processing this handwritten record takes quite big amount of time and may contain inaccurate data – for example sometimes the driver may intentionally write the wrong time of border crossing to obtain higher compensation allowance.

In this case, Webdispecink is a huge time saver for company accountants. The driver is assigned to vehicle by inserting his tachograph card into tachograph (even as a crew if there are 2 drivers in vehicle). Webdispecink knows the exact moment vehicle crossed the state border. Therefore, Webdispecink has accurate information about drivers` movement and time spent in each country. It is also possible to assign defined areas to each driver where the algorithm stops to count the time of travel.

The result is quick and accurate basis for paying off the driver.

Day	Code	Country	Date from	Date to	km	duration	Compensation allowance	Currency	Vehicle	Driver	Meal allowance + pocket money	Currency
01.02.2019	**international**				**439,86**	**24:00:00**		**45,00 GBP**				**63,00 GBP**
	GB	Great Britain	01.02.2019 00:00:00	02.02.2019 00:00:00	439,86	24:00:00			5Z7 2203	Petr Dvořan		GBP
02.02.2019	**international**				**374,96**	**24:00:00**		**50,00 EUR**				**70,00 EUR**
	GB	Great Britain	02.02.2019 00:00:00	02.02.2019 09:53:28	209,64	09:53:28			5Z7 2203	Petr Dvořan		GBP
	FR	France	02.02.2019 09:53:28	02.02.2019 11:33:10	128,08	01:39:42						EUR
	BE	Belgium	02.02.2019 11:33:10	03.02.2019 00:00:00	37,24	12:26:50			5Z7 2203	Petr Dvořan		EUR
03.02.2019	**international**				**0,00**	**24:00:00**		**50,00 EUR**				**70,00 EUR**
	BE	Belgium	03.02.2019 00:00:00	04.02.2019 00:00:00	0,00	24:00:00			5Z7 2203	Petr Dvořan		EUR
04.02.2019	**international**				**663,64**	**24:00:00**		**50,00 EUR**				**70,00 EUR**
	BE	Belgium	04.02.2019 00:00:00	04.02.2019 12:40:26	255,14	12:40:26			5Z7 2203	Petr Dvořan		EUR
	DE	Germany	04.02.2019 12:40:26	05.02.2019 00:00:00	408,50	11:19:34			5Z7 2203	Petr Dvořan		EUR
05.02.2019	**international**				**205,11**	**08:05:41**		**15,00 EUR**				**21,00 EUR**
05.02.2019	**inland**				**453,22**	**06:39:00**		**82,00 CZK**				**82,00 CZK**
	DE	Germany	05.02.2019 00:00:00	05.02.2019 08:05:41	205,11	08:05:41			5Z7 2203	Petr Dvořan		EUR
	CZ	Czech Republic	05.02.2019 08:05:41	05.02.2019 14:44:41	453,22	06:39:00			5Z7 2203	Petr Dvořan		CZK
06.02.2019	**inland**				**548,96**	**14:42:40**		**124,00 CZK**				**124,00 CZK**
	CZ	Czech Republic	06.02.2019 04:56:43	06.02.2019 08:59:00	73,46	04:02:17			5Z7 2203	Petr Dvořan		CZK
	CZ	Czech Republic	06.02.2019 09:17:20	07.02.2019 00:00:00	475,50	14:42:40			5Z7 2203	Petr Dvořan		CZK
07.02.2019	**international**				**653,58**	**13:13:10**		**30,00 EUR**				**42,00 EUR**
07.02.2019	**inland**				**7,25**	**10:46:50**		**82,00 CZK**				**82,00 CZK**

27.02.2019	**international**				**537,98**	**24:00:00**	**45,00 EUR**			**63,00 EUR**
	FR	France	27.02.2019 00:00:00	28.02.2019 00:00:00	537,98	24:00:00		5Z7 2203	Petr Dvořan	EUR
28.02.2019	**international**				**675,15**	**13:33:21**	**30,00 EUR**			**42,00 EUR**
28.02.2019	**inland**				**8,88**	**10:26:38**	**82,00 CZK**			**82,00 CZK**
	FR	France	28.02.2019 00:00:00	28.02.2019 07:45:14	276,07	07:45:14		5Z7 2203	Petr Dvořan	EUR
	DE	Germany	28.02.2019 07:45:14	28.02.2019 13:33:21	399,08	05:48:07		5Z7 2203	Petr Dvořan	EUR
	CZ	Czech Republic	28.02.2019 13:33:21	28.02.2019 23:59:59	8,88	10:26:38		5Z7 2203	Petr Dvořan	CZK
Total							**45,00 GBP**			**63,00 GBP**
							565,00 EUR			**791,00 EUR**
							1358,00 CZK			**1358,00 CZK**
Country summary										
	BE	Belgium			292,38	49:07:16	150,00 EUR			210,00 EUR
	CZ	Czech Republic			4900,88	158:52:33	1358,00 CZK			1358,00 CZK
	DE	Germany			4261,57	128:01:44	210,00 EUR			294,00 EUR
	FR	France			1449,72	54:50:27	120,00 EUR			168,00 EUR
	GB	Great Britain			649,50	33:53:28	45,00 GBP			63,00 GBP
	NL	Netherlands			338,51	25:55:08	50,00 EUR			70,00 EUR
	SK	Slovakia			257,35	19:13:41	35,00 EUR			49,00 EUR

Diet basis for paying off the driver.

Drivers terminal

Is the bridge between driver and dispatcher/fleet manager. It works for both way communication, getting route plans to driver, allows to send photos or document scans both ways.

NOTES:

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OBD diagnostics and NOx control

The aim of the lesson:
Make students familiar with OBD functions, diagnostics and NO_x control

ANNEX 1
(KWL chart)

I Know	I Want To Know	I Learned

NOTES:

SCANIA

03:14-03

Issue 1 en

OBD (On Board Diagnostics)

and NOx control

Contents

Introduction

On Board Diagnostics

OBD (On Board Diagnostics) is a legal requirement within the EU which was introduced in 2005. The requirement specifies that it must be possible to detect faults on the vehicle which affect the emission levels and warn the driver via a lamp in the instrument cluster.

NOx control

New EU legislation entered into force on 1 October 2007. The new law is called NOx control and means that there is a requirement to monitor the level of nitrogen oxides (NOx level) in the exhaust gases. If there is a fault which means that the permitted limit values are exceeded, the law indicates what action must be taken.

What does the law say?

NOx control says that monitoring of the NOx level must take place in several steps:

- If the vehicle has a fault that causes the NOx level to exceed the lower limit value, the driver must be warned.
- If the vehicle has a fault that causes the higher limit value to be exceeded, the driver must be warned at the same time as the maximum torque of the vehicle is limited.
- If the vehicle has a fault which means that the NOx level cannot be monitored, the driver must be warned and there must be a gradual reduction in torque. An example of such a fault is an electrical fault on a NOx sensor, which does not in itself cause the NOx level to be exceeded but only prevents it from being monitored.

The legal requirement also means that information, which is intended for the authorities, must be available in the vehicle. The information must be stored in the control unit for 400 days or 9,600 hours, see next section.

Function description

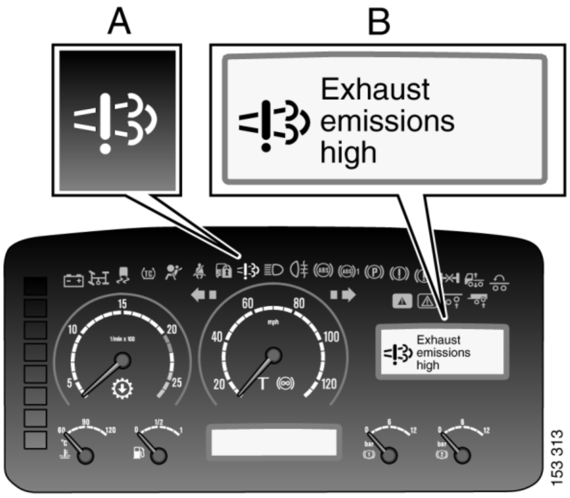
This is how it works in our vehicles

In order to comply with the new legal requirements, fault code generation has been developed in the engine management system and this has, to some extent, required the mechanic to adopt a new procedure for troubleshooting, repairing and verifying that the fault has been repaired. Fault codes which are related to the vehicle emissions of nitrogen oxides (NOx) are handled in a special way by the system. They switch on the lamp in the instrument cluster which warns about a high level of contaminants and in some cases limits the vehicle torque. Depending on how great an effect the fault has on the NOx level, the vehicle maximum torque is limited either by 40% as soon as the vehicle is stopped (speed is 0 km/h), or after 36-50 hours running time. An explanation of the relevant fault code is provided in the fault code text in SDP3.

These fault codes cannot be deleted from the control unit if they are active. This means that the fault code cannot be deleted, the warning lamp cannot be switched off nor can full torque be regained until the fault code has become inactive. In order for the fault code to become inactive so that it can be deleted, the control unit must carry out an internal test activated through SDP3 (Devalidation of fault codes for NOx control) in which it can be checked that the fault has been rectified. An alternative is to drive the vehicle until the same check is carried out on the control unit. The conditions which must be complied with in order to allow the control unit to verify that the fault has been rectified are described in the fault code text in SDP3.

When the fault code has generated a fault code which is related to NOx control, a non-erasable fault code to inform the authorities concerned is also generated as a result of this. The fault codes are only intended as an information code for the authorities and do not signify that there is anything wrong with the vehicle. When the vehicle has been repaired and the control unit has determined that the fault has been rectified, this fault code becomes inactive, but it cannot be deleted. These fault codes are stored in the control unit for 400 days or 9,600 hours after they have become inactive. It is important to note that these fault codes do not require any action on the part of the workshop.

Warning lamp A



Lights when the NOx level exceeds the lower limit value.

Note: To switch off warning lamp A when there are no active fault codes:

1. Check that warning lamp B has gone out.
2. Switch on the ignition with the starter key but do not start the engine.
3. Turn off the ignition using the starter key and wait for at least 15 seconds.
4. Repeat the procedure twice. The warning lamp goes out about 30 seconds after the starter key has been turned on for a fourth time.

Warning lamp B

- Lights when the NOx level exceeds the higher limit value.
- There is a risk of torque reduction. An explanation of the relevant fault code is provided in the fault code description in SDP3.

Note: To switch off warning lamp B the work method in SDP3 is used.

Information codes for NOx control

Some fault codes generate information codes when the fault code is activated.

Information codes cannot be deleted by using SDP3.

The information codes do not indicate a fault but are intended to provide information for the authorities.

The information codes indicate whether the control unit had previously activated fault codes in the vehicle which affected the emissions of nitrogen oxides (NOx).

If an information code has been inactive for 400 days, it is automatically deleted.

P2BA7 (11175) - Empty reductant tank

P2BA8 (11176) - Open circuit in reductant

metering P2BA9 (11177) - Inadequate

reductant quality P2BAA (11178) - Low

reductant consumption P2BAB (11179) -

Incorrect EGR flow

P2BAC (11180) - Deactivation of EGR

P2BAD (11181) - Unknown fault source

P2BAE (11182) - NOx control monitoring system

OBD diagnostics and NOx control

The aim of the lesson:

Make students familiar with OBD functions, diagnostics and NO_x control

ANNEX 3:

Finish the sentences:

1. OBD (On Board Diagnostics) is a _______________ _______________ within the _______________ which was _______________ in _______________ .

2. The new law is called NOx _______________ and means that there is a requirement to _______________ the level of nitrogen oxides (NOx level) in the _______________ gases.

3. Depending on how great an effect the fault has on the NOx level, the vehicle _______________ _______________ is limited either by _______________ % as soon as the vehicle is stopped (speed is 0 km/h), or after _______________ hours _______________ time.

4. If the malfunction influences the increase of NO_x to allowed _______________ , maximum _______________ _______________ will be limited to _______________ 40%.

5. The information must be stored in the control for _______________ days or _______________ hours.

6. If the vehicle has a _______________ that causes the _______________ limit value to be exceeded, the driver must be _______________ at the same time as the _______________ torque of the vehicle is limited.

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Tachograph

The aim of the lesson:
Get acquainted with the functionality of tachograph.

Annex 1

Source and more information can be found at:
https://fleetgo.com/tachograph/what-is-a-digital-tachograph/

What are Tachographs?
A digital tachograph is a radio-sized device fitted on goods and passenger vehicles. The tachograph digitally records various types of driver and vehicle data such as journey distance, speed, driving time and driver's activity. The data is stored in the vehicle unit memory and on driver cards. The leading European tachograph brands are VDO (Siemens), Stoneridge, Intellic and Actia.

When is a Digital Tachograph Mandatory?

The installation of a digital tachograph has been mandatory for new vehicles brought into service from May 1st, 2006, as well as for the replacement of an analogue tachograph that has broken down on vehicles transporting passengers over 9 seats and on vehicles over 3.5 tonnes registered since January 1st, 2003 if technically feasible.

How does a Digital Tachograph Work?

Digital tachographs consist of the vehicle unit, motion sensor and tachograph cards. The vehicle unit is the mother brain of the tachograph, it has a processor, a clock, two card slots, a display, a printer, a download connector and a controller for manual entries.

The vehicle unit is located in the driver's area of the cabin. The motion or speed sensor is located on the gearbox. The sender unit produces electronic pulses as the gearbox output shaft turns. The encrypted signals are sent to the vehicle unit where they are recorded.

What does a Digital Tachograph record?

A digital tachograph collects and stores the following data:

- Date Vehicle registration number
- Vehicle speed
- Single or co-driver
- Number of times a driver card is inserted each day
- Distance travelled by the driver, captured via odometer
- Driver activity (driving, rest, breaks, other activities, availability)
- Date and time of activity change
- Events (over speeding, driving without a driver card, tampering, fraud attempts) and errors
- Enforcement checks
- Details of tachograph calibrations

.DDD Files

Data is stored as a .ddd file that can be imported into tachograph analysis software. In Spain and France the .ddd files have different formats. In Spain the digital tachograph files format is .tgd and in France there are 2 types of digital tachograph file formats: the vehicle information is stored in the V1B format and the driver data is stored in the C1B format.

Remote Tacho Download

The Remote Tacho Download solution has been designed in order to unburden fleet managers by automating the download of digital tachograph files. Instead of manually downloading tachograph and driver data from the vehicle, our solution enables the fleet manager to see all digital tachograph files in one single platform. Data is sent via our control unit directly into the platform. All files are check on completeness and integrity so you always know if your archive meets the EU-regulations.

Learn more about The Remote Tacho Download!

Types of Tachograph Cards

Data can be locked in the tachograph unit by using a company card. This ensures that the data cannot be retrieved by another company if the vehicle changes ownership. All data can still be retrieved by use of a control card or a workshop card.
There are four types of tachograph cards. The driver card, the control card, the workshop card and the company card. Driver cards are used by drivers to record driving, rest and activity information. Control cards are used by law enforcement agencies to retrieve data from the tachograph. A control card is able to override any company lock put in place by operators. Workshop cards are used by authorised and official tachograph technicians to calibrate, install or repair tachographs. Company cards are used by operators to retrieve data from the tachograph regarding their employees and vehicles. Companies can also lock information using their company card or authorise third parties, including telematic providers, to collect data.

Tachograph Modes

The tachograph allows 4 different modes: driving, other activities, rest and availability. The ‘driving mode’ is activated automatically when the vehicle is in motion. The digital tachograph usually chooses the ‘other work’ mode automatically upon coming to a standstill. The ‘rest’ and ‘availability’ modes can be manually selected by the driver whilst stationary. The tachograph symbols display the current tachograph mode. The activity information is stored in the tachograph unit’s internal memory and simultaneously onto the digital driver card chip whilst it is inserted into the head of the tachograph. When either memory bank is full, the oldest data is automatically overwritten with the current data. This is one of the reasons why companies use digital tachograph download solutions which allow them to store tachograph data as long as they want to.

Other sources:

https://dtc.jrc.ec.europa.eu/
https://en.wikipedia.org/wiki/Tachograph

Annex 2

„INSERT“ table, TACHOGRAPH

√ what I already know	+ what was new for me	? what I want to know	- what was in contrast to what I originally thought

NOTES:

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Tesla electric vehicles batteries

The aim of the lesson:
To gain knowledge about the constitution and function of electric vehicles batteries cells.

APPENDIX 1

Tesla Electric Vehicles Batteries

Authors:
Juan Francisco Susarte Zamora
Álvaro Doural
Juanjo Martínez

Tesla Batteries

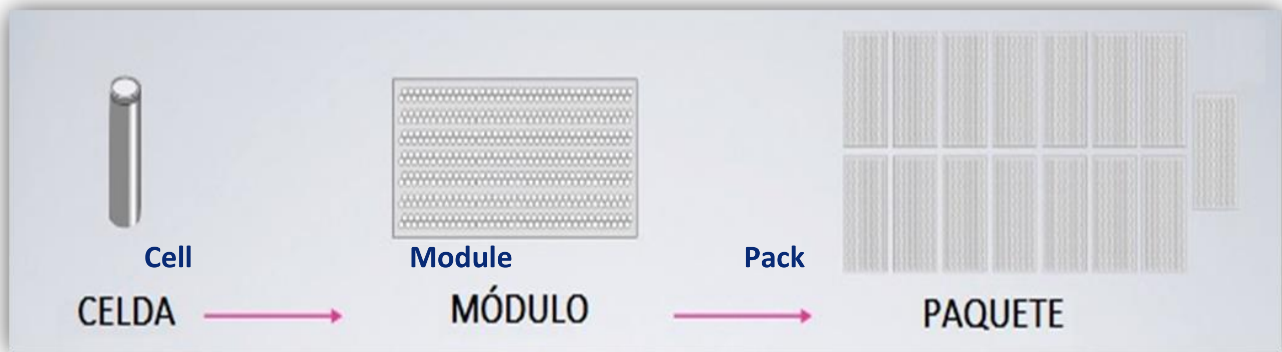
Introduction

Tesla is a North American company situated in Silicon Valley (California), under the leadership of Elon Musk who designs, manufactures and sells electric vehicles.

Tesla was founded to speed the transition towards sustainable transport with the aim to fight global warming and reduce the deaths caused by pollution.

The company core is focused on the electric vehicle propulsion system engineering, which includes: battery packs, engine, power electronics and control software.

In this teaching unit we are going to focus on the battery pack, learning about the three parts it is composed by. We will explore the chemistry and the cells format. We will also have a look at the modules pack model, as well as their design. To finish we will focus on how these battery packs are assembled.



Tesla claims they have the battery with the highest energy density in the market, but also de lowest cost per kilowatt/hour (from now on, kwh).

To test to which extent this is true, we will explain the different parts of a Tesla battery, as well as its characteristics and its functioning.

Cells

For a start we will talk about cells, which is the main component of these batteries.

Types

Cells can be found in three different formats: cylindrical, prismatic and cartridge cells.

Cylindrical cells. Tesla Model S

Cylindrical cells

These cells are made by winding up the electrodes materials and inserting them on a aluminium cylindrical capsule.

Cylindrical cells are the cheapest option, compared to those prismatic or cartridge cells, because they can be manufactured in huge quantities in standard sizes.

As there are several companies manufacturing this type of cell with a standard size from the very first moment of lithium-Ion batteries commercial application (in 1991 by Sony company) the manufacturing process and the internal design of those cells have been highly optimized. This greatly improved design reduces the non-active components, that is, those which do not directly combine energy storage with reduction of space which is not used to store it. That is why, cylindrical cells usually have the highest volumetric power density.

Nevertheless, not everything is positive, as these cells are very difficult to cool and this problem means a reduction in efficiency and a shortening in the cell life. Moreover, cylindrical cells have a further inconvenience, which is, geometrically speaking, cylindrical cells are not ideally packed in battery modules with cuboidal shapes.

Prismatic cells

They can be presented with several settings. However, automotive prismatic cells have cuboidal shapes to fit better within the module.

94Ah and 37Ah Samsung prismatic cells

Internally they have a quantity of windings similar to those of cylindrical cells which are compressed afterwards to fit the cell inner volume. Prismatic cells can present a certain design complexity for their manufacturer, but they make things easy for the car assembler as they adapt easily to modules, and they are relatively easy to cool thanks to their geometry, whether internal or external, which helps to heat transfer. Manufacturers such as BMW assemble them in highly automated batteries in models such as i3.

Although bigger size cell terminals help to reduce resistance and allow a greater heat transfer, both add moisture content, which at the same time reduces the energy density in cells. In addition, as we are compressing the cylinders around two electrodes, the compression is not the same at all points. This implies some problems with the lifespan after repeated charging and discharging cycles.

Prismatic cells also tend to offer high capacity to keep non-active material at a minimum. That is why BMW i3 from 2016 uses 94Ah prismatic cells or Volkswagen e-Golf from 2017 assembles 37Ah prismatic cells. These data stand out if we compare them with the 3.4 Ah prismatic cells used by Tesla. All this situation limits the final capacity of manufacturers to offer battery packs in different sizes.

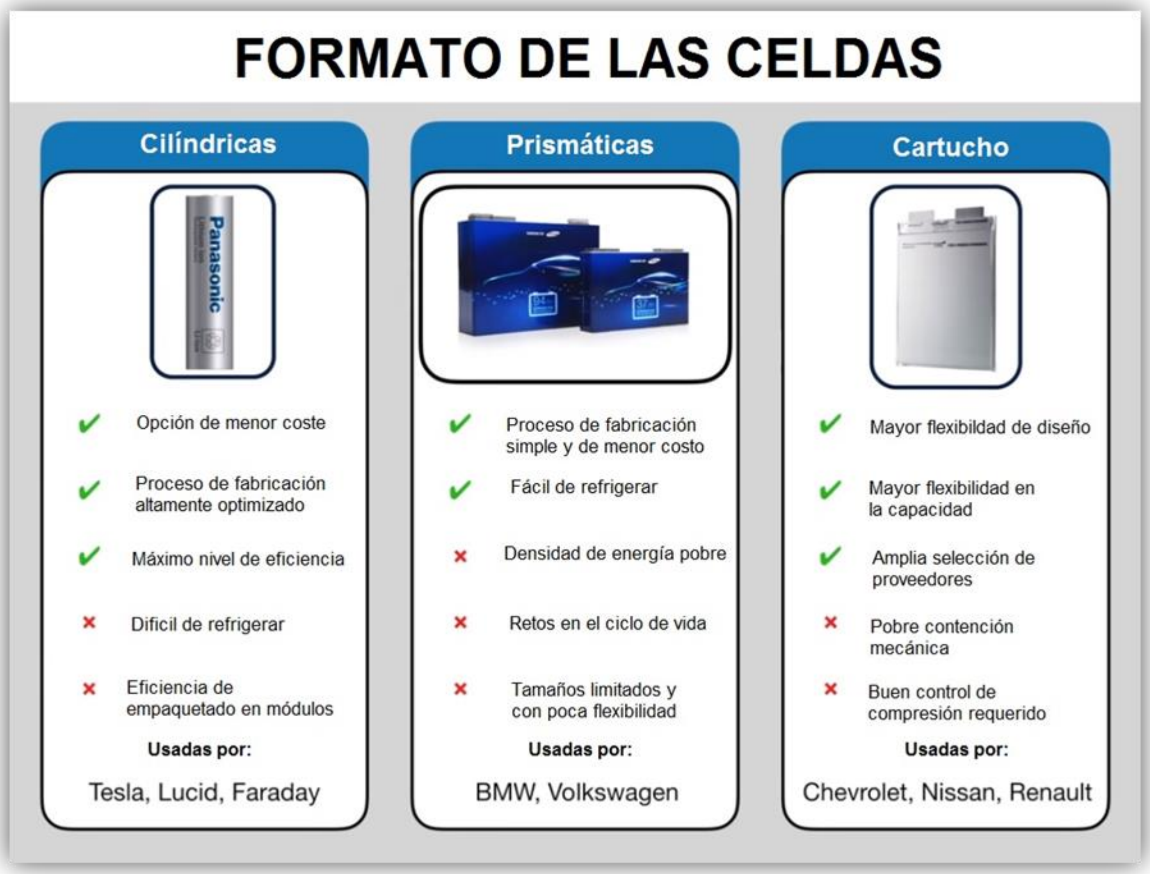
Cartridge cells

These cells use stacked electrodes and separators which are afterwards inserted in a polymer sheeting.

Cartridge Cell

Cartridge cells offer a maximum flexibility in their design, as they can usually be scaled to different sizes and the manufacturer can easily modify their capacity, by adding or removing layers.

An important number of battery manufacturers offer this type of cells because their gravimetric energy density is very competitive if compared to cylindrical cells. Gravimetric energy is the quantity of energy stored in a battery per kilo. This means, the higher this value, the higher capacity, autonomy and power we get. It can also be said that in a battery with the same capacity we get a lower weight and that is very important as well.



The main disadvantage of this type of cells is that they are much more complex to get them integrated in modules. Their cooling process also needs a very careful control.

Which type of cells does Tesla use?

Tesla Model S.

Tesla uses **cylindrical cells**, and the question is, why did they decide to assemble them in the battery pack of Model S? The answer is easy.

Cylindrical cells offered the greater energy density per cell. It should also be highlighted that at that time cylindrical cells were manufactured in huge quantities for the portable electronics. This meant that those cells had a lower price per kwh, which implied a reduction of the initial capital investment, something essential for a new company with a limited capital available.

Since the cost of these cells is still the lowest of the three formats, these are still used in Tesla new models such as Model 3 or even today at the mega-factory.

Before Model S was released big battery packs were used to produce an enormous quantity of energy. However, they were very expensive and they needed electric cars to be more reachable for most customers.

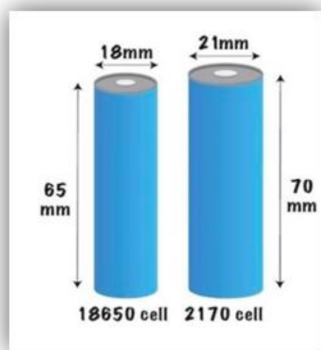
To produce a battery pack extendable to multiple capacities, it is necessary to have small capacity cells, and connect a great number of those cells connected in parallel.

BMW i3 with 94 Ah prismatic cells

Let's consider BMW i3 for example. This car uses very big prismatic cells by Samsung, all of them connected in series to build a 33kwh battery pack. To offer a 45kwh it is not possible to simply add cells in series because the voltage would change. So, the Battery Management System (BMS) and the inverter should be changed as well. However, if we add a chain of cells connected in parallel, we are doubling the number of cells, which will result in an increase capacity of the pack to reach 66 kwh, although this will be impossible to fit within the car chassis.

When we use small capacity cells and change the number of cells connected in parallel, Tesla gets greater flexibility: the 100kwh battery pack includes 96 cells connected in series and 86 in parallel, the 75kwh battery has 86 cells connected in series and 63 in parallel.

Among cylindrical cells used by Tesla there are two types: 18 650 type, used in models like *Model S and Model X*; and the 21 700 model, used in *Model 3*. Both types are manufactured by Panasonic.



Cells size 18 650 and 21 700.

18 650 cells have this name because their diameter is 18 mm and are 65mm long. The same way, 21 700 cells have a diameter of 21mm and are 70mm long. This additional length, apart from the bigger diameter, offers an increase of 33% of active material to store energy within the cell.

A 18 650 cell has a capacity of 3,4Ah or 12,4Wh and a nominal voltage of 3,66V. The resistance changes with the battery's state of charge and with its temperature, although in general it is over 30mΩ.

Giving a cell a volume of 16mL and a mass of 49gr, the cell reaches the impressive energy density of 254Wh per Kg or 755Wh por L.

NCA cell composition

If we have a look inside a 18 6500 cell, we can observe the different layers of the battery, which has a cathode composed by 80% nickel (Ni), 15% cobalt (Co), approximately 4% aluminium (Al) and less than 1% lithium (Li). On the other hand, the anode composition includes graphite although there is a tendency to replace it with silicon. The electrolyte is a solution of Li and the rest of components are made of Al and copper (from now on Cu).

Both, the anode and the cathode are two rolled sheets meant to occupy the shortest possible volume. Tesla calls it *Jelly Roll*.

On the positive terminal side, there is a compound made of carbon fibre which keeps the Jelly Roll placed. The fact that it is made of carbon fibre is to reduce the cell weight in a small proportion. When considering a huge number of cells, as we find in a complete battery pack, the weight loss is important helping to improve the battery energy density.

The positive terminal also has three ventilation openings, which help to free pression when there is a change in altitude or when there is an inner error in the cell. It also has an O ring to ensure sealing.

If we would unwind the *Jelly Roll*, we would be able to observe the anode and cathode sheets previously mentioned, separated by another plastic sheet which used as insulator between them. Their measures are approximately 1 m long and 60 mm wide.

We should underline that the Li sheet is the one containing the potential of the batteries, but it also arises a problem, as it is highly inflammable. To solve this issue, some manufacturers use a flame retardant between the layers. This causes another inconvenience, as it increases the non-active material within the cell, just the opposite effect Tesla is looking for, together with Panasonic, as they focus their research in manufacturing these sheets as thin as possible keeping their capacity to store energy with materials such as graphene.

Keeping up with the chemistry within the cell, we should mention that main manufacturers are nowadays using cobalt oxide cathodes and nickel- manganese or NMC

Tesla, however, uses LiNixCoxAlxO2 cells, as we have previously said, also called NCA. These are similar to NMC cells but they use Al instead of manganese to stabilize the crystalline structure of the Li oxide.

NCA cells have a greater energy capacity, however, these will cause thermal exhaust at a lower temperature. That is why they are considered appropriate for small 6A cells as maximum power. This explains why vehicles such as Nissan Leaf, Renault Zoe or BMW i3 use NMC.

As we have previously mentioned, the anode in almost of Li-ion batteries is made of graphite, but they are willing to change it to Si, because of their greater storage capacity.

In each new cell generation, Tesla has increased the quantity of Si in the anode, which ensures that 21 700 cells for Model 3 will have a bigger quantity of Si than the current 18 650.

NOTES:

Tesla electric vehicles batteries

The aim of the lesson:
To gain knowledge about the constitution and function of electric vehicles batteries cells.

APPENDIX 2

Tesla Electric Vehicles Batteries

(Source 2019-11-15 https://es.m.wikipedia.org/wiki/Archivo:Tesla_Model_S_(Facelift_ab_04-2016)_trimmed.jpg)

Authors:
Juan Francisco Susarte Zamora
Álvaro Doural
Juanjo Martínez

Tesla Electric Vehicles Batteries

Modules

Tesla 18 650 cells of Lithium-Ion are inserted in the battery pack. Modules themselves are from different sizes, as their configuration in parallel changes for different capacity battery packs which are available.

Tesla first generation battery packs, as those we find in 85 and 90 kwh batteries had 15 modules. Second generation packs introduced with Model S facelift have 16 modules.

Then, what is a battery module and what it is used for? Why are not cells directly placed in a battery pack?

One of the main reasons is the manufacturability. In a Tesla 100kwh battery pack, there are more than 8.000 cells, which means there are approximately 16.000 electric cells connections, which are divided in approximately 1.000 per module, which is finally a more manageable task.

Another key reason to use modules is safety while manufacturing them. The 85kwh module of Tesla pack has a configuration of 6s 74P, which means it has 6 groups connected in series and 74 cells connected in parallel per module. On the whole, that would be 444 cells per module. This produces a voltage of approximately 23,4V.

According to IEC 60038 rule, any device under 120 volts continuous stream (from now on DC) will be considered to cause a low risk electric shock through the dry skin of a person.

An additional reason for the use of modules is that they work as firewalls. In case one of the cells have a fault or in case of a car crash, if only one cell gets on fire, the number of cells exposed to the fire is lower and as a consequence, the seriousness of fire is reduced.

Moreover, from a service capability perspective, if there is an error for any reason in one cell, it is better to replace a module instead of a complete battery pack.

Nowadays there are three Tesla battery modules in the market.

1- The most extended and known model which is assembled in *Model S* and *Model X.* This has been updated and developed along the years.

2- The module Tesla assembles in its Power Packs (Batteries for industrial energy supply) which was the beginning of the transition between 18 650 cells and 21 700 cells. In addition, this uses a cooling system in the base of each module instead of cooling using pipes between cells, which reduces cost and complexity.

3- The Tesla Model 3 module. There is not much information about this module, we just know that it is longer than those modules used in *Model S* and *Model X*. It uses 21 700 cells the same as Power Packs. It has a refined thermal management system and they join the positive terminal and the negative terminal on the same side of the cell instead of using opposite sides.

Hereafter we will focus on the Model S and Model X modules.

Image Source (15 November 2019):
http://skie.net/skynet/projects/tesla/view_post/20_Pics+and+Info%3A+Inside+the+Tesla+100kWh+Battery+Pack

This image represents the top view and bottom view of a 100kwh battery pack module belonging to a Model S 100D.

In the top view, we can appreciate that it is divided in four segments. Meanwhile in the bottom view we can only observe the division into three segments.

Each segment of the module connects 86 terminals from positive cells in parallel with 86 terminals of negative cells also in parallel. It included a connection in series between both of them, with the exception of the segments connecting orange terminals that can be observed at the top of the image.

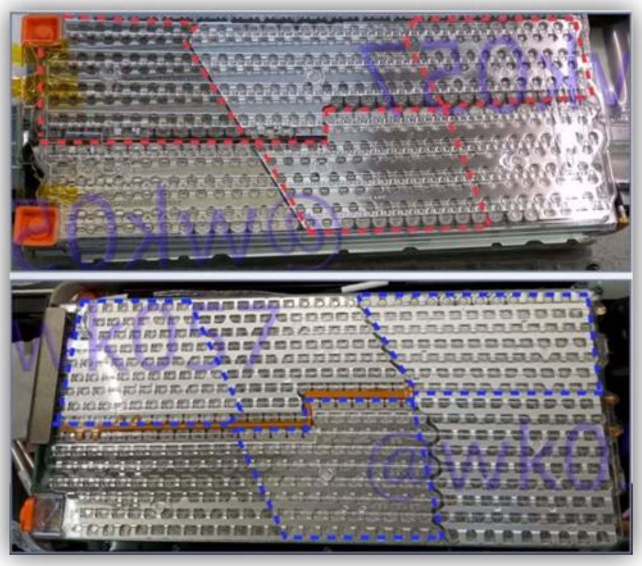


Image Source (15 November 2019):
http://skie.net/skynet/projects/tesla/view_post/20_Pics+and+Info%3A+Inside+the+Tesla+100kWh+Battery+Pack

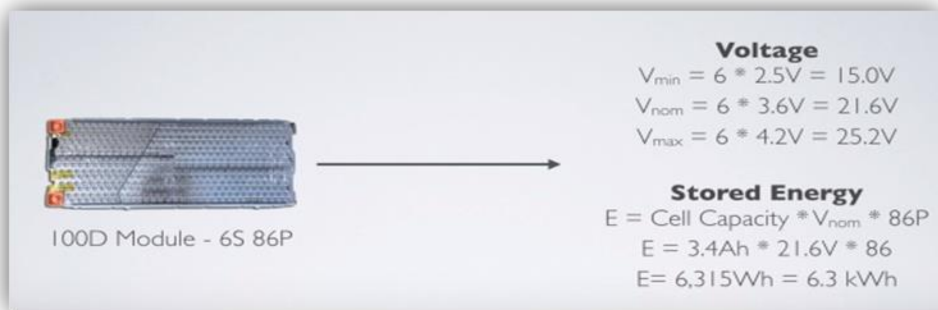
In the top view, the red segments show where the connections with the positive terminal are made. We can see the placement of the negative terminals in blue in the bottom view. The adjacent segments have opposite polarity.

Cells Electrical connection to Bus Bar.

Tesla used wire connections to connect electrically cells to the Bus Bar. Although this method increases resistance, which reduces the operative efficiency and increases heat, it has a number of advantages. During the connection process no significant heat is generated in the cell, the connection using a wire also works as a fuse, and if the connection has a fault for any reason, it is not very likely that the cell is damaged, which reduces the number of cells wasted while being manufactured.

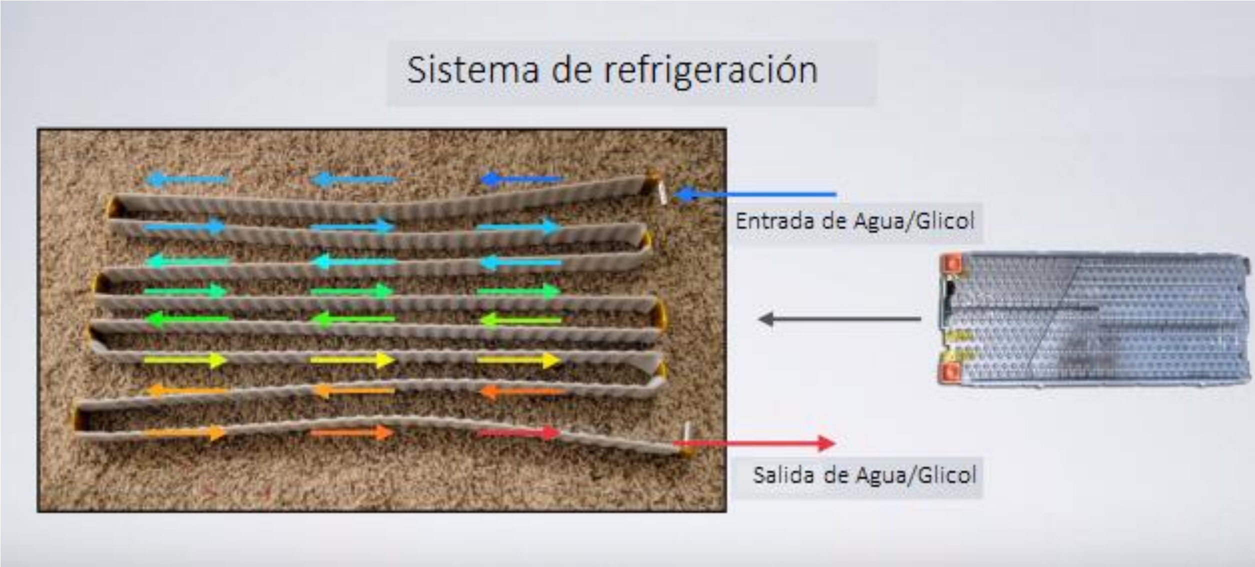
A 100 kWh module has 516 cells so it requires 1.032 wire connections. If this process was 99,9% effective, an error per module would be possible, which means the manufacturing capacity is the key.

The voltage can be calculated multiplying the minimum voltage, each cell nominal and maximum by the number of cells connected in series. This module, of a 100kwh pack is 6s 86P with a minimum voltage of 2,5 V, nominal voltage 3,6 V and maximum voltage 4,2 V. Acknowledging this we know that this module has a nominal voltage of 21,6 V.



To calculate the stored energy in a module, we multiply the cell capacity by the nominal voltage of that module and by the number of cells connected in parallel. Tesla cells have a capacity of 3,4A, the nominal voltage for this module is 21,6 V and as it is 6s 86P we have 86 cells connected in parallel, so we can say that this module stores 6,3 kWh of energy.

In the image we can observe the cooling pipes inside the module. This thermal management system consists of a metal pipe, flat on the most of its surface and straight, it crosses the module following zig-zag patterns. This pipe is covered by grey colour heat insulating material which provides electrical insulation between the cooling system and the battery cells. At the same time it causes a certain level of heat transfer



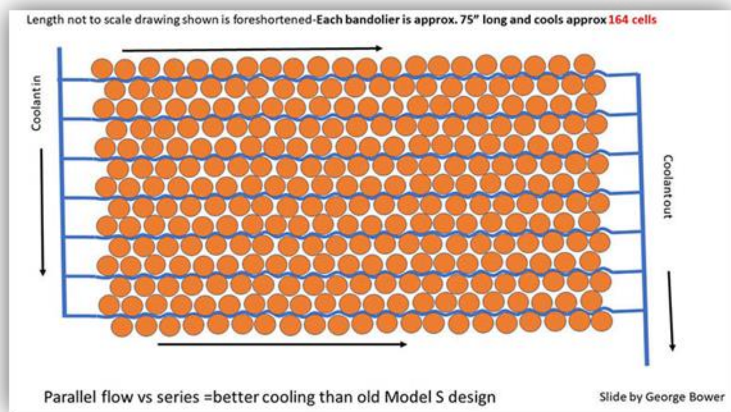
As we can see in the bending of the pipe, it is there where the connection between the cells and itself happens.

The orange tape we can observe in the image is the so-called Captain Tape in the US and provides additional electrical insulation.

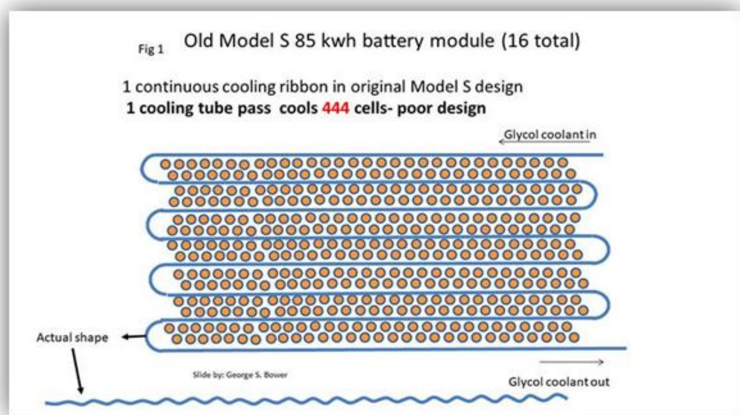
A water and glycol solution is introduced through the opening which goes across the cooling pipe to be discharged at the end of the module.

This is the cooling system used in Model S and in Model X, although Tesla made a major progress for Model 3.

Tesla managed to almost double the cooling capacity of the Thermal Management System (TMS) with a new pipe design which reduces the number of cells per each cooling pipe, adding more of these in parallel, and doubling the cooling fluid volume.



Tesla Model S and Model X TMS



Tesla Model 3.TMS

NOTES:

Tesla electric vehicles batteries

The aim of the lesson:
To gain knowledge about the constitution and function of electric vehicles batteries cells.

APPENDIX 3

Tesla Electric Vehicles Batteries

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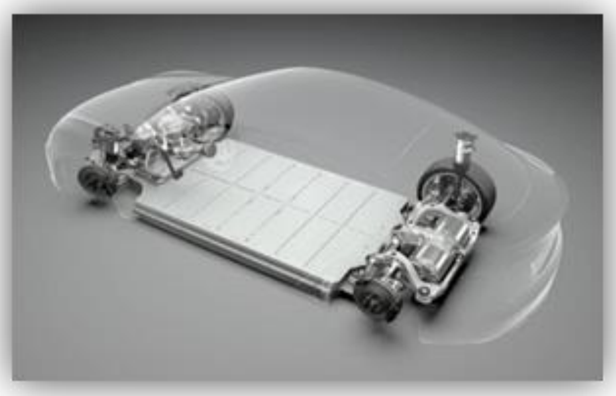
(Source 2019-11-15 https://es.m.wikipedia.org/wiki/Archivo:Tesla_Model_S_(Facelift_ab_04-2016)_trimmed.jpg)

Authors:
Juan Francisco Susarte Zamora
Álvaro Doural
Juanjo Martínez

Tesla Electric Vehicles Batteries

Packs



Paquete de baterías Model 3.

Distinct from the cell and the module, the battery pack is an intelligent device which can be controlled by the Battery Management System (BMS) to maximize the performance, to guarantee a safe functioning and to adapt the output to avoid excessive degradation of its performance capacity in the long run.

Cells became modules by adding mechanical frames, Bus Bars, the cooling interface and a sensor harness. Each of these elements has an additional support to transform modules into intelligent and safe battery packs.

Modules mechanical frames are interconnected with the mechanical structure of the battery. This structure must hold a battery pack of more of 600 kg. This provides enough rigidity and resistance for the rest of the car, improving the driving dynamics and its safety in case of a car crash.

Modules are electrically connected by high voltage Bus Bars, in addition to a thermal connection by means of the cooling system with the combination of rigid and flexible pipes.

The sensors harness is in charge of powering BMS, which works as a controller for the battery system to maximise its performance and safety.

Moreover, the battery includes fuses to avoid an excessive power surge, a contact to turn on and off the battery from the rest of the vehicle, and an input-Output I/O connector to connect electrically and thermally the battery to the car.

Model S and X 100kwh battery pack has an absolute energy capacity of 102,4kWh. Its type 18 650 8.256 cells are arranged in a 96s 86P configuration with a nominal voltage of approximately 400V.

The weight of the battery is 641kg, which offers a gravimetric energy density of 182,5W*kg. This means 63% of the battery is the mass corresponding to the cells.

Energy capacity is calculated by multiplying the cell capacity by the pack nominal voltage and the number of cells connected in parallel.

$$E = Capacidad\ de\ la\ celda\ \times Vnominal\ paquete\ \times Celdas\ en\ Paralelo$$
$$E = 3{,}4Ah \times 400V \times 86P = 116.9kWh$$

The gravimetric energy density of the battery is calculated by dividing the energy capacity by the battery mass.

$$DEG = \frac{E}{masa\ de\ la\ batería} = \frac{116.9kWh}{641kg} =$$ 182,5W*kg

As we know the definite mass for each cell, we can also conclude that the battery has an approximate weight of 404 kg, therefore, 237 kg of the battery are components which are not cells

$$Masa\ total\ de\ las\ celdas = (96s * 86P) * 49g = 404{,}5kg$$

$$\frac{404{,}5kg}{641kg} = 0{,}63 = 63\%$$

The maximum power Tesla can get from its battery is 567kwh. The power output of our battery is affected by our voltage, which is defined by the voltage in a cell by the number of these cells connected in series, the maximum electric current of the cell and by the battery resistance.

The alfa power (Pα) is simply the battery voltage multiplied by the intensity of its electric current

Pα = V * I

The voltage of the battery (V) when it is producing energy will be lower than when the circuit is open (Vca). That difference is also known as delta voltage (Vδ).

V = Vca – Vδ

Vδ is calculated by multiplying the maximum intensity of the combined cells by the resistance of the battery.

Vδ = I * R

Therefore, to calculate the maximum power of a battery first we have to know its resistance. Cells resistance is very much affected by factors such a change in its state, the temperature of the discharging speed. To simplify it we will use a number for a discharge of 10 seconds of 1 C to 25ºC. The resistance of an individual cell would be approximately 30mΩ.

The resistance of the wire link (Rec) which connects cells with Bus Bar is approximately 1mΩ per union. Each Bus Bar has an approximate resistance of 0,1mΩ to room temperature.

The resistance of a series (R-series) is, therefore, the cell resistance (R-cell) plus the double of the wire link resistance, since there would be a union in the positive terminal as well as in the negative terminal. All this has to be divided by the number of cells connected in parallel.

R-series = R-cell+ (2*Rec) / number of cells in parallel
R-series = 30mΩ + (2*1mΩ) / 86 = 0,372mΩ

The resistance of the module (R-module) is the resistance of the series plus half resistance of the Bus Bar, all of it multiplied by the number of cells in series within the module, we previously mentioned modules were 6.

R-module = (R-serie + (R del Bus bar/2)) * number of cells in series
R-module = (0,372mΩ + (0,1mΩ / 2)) * 6 = 2,53mΩ

in addition to the resistance of the module, we can also observe the resistance of the high voltage Bus Bar which is connecting modules.

It would be approximately 0,02mΩ.
The resistance of the high voltage connection is 0,20mΩ.
The fuse resistance is 0,23mΩ.
The shunt resistance allows BMS to measure the pack current intensity which is 0,05mΩ and the high voltage connector resistance which is 0,2mΩ.

Therefore, the total resistance of the pack is calculated as the module resistance (R-module) multiplied by the number of modules in series (Ms), plus the resistance of the high voltage Bus Bar by the number of modules in series minus the intensity of these, plus the resistance of the connector (R-ct), plus the fuse resistance (R-fus), plus the shunt resistance (R-sh) and plus the HV connector resistance (RCHV)
RT = (R-module * Ms) + (R de HV Bus Bar *(Ms - I)) + Rct + Rfus + Rsh + RCHV

This gives us as a result the resistance of the pack, 41,8mΩ.

The cells resistance represents approximately 80% of the total resistance of the battery.
With this information we can deduce that with a maximum output power of 567kW, the intensity of our battery pack will be from 1.800A to 2.000A depending on the charging state and the cell temperature.

The result of this is a cell current intensity of about 21A to 23A, which is equivalent to 6,2C to 6,7C per cell like a short - term power peak

Hereafter we will have a look at the structure of a battery pack:

Mechanical structure of a battery pack

The mechanical structure of a pack holds more than 600 kg of the battery plus the fact of being the base to support the rest of the vehicle structure. It has been designed to provide enough rigidity, to allow the car to have a nice, driving dynamics and to pass the Crash Tests.

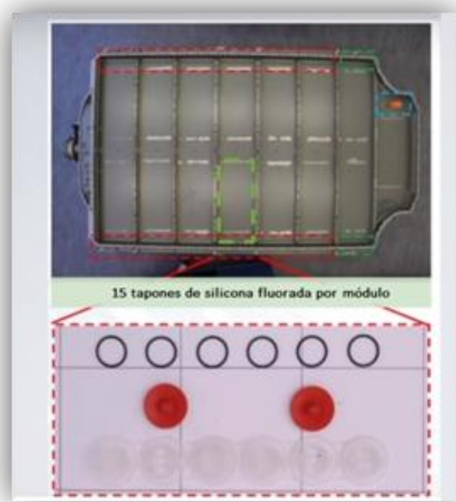
Thicker longitudinal crossbars increase resistance to lateral impacts and the longitudinal bending. Meanwhile the other crossbars provide additional torsion rigidity and also resistance of lateral impact. Tesla also used internal sections to physically separate each module, which is useful to prevent the spread of fire in case of fault.

The results in a test done in 2015 showed what happens to a cell when it is pierced by nails and when it is kept at high temperatures for long periods of time. Considering US requirements, the results shown that fire is possible, so it is important to design a strategy to extinguish battery fires.

Celda perforada

Celda sometida a alta temperatura

Let's see how this strategy goes:



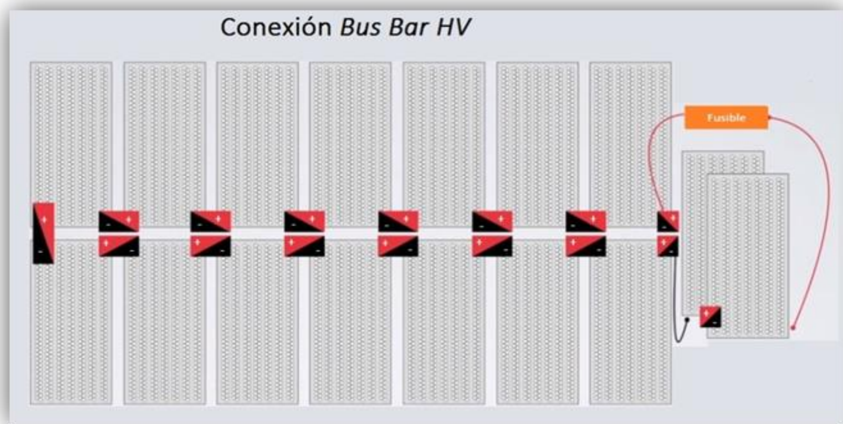
Physical separation between modules (upper part) and the fluoridated silicon plugs (lower part).

Starting with the modules, they are separated by mica layers which are placed around the module to provide electric insulation among these. These sheets are also very stable till they reach temperatures of about 900ºC, therefore, in case of an error within a cell it won't immediately decomposed and it will keep an ideal electric insulation from module to module.

Modules are also separated on its upper side and lower side by metal sheets which keep the battery assembled. Moreover, it has an insulation layer 9,3mm thick which avoids the heat getting into the compartment.

If there is any error in a cell gas pressure will be generated, that is why it is important to have good ventilation within the pack. Since each module is physically separated, each of them should have their own ventilation openings. Except those two modules on the front part which are stacked one over another and share their ventilation ports.

For these openings, fluorated silicon plugs are used, because they allow a good sealing of the battery as they do not degrade as they get older. When there is a presence of hot gases, these decomposed easily allowing the flow through the openings.



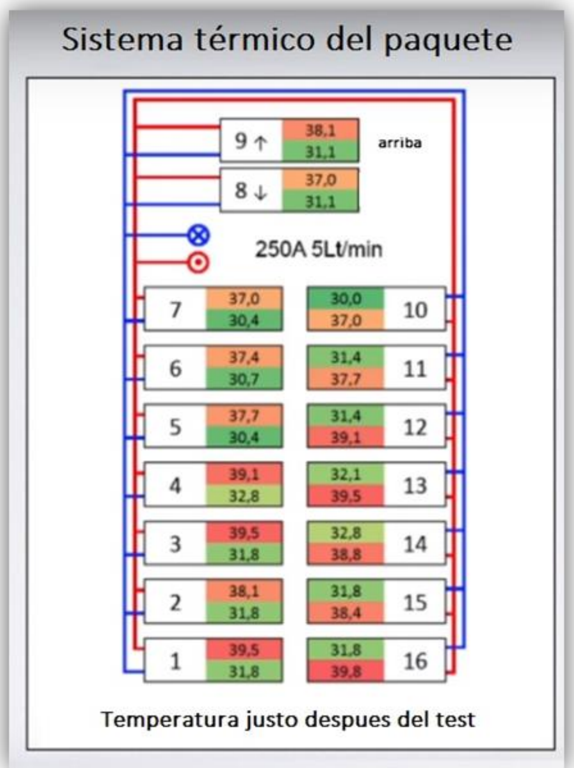
High Voltage Bus Bars connect 16 modules in series as we can observe in the image, the red part is the positive terminal and the black one the negative.

These Bus Bars are made of tin, they have a transversal section of 75mm2, longer than the ones used to match together the stacked front modules, which are connected through the main fuse. To finish with the packs, we will deal with its cooling system.

Results of different tests made by AVL show that the 100kwh battery pack provides good information about the cooling system.

The test consisted of repeated cycles of charging and discharging of 250A till the moment a stable temperature was reached. The test started at 20ºC with a coolant flow of 5L/m.

In the following diagram the cold side of the coolant flow is shown in blue and the hot one in red.



The coolant is divided from the very beginning to provide service to the 16 modules in parallel. The hot side in each module is connected in parallel to the hot output of the battery. Each module has two NTC sensors, which allow to measure the temperature of the coolant when going into the circuit and when getting out of it.

It is important to minimize the temperature changes in each cell, as the hotter they get, the sooner they degrade.

We can see in the image that under the conditions previously mentioned there are important temperature differences, reaching 8 degrees of difference between the entry and exit points as we can see in module 16. Moreover, there are almost 10 degrees temperature difference on the whole pack.

This temperature difference in modules arises because of the way in which the coolant circulates between cells. As it is an “s” shape movement it gets hotter and hotter till it goes out. As we have previously seen the cooling process in modules, Tesla has already started to replace this cooling system used in Model S and X, with a new one they are using in Model 3.

Conclusion

21 700 cells are the future in the short run for Tesla cells. The company will stop manufacturing 18 650 cells. They are already working on it for next Model 3 and Power Wall. According to Elon Musk, from Tesla, they will be cheaper and with a greater energy density, the greatest all over the world.

Tesla has relied on these battery formats, just the contrary as other traditional manufacturers have done. The intention of the Californian brand is to reduce costs with this type of cell. No doubt, they have already got the honour to be leading the sector of 100% electric vehicles.

The technology of Tesla batteries will be remembered as a key technological development in history, completely transforming automotive industry and that in just 5 years since it was released with the initial researches of Model S has proved that the lifespan and performance of the battery in real world is very efficient. And for sure, they will continue overcoming expectations.

The prospective for this technology is based in getting a battery ready to store a huge quantity of energy in a smaller space. The aim is to solve the main inconvenience of electric vehicles according to customers, that is, the autonomy and the charging time of these vehicles.

With current progresses in cells research, which show they are able to store more energy for longer periods of time, and with the possibilities opened by capacitors, it won’t be long the moment in which we could see cars with an equal or superior autonomy to that of a combustion engine vehicles, and with faster charging times.

NOTES:

The opinions presented in this document are the views of the STEP AHEAD II project partnership and do not have to express the opinions of the EU.

The impact of hybrid vehicles on the environment

The aim of the lesson:
To gain knowledge about the impact of hybrid vehicles on the environment.

ANNEX 1

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ANNEX 2

Introduction

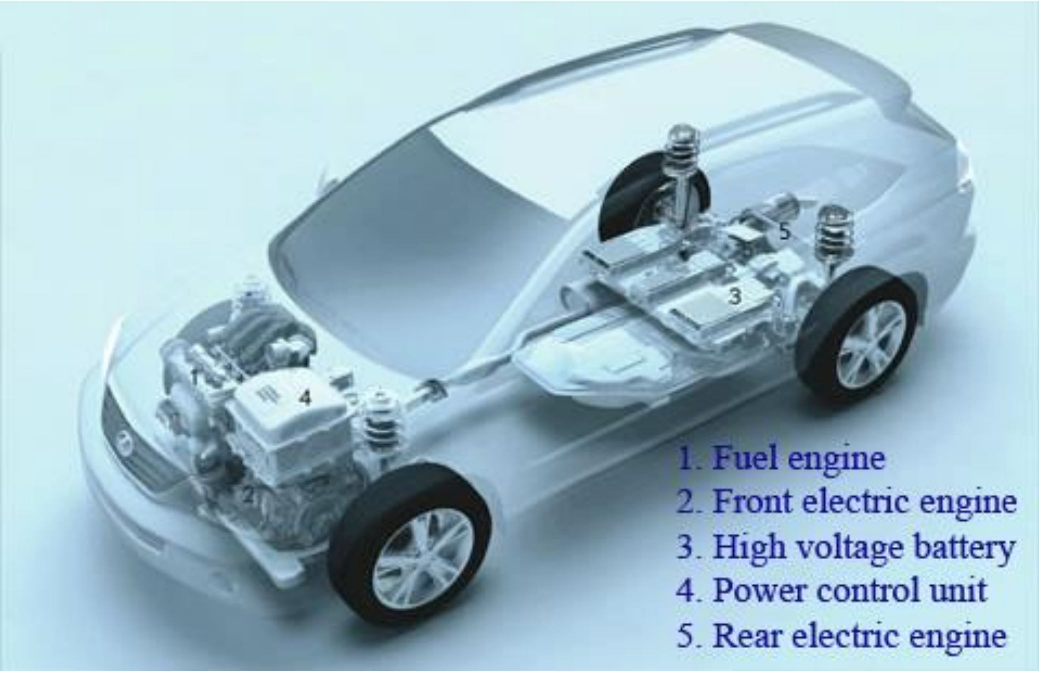
At the end of the 20th Century, first hybrid vehicles were developed. At that time, the main motivation to develop them was to offer an alternative for mobility for those who were interested in using accessible energies for mobility. Crude oil was scarce at the time, not because there was no more of it, but because of the limited infrastructural development of the techniques used for its extraction and further processing.

In the mid 70s, the lifetime of oil reserves was calculated for the first time. They had into consideration the hypothesis that oil consumption will remain at the same level that it was at that time. They concluded that we would have enough reserves for only about 50 years. Car manufacturers reacted to this statement and they started to get interested in looking for a replacement of internal combustion engines, and consumption of mineral oils, by using alternative engines fed by bio fuels, alcohol, hydrogen....

At the beginning of the 90s, a new worry shows up: the ecological impact of using crude oil, as the number one source of energy. It is currently causing on planet Earth a negative impact and there will also be possible negative consequences in the future related to crude oil use.

Over the year's, automotive industries have been concerned about developing cars which were as efficient as possible and they have been ahead of governmental administrations imposing themselves restrictions on emissions of on-road vehicles and on the engine fuel consumption.

In this context, the development of hybrid cars has arisen as a self-made need, in most cases, or determined by law regulations to manufacture more environmentally friendly cars. This has prompted the development of innovative solutions, more efficient to reduce the use of non-renewable energy sources as fuels, and often, more polluting. One of these solutions was hybrid cars, and the market, also influenced by this situation, has welcomed this extra effort of different brands, and has supported this type of vehicles with their decision to purchase the product.



Picture by DRMA20 Project. Spain

Environmental Impact and Fuel Consumption Decrease

Motor vehicles constitute one of the main sources of environmental pollution and gas emissions responsible for the greenhouse effect. The two most important types of greenhouse emissions are CO2 and methane.

On the other hand, the main polluting emissions caused by vehicles are the nitrogen oxides (NOx), hydrocarbons (HC) and the carbon monoxide (CO). These gas emissions coming from cars respectively account for 58%, 50% and 75% of total atmospheric emissions.

Moreover, cars contribute to other toxic pollutants such as lead, benzene, butadiene and some other carcinogens associated to the small solid particles emitted by car exhausts.

Gasoline produces a different type of pollutants through evaporation of fuel at specific parts of the car drive system; This evaporation represents about 30% of global emissions of hydrocarbons coming from mobile sources.

Suspended particles do not only proceed from the combustion process, since some of them are detached from the pavement itself due to the transit of vehicles. It is estimated that between 40% and 60% of suspended particles in urban areas come from road traffic; the rest of it proceeds from other type of activities (industry, farming, public and private works...)

Diesel vehicles cause five times more solid particles than petrol power units: meanwhile the former beams between 20 and 30 micrograms of particles per kilometre, cars powered by petrol only beam 5 micrograms covering the same distance.

As far as hybrid cars use an internal combustion engine, they can not be considered zero emission vehicles and they are still a source of atmospheric, as well as noise, pollution, exactly the same as conventional cars are.

On the other hand, the improved environmental performances of hybrid cars tend to decline over time, increasing polluting emissions as the car gets older.

On the following chart you can observe the average reduction of emissions of a hybrid car comparing it to a conventional car fulfilling current standards as far as EURO IV emissions, and depending on the fact they are petrol or diesel cars.

Average reduction of emissions. Comparison between hybrid vehicles and conventional vehicles.

		Gasoline		Diesel	
Emissions	Hybrid	Euro IV	% Reduction	Euro IV	% Reduction
NOx	0,01	0,08	87,5	0,25	96
CO	0,18	1,0	82	0,50	64
HC	0,02	0,10	80	0,05	60
PM	--	--	--	25	100
CO2	104	165	37	146	29

Reduction of emissions percentage, hybrid vehicle (Toyota Prius), with respect to one that complies with Euro IV regulations
Data CO2: Average values in new vehicles 2004. Data in g/Km except for PM that are indicated in mg/km

Worrying about CO_2 emissions is pretty common for customers and governments, due to, among other factors, the commitments undertaken through the signature of Kioto Protocol.

Because of specific mechanical features, like the regenerative braking, some hybrid cars can reach low average fuel consumption or even match those of smaller cars, not only in urban, but also in interurban trips.

As in the case of polluting emissions, hybrid cars offer a greater consumption decrease when driving in the city and the heavier the traffic. The possibility of turning off the combustion engine and keep moving by using the electrical engine together with the regenerative brake brings energy savings in vehicle fuel consumption.

Savings resulting from the use of the regenerative breaking equal a litre of fuel for each 100 kilometres when driving in urban areas. A generative braking, KERS (Kinetic Energy Recovery System) is a device which allows reducing car speed by transforming part of its kinetic energy into electrical energy. This energy is stored for future use.

The engine stop sequence of a combustion engine may represent on its own a saving in terms of energy consumption of about 10% in the ‘urban cycle’, reaching 17% if there is very heavy traffic, and a 6% savings in the ‘mixed cycle’

Waste generation

The use of cars generates a number of waste products:

- In the manufacturing process
- Throughout the vehicle's life
- At the end of the vehicle life (VFU)

Cars as waste generators:

Solid waste: Car bodywork parts (sheet metal panel, plastic, glass,….) tyres, batteries, mechanical components, electrical components, heavy metals….

Image https://pxhere.com/es/photo/775488

Liquid Waste: engine and transmission oils, liquid from the braking system, steering system, coolant, grease, lacquer and paint, solvent, paraffin's...

Image by Dvortygirl - His own work , CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=2584787

Gaseous waste: Emissions produced by thermal engines (CO_2, CO, HC, NO_x, SO_2...), air - conditioning systems, shock absorbers, airbags….

Image https://pxhere.com/es/photo/774074

Gaseous Waste (Exhaust emissions):

- Carbon Dioxide (CO_2): Generated during combustion and responsible for the greenhouse effect.
- Sulphurous Anhydride (SO_2): Generated during combustion, especially by diesel engines, as they use high-sulphur fuels, causing acid rain (SO_4H_2).

- Nitroxides (Nox): They appear during combustion causing acid rain (NO3H).
- Particles (PM): Generated during engine combustion, especially by diesel engines. They cause mist and respiratory ailments.
- Hydrocarbons (HC): Volatile compounds. Gasoline. They cause mist.
- Carbon Monoxide (CO): Very toxic. Almost non-existent.

Low performance of thermal engines

Combustion engines performance may vary a lot depending on the intended usage at any stage. The optimum use of energy produced by gasoline engines of this type are the following: 30% is obtained when the engine is running in conditions akin to full load. According to Bosch estimates, the thermal performance of an engine during an urban cycle for type- approval barely exceeds 10%.

Every modification in the charge of operation closer to partial or lower loads, as for example city slow traffic, involves accepting an inefficient use of gasoline, due to the consumption and emissions involved.

According to this, the best way to run a gasoline engine would be using it as close as possible to a full load. This cannot be done with a conventional vehicle, as the power generated by the engine is directly sent to the wheels and it would imply a constant acceleration.

Nevertheless, in some hybrid cars combustion engines are forced to run on a high level load, over 80%, only sending to the floor the power the driver demands by using the electronic throttle. The rest of the power would be stored as electric energy to a later use. The performance of both engines adapts automatically to the driving conditions and to the charge status of the batteries.

During the car first start-up, the gasoline engine remains inactive, and it is the electric engine the one in charge of moving the vehicle. This situation is maintained provided that the power required by the driver is moderate and the battery charge is enough. This allows a smooth, silent, and completely clean driving.

When a higher power is required or when the battery charge is lower, the gasoline engine starts running, as we mentioned before, on a load range over 80%. As soon as the battery charge is enough, the combustion is deactivated and the car is again driven by electrical means only. With this, we avoid getting the gasoline engine working with partial and lower loads, where it is particularly inefficient.

Power recovery

As it’s said, one of the new features provided by hybrid cars is the possibility of recovering part of the power by using the regenerative braking.

This brake system is able to restore during braking part of the kinetic energy of the vehicle, just because the car is moving at a certain speed.

In a conventional braking system, the kinetic energy is converted (it fades) to heat or thermal energy as a result of friction between the brake lining or brake blocks, on one side, and brake discs or brake drums on the other.

During deceleration and braking, the electric engine behaves as an electricity generator and makes the most of the kinetic energy of the car to get electricity to be stored in the batteries.

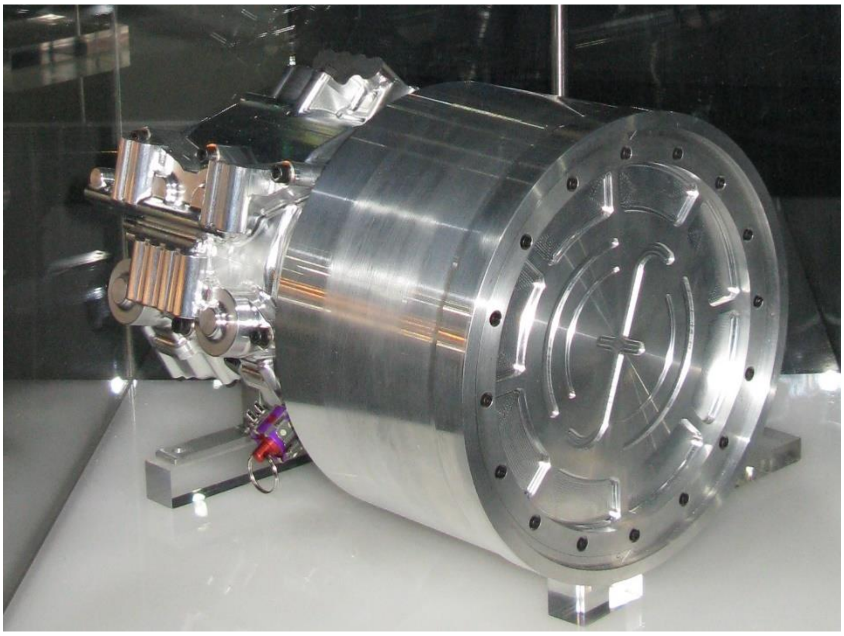


Image: By Geni - Photo by user:geni, CC BY-SA 4.0,
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This allows to get some power back, which otherwise would be lost as heat with a conventional braking system. The regenerative braking system works as long as the brakes are used and when the car stops speeding. This way, the system offers its greatest performance in those situations in which we find continuous speeding and non - speeding, as for example in an urban context.

When driving on a highway the regenerative braking system works from time to time, for example, when driving down a slope for a long time or when speed is reduced after overtaking another car.

It is calculated that it is possible to get back 30% of kinetic energy, which means saving about a litre of gasoline in 100 km when driving in an urban context, where you can find constant braking. Moreover, regenerative braking allows the reduction of weight of the conventional braking system in about 22%, lengthening its lifetime.

Silent advantages

There is another type of pollution which is not so easily recognised, but equally harmful: that is acoustic contamination caused by engine cars. The main sources of acoustic pollution in nowadays society are caused by engine vehicles. They are considered to be responsible for almost an 80% of that type of pollution.

Industry is thought to be responsible for at least 10% of noise emissions; railway services cause another 6% and public places, such as bars, the other 4%.

In Spain, the second noisiest country in the world after Japan, the vehicle fleet – consisting of 22 million vehicles nowadays – generates some areas of intense urban noise close to 85 dB(A).

From 65 dB(A) upwards, which is the limit accepted by the World Health Organization, human beings suffer some symptoms caused by that constant noise. In urban areas with heavy traffic, part of it comes from engines, another part from the high friction of tyres and the road itself which causes a considerable degree of noise levels.

During the last decades car manufacturers have made a great effort to reduce the noise caused by vehicles. Thus, the exhaust systems have been improved; the engine compartment has been isolated and encapsulated, and some other noise sources have been acoustically optimized like the air inlets or the external aerodynamic shape.

To a certain extent, hybrid cars are still conventional cars, as long as they have a combustion engine which is more or less used. That is why, when the combustion engine is running to medium or high speed, almost 100% of the noise sources match those of a conventional vehicle.

Nevertheless, when the hybrid car is stopped or is moving at a low speed, some of them stop their gasoline engine and drive only using the electrical system to move. In that way, the noise emissions can be reduced in more than 95%. In an urban context, this circumstance is quite usual, as most of the time cars move with heavy traffic, and very slowly (below 45km/h) or, simply, they are stopped.

Thus, the great advantage of hybrid cars is the silent use which it allows in urban areas, where the negative impact of acoustic pollution is bigger.

* Front page image by the authors of the digital book Hybrid vehicles II belonging to the project *DRMA2O (Spain) All images used in this document have been included for educational purposes only and are non-profit.*

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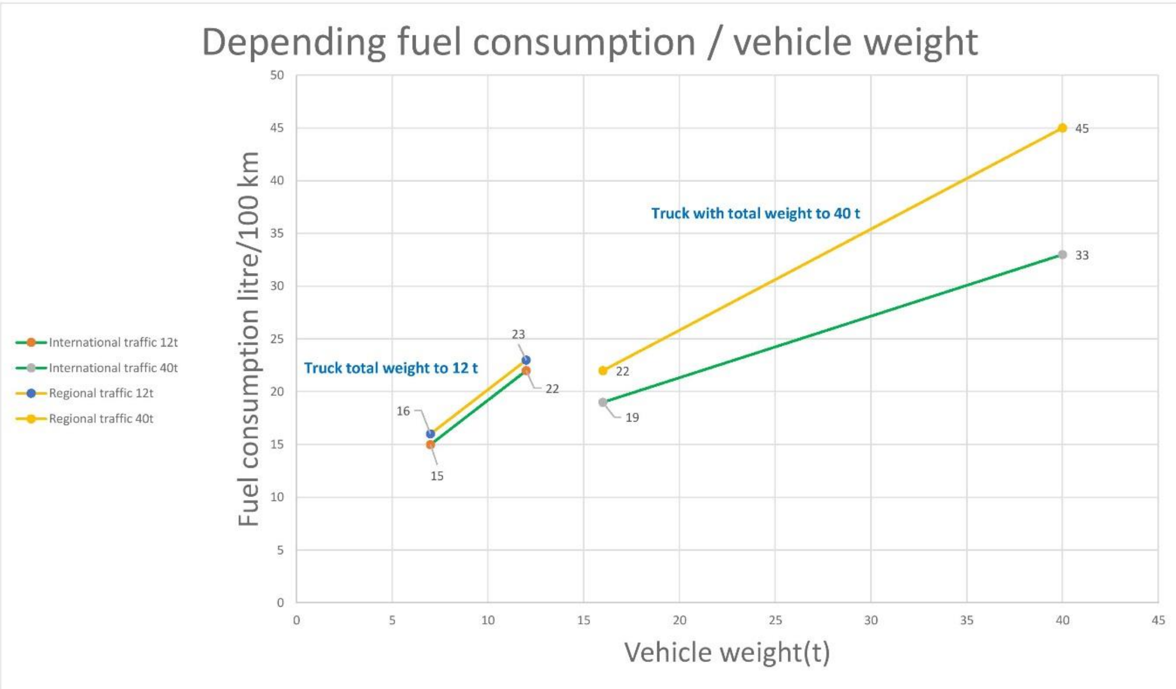
Truck fuel consumption

The aim of the lesson: Students will know the main important factors influencing fuel consumption

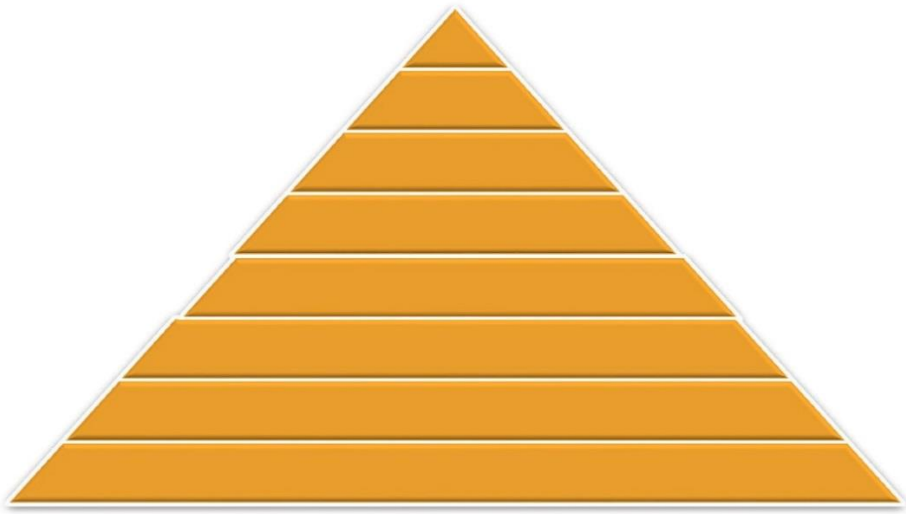
ANNEX 1



ANNEX 2

ANNEX 3

Order the factors influencing truck fuel consumption according to their importance:



vehicle configuration, type of traffic, road health, gradient (hill), weather, driving style, vehicle weight, vehicle health

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Trucks and the environment

The aim of the lesson:
To motivate the students to think about the impact of heavy road traffic on the environment.

ANNEX 1

Cleaner, safer trucks

Source: https://www.transportenvironment.org/what-we-do/cleaner-safer-trucks

Trucks have a major impact on global warming, the air we breathe, and the safety of pedestrians, cyclists and other road users.

Trucks have a major impact on global warming. While only accounting for 2% of the vehicles on the road in the European Union, they are responsible for 22% of road transport CO2 emissions and 15% of road collision fatalities, which is 4,000 EU citizens a year. What's more, road freight transport is projected to increase by 56% between 2010 and 2050. This means Europe needs to tackle truck emissions urgently to decarbonise transport.

The good news is that the EU is acting and that technology is developing rapidly too. Europe's first truck CO2 standards were agreed in 2019. In another first, Europe also agreed a 'direct vision' standard for trucks in 2019, along with design changes to enable truck-makers build safer and more aerodynamic cabs. But much remains to be done.

From more fuel efficiency to zero emissions trucks

T&E works on making trucks more fuel efficient and reducing their CO2 emissions while at the same time starting the shift away from fossil fuel trucks to zero-emission vehicles. With battery technologies improving, cities cleaning up their air, and looking at the recent announcements from different European truckmakers, electric trucks will enter our markets fast in the coming years. Industry players and companies also support our call for more fuel-efficient and zero- emission trucks. But we now need the supply and infrastructure to make this shift away from diesel and gas happen.

We are particularly focused on CO2 standards for trucks and the EU's upcoming revision of these targets in 2022. Truck CO2 standards agreed in 2019 require new trucks to be 15% more fuel efficient by 2025. For 2030 the emission reduction target is 30%. This will reduce the CO2 emissions coming from trucks while at the same time helping drivers and companies to save money and fuel. From 2025 truckmakers that sell more than 2% zero and low-emission trucks will gain a bonus. In the revision in 2022, ambition needs to be increased to really kickstart the market for low and zero-emission trucks.

The reform of the weights and dimensions legislation in 2019 means that truckmakers can put cleaner and safer truck cabs on the road from September 2020. The work on truck efficiency is complemented by our work on road charging and fuel taxation. At the same time we reject claims that increasing the load capacity of lorries (megatrucks) contributes to lower emissions in road freight in any meaningful way.

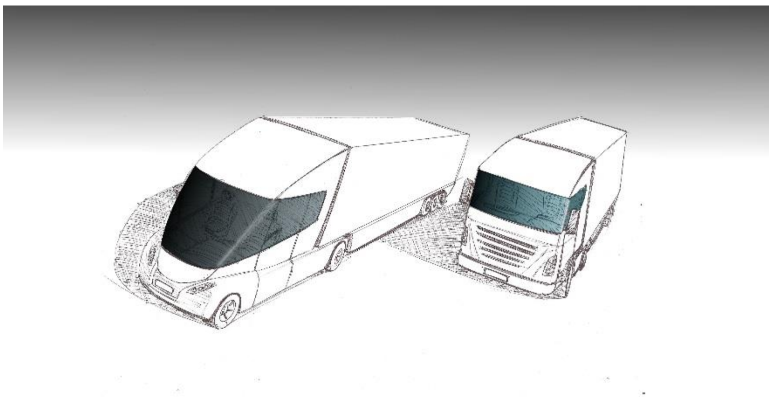

Image courtesy of PEM Motion Gmbh

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Truck hybrids

The aim of the lesson: To teach students the basics of Hybrid truck powerline

ANNEX 1

K – W – L table - Truck hybrids

"K" (I Know)	"W" (I Want to know/learn)	"L" (I Learnt)

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Truck hybrids

The aim of the lesson: To teach students the basics of Hybrid truck powerline

ANNEX 2

Hybrid vehicles (passenger and trucks)

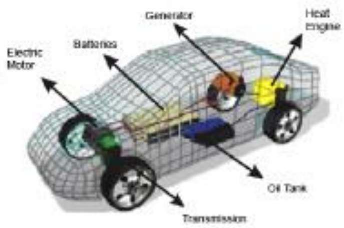
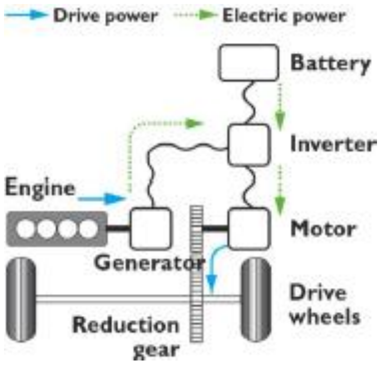
A hybrid electric vehicle (HEV) has two types of energy storage units, electricity and fuel. Electricity means that a battery (sometimes assisted by ultracaps) is used to store the energy, and that an electromotor (from now on called motor) will be used as traction motor.
Fuel means that a tank is required, and that an Internal Combustion Engine (ICE, from now on called engine) is used to generate mechanical power, or that a fuel cell will be used to convert fuel to electrical energy. In the latter case, traction will be performed by the electromotor only. In the first case, the vehicle will have both an engine and a motor.

- Depending on the drive train structure (how motor and engine are connected), we can distinguish between parallel, series or combined HEVs. This will be explained in paragraph 1. Depending on the share of the electromotor to the traction power, we can distinguish between mild or micro hybrid (start-stop systems), power assist hybrid, full hybrid and plug-in hybrid. This will be explained in paragraph 2.
- Depending on the nature of the non-electric energy source, we can distinguish between combustion (ICE), fuel cell, hydraulic or pneumatic power, and human power. In the first case, the ICE is a spark ignition engines (gasoline) or compression ignition direct injection
- (diesel) engine. In the first two cases, the energy conversion unit may be powered by gasoline, methanol, compressed natural gas, hydrogen, or other alternative fuels.

Motors are the "work horses" of Hybrid Electric Vehicle drive systems. The electric traction motor drives the wheels of the vehicle. Unlike a traditional vehicle, where the engine must "ramp up" before full torque can be provided, an electric motor provides full torque at low speeds. The motor also has low noise and high efficiency. Other characteristics include excellent "off the line" acceleration, good drive control, good fault tolerance and flexibility in relation to voltage fluctuations.
The front-running motor technologies for HEV applications include PMSM (permanent magnet synchronous motor), BLDC (brushless DC motor), SRM (switched reluctance motor) and AC induction motor.

A main advantage of an electromotor is the possibility to function as generator. In all HEV systems, mechanical braking energy is regenerated.
The max. operational braking torque is less than the maximum traction torque; there is always a mechanical braking system integrated in a car.
The battery pack in a HEV has a much higher voltage than the SIL automotive 12 Volts battery, in order to reduce the currents and the I2R losses.
Accessories such as power steering and air conditioning are powered by electric motors instead of being attached to the combustion engine. This allows efficiency gains as the accessories can run at a constant speed or can be switched off, regardless of how fast the combustion engine is running. Especially in long haul trucks, electrical power steering saves a lot of energy.

Types by drivetrain structure
In a series hybrid system, the combustion engine drives an electric generator (usually a three-phase alternator plus rectifier) instead of directly driving the wheels. The electric motor is the only means of providing power to the wheels. The generator both charges a battery and powers an electric motor that moves the vehicle. When large amounts of power are required, the motor draws electricity from both the batteries and the generator.

Series hybrid configurations already exist a long time: diesel-electric locomotives, hydraulic earth moving machines, diesel-electric power groups, loaders.
A complex transmission between motor and wheel is not needed, as electric motors are efficient over a wide speed range. If the motors are attached to the vehicle body, flexible couplings are required. Home vehicle designs have separate electric motors for each wheel. Motor integration into the wheels has the disadvantage that the unsprung mass increases, decreasing ride performance. Advantages of individual wheel motors include simplified traction control (no conventional mechanical transmission elements such as gearbox, transmission shafts, differential), all wheel drive, and allowing lower floors, which is useful for buses. Some 8x8 all-wheel drive military vehicles use individual wheel motors.

Advantages of series hybrid vehicles:

- There is no mechanical link between the combustion engine and the wheels. The engine-generator group can be located everywhere.

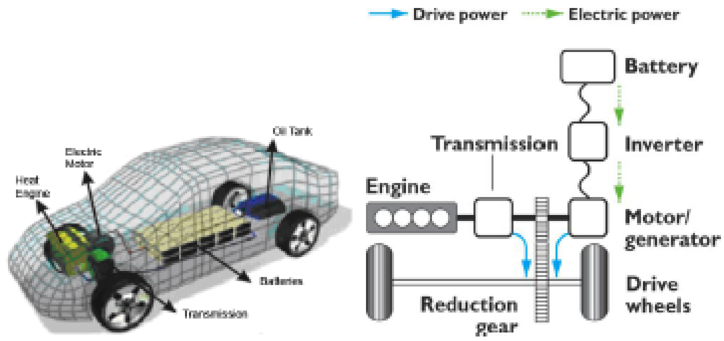
- There are no conventional mechanical transmission elements (gearbox, transmission shafts). Separate electric wheel motors can be implemented easily.
- The combustion engine can operate in a narrow rpm range (its most efficient range), even as the car changes speed.
- Series hybrids are relatively the most efficient during stop-and-go city driving.

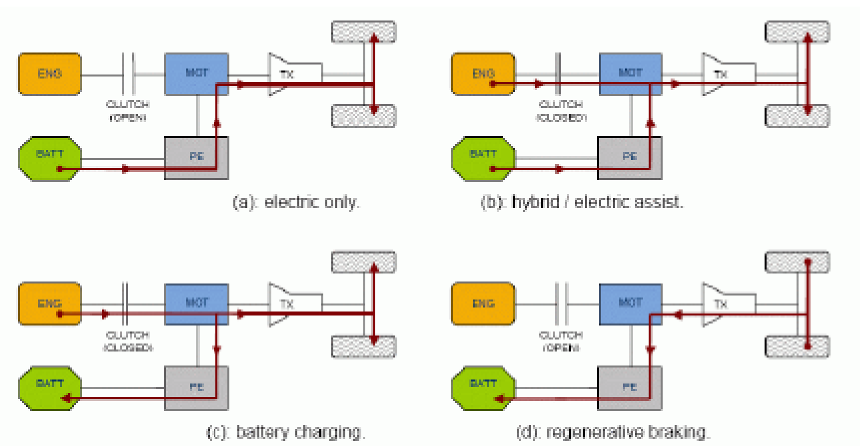
Weaknesses of series hybrid vehicles:

- The ICE, the generator and the electric motor are dimensioned to handle the full power of the vehicle. Therefore, the total weight, cost and size of the powertrain can be excessive.
- The power from the combustion engine has to run through both the generator and electric motor. During long-distance highway driving, the total efficiency is inferior to a conventional transmission, due to the several energy conversions.

Parallel hybrid

Parallel hybrid systems have both an internal combustion engine (ICE) and an electric motor in parallel connected to a mechanical transmission. Most designs combine a large electrical generator and a motor into one unit, often located between the combustion engine and the transmission, replacing both the conventional starter motor and the alternator (see figures above). The battery can be recharged during regenerative breaking, and during cruising (when the ICE power is higher than the required power for propulsion). As there is a fixed mechanical link between the wheels and the motor (no clutch), the battery cannot be charged when the car isn't moving. When the vehicle is using electrical traction power only, or during brake while regenerating energy, the ICE is not running (it is disconnected by a clutch) or is not powered (it rotates in an idling manner).





(a) electric power only: Up to speeds of usually 40 km/h, the electric motor works with only the energy of the batteries, which are not recharged by the ICE. This is the usual way of operating around the city, as well as in reverse gear, since during reverse gear the speed is limited.
(b) ICE + electric power: if more energy is needed (during acceleration or at high speed), the electric motor starts working in parallel to the heat engine, achieving greater power
(c) ICE + battery charging: if less power is required, excess of energy is used to charge the batteries. Operating the engine at higher torque than necessary, it runs at a higher efficiency.
(d) regenerative breaking: While braking or decelerating, the electric motor takes profit of the kinetic energy of the he moving vehicle to act as a generator.

Advantages of parallel hybrid vehicles:

- Total efficiency is higher during cruising and long-distance highway driving.
- Large flexibility to switch between electric and ICE power
- Compared to series hybrids, the electromotor can be designed less powerful than the ICE, as it is assisting traction. Only one electrical motor/generator is required.

Weaknesses of parallel hybrid vehicles:

- Rather complicated system.
- The ICE doesn’t operate in a narrow or constant RPM range, thus efficiency drops at low rotation speed.
- As the ICE is not decoupled from the wheels, the battery cannot be charged at standstill.

Combined hybrid

Combined hybrid systems have features of both series and parallel hybrids. There is a *double connection between the engine and the drive axle: mechanical and electrical*. This split power path allows interconnecting mechanical and electrical power, at some cost in complexity.
Power-split devices are incorporated in the powertrain. The power to the wheels can be either mechanical or electrical or both. This is also the case in parallel hybrids. But the main principle behind the combined system is the *decoupling of the power supplied by the engine from the power demanded by the driver*.

In a conventional vehicle, a larger engine is used to provide acceleration from standstill than one needed for steady speed cruising. This is because a combustion engine's torque is minimal at lower RPMs, as the engine is its own air pump. On the other hand, an electric motor exhibits maximum torque at stall and is well suited to complement the engine's torque deficiency at low RPMs. In a combined hybrid, a smaller, less flexible, and highly efficient engine can be used. It is often a variation of the conventional Otto cycle, such as the Miller or Atkinson cycle. This contributes significantly to the higher overall efficiency of the vehicle, with regenerative braking playing a much smaller role.
At lower speeds, this system operates as a series HEV, while at high speeds, where the series powertrain is less efficient, the engine takes over. This system is more expensive than a pure parallel system as it needs an extra generator, a mechanical split power system and more computing power to control the dual system.

Advantages of combined hybrid vehicles:

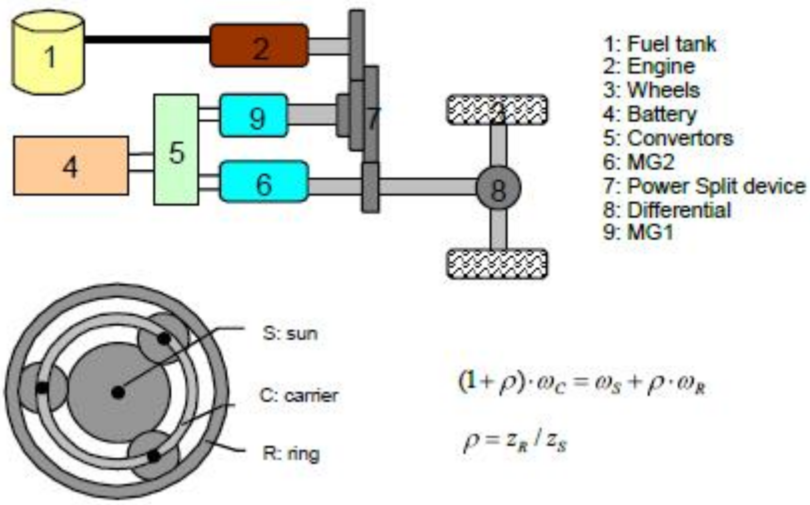
- Maximum flexibility to switch between electric and ICE power

- Decoupling of the power supplied by the engine from the power demanded by the driver allows for a smaller, lighter, and more efficient ICE design.

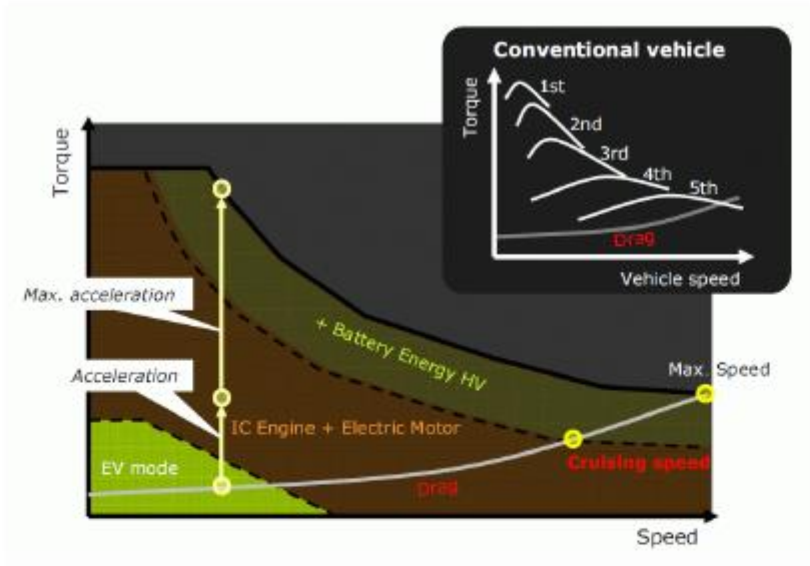
Weaknesses of combined hybrid vehicles:

- Very complicated system, more expensive than parallel hybrid.

- The efficiency of the power train transmission is dependent on the amount of power being transmitted over the electrical path, as multiple conversions, each with their own efficiency, lead to a lower efficiency of that path (~70%) compared with the purely mechanical path (98%).



Combined HEV with planetary unit as used in the Toyota Prius



Combined hybrid drive modes

Plug-in hybrid (= grid connected hybrid = vehicle to grid V2G)

All the previous hybrid architectures could be grouped within a classification of charge sustaining: the energy storage system in these vehicles is designed to remain within a fairly confined region of state of charge (SOC). The hybrid propulsion algorithm is designed so that on average, the SOC of energy storage system will more or less return to its initial condition after a drive cycle. A plug-in hybrid electric vehicle (PHEV) is a full hybrid, able to run in electric-only mode, with larger batteries and the ability to recharge from the electric power grid. Their main benefit is that they can be gasoline-independent for daily commuting, but also have the extended range of a hybrid for long trips.

Grid connected hybrids can be designed as charge depleting: part of the "fuel" consumed during a drive is delivered by the utility, by preference at night. Fuel efficiency is then calculated based on actual fuel consumed by the ICE and its gasoline equivalent of the kWh of energy delivered by the utility during recharge. The "well-to-wheel" efficiency and emissions of PHEVs compared to gasoline hybrids depends on the energy sources used for the grid utility (coal, oil, natural gas, hydroelectric power, solar power, wind power, nuclear power). In a serial Plug-In hybrid, the ICE only serves for supplying the electrical power via a coupled generator in case of longer driving distances. Plug in hybrids can be made multi-fuel, with the electric power supplemented by diesel, biodiesel, or hydrogen.

For typical driving cycles, the achieved efficiencies are lower. The battery powered EV achieves efficiencies in the range of 50 to 60%. The hydrogen powered EV has a total efficiency of about 13% only at those drive cycles.

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