FIA ENECC

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E-Rally Regularity Organizer's meeting

Charging of electric vehicles

- General considerations for EV charging
- We consider here two families of vehicles:
- **BEV** (Battery Electric Vehicles), where “refueling” is done by electric cables, connected to an AC or DC source of electric power
- **FCEV** (Fuel Cell Electric Vehicles), where “refueling” is done by high-pressure pipes connected to an hydrogen tank

. All BEVs have always the possibility to be charged in AC, using an onboard charger. There are different modes available for AC charging. Some BEVs are suitable for fast charging, usually in DC (mode 4).

Actually FCEV vehicles are still not widespread, but some models are starting to circulate in the world.

BEV e-cars approved for Class M1 on sale 2018/19 on European/USA market as new or used and their on-board charge systems - #1

Manufacturer	Model	AC Connector	DC mode 4	kWh nominal	kWh usability	Operating Range km	Consum-ption Wh/km
Audi	Q2	Type 2	CCS 150 kW	95		400	
Audi	R8						
Baic	407				43	200	
Baic Bjev	Arcfox Lite						121
Baic Bjev	EX5 EV SUV					350	
BMW	i3	Type 2	Option CCS Combo	22			
BMW	i3 RE	Type 2	Option CCS Combo	22			
BMW	i3 94Ah	Type 2	Option CCS Combo	28		200	132
BMW	i3s 94Ah	Type 2	Option CCS Combo	28		200	143
BMW	i3 94Ah RE	Type 2	Option CCS Combo	28		330	132
BMW	I3 120 Ah	Type 2	Option CCS		43.2	350	
BMW	Active E					151	

BEV e-cars approved for Class M1 on sale 2018/19 on European/USA market as new or used and their on-board charge systems - #2

Manufacturer	Model	AC Connector	DC mode 4	kWh nominal	kWh usability	Operating Range km	Consum-ption Wh/km
Bollorè	B0 Bluecar	Type 1		30		250	
Bollorè	Bluesummer	Type 2	CHAdeMO	30		200	
BYD	E6			82	75	300	180
BYD	Tang EV500					500	
Mercedes	EQC 400 4MATIC	Type 2	CCS 110 kW	80	78	369	209
Changan	Niou II EV					205	
Changan	Eado ET				53	400	
Chevrolet	Spark	Type 1				112	
Chevrolet	Bolt	Type 2	CCS Combo	60		381	
Citroen	C0	Type 1	CHAdeMO	16	14.5	150	106
Citroen	E-mehari	Type 1		30		200	133
Citroen	E-Berlingo Feel	Type 1				170	175

BEV e-cars approved for Class M1 on sale 2018/19 on European/USA market as new or used and their on-board charge systems - #3

Manufacturer	Model	AC Connector	DC mode 4	kWh nominal	kWh usability	Operating Range km	Consum-ption Wh/km
Dok-Ing	LOOX				33		140
Dongfeng Yueda Kia	KX3 EV SUV					300	
EVEasy-JMC	E300 A0					252	
FAW	Besturn X40 EV SUV				52.5		
FIAT	500e	Type 1				140	181
Ford	Focus E	Type 1				160	154
GAC	Aion S					500	
Han Teng	Happiness e+					300	
Han Teng	X5 EV						
Honda	Clarity Fuel Cell						
Honda	FiT	Type 2		20		131	
Honda	Everus				54		

BEV e-cars approved for Class M1 on sale 2018/19 on European/USA market as new or used and their on-board charge systems - #4

Manufacturer	Model	AC Connector	DC mode 4	kWh nominal	kWh usability	Operating Range km	Consum-ption Wh/km
Hozon New Energy	Neta 01					302	
Hozon New Energy	Neta 03					400	
Hyundai	Ioniq electric	Type 2	CCS Combo 100 kW			280	115
Hyundai	Kona EV SR	Type 2	CCS Combo 100 kW			250	
Hyundai	Kona EV LR	Type 2	CCS Combo 100 kW			312	
Hyundai	Ioniq		CCS Combo 100 kW			482	
Jaguar	i-Pace	Type 2	CCS Combo 100 kW		39.2	480	
Kia	Soul EV	Type 2	CHAdeMO		64	190	130
Kia	Niro BEV	Type 2	CCS Combo 100 kW		90		
Kia	Niro BEV	Type 1	CCS Combo 100 kW				

BEV e-cars approved for Class M1 on sale 2018/19 on European/USA market as new or used and their on-board charge systems - #5

Manufacturer	Model	AC Connector	DC mode 4	kWh nominal	kWh usability	Operating Range km	Consum-ption Wh/km
Luxgen	Yulon U5 EV					320	
Mercedes	Classe B Electric Drive	Type 2		28		230	
Mia	Mia Electric	Type 1					
Mini	ED						
Mitsubishi	i-Miev	Type 1	CHAdeMO	16	14,5	150	106
Nio	ES8						
Nissan	Leaf	Type 1	Option CHAdeMO	30	22	250	150
Nissan	Leaf 2 40 kWh	Type 2	Option CHAdeMO	40		242	
Nissan	Leaf 2 60 kWh	Type 2	Option CHAdeMO	60		378	192
Nissan	E-NV200 Evalia Combi	Type 1	Option CHAdeMO	24		167	165
Opel	Ampera-e	Type 2	CCS Combo	60		381	
ORA	IQ5 SUV					401	

BEV e-cars approved for Class M1 on sale 2018/19 on European/USA market as new or used and their on-board charge systems - #6

Manufacturer	Model	AC Connector	DC mode 4	kWh nominal	kWh usability	Operating Range km	Consum-ption Wh/km
ORA	R1					310	
Peugeot	Ion Active	Type 1	CHAdeMO	16	14.5	150	106
Peugeot	Partner Tepee El. Active					170	175
Peugeot	E-Berlingo	Type 1	CHAdeMO		22.5	170	
Porsche	Taycan					440	
Qianto	K50				79	380	199
Qoros	3 EV					450	
Renault	Zoe Q210	Type 2		26	22	195	135
Renault	Zoe R240	Type 2		26	22	225	135
Renault	Zoe R90	Type 2		45,6	41	403	133
Renault	Zoe Q90	Type 2		45,6	41	367	133
Renault	Fluence ZE					185	

BEV e-cars approved for Class M1 on sale 2018/19 on European/USA market as new or used and their on-board charge systems - #7

Manufacturer	Model	AC Connector	DC mode 4	kWh nominal	kWh usability	Operating Range km	Consum-ption Wh/km
Renault	Kangoo ZE	Type 2					
Saic GM	MG ZS EV					428	
Saic GM	Marvel X						
Saic GM	Bojun E200						
Smart	ForTwo ED Coupè	Type 2		17,6		145	
Smart	ForTwo ED Cabrio	Type 2		17,6		145	
Smart	ForFour ED	Type 2				155	
Sono	Sion					200	
Tata	Tigor EV					100	
Tata	Megapixel Reev				13	87	

BEV e-cars approved for Class M1 on sale 2018/19 on European/USA market as new or used and their on-board charge systems - #8

Manufacturer	Model	AC Connector	DC mode 4	kWh nominal	kWh usability	Operating Range km	Consum-ption Wh/km
Tazzari	EM2	Type 1		13		146	
Tesla	Roadster		Tesla		25	340	
Tesla	Model S 75	Type 2	Tesla	75			
Tesla	Model S 75 - 7 seats	Type 2	Tesla	75			
Tesla	Model S 75D	Type 2	Tesla	75		490	
Tesla	Model S 75D - 7 seats	Type 2	Tesla	75		490	
Tesla	Model S 100D	Type 2	Tesla	100		632	
Tesla	Model S 100D - 7 seats	Type 2	Tesla	100		632	
Tesla	Model S P100D	Type 2	Tesla	100		613	
Tesla	Model S P100D - 7 seats	Type 2	Tesla	100		613	
Tesla	Model X 75D	Type 2	Tesla	75		417	
Tesla	Model X 90D	Type 2		90			

BEV e-cars approved for Class M1 on sale 2018/19 on European/USA market as new or used and their on-board charge systems - #9

Manufacturer	Model	AC Connector	DC mode 4	kWh nominal	kWh usability	Operating Range km	Consum-ption Wh/km
Tesla	Model X 100D	Type 2	Tesla	100		565	
Tesla	Model X P100D	Type 2	Tesla	100		542	
Tesla	Model 3		Tesla + CCS Combo	50		350	
Tesla	Model 3 – Long range		Tesla + CCS Combo	74		496	
Tesla	Model 3 Dual Motor		Tesla + CCS Combo			496	
Tesla	Model 3 AWD		Tesla + CCS Combo			496	
Think	Th!nk						
VW	eUP!	Type 2	CCS Combo 40 kW	19		120	140
VW	eGolf	Type 2	Option CCS Combo	25		200	117
VW	eGolf 2017	Type 2	Option CCS Combo	40	35.8		
Xpeng	G3 EV SUV						
Zotye	Z500 Pro EV						

e-cars on board 2018 charging systems

On all these e-cars, there is at least one socket for single-phase or three-phase power supply. AC power could vary from 2,7 kW for Tazzari cars to 43 kW for some types of Renault Zoe.

Some cars have an additional DC socket for fast charging up to 150 kW.

On CCS Combo and CCS Combo 2 connectors there are both supply types, AC+DC. On some models of cars the DC socket could be an option, available only with an extra price.

CHAdeMO sockets have different ratings, from 22 kW to 150 kW. Tesla cars have a custom connector specific for Tesla Superchargers, only the Model 3 has also a CCS Combo socket.

FCEV Hydrogen Cars Class M1 on sales on European market as new or used in Year 2018. The fuel is Hydrogen.

Manufacturer	Model	AC Connector	DC mode 4	kWh nominal	kWh usability	Operating Range km	Consum-ption Wh/km
Honda	Clarity Fuel Cell			17		480	
Hyundai	Nexo			1.56		600	
Hyundai	Tucson FCEV					426	
Mercedes	F-Cell Class B					310	
Riversimple	Rasa					480	
Toyota	Mirai			1.6		500	

Supply of hydrogen to a fuel cell car

Hyundai Nexo display

Charging systems and modes for BEVs

Charging systems

All battery e-cars on European territory can have on-board at least one, or also two of the following charging systems:

A) Single-phase or three-phase AC charging system, with on-board charger
B) DC charging system, without on-board charger

Charging modes

To connect electric vehicles to the main supply there are **4 standard modes**, as defined by IEC 62196 standard, as follows:

Mode 1: AC direct connection, max 16 Ampere

Mode 2: AC semi-active connection, with control box

Mode 3: AC with active connection, up to 250 Ampere

Mode 4: DC with active connection, up to 400 Ampere

Plugs for BEVs

1) IEC **Type 1** (Yazaki – SAE J1772)
2) IEC **Type 2** (Mennekes - CharIN)
3) Type 4 (ChadeMo) up to 500 VDC, up to 125 A
4) CCS Combo up to 400 VDC, up to 200 A
5) CCS Combo 2 up to 1000 VDC, up to 350 kW
6) Tesla custom type

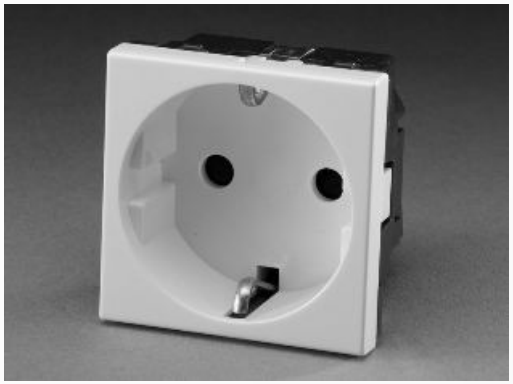
Tesla DC connector

IEC DC Charging Systems

	System A	System B	System C	
	CHAdeMO (Japan)	GB/T (PRC)	COMBO1 (US)	COMBO2 (DE)
Connector				
Vehicle Inlet				
Communication Protocol	CAN		PLC	

Electrical sockets and plugs for Eco-Rallies

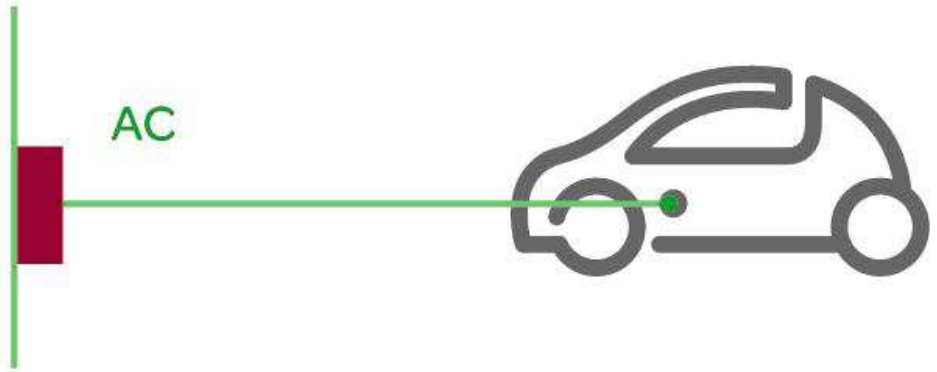
Well-known Schuko sockets are suitable for loads of 16 A but only for intermittent duty. For continuous use the maximum current must be reduced to 10 A or less, to avoid dangerous risk of fire, specially if sockets are not enough cooled or if they are too close to one another. Maximum AC voltage is 250 V.



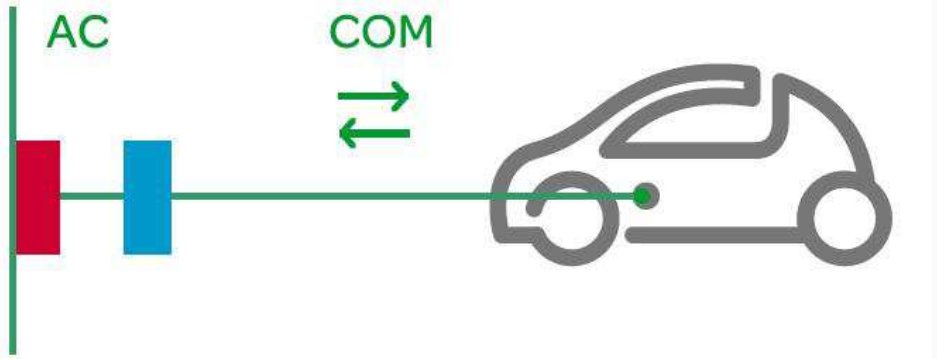
The IEC309 industrial sockets are more suitable for e-cars than Schuko types. The blue type can support continuously 16 A with AC voltages up to 250 V. For higher voltages up to 600 V there are sockets and plugs with different colours and sizes.

Mode 1 and Mode 2 for charging

Mode 1: direct connection, at maximum current of 16 A, at max 250 VAC if single-phase or max 480 VAC if three-phase. In some countries, Mode 1 is prohibited. It is never recommended for e-cars. On public areas Mode 1 cannot be used.

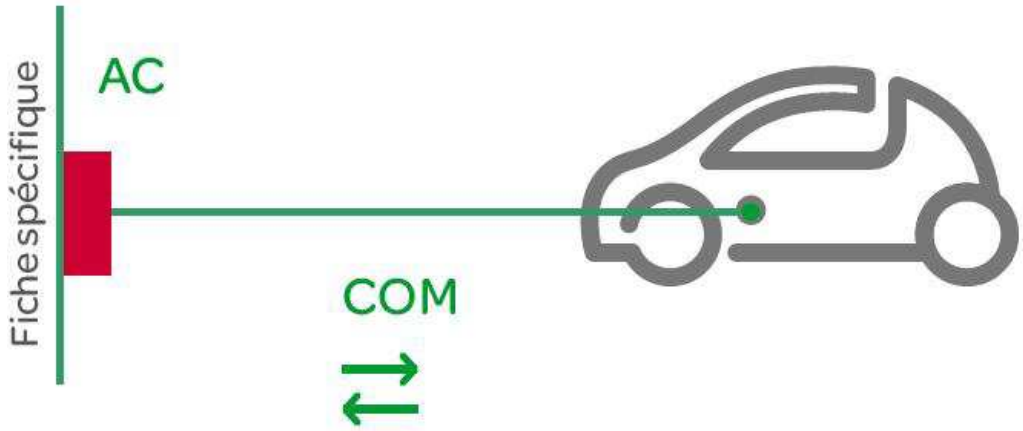


Mode 2: semi-active connection, similar to Mode 1, but with an additional “control box” on the middle of the charging cable. The control box offers much better safety to the charging system, so Mode 2 charging should be considered as minimum requirement for use in eco-rallies.

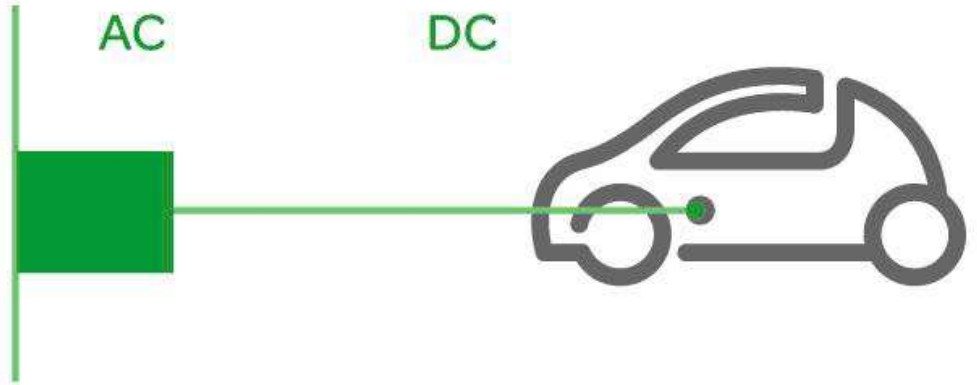


Mode 3 and Mode 4 for charging

Mode 3: for AC charging currents up to 250 A, an active connection between EV and the EVSE (Electric Vehicle Supply Equipment) is mandatory. The charging power is available only after communications with the EV charger on-board.



Mode 4: for DC charging currents up to 400 A, with mandatory active connection. The programmable rectifier is placed on the ground.



Set of plugs and cables
equipped for charging a BEV

Mode 2 adapter

Electric panel with N. 2 single-phase IEC 309 16 A sockets and N.2 Shuko sockets

Service vehicle by e-rally organizer with cables, plugs and panels for charging culumn plant sufficient for 30 BEV

Recharge area with culums in a park fermè. Every socket have the number of the car

Example for power and energy needed to charge 20 vehicles at the same time

Using slow chargers onboard on vehicles it is possible to connect the cars to power outlets to withdraw power for a certain time. For example, if the AC charger ask 10 A @ 230 V, 2.3 kW (kilowatts) are needed. For every hour are 2.3 kWh. For 16 A are needed 3.7 kW. For every hour are 3.7 kWh.

If 20 vehicles ask for 2.3 kW each, the total needed power will be 46 kW.

In one hour, the energy consumption from the main will be 46 kWh.

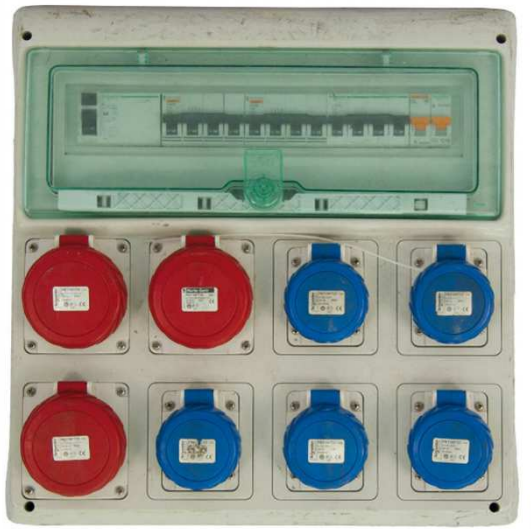
If 20 vehicles at 3.7 kW each, the total needed power will be 74 kW.

In one hour, the energy consumption from the main will be 74 kWh.

Power and energy needed to charge 20 vehicles at the same time

For safety reasons, it is mandatory that a professional electrician will check the right configuration, cable sizing, electrical insulation and protection devices of the sockets for chargers. All of these components are calculate for the correct number of BEV. The weakest link should be probably the socket Schuko, limiting the current to 10 A means that the available power at each charger will be in the order of 2,3 kW. Instead, using IEC309 sockets for 16 A, available power will be about 3,7 kW.

For sockets placed outside it is mandatory to use components with a very high degree of protection (IP grade) against rain, also when the covers are open.



Adapters for sockets and plugs in Mode 2

Example of charging cable (7.5 m length) for AC MODE2 with control box and plug standard IEC309-2 2P+E 16 A. From the control box it is possible to select the charging current to adapt it to the main availability.

State of charge – range displays examples #1

Nissan Leaf

Cadillac CT6

Tesla S

State of charge – Range display examples #2

Chevrolet Bolt EV

Ford Focus Electric

State of charge – Range display examples #3

Chevrolet Spark EV

Kia
Soul EV

Mercedes Benz Call B Electric

Volkswagen e-Golf

Power meters

On the market there are very cheap kWh-meters useful to measure current up to 16 A @ 230 VAC. Some of these devices have an integrated Schuko plug.

It is important that the meter is CE approved and tested by some reliable certification bodies, for example:

TÜV SÜD TÜV GS TÜVRheinland® Precisely Right. CE QA INTERNATIONAL

Formula to get the consumption winner slide 1

True Energy (TrEn)
In order to establish the true energy used during the event, the following formula must be applied:

$$TrEn = (NTE + REM) - FRE$$

With the abbreviations:

TrEn	True Energy used in the event
NTE	Nominal Theoretical Energy [kWh]
REM	Recharged Energy from the Main
FRE	Final Remaining Energy at the end of the event

Consumption Index (C.I.)
In order to establish the energy classification the following formula must be applied:

$$C.I. = \frac{TrEn}{km}$$

km: Total length of the itinerary (km). The total length of the itinerary as given in the Road Book and/or in the Supplementary Regulations in km.

The lowest index value C.I. establishes the winner.

Formula to get the consumption winner – slide 2

For vehicles, which must start the event with a fully charged battery pack, this value should be the nominal capacity in kWh of the propulsion battery pack. This data must be provided by an official document issued by the vehicle manufacturer.

For vehicles FCEV which must start the event with completely filled fuel tank, NTE should be the equivalent energy in kWh of the necessary fuel for the complete replenishment of the tank at the end of the event.

The equivalent energy of 1 kg of Hydrogen is 33393 Wh.

For vehicles FCEV, which must start the event with a fully charged battery pack and with completely filled Hydrogen tank, NTE should be the combination of the capacity in kWh of the propulsion battery pack (provided by an official document issued by the accumulator manufacturer) and the equivalent energy in kWh of the necessary fuel for the complete replenishment of the tank during and at the end of the event.

Glossary

Initials	Full name		Initials	Full name
AC	Alternating current		EVSE	Electric vehicle supply equipment
Ah	Amper-hours, units for batteries		FCEV	Fuel Cell Electric vehicle
bar	Unit for pressure, 1 bar = 0.1 MPa		FIA	Federation Internationale de l'Automobile
BEV	Battery Electric Vehicle		GS	Geprüfte Sicherheit (German mark for safety)
CCS	Combined Charging System		HEV	Hybrid Electric Vehicle
CE	Certification mark in EU		IEC	International Electrotechnical Commission
CHAdeMO	CHArge de MOve (Japanese standard)		IP	International Protection
Combo	Combination of AC+DC charging		kg	Kilograms, units for weight
DC	Direct Current		km	Kilometres, units for lenght
ENECC	Electric and New Energy Championships Commission		kW	Kilowatts, units for power
EPA	Environmental Protection Agency		kWh	Kilowatt-hours, units for energy
EREV	Extended-range electric vehicle		PHEV	Plug-in Hybrid Electric Vehicle)
EV	Electric Vehicle		TUV	Technischer Überwachungs-Verein (Certification body)

References and copyrights

https://greentransportation.info/ev-charging/range-confidence/chap8-tech/ev-dc-fast-charging-standards-chademo-ccs-sae-combo-tesla-supercharger-etc.html

More information about IEC 62196 standard: https://en.wikipedia.org/wiki/IEC_62196
More information about EV charging systems: https://en.wikipedia.org/wiki/Charging_station

Thank you for your kind attention

Geneve 23-11-2018
Mario Bonifacio
E-Rally Regularity Organizer's meeting