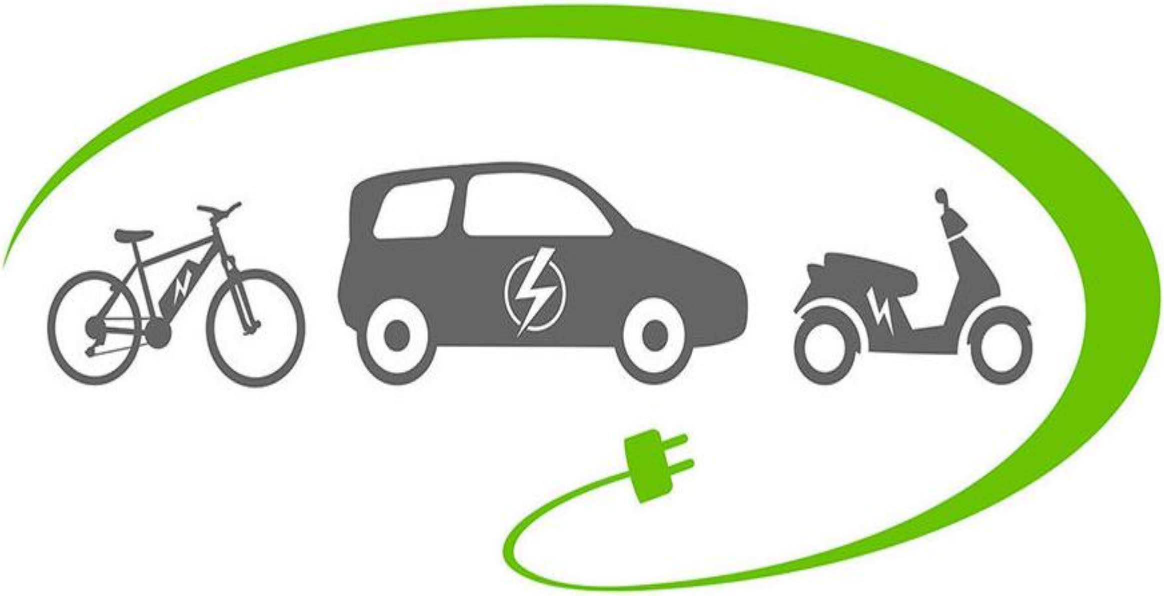


Electric, Electronic and Green Urban Transport Systems – eGUTS

Code DTP1-454-3.1-eGUTS

D3.2.2 Catalogue of e-rules and specifications

Responsible partner: No Gravity

Version: Final
August 2019

Dissemination level	Public
Component and Phase	D 3.2.2
Coordinating partners	No Gravity, VUD (WP3 Leader)
Editor(s)	Jozef Wallner
Authors:	Gabriel Adamek, Jozef Knotek (No Gravity) YARDO Institute
Due date of deliverable	31.4.2019
Actual date of deliverable	31.8.2019
Status (F: final, D: draft)	F
File name	Catalogue of e-rules and specifications

PREFACE

Electromobility is the most promising future technology to decarbonize road transport. Grid management is critical to electric vehicle(EV) adoption. Smart charging is key to minimize the amount of investments needed in the grid. Large scale deployment of EVs represents an opportunity to store large amounts of renewable electricity in batteries, reducing curtailment. EVs can even work as virtual power stations.

Mobility and energy are the twin pillars of these transformations, and both will require radical adaptation to meet demographic and economic growth without increasing congestion and pollution. Cities will require mobility and energy solutions that are sustainable, affordable, secure and inclusive, and integrated with customer-centric infrastructure and services. Thus, the convergence of energy and mobility is critical.

A more **extensive transformation** will require policy and regulatory reforms to support the electrification of transport that goes beyond decarbonization goals. Policy and regulatory objectives can aim to achieve smarter cities, aggregated efficiency and productivity, and broader economic development. These will rely on the convergence of energy, mobility and infrastructural planning objectives and complementary municipal, regional and national policies.

Recent years have shown a large increase in **electric vehicles (EVs)**, which could make a significant contribution meeting European, national and municipal energy- and climate goals. However, most EVs are not used for about 90% of the time, which makes their batteries available too for other purposes.

Urban mobility and infrastructure are evolving to incorporate more EVs.

Interreg
Danube Transnational Programme
eGUTS

Table of contents

List of Tables......7
List of Figures......7
List of Pictures......7
List of Abbreviations......8

1 ELECTRIC, HYBRID ELECTRIC AND FUEL CELL VEHICLES......10
1.1 Electric Vehicles......10
1.2 Hybrid Electric Vehicles......11
1.2.1 Concept of Hybrid Vehicle......11
1.3 Plug-in Hybrid Electric Vehicles......12
1.3.1 AER Mode Operation Strategy......13
1.4 Fuel Cell Vehicles......13
1.4.1 Fuel Cell System......14
1.4.2 Fuel Cell Technologies......15
1.5 Architectures of Electric Vehicles......15
1.6 Advantages and Disadvantages of Electric Coupling (Series) Drive Train......20
1.7 Mechanical Coupling Hybrid Drive Trains......21
1.7.1 Torque Couplers......21
1.7.2 Technical specifications of the EV......21
1.8 Battery......22
1.8.1 Charging......22
1.9 Compatibility between EV and the charging network......23
1.9.1 De jure and de facto standards......24

2 IMPORTANT STANDARDS FOR E-MOBILITY......26
2.1 Recommendations for electrifying mobility......27
2.2 Electrical Ratings of different EVs Charge Methods in Europe......29

2.3 EV Connector Types (charging connectors)....................................31
2.3.1 Rapid chargers...31
2.3.2 Fast chargers...33
2.3.3 Slow chargers..35
2.3.4 Connectors and cables..36
2.4 Charging Stations...37
2.4.1 Energy Storage Systems for EV Charging Stations...........37
2.5 Example of the DC Fast Charging Station for Electric Vehicles.....40
2.5.1 Charging infrastructure needs for electric vehicles............41

3 E-RULES...43
3.1 Electric Range..43
3.2 Energy Consumption/Efficiency...44
3.3 Electrified Vehicle Driver-User Information....................................44
3.4 Electrified Vehicle Recycling and Re-use..45
3.5 Vehicle Labelling..46
3.6 Battery Attributes...47
3.6.1 Battery Performance..47
3.7 Battery Durability..49
3.7.1 Battery Recycling...50
3.7.2 Battery Re-use (post-mobility)...50
3.8 On-board Charging System...51
3.8.1 Off-board Charging Standard Related to the Vehicle.......52
3.8.2 Wireless Charging..53
3.9 Vehicle as Electricity Supply...54
3.9.1 Method of Stating Energy Consumption..............................55

4 FUTURE OF THE E-MOBILITY...57
4.1 Which technical alternatives to e-mobility exist?..............................59

5 E-ROUTES......62
5.1 EUROVELO......62
5.2 Eurovelo Trails......62
5.3 Eurovelo Marking......62
5.3.1 Trail management EuroVelo......62
5.3.2 Eurovelo Services......64
5.3.3 Future Directions......64

6 SPECIFICATIONS......66

7 A GLOSSARY OF TERMS RELATED TO ELECTRIC VEHICLE/EV CHARGING: from connector types, key concepts, types of charging to measures of electric range and efficiency......73
7.1 EV charging connector types......73
7.2 KEY concepts......74
7.3 Types of charging......75
7.4 Measures of electric range and efficiency......76

REFERENCES......77

LIST OF TABLES

Table 1: Operating data of various fuel cell systems.....................................15

Table 2: Recommendations for electrifying mobility......................................27

Table 3: Electrical Ratings of Different EVs Charge Methods in Europe countries...29

Table 4: Mode and Type of Plugs for EVs Chargers in Europe countries.......30

Table 5: Energy Storage Technologies...38

LIST OF FIGURES

Figure 1: Primary electric vehicle drive train..16

Figure 2: Steady power and dynamic power..17

Figure 3: Possible electric vehicle configurations..17

Figure 4: Conceptual illustration of an electric vehicle configuration...............19

Figure 5: IEC 61851-1 charging modes...29

Figure 6: CHAdeMo connector..34

Figure 7: „Type 2“ connector...34

Figure 8: Scheme for the integration of the ESS with the EV charging station...40

LIST OF PICTUES

Picture 1: Concept of Hybrid Vehicle..11

Picture 2: Eurovelo Network...63

Picture 3: EVs charging station in Paks (Hungary) with Type 2 standard connector for E-cars and integrated with e-Bike charging slots……………….65

Picture 4: DC Fast Charging Station for Electric Vehicles (CCS Combo 2, CHAdeMO; 10, 20, 50, 100kW charger), and solar version of SETEC 50kW CCS Combo EV Charger…………………………..65

LIST OF ABBREVIATIONS

AC/DC – Alternating Current/Direct Current

AER – All-Electric Range

AFCs – Alkaline Fuel Cells

AMP – Ampere, electrical unit

AWD – All Wheel Drive

BMS – Battery Management System

BEV – Battery Electric Vehicle

CCIC – Charge Circuit Interrupting Device

CCS – Combined Charging System

DEVC – Dynamic Electric Vehicle Charging

DMFCs – Direct Methanol Fuel Cells (DMFCs)

DSO – Distribution System Operator

EPA – Environmental Protection Agency (U.S.A.)

EREV – Extended Range Electric Vehicle

EV – Electric Vehicle

EVSC – Electric Vehicle Supply Equipment

EVSE – Electric Vehicle Supply Equipment

GHG – Green-House Gass(-es)

HEV – Hybrid Electronic Vehicle

ICE – Internal Combustion Engine

IEC – International Electrotechnical Commission (standard)

LiB (LIB) – Lithium-ion battery

ESS – Energy Storage System

EVSE – Electric Vehicle Supply Equipment

MCFCs - Molten Carbonate Fuel Cells (MCFCs)

MPGE – miles-per-gallon equivalent

NEDC – New European Driving Cycle

NiMH (NIMH) – Nickel Metal Hybride

PAFCs – Phosphoric Acid Fuel Cells (PAFCs)

PEMFCs – Proton Exchange Membrane Fuel Cells

PHEV – Plug-in hybrid electric vehicle

RPH – range per hour

SOC – State of Charge

SOFCs – Solid Oxide Fuel Cells (SOFCs)

V2G – Vehicle to Grid

ZEV – Zero Emissions Vehicle

WLTP – Worldwide harmonized Light vehicles Test Procedure

1 ELECTRIC, HYBRID ELECTRIC AND FUEL CELL VEHICLES

The architecture design of an electric vehicle is to design its energy flow route from the energy source to the energy destination. Usually, chemical batteries are used as its energy source and electric motors are used to produce mechanical power to propel the vehicle. For satisfying vehicle performance, the batteries, electric motor, and transmission should be properly designed.

A hybrid electric vehicle uses two power sources to power the vehicle. There are many methods to connect the two power sources together, each of which has its special operation characteristics. For different vehicles that have different mission requirements and operation environments, a special architecture should be used to fully use its advantages and avoid its shortcomings.

Fuel cell vehicle is the vehicle which is powered by a fuel cell system. Compared with internal combustion engine, fuel cell is more efficient and cleaner. Architectural design of a fuel cell vehicle consists in designing the drive train structure and components to meet the vehicle performance requirements.

1.1 Electric Vehicles

Electric vehicles (EV) are receiving significant attention as an environmental-sustainable and costeffective substitute of vehicles with internal combustion engine (ICE), for the solution of the dependence from fossil fuels and for the saving of Green-House Gasses (GHG) emission.

Electric vehicle (EV) is referred to as a vehicle that employs electric energy storage as its energy source and electric machines as its power source. Electric energy is a multisource energy type which can be obtained from many primary energy sources, such as traditional fossil energy sources (coal, petroleum, and natural gas), nuclear energy, hydraulic power, bioenergy, solar energy, wind energy, etc. With continuous depletion of petroleum resources and more and more concerns about environmental issues, it has been well recognized that electric vehicle is one the most viable substitutes to the current petroleum-fueled vehicle. Electric vehicle also possesses other advantages of absence emissions, high efficiency, quiet and smooth operation, etc. With continuous progress on the technologies of chemical batteries, electric propulsion systems, and electronic control, electric vehicles are much closer to meeting a user's requirements than ever before.

Compared with petroleum fuels, the energy density of chemical batteries is much lower, which results in shorter driving range per battery charge. Long time battery charging also causes incontinence to users. At present, the battery-powered electric vehicles cannot challenge the petroleum-powered vehicles in terms of performance and use convenience.

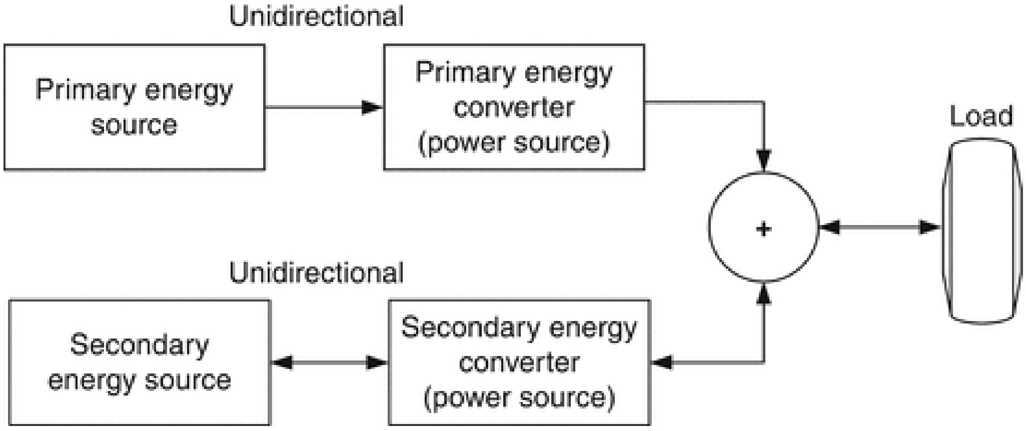
1.2 Hybrid Electric Vehicles

Hybrid electric vehicles are the combination of conventional vehicles and battery-powered electric vehicles. They can adopt the advantages and avoid the shortcomings of both. It has been recognized that hybrid electric vehicles, especially plug-in hybrid vehicles, are the major substitutes of conventional vehicles before technologies of chemical batteries have substantive progress in energy density, safety, and cost.

1.2.1 Concept of Hybrid Vehicle

In a hybrid vehicle, two power sources supply powers to drive wheels. The total power should meet the vehicle performance requirements, in terms of maximum speed, gradeability, acceleration time requirement, and driving range. The vehicle performance requires the vehicle possessing sufficient power, and sufficient energy for continuous driving range. In operation, any one of the two power sources or both can be used for traction. Thus, there are many possible operation modes as shown in the Picture1:

Picture 1: Concept of Hybrid Vehicle



Source: [24].

The primary energy source and energy converter allows unidirectional energy flow, whereas, the secondary energy source and energy converter are required to have the capability of bidirectional energy flow. With today's technologies, the common primary energy sources are chemical fuels and primary energy converters are internal combustion engines (ICE) and fuel cells. The secondary energy sources are chemical batteries and/or ultracapacitors and the secondary energy converters are electric motors. The final destination of the energy flow (energy sink) is the vehicle wheels with the form of mechanical energy.

As shown in the Picture 1, the wheels can be powered by selecting power sources, which are referred to as operation modes, which include:

1. Primary power source alone propelling,
2. Secondary power source alone propelling,
3. Both power sources propelling (hybrid drive),
4. Regenerative braking (secondary power source absorbs energy form load),
5. Primary power source splitting for propelling and secondary power source charging.

So many available operation modes create higher flexibility over single power source vehicles. It provides the drive train with opportunities for maximizing its operation efficiency and/or minimizing its emissions at any driving conditions by selectively using a best operation mode.

1.3 Plug-in Hybrid Electric Vehicles

The plug-in hybrid electric vehicle (PHEV) is vehicle that has the capability of accepting part of its propulsion energy from the electric utility grid. However, like the conventional hybrid electric vehicles, it also draws part of its traction energy from its fuel tank. This will afford the plug-in hybrids dual fuel flexibility, electric charge, and fossil fuel. Depending on the design of the vehicle drive train and its operation, the plug-in hybrid vehicle can behave as pure electric, pure engine, or hybrid vehicle.

The all-electric range (AER) of a PHEV is determined by the energy capacity of the battery and the energy consumption in drive cycle. The amount of energy consumed in a typical drive cycle can be obtained by integrating over the driving time period, in which no regenerative braking is included. Considering the energy losses in the power electronics, motor, and transmission, the usable energy in the battery for 32 and 64 km (20 and 40 miles) of AER in typical drive cycles.

1.3.1 AER Mode Operation Strategy

The principle of this operation strategy is to use the energy of the battery exclusively. One possibility is to allow the driver to manually select between the CS HEV mode and the pure EV mode. The availability of AER with sufficient range allows the vehicle to be driven in areas where emissions are restricted. This strategy provides flexibility for the driver to choose the time when the pure EV mode is used. For example, in a trip that includes a distance where pure EV operation is required, the driver can select the pure EV mode just prior to entering this area in order to have sufficient range. In other places, the vehicle may be operated in pure EV mode or CS HEV mode, depending on the charge status in the battery and the power demand. In normal conditions where the trip does not have an imperative pure EV operation, the driver may select pure EV mode at start of the drip in order to fully use the energy of the battery to save petroleum fuel, until the charge in the battery reaches its design specified level at which the CS HEV mode will start automatically.

1.4 Fuel Cell Vehicles

Fuel cell vehicles have been considered to be the final solution as the future high-efficiency and clean vehicles. Compared with conventional vehicles, fuel cell vehicles are independent from the petroleum resource and potential has high efficiency and zero emission.

Compared with battery-powered electric vehicles, they potentially have the advantages of long driving range and quick fuel replenishing. However, at present, the hydrogen sources and onboard storage are the major challenges.

It is now well recognized that the hybrid electric vehicle (HEV) is much more efficient and cleaner than the vehicle powered by gasoline and diesel engine alone.

The HEV also has high vehicle performance and more user acceptability than pure battery powered electric vehicle (EV). However, all of the HEV still comes from burning fossil fuel, gasoline, or diesel. On the other hand, the EV has curtain advantages over HEV, mostly zero emission, independence from petroleum, and perhaps low operating cost. However, the major disadvantage of EV is the range limitation and long battery charging time. It should be noted that only fraction of battery energy is used in a conventional HEV, in which the variation of the battery state of charge (SOC) is limited to a narrow band.

1.4.1 Fuel Cell System

A fuel cell is a chemical device that converts the chemical energy into electric energy by means of redox reaction with the operation principle exactly the same as in a chemical battery. In a battery cell, the reactive chemicals are pro-installed in the cell. When the active chemicals are used up, the cell is dead and has to be recovered by charging it from an outside electrical source. Instead, a fuel cell is fed with its reactive chemicals continuously from outside of the cell. It is more like an internal combustion engine which is fed with fuel and produces mechanical energy. However, the energy conversion efficiency in a fuel cell is higher than internal combustion engine due to its free from the Carnot cycle limitation. Compared to chemical batteries, it has the advantages of quick refueling and much more energy in an outside energy storage, similar to a fuel tank.

A fuel cell has a very similar structure of chemical battery cell. Fuel and the oxidizing agency are continuously and separately fed into the anode and cathode electrodes, where they are ionized. Electrolyte is used to conduct positive ions from the anode to the cathode, and at the same time, electrons are conducted from the anode to the cathode through an electrical load.

A single fuel cell has very low voltage. In practice, a fuel cell stack may include hundreds of single cells serially connected together. A fuel stack needs auxiliaries to support its operation. The auxiliaries mainly include air circulating pump, coolant circulating pump, ventilation fan, fuel supply pump, and electric control devices. Part of the power developed from the fuel cell stack is used to support the operation of the auxiliaries.

1.4.2 Fuel Cell Technologies

There are several types of fuel cells, depending on their electrolytes. Table 1 lists the operation temperature and electrolytes:

Table 1: Operating data of various fuel cell systems

Cell system	Operating temperature [in Celsius]	Electrolyte
Proton exchange fuel cells (PEMFCs)	60-100	solid
Alkaline fuel cells (AFCs)	80-230	liquid
Phosphoric acid fuel cells (PAFCs)	60-200	liquid
Molten carbonate fuel cells (MCFCs)	600-1000	liquid
Solid oxide fuel cells (SOFCs)	1000-1200	solid
Direct methanol fuel cells (DMFCs)	100	solid

Source: [24].

1.5 Architectures of Electric Vehicles

In principle, electric vehicles share the common characteristics of internal combustion engine–powered vehicles. A chemical battery pack replaces the fuel tank as its energy storage.

Hybrid vehicles (HV) are referred to as the vehicles that are powered by at least two energy sources and two power sources, in which at least one energy source and one power source have bidirectional energy flow capability, delivering energy to drive wheels and accepting energy from braking. When electric energy source and electric power source are used, they are referred to as hybrid electric vehicles (HEV). It is possible to replace the electric system with a hydraulic system. This kind of hybrid vehicle is referred to as hydraulic hybrid vehicles (HHV) . Fuel cell vehicles (FCV) are usually referred to the vehicles in which fuel cells are used as the primacy power source. A fuel cell vehicle may use two energy sources, fuel cells and chemical batteries, which is referred to as fuel cell hybrid vehicles (FCHV) .

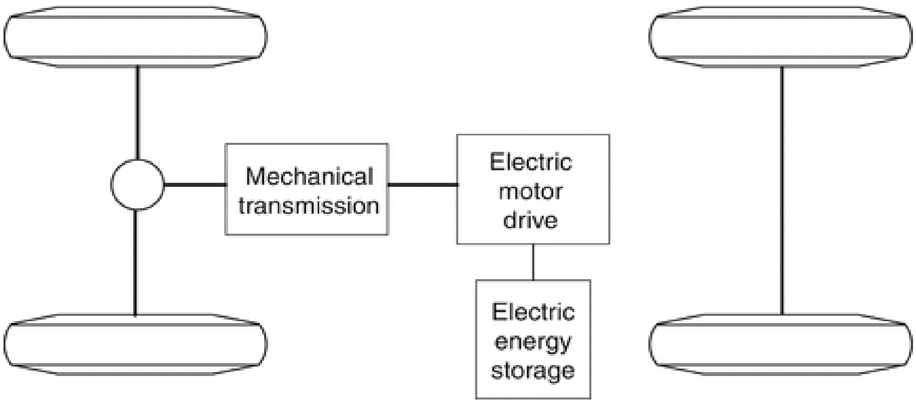
Since there are two power sources and only one energy sink (wheels), there are many ways to combine the two powers together. The design of the energy flow routes are referred to as drive train architecture design. Control of the energy flows in hybrid drive train is referred to as vehicle control strategy.

Electric machine replaces the internal combustion engine as the power source. Both share the similar performance requirements, such as, speed, acceleration, gradeability, and driving range. The design principles as discussed in the chapter of Vehicle Dynamics and Performance are still valid for electric vehicles. However, unique operating characteristics of the electric propulsion system have to be involved into the design process.

It simply replaces the engine with an electric motor and fuel tank with a chemical battery pack.

Previously, electric vehicles were designed to have a similar drive train structure to conventional internal combustion engine–powered vehicles as shown in the Figure 1:

Figure 1: Primary electric vehicle drive train

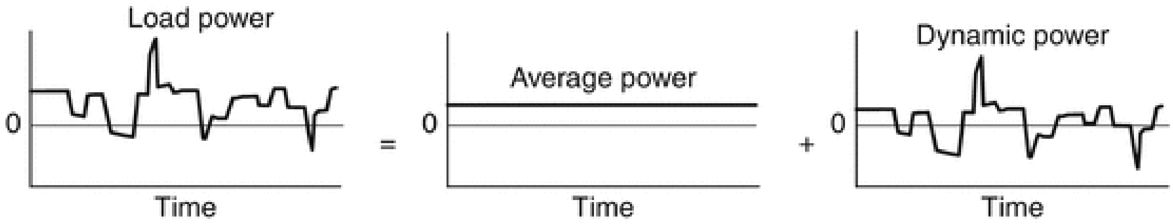


Source: [24].

In normal driving, average power is relative small (few 10 kW). Thus, the primary power source can be designed with a small power capacity. When the internal combustion engine is used as a primary power source, it can be downsized and operated near its most efficient region. In addition, other types of engines may be used, such as Sterling engine, gas turbine engine, and others. The secondary power source may be batteries, ultracapacitors, flywheels and their combination, and electric motors.

Vehicle load in normal driving varies randomly as shown in the Figure 2. Conceptually, the random load is composed of two components, one is the steady power (average) and the other is the dynamic power with zero average. Ideally, hybrid vehicle can be designed and controlled in such a way that one power source supplies a constant power for the average load, which is referred to as energy source, since all the energy comes from it, and the other power source supplies dynamic power, which is named peaking power source, since it consumes zero energy in a whole driving cycle.

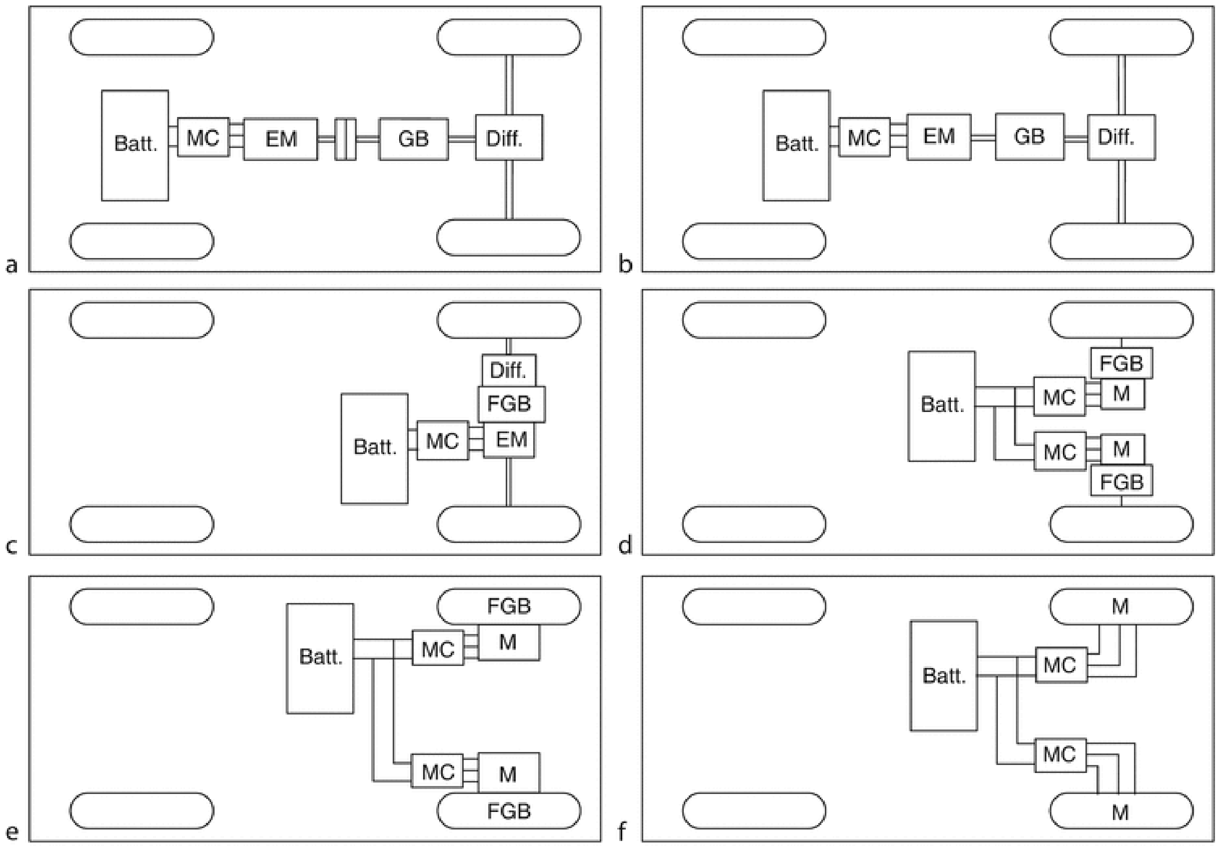
Figure 2: Steady power and dynamic power



Source: [24].

With development of the technologies of light weight, compact electric drive system, and advanced control, an electric vehicle drive train can be designed to various configurations as shown in the Figure 3:

Figure 3: Possible electric vehicle configurations



Source: [24].

Figure 3a shows the first alternative configuration that is most alike a conventional one. An electric motor (EM) drive replaces the internal combustion engine. A clutch is used to connect the motor drive to or disconnect from the final drive and differential.

A transmission gear box (GB) is used to modify the output speed–torque profile for meeting the performance requirement and supply a reverse gear. This drive train may be used for the motor drives which are only capable of operating in one or two quadrants, forward motoring and/or forward regeneration. Since a transmission gearbox is used, the torque-speed profile may not be required to close the ideal profile, which has constant torque in low speed range and constant power in high speed range. A motor drive with simple control may meet the requirement, such as series-excited DC motor.

Similar to the configuration shown in the Figure 3a, b shows the configuration in which clutch is not further needed. The motor starts producing its torque from zero speed. The transmission gear box may be either multi-gear or single gear, depending on the motor torque-speed profile. With a multi-gear transmission , the motor torque needs to be stopped during shifting. This can be carried out by cutting the current supply to the motor drive by the motor controller.

The Figure 3c illustrates a configuration with a more compact design. A fixed gear ratio single gear transmission (FGB) is installed between the motor drive and the final drive (differential). This design requires the motor drive to be capable of producing a torque-speed profile which is closer to the ideal one. It also requires the motor be capable of operating in four quadrants, that is, forward and backward motoring and generating.

The Figure 3d illustrates a configuration in which two motor drives are used. Each motor drives an individual wheel through a fixed gear ratio single gear box (FGB) which is used to match the motor speed to the wheel speed. A differential function is carried out by controlling the two motors. One advantage of this configuration is that it can fully utilize the road adhesive capability to improve the drivability of the vehicle. For example, when one wheel is on a slip road and loses its drive force, another wheel can produce a big driving force to help the vehicle get out of trouble.

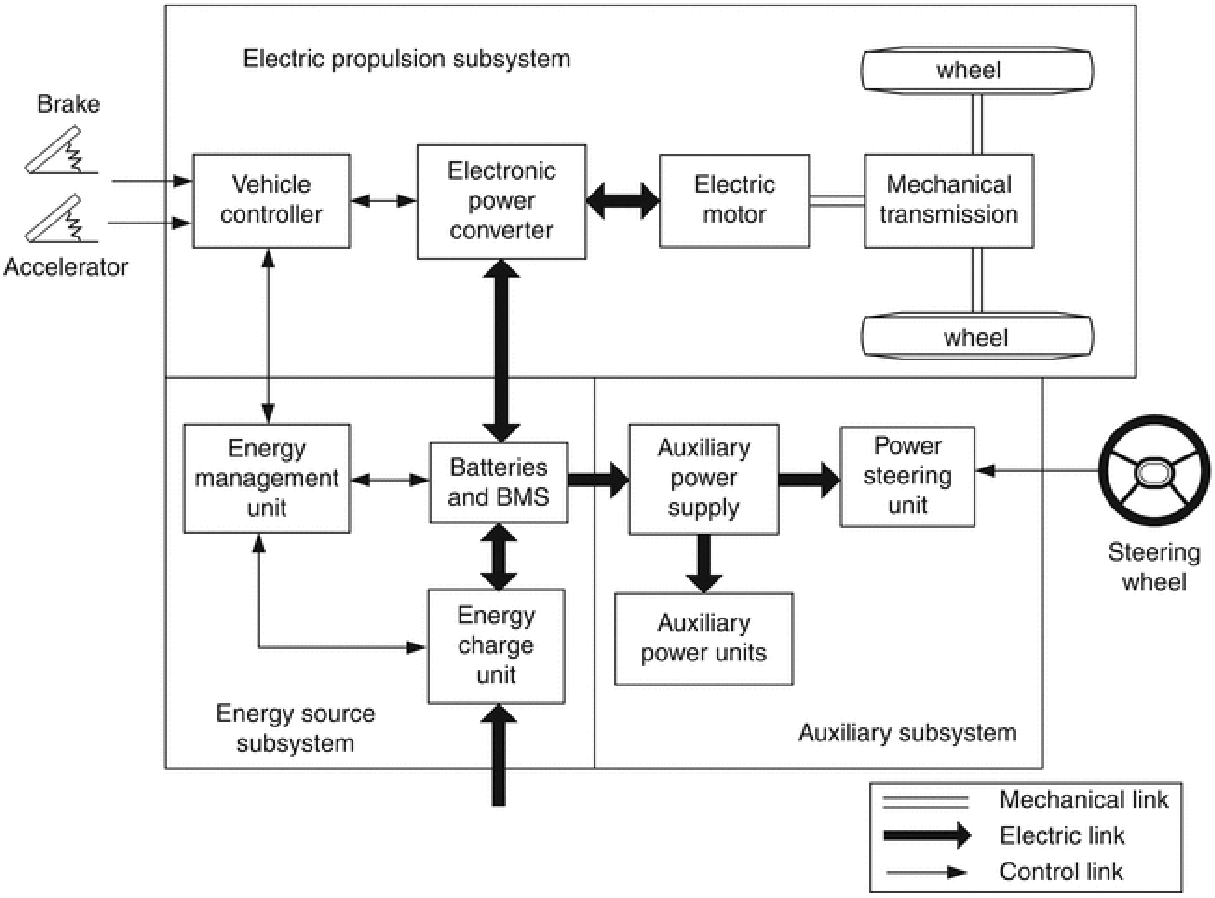
The drive train shown in the Figure 3e is very similar to the one in the Figure 3d. The difference is that the two fixed gear ratio single gear boxes (FGB) are attached to wheels rather than to the vehicle frame. This design can save much space and may make packaging easier.

The Figure 3f shows a simplest drive train structure, in which the wheel is designed as the rotor of the motor. This configuration is the most compact one and saves a lot space. This structure is generally termed as wheel motor. In the design of the drive trains shown in the Figure 3e, f, the impact of additional wheel weight to vehicle handing and vibration performance should be considered.

In all the architectures, the electric motors are powered by a battery pack and corresponding motor controller(s).

Except electric motor(s) and corresponding transmissions, a modern electric vehicle also needs other components for fulfilling its functions as shown in the Figure 4.

Figure 4: Conceptual illustration of an electric vehicle configuration



Source: [24].

The drive train consists of three major subsystems: electric propulsion subsystem, energy storage subsystem, and auxiliary subsystem. These three subsystems are interfaced through power routes and control signal routes. The electric energy from power grid is charged to the energy storage (batteries) through an energy charge system (battery charger). The energy storage delivers its energy to or absorbs energy from the electric motor through an electronic power converter which functions as a motor controller.

The electric motor operation is controlled by a vehicle controller which commands the torque requirement to the motor controller based on the accelerator or brake pedal position and energy source operation parameters and energy management algorithm. The energy source also supplies energy to the vehicle auxiliaries. A battery management system (BMS) is used to monitor the operation of the battery pack, generate operation information, such as state-of-charge (SOC), and protect battery pack from abusing.

1.6 Advantages and Disadvantages of Electric Coupling (Series) Drive Train

Electric coupling (series) hybrid vehicles have the advantages of:

1. Internal combustion engine is completely mechanically decoupled from wheels. Thus the engine operation can be operated in its most efficient speeds range. On the other hand, since batteries supply supplementary power, engine power is also decoupled from load power. Therefore, the engine can be operated in its most efficiency power range.

2. Since the engine can be potentially operated in a very narrow speed and power region, it becomes much easier for further improvement of fuel economy and emission characteristics by using some engine special design and control technologies in this narrow region than in the whole operation domain.

3. Completely mechanical decoupling of engine from driving wheels allows using engines that may not be suitable for direct vehicle propelling, such as gas turbine engine, sterling engine, etc.

4. A multi-gear transmission and torque converter may not be required, since the vehicle is solely driven by an electric motor, which has proper torque-speed profile for vehicle traction.

5. In-wheel motors may be used similar to a pure electric vehicle.

6. The control of the drive train may be simple, compared with other configurations.

However, electric coupling (series) drive train is also suffered from some disadvantages such as:

- two times energy form transformations from engine to wheels (mechanical to electrical and then to mechanical again) may cause significant energy losses.

- additional electric machine (generator) adds weight and cost.

- traction motor(s) have to be designed big enough to meet vehicle performance, such as maximum speed, acceleration, and gradeability.

1.7 Mechanical Coupling Hybrid Drive Trains

In mechanical coupling hybrid vehicles , mechanical coupling devices are used to couple two mechanical powers together. Mechanical power composes of force and speed in linear motion, and torque and angular speed in rotary motion. Accordingly, a mechanical coupling device may add to torques together or add two angular speeds together, depending on its mechanical structure.

1.7.1 Torque Couplers

A torque coupler is a three-port mechanical device which adds two input torques together and delivers them to output port as conceptually. Port 1 is a unidirectional input port (e.g., engine port), port 2 is bidirectional input port (e.g., electric motor port), and port 3 is a bidirectional output port (e.g., wheel port).

1.7.2 Technical specifications of the EV

Electric vehicles technical specifications including features:

- range,
- horsepower,
- performance,
- acceleration,
- top speed and
- charging options.

Exploring of the electric vehicle specifications bring compare available features to find the right electric car that best fits which are needs.

EV - short for "electric vehicle," it refers to any mode of transportation that uses one or more electric motors powered a rechargeable battery for propulsion. It's alternatively called BEV, for "battery electric vehicle."

1.8 Battery

An essential EV component, this is an electric storage unit in which chemical energy is converted into electricity and used as a source of power. Federal regulations require automakers to cover EV batteries under warranty for at least eight years or 100,000 miles (whichever comes first). Electric vehicles use lithium-ion batteries of various design, similar to those used in cell phones and laptop computers, only on a much larger scale. Lithium-ion batteries have a high energy density and are less likely than other types of batteries to lose their charge when not being used.

An EV's battery capacity is expressed in terms of kilowatt-hours, which is abbreviated as kWh. More is better here. Choosing an EV with a higher kWh rating is like buying a car that comes with a larger gas tank in that you'll be able to drive for more miles before needing a "fill up." But be aware that because of the way EVs work, you'll never actually have access to the full battery capacity. That's because the car's management system prevents the battery from either becoming 100 percent fully charged or 100 percent discharged to preserve its efficiency and extend its usable life.

Battery capacities of current EVs range from a mere 17.6 kWh in the Smart EQ ForTwo with a range of just 95 km, up to 100 kWh (f. ex. in the Tesla Model S and Model X) that can run for over 480 km before needing a charge. Battery capacities and other pertinent specs for all current EVs can be found on our companion website InsideEVs.com. They're also provided in

1.8.1 Charging

The charging equipment for EVs plays a critical role in their development, grid integration and daily use: a charging station generally includes charge cord, charge stand, attachment plug, power outlet and vehicle connector and protection system. The configuration of the charging station can vary from Country to Country depending on frequency, voltage, electrical grid connection and standards. In any case, charging time and lifetime of an EV's battery are linked to the characteristics of the charger that first must guarantee a suitable charge of the battery. Then a good charger should be efficient and reliable, with high power density, low cost and low volume and weight.

The EV charging system, that can be categorized into off-board and on-board types with unidirectional or bidirectional power flow:

– a unidirectional charging limits hardware requirements and simplifies interconnection issues;

– a bidirectional charging supports battery energy injection back to the grid.

The process of replenishing an electric vehicle's battery with electricity; this can either be accomplished at home via a standard wall outlet or a 220-volt line, or via a public or workplace-based charging station.

The charger power level is the main parameter that has an influence on charging time, cost, equipment and effect on the grid.

1.9 Compatibility between EV and the charging network

An EV owner who is not in a hurry can always connect a battery to their home's electricity supply. The same applies at work, and they can charge between when they arrive in the morning and leave in the evening. However, fuel-powered cars have been so successful because they reduce travel time between cities. Whether or not the electric car is a success will, therefore, depend on its performance over medium and long distances. To offer the same service, it must be possible to charge an EV in roughly the same amount of time it takes to fill up a fuel tank – a maximum of ten minutes, which requires fast charging stations. These facilities are created by electricity distribution companies, regional authorities, motorway concession owners and EV´s manufacturers. The majority of the latter group quite rightly believe that the vehicle and the charging stations are two crucial parts of the same product. Tesla is a famous example.

EV´s manufacturers have a common interest to ensure that there are a large number of fast charging stations along roads and motorways which can be used by all types of electric vehicles. Consequently, they just need to sit down to define the technical features and communication protocols applicable to all charging points. This would be simple – if manufacturers hadn't already defined multiple standards, whether individually or in small groups. And as each of these standards is protected by a collection of patents and proprietary protocols, the collective benefits of adopting unique specifications disguise royalties which would benefit the company or group of companies whose standard is adopted.

1.9.1 De jure and de facto standards

There are essentially two solutions to break the deadlock. The first is that a political or professional authority – a standardisation organisation such as Cenelec – obtains a *de jure* solution from manufacturers, with the benefits shared to compensate those whose technical solution was not chosen, and who must, therefore, adapt their technology. To an extent, the initial game is made cooperative, by adding a stage where the benefits are shared among the participants in the agreement.

In the other solution, the current war becomes a war of attrition, resulting in a *de facto* standard – the winner's standard. If one of the competitors convinces a sufficient number of buyers that their technology is superior, their charging network grows more quickly than other manufacturers, and this continues to reinforce its appeal, as any person buying a new EV will prefer to opt for this network. That was how the combustion engine prevailed over the electric engine over a century ago.

The choice between them is left to the market and will depend on the different National regulatory frameworks. Today the only standards available at European level, dealing with the charging system, plugs and sockets, are contained in the IEC 61851. The actual standards provide a first classification of the type of charger in function of its rated power and so of the time of recharge, defining three categories here listed:

– Normal power or slow charging, with a rated power inferior to 3,7 kW, used for domestic application or for long-time EV parking;

– Medium power or quick charging, with a rated power from 3,7 to a 22 kW, used for private and public EV;

– High power or fast charging with a rated power superior to 22 kW, used for public EV.

2 IMPORTANT STANDARDS FOR E-MOBILITY

Which standards have to be considered for the e-mobility charging infrastructure?

The IEC 60364 standard series consists of installation standards and therefore has to be used for fixed installations. If a charging station is not movable and connected via fixed cables, it falls under the scope of IEC 60364.

IEC 60364-4-44, clause 443 (2007) provides information on WHEN surge protection is to be installed. For example, if surges can have effects on public services, commercial and industrial activities and if sensitive equipment of overvoltage category I + II is installed.

IEC 60364-5-53, clause 534 (2001) deals with the question WHICH surge protection is to be selected and HOW it is to be installed.

Ensuring mobility

Protect the charging infrastructure and electric vehicles from lightning and surge damage according to the requirements of IEC 60364-4-44 clause 44, IEC 60364-7-722 and VDE AR-N-4100.

Electric vehicles – clean, fast and quiet – are becoming increasingly popular

The quickly growing e-mobility market is sparking great interest in industry, utilities, communities and with citizens. Operators aim to make a profit as soon as possible, so it is vital to prevent downtime. This is done by including a comprehensive lightning and surge protection concept at the design stage.

Safety – a competitive advantage

Lightning effects and surges jeopardise the integrity of the sensitive electronics of charging systems. But it is not only the charging post which is at risk, but the customer’s vehicle. Downtime or damage can soon get expensive. Beside the repair costs, you also risk losing the trust of your customers. Reliability is the top priority in this technologically young market.

Develop a multistakeholder approach in electrification strategy – Design internal organizations to ensure convergence of energy, urban and mobility planning objectives The energy, mobility and infrastructure sectors, along with policy-makers, regulators and urban planners, can collectively define a new paradigm for cities. For example, at a practical level, an electric mobility programme can bring together human and financial resources from urban energy and mobility planning departments to ensure adoption of a comprehensive approach to the electrification of mobility.

Ensure city, regional, national policies support and reinforce each other – Build a national platform for electric mobility with city representation. Coordination among the local, regional and national levels will be necessary to anticipate and enable the integration of the grid edge and mobility transformations. For example, public bus systems can be operated by federal or provincial governments, depending on circumstance.

Certain policies and regulations, for example, dynamic pricing, may fall under the domain of national policy-makers. A national platform for electric mobility with city representation can facilitate cooperation among different regulatory and policy-based entities.

2.1 Recommendations for electrifying mobility

Table 2: Recommendations for electrifying mobility

Take multistakeholder and market-specific approach	• Develop a multi-stakeholder approach in electrification strategy: - Design internal organizations to ensure convergence of energy, urban and mobility planning objectives, • Ensure city, regional, national policies support and reinforce each other: - Build a national platform for electric mobility with city representation, • Assess local characteristics to inform action: - Assess current and projected local characteristics in terms of city infrastructure and design, energy system, and mobility cult ure and patterns

Prioritize high- use vehicles	• Focus on electrifying public and commercial fleets, including mobility-as-a-service: - Introduce financial and/or non-financial incentives for high utilization vehicles, • Complete electrification of public transport system - Secure funding for electric buses and infrastructure, and renew the fleet gradually through public procurement: - Collaborate with the public transport operator(s) to define the fleet electrification targets, - Involve electricity network operators and electricity, suppliers to enable smart charging and ancillary services at bus depots, • Enable the integration of AVs: - Develop national regulatory frameworks that allow regions and cities to begin testing and introducing AVs - Investigate the impact of AVs on urban spatial and infrastructure planning
Deploy critical charging infrastructure today while anticipating the transformation of mobility	• Focus on reducing range anxiety and promoting interoperability: - Develop fast-charging network through public-private funding to connect different cities, - Include standardization and interoperability in minimum requirements, • Prioritize energy-efficient charging hubs with grid edge technologies and smart charging: - Locate charging hubs on the outskirts of cities, connected with public transport systems and alternative mobility means - Support the evolution of regulatory paradigms to enable new energy-related services, - Decide on the approach to charging mobility hubs: public, private or public and private cooperation • Develop digitalized end-to-end customer experience to enhance access to charging services: - Create a national database of public charging points through public-private partnership, - Standardize and simplify the payment of the charging services

2.2 Electrical Ratings of different EVs Charge Methods in Europe

Table 3: Electrical Ratings of Different EVs Charge Methods in Europe countries

Charge Method	Connection	Power [kW]	Max current [A]	Location
Normal power	1-Phase AC connection	3,7	10-16	domestic
Medium power	1- or 3-phase AC connection	3,7 – 22	16-32	semipublic
High power	3-phase AC connection	> 22	> 32	public
High power	DC connection	> 22	> 3,225	public

The IEC 61851-1 Committee on “Electric vehicle conductive charging system” has then defined 4 Modes of charging, concerning:

– the type of power received by the EV (DC, single-phase or three-phase AC),

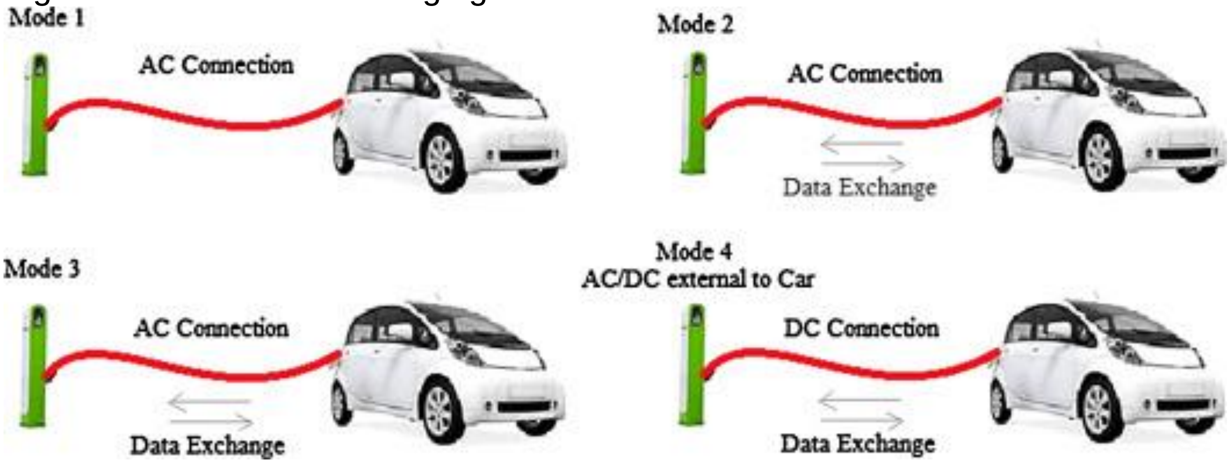
the level of voltage (for AC in range between single-phase 110V to three-phase 480V),

- the presence or absence of grounding and of control lines to allow a mono or two-way dialogue between the charging station and EV,

- the presence and location of a device protection.

The 4 Modes are described below and shown in this Figure 5:

Figure 5: IEC 61851-1 charging modes



Legend:

- Mode 1: slow charging from a household-type socket-outlet in AC,

- Mode 2: slow charging from a household-type socket-outlet with an in-cable protection device in AC,

- Mode 3: slow or fast charging using a specific EV socket-outlet with control and protection function installed in AC,

- Mode 4: fast charging using an external charger in DC.

For the Mode 1 (fast charging) in DC two sub-modes of operation are then considered: DC Level 1 (voltage inferior to 500 V, current inferior to 80 A, power at 40 kW); DC Level 2 (voltage inferior to 500 V, current inferior to 200 A, power at 100 kW).

Three types of socket-outlets:

1. **IEC 62196-2 "Type 1"** - single phase vehicle coupler – reflecting the SAE J1772/2009 automotive plug specifications – Yazaki;

2. **IEC 62196-2 "Type 2"** - single and three phase vehicle coupler – reflecting the VDE-AR-E 2623-2-2 plug specifications – Mennekes;

3. **IEC 62196-2 "Type 3"** - single and three phase vehicle coupler with shutters - reflecting the EV Plug Alliance proposal – SCAME.

Table 4: Mode and Type of Plugs for EVs Charger in Europe countries

Mode and type of plugs for EVs charger in Europe	**private domestic socket**	**private dedicated E-mobility socket**	**semi-public AC**	**public AC**	**public DC****
Power connection	≤3,0 kW / ≤3,7 kW 1-phase AC	Up to 22 kW	Up to 22 kW	Up to 22 kW	50 kW (CHAdeMo)*
Plug (Infrastructure side)	Domestic	IEC 60309-25 Type 2/Type 3	Type 2/ Type 3	Type 2/ Type 3	Yazaki (CHAdeMo)**
Charging mode	Mode 2	Mode 2 Mode 3	Mode 2 Mode 3	Mode 2 Mode 3	Mode 4

Legend: * – CHAdeMO protocol is a Japanese socket for the DC connection, with a maximum power level of 50 kW [not internationally standardised yet, http://www.chademo.com/]; CHAdeMO Association announced a major milestone as the CHAdeMO protocol is now officially recognized as an international DC charging standard by the International Electrotechnical Commission (IEC) alongside Combo plugs for U.S. and Europe and Chinese GB/T plug.

** Note: CHAdeMO is officially recognized as international DC Charging Standard by IEC; "**IEC 61851-23:2014**, gives the requirements for d.c. electric vehicle (EV) charging stations, herein also referred to as "DC charger", for conductive connection to the vehicle, with an a.c. or d.c. input voltage up to 1

000 V a.c. and up to 1 500 V d.c. according to IEC 60038. It provides the general requirements for the control communication between a d.c. EV charging station and an EV. The requirements for digital communication between d.c. EV charging station and electric vehicle for control of d.c. charging are defined in IEC 61851-24." "**IEC 61851-24:2014**, together with IEC 61851-23, applies to digital communication between a d.c. EV charging station and an electric road vehicle (EV) for control of d.c. charging, with an a.c. or d.c. input voltage up to 1 000 V a.c. and up to 1 500 V d.c. for the conductive charging procedure. The EV charging mode is mode 4, according to IEC 61851-23. Annexes A, B, and C give descriptions of digital communications for control of d.c. charging specific to d.c. EV charging systems A, B and C as defined in Part 23."

Recognising that there is a need to offer customers a highpower charging possibility that allows them to recharge the EV battery within a limited timeframe, only the high power connection would satisfy this aim. Two technologies are at hand for high-power charging: DC off-board charging or AC on-board charging.

The European Automotive Industry is however promoting the combined charging system with the Combo connector, which features a single inlet for AC and DC charging on the side of the EV and can potentially deliver high-power charging of up to 100 kW in future. The Combo connector is currently under development and going through the IEC standardisation process.

2.3 EV Connector Types (charging connectors)

As mentioned in the overview, there are three main types of EV charging – rapid, fast, and slow. These represent the power outputs, and therefore charging speeds, available to charge an EV. Note that power is measured in kilowatts (kW).

Each charger type has an associated set of connectors which are designed for low or high power use, and for either AC or DC charging. The following sections offer a detailed description of the three main charge point types and the different connectors available.

2.3.1 Rapid chargers

– 50 kW DC charging on one of two connector types,

– 43 kW AC charging on one connector type,

– 120 kW DC charging on Tesla Supercharger network.

Note: All rapid units have tethered cables

Rapid chargers are the fastest way to charge an EV, often found in motorway services or in locations close to main roads. Rapid devices supply high power direct or alternating current – DC or AC – to recharge a car to 80% in 20-40 minutes. In most cases, the charging units power down when the battery is around 80% full to protect the battery and extend its life. All rapid devices have the charging cable tethered to the unit.

Rapid charging can only be used on vehicles with rapid-charging capability. Given the easily recognisable connector profiles – see images below – the specification for your model is easy to check from the vehicle manual or inspecting the on-board inlet.

Non-Tesla rapid DC chargers provide power at 50 kW (125A), use either the CHAdeMO or CCS charging standards, and are indicated by purple icons on Zap-Map. Both connectors typically charge an EV to 80% in 20-40 minutes depending on battery capacity and starting state of charge. The next generation of rapid DC units will increase the power first to 150 kW and then to 350 kW which will significantly reduce overall charging time.

Tesla's Supercharger network also provides rapid DC charging to drivers of its cars, but use a Tesla Type 2 connector and charge at up to 120 kW. While all Tesla models are designed for use with Supercharger units, many Tesla owners use adaptors which enable them to use 50 kW rapid units fitted with a CHAdeMO connector. While these provide less power than a Supercharger, they are more common in the UK and elsewhere.

Rapid AC chargers provide power at 43 kW (three-phase, 63A) and use the Type 2 charging standard. They are indicated by green icons on Zap-Map. Rapid AC units are typically able to charge an EV to 80% in 20-40 minutes depending the model's battery capacity and starting state of charge.

EV models that use CHAdeMO rapid charging include the Nissan® Leaf, Mitsubishi® Outlander PHEV, and Kia® Soul EV. CCS compatible models include the BMW® i3, VW® e-Golf, and Hyundai® Ioniq Electric. Tesla's Model S and Model X are exclusively able to use the Supercharger network, while the only model currently able to charge on Rapid AC is the Renault® Zoe.

2.3.2 Fast chargers

– 7kW fast charging on one of three connector types,

–22kW fast charging on one of three connector types,

– 11kW fast charging on Tesla Destination network,

Note: Units are either untethered or have tethered cables.

Fast chargers, all of which are AC, are typically rated at either 7 kW or 22 kW (single- or three-phase 32A). Charging times vary on unit speed and the vehicle, but a 7 kW charger will recharge a compatible EV with a 30 kWh battery in 3-5 hours, and a 22 kW charger in 1-2 hours. Fast chargers tend to be found at destinations, such as car parks, super-markets, or leisure centres where you are likely be parked at for an hour or more.

The majority of fast chargers are 7 kW and untethered, though some home and workplace based units have cables attached, usually with a Type 1 connector. The latter units mean only those vehicles that can use that connector will be able to charge on them; in contrast to the more common use of a driver's own connector cable. Untethered units are therefore more flexible and can be used by any EV with the correct cable.

Charging rates when using a fast charger will depend on the car's on-board charger, with not all models able to accept 7 kW or more. These models can still be plugged in to the charge point, but will only draw the maximum power accepted by the on-board charger. For example, a Nissan Leaf with standard 3.3 kW on-board charger will only draw a maximum of 3.3 kW, even if the fast charger is 7 kW or 22 kW.

Tesla's 'destination' chargers provide 11 or 22 kW of power but, like the Supercharger network, are intended only or use by Tesla models. Tesla does provide some standard Type 2 chargers at many of its destination locations, and these are compatible with any plug-in model using the correct cable.

Almost all EVs and PHEVs are able to charge on a Type 2 units, with the correct cable at least. It is by far the most common public charge point standard around, and most plug-in car owners will have a cable with a Type 2 connector charger-side.

The European Commission has decided that all electric vehicles must have installed the "Type 2" connector, showed in Figure 6 and Figure 7:

Figure 6: CHAdeMo connector

Specification

Item	CHAdeMO	CCS	GB/T
Rated voltage	500VDC	200-850VDC	400-750VDC
Rated current	125A	200A	63A-250A

Figure 7: „Type 2“ connector

This should resolve a central problem regarding EV charging stations: lack of interoperability.

This connector can also be used in three-phase 400 V, having seven contacts in total. Type 2 connector can reach enough high values of charging power: up to 43 kW with fixed cable (63A/400V), up to 22 kW with detachable cable

(32A/400V). The technological choice between on- or off-board chargers will be determined by what suits the EV on the market and the relative cost of both systems for the infrastructure provider. For the electricity industry, it does not matter much whether the conversion from AC to DC is done on- or off-board.

2.3.3 Slow chargers

– 3kW slow charging on one of four connector types,

– Charging units are either untethered or have tethered cables,

– Includes mains charging and from specialist chargers,

Note: Often covers home charging.

Most slow charging units are rated at up to 3 kW with some lamp-post chargers being rated at 6 kW. Charging times vary depending on the charging unit and EV being charged, but a full charge on a 3 kW unit will typically take 6-12 hours. Most slow charging units are usually untethered, meaning that a cable is required to connect the EV with the charge point.

Slow charging is a very common method of charging electric vehicles, used by many owners to charge at home overnight. However, slow units aren't necessarily restricted to home use, with workplace and public points also able to be found. Because of the longer charging times over fast units, slow public charge points are less common and tend to be older devices.

While slow charging can be carried out via a three-pin socket using a standard 3-pin socket, because of the higher current demands of EVs and the longer amount of time spent charging, it is strongly recommended that those who need to charge regularly at home or the workplace get a dedicated EV charging unit installed by an accredited installer.

All plug-in EVs can charge using at least one of the above slow connectors using the appropriate cable. Most home units have the same Type 2 cable as found on public chargers, or be tethered with the a Type 1 connector where this is suitable for a particular EV.

2.3.4 Connectors and cables

The choice of connectors depends on the charger type (socket) and the vehicle's inlet port. On the charger-side, rapid chargers use CHAdeMO, CCS (Combined Charging Standard) or Type 2 connectors. Fast and slow units usually use Type 2, Type 1, Commando, or 3-pin plug outlets.

On the vehicle-side, European EV models (Audi®, BMW®, Renault®, Mercedes®, VW® and Volvo®) tend to have Type 2 inlets and the corresponding CCS rapid standard, while Asian manufacturers (Nissan® and Mitsubishi®) prefer a Type 1 and CHAdeMO inlet combination. This doesn't always apply, however, with the Hyundai® Ioniq Electric and Toyota® Prius Plug-In being exceptions.

Most EVs are supplied with two cables for slow and fast AC charging; one with a three-pin plug and the other with a Type 2 connector charger-side, and both fitted with a compatible connector for the car's inlet port. These cables enable an EV to connect to most untethered charge points, while use of tethered units require using the cable with the correct connector type for the vehicle.

Examples include the Nissan® Leaf which is typically supplied with a 3-pin-to-Type 1 cable and a Type 2-to-Type 1 cable. The Renault® Zoe has a different charging set up and is comes with a 3-pin-to-Type 2 and/or Type 2-to-Type 2 cable. For rapid charging, both models use the tethered connector which are attached to the charging units.

AC Connectors	DC Connectors
– UK 3-pin (BS 1363) – Industrial Commando (IEC 60309) – American Type 1 (SAE J1772) – European Type 2 (Mennekes, IEC 62196)	– Japanese JEVS (CHAdeMO) –European Combined Charging System (CCS or 'Combo') – Tesla's proprietary supercharger connector

2.4 Charging Stations

EV charging stations European electricity companies, particularly distribution system operators (DSOs), are investing in the necessary infrastructure to stand-in a single European market for EV. European standards are indispensable to safeguard that drivers enjoy convenient EU-wide charging solutions that avoids a multiplicity of cables and adaptors and so retrofit costs. In June 2000, the European Commission issued a standardization mandate to the European standardization bodies CEN, CENELEC and ETSI (M/468) concerning the charging of EVs.

The mandate stressed the need for interoperable plugs and charger systems to promote the internal market for EV and to discourage the imposition of market barriers. The Focus Group set up to respond to M/468 delivered a comprehensive and valuable report. However, given that the mandate objective was to achieve interoperability, not the adoption of a single connector, no recommendation has been made with regards to the choice of the AC mains connector. As a consequence, two types of connectors have been assessed as appropriate for the European situation.

2.4.1 Energy Storage Systems for EV Charging Stations

One of the major challenges for EV charging stations, especially the public one, is to reduce charging time. As seen in the International standards, this aim can be addressed by increasing the rate of power transfer: the fast charge method corresponds in Europe to the maximum value of power (50-100 kW). When a large number of EVs are charged simultaneously, problems may arise from a substantial increase in peak power demand to the grid. Addressing this peak power requirement may increase the generation cost of the energy, as well as the cost of the distribution and public charging infrastructure.

The integration of an Energy Storage System (ESS) in the EV charging station cannot only reduce the charging time, but also reduces the stress on the grid.

A suitable comparison among the various energy storage technologies applicable for this scope is among electrochemical storages (batteries), electromechanical storages (flywheels) and electrostatic storages (ultracapacitors).

The batteries are electrochemical storages that alternate charge-discharge phases allowing storing or delivering electric energy. The main advantage of such a storage system is high energy density, the main inconvenience is their performance and lifetime degrades after a limited number of charge and discharge cycling. This affects the lifetime for all application (from 100 to 1,000 cycles).

The flywheels are electromechanical energy storage devices, where energy is stored in mechanical form, thanks to the rotor spinning on its axis. The amount of stored energy is proportional to the flywheel moment of inertia and to the square of its rotational speed. The life of flywheels is greater than the batteries (up to 100,000 cycles) and the frequent charging and discharging does not adversely affect their life time.

Additionally, flywheels have a power density that is typically a factor of 5 to 10 times greater than batteries. A drawback of the flywheel technology is the time of reply to fast variations of required power: it is also proportional to the inertia of the system, so the gradient of the power in time is generally high.

The ultra-capacitors are electrostatic storage system, characterized by a very high power density, but with a lower energy density than batteries and flywheel. Ultra-caps have also the benefits of charging and discharging much faster than batteries, a longer service life and a higher the efficiency than batteries.

Another important issue in the comparison of these three storage technologies deals with the cost: the installation, maintenance and replacement costs of the batteries make them no so attractive as a feasible solution as stationary energy storage system; the installation cost of a flywheel is usually greater than batteries, but its longer life and simpler maintenance results in a lower total costs.

Comparing the different types of batteries shown in next Table 5:

Table 5: Energy Storage Technologies

Type	**Energy Efficiency[%]**	**Energy Density [Wh/kg]**	**Power Density [W/kg]**
Batteries Pb-Acid	70-80	20-35	25
Batteries Ni-Cd	60	40-60	140
Batteries Ni-MH	50-80	60-80	220
Batteries Li-ion	85-95	100-200	300-2000
Batteries Li-polymer	80-90	100-200	300-2000

Super-caps	90+	25-75	5000-20000

– **Pb-Acid batteries**, with a life time of 200-300 cycles, have high capacity, low volume energy density, low capital cost, long life time, but on the other hand they are characterized by low efficiency (75%), potential adverse environmental impacts;

– **Ni-MH batteries**, with a life time of 100-200 cycles, a very high energy density;

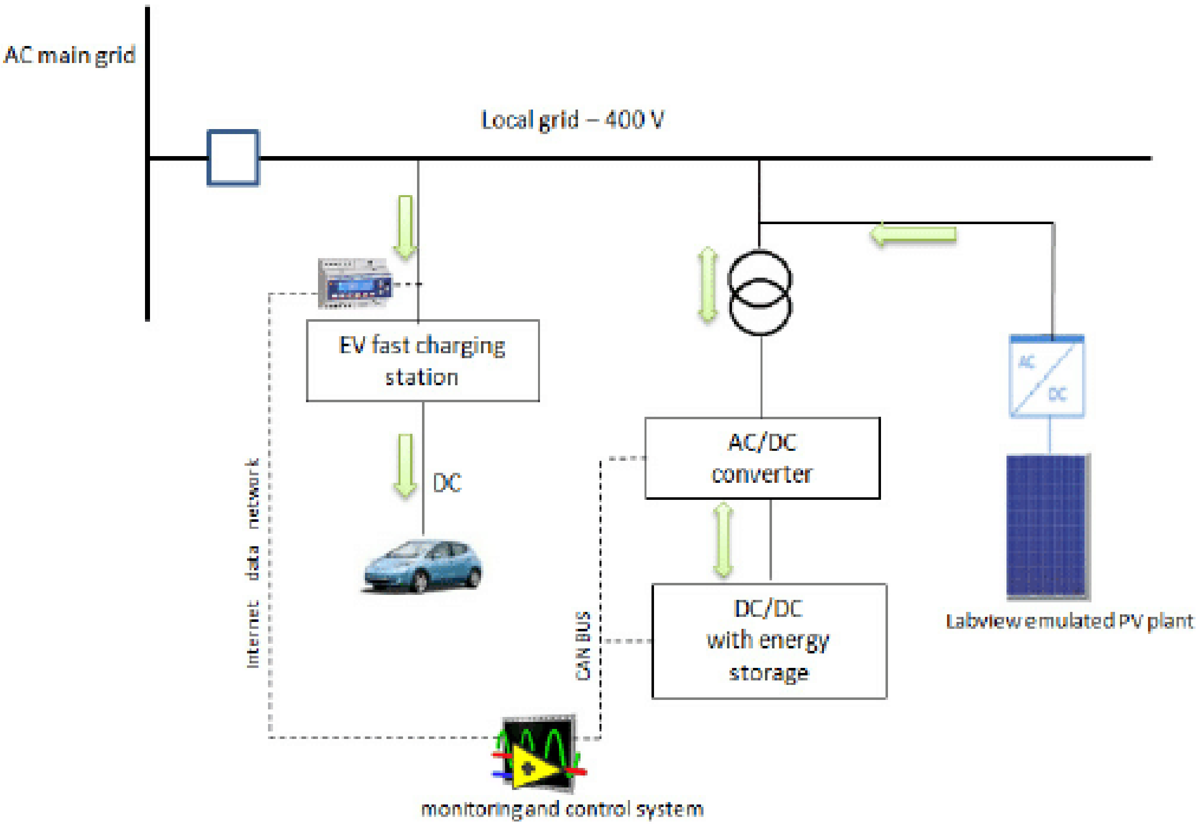
– **Li-Ion batteries** have a very high efficiency (95%) and energy density, and high number of life cycles (3,000-5,000);

– **Li-Polymer batteries** have lower energy density than Li-Ion ones, but they are not flammable as Li-Ion and so offer more safety.

– **Ni-Cd batteries** have low energy density (40-60 Wh/kg), low efficiency (60%) and suffer of memory effect.

At these technologies it is necessary to add the Sodium-Sulphur (Na-S) batteries that, with a life time of 2,000-3,000 cycles, have a very high energy and power capacity, high energy density, but they are characterized by high production cost and safety concerns, that make them not commercially sustainable at the moment. The most common technology for batteries used for EV application is Li-Ion battery, with energy capacities included between 5 kWh to 53 kWh.

Figure 8: Scheme for the integration of the ESS with the EV charging station



Note: The AC-bus scheme is generally preferred, because the AC components have well defined standards, ans AC technologies and products are already available in the market. DC-bus based system profides a more convenient way to integrate renewable energy sources and also higher energy efficiency thanks the inferior number of conversion stages.

2.5 Example of the DC Fast Charging Station for Electric Vehicles

1. CCS CHAdeMO 50KW EV charging station is combined with CHAdeMO and CCS Combo 2, Dual connectors, Fast charging Station. That can be fit for all CHAdeMO and CCS Electric Cars (CHAdeMo + CCS, or +Type 2 AC). [see the Picture 4]

2. SETEC Power 50kW DC Quick charging station offers Electric Vehicle owners an opportunity to charge their car safely and quickly. A typical electric car with 24kWh battery pack may be charged as quickly as less than 10 minutes to get up to 80% of its capacity.

SETEC combines industry standardization with advanced charging technology to support next-generation electric vehicles. Its multi-protocol design allows for easy tailoring to support CHAdeMO and CCS standards for DC fast charging applications. Payment & billing platform solutions enable easy and secure payments via station payment terminals and RFID card.

Features and applications of this CD fast charging station included:

- built-in safety measures,
- user friendly interface,
- flexible multi-protocol design,
- CHAdeMO and CCS protocol compatible TYPE2 AC charger 22 kW optional,
- durable enclosure and OCPP,
- wide temperature range between -25 degrees of Celsius to +65 degr. of Celsius,
- data management and metering options, and applications:
- service station operators,
- public corridor charging along the highways,
- busy urban areas,
- commercial fleet operators, and
- EV infrastructure operators and EVSE providers.

2.5.1 Charging infrastructure needs for electric vehicles

Whenever they are connected to the electricity grid, electric vehicles are dependent on a charging station - at home, at work or at a public charging station. As most of the charging will be carried out in private areas, distribution grids at the low-voltage level will be mostly affected by the uptake of electric vehicles. In the future, different options for load management should become possible concerning charging with normal and medium power in both residential and commercial areas. [32]

At present, Today, more than 80% of EV charging is carried out at residential and workplace premises. Charging at home, parking lots near home and office buildings every time the vehicle is parked during the day and night is often the most convenient and cost-effective solution. AC charging with normal/medium power opens up more possibilities for smart charging than DC charging.

By 2030, as owning an EV will become more commonplace even for those drivers without the possibility to have a charging point installed at their home, it is expected that the demand for (semi-) public charging will rise. The lack of access for home charging i.e. parking facilities such as private garages or driveways is a practical limitation which can differ from country to country, rural versus urban, or even from district to district. [32]

3 E-RULES

On based of the Proposal for an Electric Vehicle Regulatory Reference guide results review of the examples or definitions related to the e-mobility elements. [33]

3.1 Electric Range

Atribute definition is as the maximum distance an electrified vehicle can travel using only battery power. In the case of off-vehicle-chargeable hybrid electric vehicles (OVC-HEV) also indicate the "total range". Vehicle range determination can include a specific drive cycle, test procedures and vehicle preconditioning. (Note:This attribute refers to the vehicle's electric range and is not intended to consider any minimum range standard to be classified as an OVC-HEV). [33]

Electrified vehicle range is widely regulated. A memorandum of understanding is in place between the Government of Canada and industry for the purposes of vehicle labellingonly, which involves range determination.

China has a voluntary Chinese National Standard that is available for adherence to (GB/T 18386-2005), which is quoted in the regulation 'Management Rules for New Energy Vehicle Production Enterprises and Product Access', and thus recognized as mandatory.

Switzerland and the European Union determine range in accordance with UN Regulation No. 101 (UN-R101), Annex 9 with respect to light duty motor vehicles and has custom-tailored these electric range requirements for L-category vehicles. India has adopted many aspects of UN-R101, Annex 9 in its own test procedure (AIS 040).

Japan specifies its own test procedure based on the JC08 dynamometer test cycle (TRIAS 99-011-01).

The Republic of Korea employs a procedure similar to that of the United States Environmental Protection Agency – National Highway Traffic Safety Administration (US EPA/NHTSA). The standard SAE J1634 recommended practice has been adopted as the test procedure for the USEPA/NHTSA. The California Air Resources Board (ARB) has its own range test procedure employed in determination of allowance credits in connection with its Zero Emission Vehicle (ZEV) Regulation.

3.2 Energy Consumption/Efficiency

Attribute Definition: Energy required to travel X km in standardized conditions. Energy consumption/efficiency determination can include a specific drive cycle, test procedures and vehicle preconditioning.

The European Union (EU) and Switzerland regulate EV energy consumption through the test procedure outlined in UN-R101, Annex 7. India's test requirements (AIS 039) draw extensively from UN-R101, Annex 7.

Japan specifies its own test procedure based on the JC08 dynamometer test cycle (TRIAS 99-011-01).

The Republic of Korea has adopted the same requirements specified by the US EPA/NHTSA. The US EPA/NHTSA require that electrified vehicle energy consumption be determined in accordance to SAE J1634 (PEV), J1711 (NOVC-HEV and including OVC-HEV) and J2841 (Utility Factor Definitions for OVC-HEV). California does not have separate requirements for energy consumption and is generally aligned with the preceding US Federal regulations.

Canada does not presently have in place any requirements relating to electrified vehicle energy consumption/efficiency. There are voluntary Chinese National Standards pertaining to energy efficiency of EVs (GB/T 18386-2005) and HEVs (GB/T 19753-2005),which have been subsequently recognized as mandatory.

3.3 Electrified Vehicle Driver-User Information

Attribute Definition: The requirement for EVs to include standardized symbols for system warnings, charge systems, etc. For example, a symbol that would indicate to the driver that the gasoline engine is running in a OVC-HEV.

Driver-user information is an attribute that is largely lacking any formal regulation globally at the present time. China has a voluntary Chinese National Standard GB/T 4094.2-2005 that specifies EV-specific symbols relating to controls, indicators and tell-tales.This standard is quoted in regulation 'Management Rules for New Energy Vehicle.

Japan has voluntary standards for EV driver-user information.

3.4 Electrified Vehicle Recycling and Re-use

Attribute Definition: Requirements for recycling and/or reusing vehicle components and/or electric machine.

Canada employs a voluntary code of conduct to guide recyclers,knownas the Canadian Auto Recyclers 'Environmental Code (CAREC).

China has a mandatory Chinese National Standard that governs vehicle end-of-life recycling and dismantling (GB 22128-2008).

The EU regulates M1and N1type vehicle recycling through its Directive on End-of-Life Vehicles (2000/53/EC). Directive 2005/64/EC is a subsequent law that further stipulates the degree of recyclability, reusability and recoverability required for M1and N1vehicles prior to their approval for sale in the EU.

India is in the process of formulating standards for vehicle recycling. It is assumed that these will initially be voluntary in nature.

Japan governs vehicle recycling through Act No. 7 of the Ministry of Economy, Trade and Industry (Act on Recycling, etc. of End-of-Life Vehicles).

The Republic of Korea stipulates requirements for vehicle recycling through Act No. 11913, managed by the Ministry of Environment.

Swiss federal regulations for recycling are based on EC Directive 2000/53/EC mentioned previously.

The USA does not presently have any federal requirementsthat govern vehicle recycling.

It should be noted that,in addition to governing the recycling of vehicles, Japan and the Republic of Korea have laws that require ehicle manufacturers to pro-actively emphasize recyclability in the design and manufacture of their products.

3.5 Vehicle Labelling

Attribute Definition:Requirements for vehicle labelling, including the drive cycle and test procedure used to obtain information for the label. Labels may indicate, but are not limited to, fuel efficiency, emissions, range, total battery capacity (kWh), cost, etc.

Vehicle labelling worldwide is predominantly in relation to fuel economy, with some countries also reporting additional characteristics such as CO_2 emissions and estimated fuel costs.

A memorandum of understanding is in place between the Government of Canada and industry for the purposes of vehicle labelling.

China's light vehicle labellingrequirements are captured in a mandatory National Standard (GB 22757-2008). The label features three fuel economy ratings covering urban, suburban driving conditions and a composite of the two referred to as 'integrated operating conditions'. This label only applies to vehicles equipped with conventional internal combustion engine powertrains and will extend to electrified vehicles in the near future.

The EU employs a fuel economy label that provides fuel consumption, annual operating cost, and CO_2 emissions for light duty motor vehicles. In the EU countries this labelling scheme is not yet applicable to L-category vehicles but vehicle manufacturers are required to ensure that the CO_2 emission, fuel consumption, electric energy consumption and electric range data are provided to the buyer of the vehicle at the time of purchase of a new vehicle, in a format which they consider appropriate. CO_2 emissions are ranked using an alphabetized grade (A-G) system. Emissions of vehicles determine in turn the level of Vehicle Circulation Tax imposed for usage of the vehicle.

India does not have regulations governing vehicle labelling, there are however two voluntary label formats available for adherence to by vehicle manufacturers. The two formats are from the Society of Indian Automobile Manufacturers (SIAM) and Bureau of Energy Efficiency (BEE) of which both mainly focus on a single average value for vehicle fuel consumption. Electrified vehicles are not addressed by either one of these labels.

Japan has voluntary fuel economy performance stickers that can be affixed to vehicles that meet or exceed fuel economy standards.These labels indicate that the vehicles bearing them are eligible for fiscal incentives only and do not provide any specifications or actual statement of fuel consumption. There is no label available for PEVs, OVC-HEVs, or vehicles featuring natural gas or clean diesel powertrains, despite these vehicles being included under the same fiscal incentive scheme.

The Republic of Korea introduced fuel economy labels according to the 'Energy Use Rationalization Act' in 1989, and improved the label scheme extensively with the new fuel economy adjusted by the 5-cycle formula to reflect real-world driving conditions as done in the USA in 2011. The values on the label represent the performance of the vehicle in terms of the fuel economy values.

Switzerland requires labels indicating fuel consumption, CO_2 emissions, and a letter grade between (A-G) denoting performance in fuel economy; A indicates the lowest consuming vehicle and G the highest, where the indication from A to G is segment specific by considering inter alia the vehicle curb weight.

The US EPA employs a series of 'fuel economy and environment'labels that address conventional gasoline/diesel powered vehicles, flex-fuel vehicles, CNG vehicles, OVC-HEVs (both series and blended4), PEVs, and hydrogen FCVs; the label is not segment specific, in that it applies to all light duty vehicles. Labels include fuel economy information, as well as greenhouse gas and smog ratings based on a relative scale of 1 to 10.Alternative fuel and electrified vehicles feature gasoline equivalent Miles Per Gallon (so-called MPGe) ratings to facilitate comparison activity as well as a statement of range attainable on a single tank of fuel and/or a single full charge of the on-board battery pack.

3.6 Battery Attributes

Usage of the term 'battery'in this text includes all Rechargeable Electric Energy Storage Systems (REESS) pertaining to electrified vehicles, which to-date are principally comprised of batteries and capacitors.

3.6.1 Battery Performance

Attribute Definition: Methods and conditions for testing and measuring battery power delivery capability, energy storage capacity, battery charge, etc.

Canada does not presently have requirements in place that address battery performance. There are a number of voluntary standards quoted in regulation (hence becoming mandatory) relating to the performance of batteries for electrified road vehicles in China (QC/T743-2006 and others).

The EU does have stipulations concerning specifications that must be furnished for electrified vehicle battery performance through UN-R101, Annex 2. However, a test procedure is not specified at this time. ISO 12405-1:2011 (high-power applications) and ISO 12405-2:2012 (high-energy applications) are available as optional test procedures for Lithium-ion traction battery performance. The standard (from the International Electrotechnical Commission (IEC)) IEC 62660-1:2010 also represents an optional standard for battery performance testing. IEC 61982:2012 is an optional test procedure specifying performance and endurance tests for secondary batteries (except Lithium) for the propulsion of electrified road vehicles.

India has a voluntary standard that specifies requirements and test procedures for lead acid batteries for use on battery powered road vehicles and other applications (BIS 13514-1992). Lithium-ion batteries are not addressed by the standard.

Japan requires that manufacturers provide information concerning battery (and motor) capacity.

The Republic of Korea has voluntary standards for testing traction battery performance. These standards (ISO 12405-1 and KS C IEC 62660-1) have been established according to the 'Industrialization Standardization Act'.

Switzerland does not presently have in place any requirements pertaining to battery performance.

There are presently no Federal regulations in the USA that specify requirements for determining battery performance. There are, however, voluntary procedures for battery performance testing established by the United States Advanced Battery Consortium (USABC), a collaborative effort between the US domestic automakers (GM, Ford, Chrysler). There is also an SAE recommended practice that is currently in formulation (J1798).

3.7 Battery Durability

Attribute Definition: Methods and conditions for determining average life cycle count, shock and vibration resistance, temperature, etc.

Canada has adopted into Federal law the US requirements for HEVs, and does not presently have anything in place on pure electric vehicles (PEVs).

China has established voluntary guidelines quoted in regulation (hence becoming mandatory) for the determination of battery reliability and durability through the QC/T 743-2006 Automotive Industry Standard.

The EU does not presently have battery durability requirements. Voluntary standards ISO 12405-1:2011, ISO 12405-2:2012and IEC 62660-2address durability testing of Lithium-ion batteries and are expected to be referenced in an upcoming effort by WLTP.India and Japan do not presently have requirements relating to battery durability.

The Republic of Korea has voluntary standards (KS C ISO 12405-1 and KS C IEC 62660-2) based on the previously mentioned international standards in accordance with its so-called 'Industrialization Standardization Act'.

Switzerland does not presently have requirements relating to battery durability.

The US EPA/NHTSA pecify requirements that limit the deterioration of HEV batteries. The aim is to require that CO_2 emissions from the vehicle do not increase excessively over the useful life of the vehicle. Specifically, the regulation stipulates that CO_2 deterioration should not exceed 10per centof a vehicle's certified CO_2 value at full useful life.There is, however, at present no specified test procedure for determining compliance with this requirement. A similar requirement does not exist for pure electric vehicles since an increase in CO_2 emissions does not directly result from battery deterioration in these applications. The USABC has voluntary test procedures that can be followed for testing of REESS. There also exist voluntary SAE standards for battery module life cycle testing (J2288) and vibration testing.

Vehicle durability test requirements which could either generally or specifically include durability of components such as batteries are planned to be developed within the framework of the WLTP and subsequently adopted into EU law. This work is,however,not anticipated before Phase 2 of WLTP which is currently not planned to commence before 2016.

3.7.1 Battery Recycling

Attribute Definition: Battery material recycling standards.

Canada does not have a single specific requirement for the recycling of batteries but indirectly mandates the proper recycling of batteries through underlying general recycling and disposal laws in various Acts; for example, the Canada Water Act, etc.

Chinese standards relating to battery recycling do not exist at the present time, but are said to be under formulation.In the EU, battery recycling is addressed by the same legislation addressing vehicle recycling, which is Directive 2000/53/EC on end-of-life vehicles. Directive 2006/66/EC stipulates additional battery-specific requirements relating to maximum permissible quantities of hazardous elements in the batteries themselves as well required recycling, collection and disposal procedures.

European Commission Regulation 493/2012 specifies the required methodology for achievement of the recycling efficiency defined in Annex III of batteries Directive 2006/66/EC. It should be noted, however, that the previously mentioned directives do not include battery recycling requirements specifically tailored to hybrid-electric and pure electric vehicles.

Japan governs battery recycling through Act No. 87 of the Ministry of Economy, Trade and Industry (Act on Recycling, etc. of End-of-Life Vehicles).

Switzerland governs battery recycling through its Chemical Risk Reduction Ordinance.

India, the Republic of Korea, and the USA do not presently have requirements governing battery recycling.

3.7.2 Battery Re-use (post-mobility)

Attribute Definition: Alternate uses for batteries after their useful life in vehicles.

There are no standards or regulations pertaining to battery re-use currently in place worldwide.

China is said to be in the process of formulating battery re-use standards.

Existing EU legislation in the form of Directive 2005/64/EC provides a general framework for the reusability of vehicle components, systems and separate technical units. However, there are no specific provisions for battery packs of electrified vehicles.49. The latest developments (at the time of this writing, September 2013) at the UNECE level include the recently developed regulation on uniform provisions concerning the recyclability of motor vehicles. It has been based on the existing provisions of Directives 2000/53/EC (End-of-life vehicles) and 2005/64/EC (Recyclability, reusability and recovery of vehicles and components) and, therefore, does not include specific provisionsfor electrified vehicle battery re-use. Battery re-use or second-use as it is sometimes called is somewhat of a research topic at the moment. Some believe that re-purposing of these batteries could result in an EV ownership cost reduction which could subsequently spur EV adoption rates. Automakers such as BMW, General Motors and Nissan in partnership with companies like ABB and Vattenfall are actively exploring possible second-use applications for retired EV battery packs.Applications being studied range from home or neighborhood back-up power systems, to more advanced grid power buffering strategies (smart grid).

3.8 On-board Charging System

Attribute Definition: Specifications and requirements for on-board charging system, including voltage, current, port for AC and/or DC power, etc.

Globally, on-board charging is generally guided by IEC 61851 and IEC 62196 standards. The IEC 61851 standards specify the general requirements and functionality of conductive charging equipment, while the IEC 62196 standards specify connector requirements. IEC 61851-21 (ed.1.0) is currently under revision and will be split into IEC 61851-21-1 (EV on-board charger EMC requirements), and IEC 61851-21-2 (EMC requirements for off-board electric vehicle charging systems). IEC 61851-22 (ed.1.0) is scheduled to be withdrawn once the edition 3.0 of IEC 61851-1 is published.IEC 62196-2 is a standard for dimensional compatibility and interchangeability of coupling systems for AC conductive charging, and contains three types of coupling systems: Type-1 is compatible with SAE J1772 and widely used in Japan and USAfor vehicle inlet/connector, Type 2 is used in Europe for both vehicle inlet/connector and plug/socket outlet and Type 3 is used in some countries in Europe for plug/socket outlet.

China has in place voluntary standards relatedto on-board charging. These include Chinese National Standards (GB/T 20234.1-2011, GT/T 20234.2-2011), which are considered to be quoted in regulation, and an Automotive Industry Standard (QC/T 895 2011).The EU generally adheres to the definitions contained in these IEC standards on a voluntary basis (European Mennekes connector). This is also true for Japan (Type 1 connector / SAE J1772).

The Republic of Korea in accordance with its so-called 'Industrial Standardization Act'has established voluntary on-board charging standards (KS C IEC 61851-1, KS C IEC 61851-22) based on the previously mentioned IEC standards.

Switzerland, like the EU generally adheres to the IEC standards on a voluntary basis.

The USA also generally adheres to the mentioned IEC standards (Type 1 connector/SAE J1772).

Canada and India do not presently have any requirements in place relatedto on-board charging.

3.8.1 Off-board Charging Standard Related to the Vehicle

Attribute Definition: Specifications and requirements for off-board charging system, including port for DC power, battery communication interface/battery management system communication interface, etc.

Globally, off-board charging is generally guided by IEC 61851 and IEC 62196 standards. The IEC 61851 standards specify the general requirements and functionality of conductive charging equipment, while the IEC 62196 standards specify connector requirements. IEC 61851-23(DC charging stations),IEC 61851-24 (control communications) and IEC 62196-3 (vehicle couplers) will define specific requirements for conductive charging with a DC connection and are expected to be published in early 2014.

Canada does not have federal requirements for off-board charging, as this issue is under provincial jurisdiction. As with most electrical installations, chargers must comply with Canadian Standards Association (CSA) standards for electric appliances and the Canadian Electric Code. China maintains several voluntary standards in relation to off-board charging.

These include Chinese National Standards (GB/T 20234.1-2011, GB/T 20234.3-2011, GB/T 27930-2011), which are considered to be quoted in regulation, and Energy Industry Standards (NB/T 33001-2010). The EU is in-line to adopt the a new EU Directive referencing the new IEC standard IEC 62196-3 on vehicle connectors, as well as existing standard IEC standard IEC 62196-2.

Member States of the EU will be required to transpose the requirements into their national laws, regulations and standards within two-years of adoption and this is likely to be complete by 2017.

Japan has voluntary standards through the CHAdeMO connector system (JARI JEVSG105 and IEC 62196-3).

The Republic of Korea in accordance with its so-called 'Industrial Standardization Act' has established voluntary standards (KS C IEC 61851-1 and KS C IEC 61851-23) relating to off-board charging.

Switzerland, like the EU countries is also in-line to adopt the upcoming IEC standards mentioned previously.

The USA has voluntary standards for off-board DC charging through SAE J1772 (up to DC Level 2).

India does do not presently have any requirements in place relating to off-board charging.

3.8.2 Wireless Charging

Attribute Definition: Requirements and standards for wireless charging.

There areneither legislated nor voluntary requirements for wireless charging anywhere in the world at the present time, while existing regulations on radio-communication or broadcasting may apply o such systems. Within IEC, a new international standard addressing general requirements for wireless charging is being developed (IEC 61980-1). Technical specifications for charge control communication (IEC/TS 61980-2) and specific requirements for magnetic coupling (IEC/TS 61980-3) are also in development. These standards and specifications are expected to be published in Q2, 2014.The EU is expected to adopt these on a voluntary basis.

China has planned to develop the voluntary standards on wireless-charging in the near future.

Japan is said to have voluntary standards in development through Association of Radio Industries and Businesses (ARIB).

The Republic of Korea also is said to have voluntary standards in development, with charging frequencies of 20 kHz and 60 kHz already being allocated for wireless charging purposes.

Switzerland, like the EU is expected to adopt the upcoming IEC standard and technical specifications on a voluntary basis.

In the USA, there is an SAE standard that is currently in formulation (efforts commenced in 2010) that will eventually lead to a published, voluntary recommended practice (J2954).

Canada and India do not have anything in place in regards to wireless charging at the present time. However, it is expected that these countries will eventually adopt in some fashion the upcoming IEC or SAE standards governing wireless charging.

3.9 Vehicle as Electricity Supply

Attribute Definition: Vehicle-related specifications and requirements for transferring electricity from EVs to the grid.

There are no legislated regulationsin place anywhere in the world that govern the requirements of a vehicle functioning as an electricity supply.

China does not have any national or professional standards in place, but has several so-called enterprise standards that stipulate basic requirements relating to bi-directional charging equipment (Q/GDW 397-2009, Q/GDW 398-2009, Q/GDW 399-2009).

In the EU, initial portions of an eightpart ISO/IEC standard (ISO/IEC 15118) are currently available while the remaining portions are in formulation.

Japan is said to have enterprise standards that stipulate basic requirements relating to bi-directional charging equipment (Electric Vehicle Power Supply Association Guideline EVPS-001/002/003/004 2013).

In the USA, initial voluntary standards are available in the form of SAE recommended practices J2836, J2847, and J2931 which are continuing to be developed and extended to more fully address the necessary requirements. The maturity level of the ISO/IEC standards and their SAE counterparts are generally similar, with a substantial amount of remaining effort required to finalize them for their intended purpose. It should be noted that the preceding efforts relate primarily to the development of the appropriate grid communication interface. None of them are yet addressing the actual functionality of the vehicle as an electricity supply. The only modest exception is Japan where requirements that allow an electrified vehicle to be used as an electricity supply in emergency cases are said to already be available.

Canada, India, the Republic of Korea and Switzerland do not yet have any requirements in place relating to this attribute, but are expected to eventually adopt in some fashion the ISO/IEC or SAE standards that are presently in development.

3.9.1 Method of Stating Energy Consumption

Besides a uniform test procedure for measuring energy consumption, commonality in stating the outcome of the corresponding measurement (i.e. MPG, L/100km, or kWh/100km, etc.) can be an equally important environmental issue. A standardized method for calculating and stating energy consumption andthe associated GHG emissions for electrified vehicles is, therefore, recommended for consideration. The development of such an assessment method is important as the expected increase in use of electric vehicles will lead to displaced emissions from the vehicle to electricity grids; depending on the GHG accounting methods used, the impact of electric vehicles on a region's emissions profile may be underestimated if only considered for transportation.

However, the development of such a method is very challenging.It requires expertise in the composition of regional electrical grids as well as knowledge of the energy consumed for both electricity generation and distribution and conventional fuel production and distribution.In addition, vehicle energy sources and their associated GHG emissions are geographically highly variable. For this reason it is recommended that a method be developed rather than attempt to establish a common value.

Other considerations for electrified vehicle energy consumption include geographical and seasonal variation in liquid fuel lower heating values, and the relative efficiency associated with the upstream production of fuels and other energy carriers. The latter can vary depending on the method of power generation and source of raw input energy (heavy fuel, gas, biofuel, wind, solar, hydro, etc.). These considerations also merit further research and discussion.

4 FUTURE OF THE E-MOBILITY

Today, e-mobility plays a relatively minor role in electricity demand. However, the intensive electrification of transport in future, which is the goal, will create substantial additional electricity demand, which must be met by increasing installed renewables capacity. A high proportion of battery electricity vehicles in the fleet would lead to annual demand of up to 100 terawatt-hours (TWh), equivalent to 20 per cent of Germany's current electricity consumption.

Electromobility is more energy-efficient than conventional vehicles powered by diesel or petrol engines, so switching to e-mobility would cut energy demand in the transport sector. This would substantially reduce fossil fuel use but drive up electricity demand.

In the short term, this is likely to have minimal impact on the electricity sector. Even if the German Government's goal of having six million electric vehicles in use by 2030 is achieved, the additional electricity demand will amount to less than 20 TWh per year– equivalent to roughly 4 per cent of Germany's total electricity consumption in 2014.

eMobil 2050 – Scenarios for possible contribution of electric mobility to long-term climate change mitigation

The effects of increasing electrification of the transport sector on electricity generation are discussed within the scope of the project, inter alia on the basis of differential current consideration. The selected approach makes it possible to quantify the long-term effects of an additional electricity demand on the use of power plants and related emissions by the year 2050 and to identify the additional need for action in the energy sector. Since the electricity demand for electricity in the electricity market model is mapped in its entirety, there is no direct allocation of the electricity demand Emissions to individual electric vehicles possible.[29]

Within the eMobil2050 project, the possible long-term interactions between the transport sector and the energy sector were examined using two scenarios, each of which assumes a very ambitious development of electromobility. The evolution of transport demand in the scenario Grenzenlos eMobil2050 assumes that transport demand will continue to grow and that greenhouse gas reduction will be achieved primarily through a technological change. In the scenario

Regional eMobils stronger changes in the traffic behavior are deposited, so that also reduces the traffic performance.

While electric transport will still have a modest impact on the electricity market by 2030, by 2050 traffic will become a major electricity demander.[29]

The direct GHG emissions of the transport sector can bereduced by more than 80 % by 2050 when a high share of electrical transport is assumed. Without anadditional expansion of renewable energies, there are additional emissions in electricity production. Particularly as a result of the increased use of electrical propulsion systems,the direct GHG emissions of the transport sector –without taking into account either the emissions caused by vehicle manufacture and disposal or the upstream emissions of the fuels or air and maritime transport – are reduced by 85% (136 bn tonnes) in the GrenzenloseMobil scenario and by 87% (139 bn tonnes) in the RegionaleMobilscenario up to 2050 compared to 1990. If the transport sector'selectricity demand is not met by anadditional expansion of renewable energies, the electricity production needed gives rise to additional GHG emissions in the electricity sector,amounting to 50 and 16 million tonnesrespectively. If these additional emissions are ascribed to the transport sector, the GHG emissions of the transport sector fall to 56% in the Grenzenlos eMobilscenario and to 78% in the Regional eMobil scenario. In order to avoid these emissionsin the electricity generation sector, an additional expansion of renewable energies is necessary.

Within the scope of the eMobil2050 project, the possible long-term interactions between the transport sector and the power sectorare analysed on the basis of two scenarios, both of which assume a very ambitious development for electric mobility. The Grenzenlos eMobil scenario assumes further growth in transport demand and reduces GHG emissions above all by means of technological change. In the Regional eMobil scenario, greater changes in transport behaviour are assumed so that the number of kilometres travelled is also reduced.In the eMobil2050 project,electrical transportis understood broadly. The analysis considers road and rail transport, but not air or maritime transport since it cannot be assumed with high probability that these forms of transport will undergo electrification in future.

When the analysis refers to electric mobilityand electric vehicles, therefore, only electrical road transport is meant. Complementing this, the use of power-based fuels in ground transport is also included in the analysis.The effects of the increasing electrification of the transport sector on electricity production in Germany are discussed in the study based on ananalysisof marginalpower generation2. This approach enables the long-term effects of an additional electricity demand on which power plant is used to supply the electricityand on the related emissions up to 2050 to be quantified and the need for additional action in the energy sectorto be shown. Since the electricity market model shows the electricity demand of electrical transport as a whole, it is not possible to classify the emissions of different means of electrical transport specifically.The eMobil2050 project was carried out from 2011-2013 with funding from the German Ministry for the Environment, Nature Conservation, Building and Nuclear Safety.[29]

4.1 Which technical alternatives to e-mobility exist?

Sustainable synthetic fuels allow low-carbon operation of conventional vehicles; however, compared with e-mobility, they require a far greater expansion of renewables. In future, their use will only be viable from an energy economics perspective with a very high share of renewable energies, and only because there is currently no prospect of any alternatives for aviation and shipping in particular. The potential volume of sustainable synthetic fuels globally cannot be estimated at present.

In addition to electromobility, there are various other options for a low-emissions energy supply for transport, such as natural gas and biofuels. They produce lower greenhouse gas emissions than fossil fuels but reduce climate-damaging emissions by only a few per cent (natural gas) or – viewed globally – are only available in small and insufficient quantities and conflict with food security (biofuels).

Synthetic fuels based on RES electricity (power-to-X fuels) are another climate-friendly option being discussed. Here, RES electricity is converted into liquid or gaseous fuels. Examples are hydrogen from electrolysis, synthetic methane and synthetic liquid fuels, which are produced through a chemical reaction between hydrogen and carbon dioxide.

Battery-powered e-mobility has an advantage over synthetic fuels: there are minimal energy losses during charging and the utilisation of electricity in vehicles is highly efficient. The use of hydrogen in fuel cell vehicles requires at least double the amount of electricity.

Electricity-based synthetic fuels are often referred to as a climate-friendly option in connection with sector coupling of power and transport. Studies show, however, that the long-term storage of electricity in hydrogen is only viable from an energy economics perspective once high market shares are achieved for renewables. The energy needs of the transport sector also far exceed the amount of synthetic energy required for storage purposes. The use of sustainable synthetic fuels would thus require a major expansion of renewable electricity capacity.

Furthermore, production of these fuels is likely to take place at lower-cost locations outside Germany. Initial technical and economic analyses of the global potential of synthetic fuels exist, but as happened with the debate about biofuels some years ago, sustainability issues – such as the availability of land and water resources, social impacts and political stability at potential production sites – have rarely been considered. For that reason, it is not yet possible to assess the potential of sustainably produced synthetic fuels and their possible contribution to climate change mitigation on a global scale

Compared with conventional vehicles, electric vehicles have a higher proportion of technology metals in their propulsion systems. Electric car batteries contain a number of these materials, notably lithium and cobalt, while the motors require rare earths. High demand is forecast for lithium in particular, but also for cobalt. In addition, lightweight materials are used in vehicle construction, including aluminium and carbon fibre reinforced polymer.

Temporary supply bottlenecks may occur if the quantities of raw materials – such as lithium – being extracted are insufficient to meet rising demand.

The recycling of electric vehicles should focus not only on batteries and electric motors but also on the power electronics, which contain precious metals. These raw materials should be recovered in specialist e-waste recycling plants.

Substitution can also ease the pressure on scarce resources. Substitution means the replacement of raw materials with others with similar properties. For example, neodymium-iron-boron permanent magnet motors can already be replaced by asynchronous motors, which are rare earth-free.

Increased focus on the avoidance of transport and on modal shift enables a greater reduction of the final energy demand and would thereby decrease the need to expand the use of renewable energies.

The remaining renewable energies that electric vehicles cannot integrate in the electricity generation system could be used in the flexible production of electricity-based fuels.Assuming an expansion of renewable capacitiesthat enables the electricity demand of electrical transport to be metin full, the renewable energies cannot be fully integrated in the electricity generation system in the scenarios. The flexible charging of electric vehicles allows a higher share of renewable energies to be integrated than would be the case with a static electricity demand. Nevertheless, there are times when either the batteries of the vehicles connected to the grid are fully charged or the capacity of the charging points is not sufficientto enable full integration of the renewable energies. As a result there are renewable surpluses of approx. 9-10 % in the scenariosin 2050 when compared to availability.

One possibility for using the renewable energies that cannot be integrated in the electricity system on the basis of electric vehicles is –alongside other possible flexibility options on the side of electricity demand –the production of electricity-based fuels. Some peaks in the availability of renewable energies arising from limited installed capacity of the renewable production plants as determined by the plants' necessary hours of operation can also not be integrated.

However, the predominant share of the available renewable surpluses could be used in the production of electricity-based fuels. The quantities of electricity-based fuels produced only on the basis of renewable surpluses are by no means enough,however, to meet the remaining demand for gaseous and liquid fuels in the transport sector in 2050.

Complete fulfilment of this demand would entail substantial additional expansion of renewable capacities. The transport sector'selectricity demand would, in this extreme scenario, equal that of the total electricity demand of all other sectors put together in 2050, without taking into account air and maritime transport.However, the direct use of electricity has a significantly higher overall efficiency than the use of electricity-based fuels in the transport sector and should therefore be favoured where possible technically and within the scope of the electricity generation system.

5 E-ROUTES

5.1 EUROVELO

Eurovelo is a network of 14 long distance cyclotouristic routes all over Europe. The network is used not only by cyclo-tourists but also by the local cyclists practicing everyday riding for fun and commuting to work. When the EuroVelo network is finished in 2020, the overall distance covered by the network will be more than 70 thousand kilometres.

5.2 Eurovelo Trails

The EuroVelo routes meet certain fundamental criteria determined by the character of the trails designed for cyclotourism on common tourist (trekking) bicycles. The routes are not designed to be used by mountain bikes or by fast racing road bicycles. They are convenient for slower cyclotourism and recreational cycling, i.e. to the cyclo-tourists doing their tough hundreds of kilometres as well as to one day holiday makers, families with children, elderly people, clients of travel agencies etc. The trails mainly covered by asphalt surface are located on car free roads and paths to the largest possible extent located out of busy traffic.

5.3 Eurovelo Marking

The EuroVelo routes are primarily marked in accordance with the local or national standards and with the EuroVelo standards, i.e. the EuroVelo logo is nicely incorporated in the international marking. This strategy enables leading thousands of kilometres long routes across several countries in line with the local marking standards, a cyclist is thus aware of using a EuroVelo routes and gets the information on which direction to continue.

5.3.1 Trail management EuroVelo

Within its host countries, the EuroVelo trails have no particular status as they are placed on the existing marked cyclotouristic trails being administered by local communities, cycling associations and clubs etc. As a result, these trails are managed by local organisations. The whole EuroVelo project is supervised by the European Cyclists´ Federation ECF and every country involved in the project has a EuroVelo coordinator managing the proper marking of the EuroVelo trails in accordance with the EuroVelo standards, securing the consideration of these trails in the development and marketing activities of tourist industry in regions and checking the state of trails, their marking etc.

Picture 2: Eurovelo network

Source: http://www.eurovelo.sk/en/about-eurovelo.html

5.3.2 Eurovelo Services

Due to their attractiveness to the cyclists, the EuroVelo trails represent a huge potential for services provided to cyclists and cyclo-tourists. These services are not highly developed at the moment, however, it is more and more obvious that the services suitable for cyclo-tourists (accommodation and catering in the certification scheme system Cyclists welcome, cyclo buses and cyclo taxis) are rapidly progressing for example along the EuroVelo Cycling Trails followed Danube river and the situation is supposed to be improving continuously.

5.3.3 Future Directions

The electric vehicle has a relatively simple power train structure. The most important components are the motor drive and the battery system. An advanced motor drive with high power density, high efficiency, and long extended speed range is the key technology.

The success of an electric vehicle is almost determined by the performance of the battery system. The basic requirements for electric vehicle batteries are the high energy capacity for extended range, high power for vehicle performance, high safety, and low cost. At present, lithium-ion batteries are considered to be the most promising candidates.

For hybrid vehicles, advanced primary power sources are very important that may include advantage engine technologies and alternative fuel engines. Advanced control strategies and real-time control algorithms are also very important.

The key technologies for fuel cell vehicles include enhancement of fuel cell power density, reduction of cost, and, more importantly, hydrogen production and onboard storage.

Picture 3: EVs charging station in Paks (Hungary) with Type 2 standard connectors for E-cars and integrated with e-Bike charging slots, practical solution.

Picture 4 [clockwise order]: DC Fast Charging Station for Electric Vehicles (CCS Combo 2, CHAdeMO; 10, 20, 50, 100kW charger), and solar version of SETEC 50kW CCS Combo EV Charger

6 SPECIFICATIONS

This part contains a list and or with definitions of all the terms related to a topics Electric Vehicles and Electromobility. A „glossary“ would be helpful to know the important words and terms in alphabetical order that everyone should know about eMobility.

Alternating current (AV) – an electric current that reverses direction at regular intervals,

Alternative Fuel Vehicle – this term is used for a vehicle that runs on a fuel other than traditional petrol or diesel. It includes engines that don't solely rely on petroleum such as PHEV, EV, FCEVS, but also includes HEVs,

AMP – ampere, unit of electric current,

AWD – **All Wheel Drive –** an electric vehicle whose all wheels are powered from electric motors (either from a single motor or multiple motors),

Battery – a collection of related things intended for use together,

Battery electric vehicle – vehicle with a 100% battery-powered Electric Vehicle; a car that runs purely on electric power, stored in an on-board battery that is charged from mains electricity (typically at a dedicated chargepoint),

Battery-powered – powered by one or more electric batteries, these quiet, clean, battery-powered vehicles can be charged in a wall outlet, like a giant power tool,

Battery electric vehicle (BEV) – also called „pure electric“ vehicle; a form of electric vehicle that uses a battery and traction motor and no internal combustion; it would exclude FCVs but otherwise the abbreviation BEV and EV are essentially interchangeable and in the mind of most EVs and BEVs are often seen as synonymous,

Battery management system – an electronic system within the Vehicle that manages and protects the battery,

Car – a motor vehicle wiht four wheels,

CHAdeMO plug – this quick charging system allows for charging capacities up to 50 kW at appropriate public charging stations; the following manufacturers offer electric cars which are compatible with..., the CHAdeMO plug: BD Otomotive®, Citroën®, Honda®, Kia®, Mazda®, Mitsubishi®, Nissan®, Peugeot®, Subaru®, Tesla® (with adaptor), and Toyota® companies,

Charge – assign a duty, responsibility or obligation to,

Charge circuit interrupting device (CCID) – a safety protection component within an EVSE that reduces the chance of a person getting an electric shock,

Charging – → see also **Refilling**; refilling an electric car´s battery with electricity,

Charging point – the location where electric vehicles can be plugged in and charged, whether at home, work or in a public accessible location,

Charging station – an element of infrastructure that safely supplies electric energy for the recharging of electric vehicles, also known as an EVSE (Electric Vehicle Supply Equipment); technically a misnomer as EVs and PHEVs have their chargers on board – except in the case of DC-DC charging, where it is effectively "charging", the EVSE or charging station supplying AC current is otherwise not the "charger," and actually serves as a switch to direct current of varying amperage and volts to the on-board charger via a plug port,

Charging system – → see also **Chademo plug**

Connector – a device attached to the cable from an EVSE (Electric Vehicle Supply Equipment) that connects to an electric vehicle allowing it to charge,

DC fast charging – electric charge, the fastest (high powered) way to charge electric vehicles quickly with an electrical output ranging from 50kW – 120kw.This will fully charge an average electric car in 30 to 40 minutes,

Direct current – an electric current of constant direction,

Drive train – a group of components that deliver power to the driving wheel of the vehicle. Electric motors are not included in the drive train. So they are (power train – electric motor),

Dynamic Electric Vehicle Charging (DEVC) – Wireless charging of an electric vehicle when it's being driven,

Electric car – a car that is powered by electricity,

Electric vehicle (EV) – vehicle that uses an electric motor as the means of propulsion; (**E**lectric **V**ehicle) an automobile that is powered entirely or partially by electricity; although prototype electric vehicles (EVs) were invented in the 1800s and various models were built in the 1900s, the EV industry only began in earnest after the turn of the century; the advantage of an EV is fuel economy. All-electric models can reach the equivalent of around 100 MPG, however, they have a distance limit, typically from 64 to 125 km (eq. 40 to 80 miles); when the battery runs out, they have to be charged, which is a problem away from home; there are electric charging stations, but often few and far between; for example company All-Electrics® , in 2009, the Tesla Roadster® was the first all-electric with a range of a little more than 320 km (eq. 200 miles); rather than retrofitting an electric drive train into an existing chassis, the Tesla® was engineered from the ground up as an EV; in 2014, Tesla company had sufficient charging stations in the U.S. to enable Tesla car owners to drive from Los Angeles to New York entirely free, because Tesla has thus far not collected any fee for the charges,

Electric – using or providing the flow of charge through a conductor,

Electricity – a physical phenomenon that can produce light, heat and power; the car runs on electricity, but it also has a gas engine,

Electric charge – → see also **DC fast charging**

EVSE – **Electric Vehicle Supply Equipment** – a safety protocol that enables two-way communication between a charging station and electric vehicle; basically, it controls the safe current flow between the charger and EV,

Extended-Range Electric Vehicle (EREV) – a unique system architecture, and form of plug-in hybrid acknowledged as distinct from conventional PHEVs (for example Chevy Volt®),

Fuel Cell Electric Vehicle (FCEV) – **t**his term refers to an EV which uses a hydrogen fuel cell to power its electric motor, the fuel cells create the electricity to power the car,

Gasoline – a volatile flammable mixture of hydrocarbons (hexane and heptane and octane etc.) derived from petroleum; used mainly as a fuel in internal-combustion engines,

Green House Gas (GHG) – a gas such as Carbon Dioxide that contributes to global warming through the absorption of infrared radiation,

Home charging – charging of an electric vehicle from standard home installed socket,

Horsepower – this is a measurement of an engine or motor’s maximum power output; an electric motor’s output can also be expressed in terms of kilowatts (kW). KW – kilowatt is a measurement of electrical power, usually abbreviated as “kW”; when used to express an electric motor’s maximum output, this is roughly equivalent to 1.34 horsepower,

Hybrid electric vehicle (HEV) – vehicle which have no distance limit and are less economical with fuel; generally no more than 50 MPG. In 2010, GM® introduced the plug-in, hybrid-electric Chevrolet® Volt, the Volt is a gas-powered car that runs on battery for short distances, allowing those commuters to enjoy great economy when plugged into their home's electrical panel overnight; the Volt can last up to 80 km (eq. 50 miles) on its electric charge, at which time the internal combustion engine takes over; a regular hybrid-electric vehicle such as the first Toyota Prius® is filled with gas, and the vehicle charges the battery, the Prius technology determines when to switch from the battery to the gas engine; toyota later came out with a plug-in hybrid; also: a 100% fossil fueled hybrid car.

The most common is the Toyota Prius; a small battery is charged through regenerative braking that generates some electric power in tandem to a combustion engine, but all energy originates from petrol,

ICE – internal combustion engine, this acronym describes any vehicle that runs on fossil fuels,

IEC 62196 – also known as the Mennekes, it is a type of connectors that is used to charge Electric Vehicles in Europe,

JEVS G105-1993 – also known as CHAdeMO, it is a method developed to quickly charge Electric Vehicles through the use of a special adapter that delivers up to 62.5 kW, this is used in Japan; see also → **CHAdeMO plug**

km/kWh – unit that indicates how long electric car travel with unit energy consumption,

kW – Watt is the SI unit of power which is equal to 1 Jule per second. It's equivalent to the rate of energy consumption in an electric circuit where the potential difference is 1 Volt and Current is 1A. 1 kW (**kiloWatt**) is equal to 1000W,

kWh – kilo Watt hour (kWh) is the one unit of energy. Equipment of 1kW rating consumes 1kWh energy if it operates for 1 hour,

kWh/km – energy requires to travel a unit kilometer,

Level 1 charging – involves powering the EVSE via a typical wall socket. In the U.S. this is typically a 120-volt (nominal) outlet. in European countries where there may be higher current at the wall, charge speeds can be quicker,

Level 2 charging – charging from a 240-volt outlet, and typically with higher amperage too, amperage current makes a huge differnce in charge rates, smaller EVs like the Leaf might take 30 amps or so; Tesla's high-power wall charger delvers a nominal 80 amps at 240 volts – much more recharging power – thus not all "level 2" charging is equal,

Level 3 charging – also known as DC fast charging or DC quick charging and not available for homeowners, this is high amperage, high voltage – typically 480 volts – that can charge a battery pack 80 percent full in about 30 minutes more or less, the SAE does however allow for a type of AC level three, but it's not commonly seen in use,

Lithium-ion battery (LIB) – also known as a Li-ion, it is a common rechargeable battery,

Mennekes – → see **IEC 62196**

Micro hybrid (vehicle) – some consider this a contrived term as it's the least form of hybrid there is, or not a "hybrid" at all; vehicle(s) that use an extra large battery to take some of the parasitic load off of the gas engine qualify, these vehicle(s) don't actually have electric drive, thus do not merge two propulsion sources and therefore they aren't really a "hybrid" by the stricter definition,

Mild hybrid (vehicle) – a form of hybrid that uses both sources together. An example would be a Chevy Malibu eAssist® or Honda Civic® hybrid which never allow the gas engine to fully shut off and decouple for pure electric drive; the motor and electrified portion of the system is not typically strong enough for pure EV drive, so it's more a "helper" motor; even if in cases it is strong enough, the system architecture does not decouple the mated internal combustion engine and electric motor,

Molten salt battery – a type of battery that utilizes molten salts as an electrolyte,

MPGE – a miles-per-gallon equivalent measurement the Environmental Protection Agency created to help consumers compare an electric car's energy consumption with those that run on fossil fuel. MPGe is calculated based on a conversion factor of 33.705 kilowatt-hours of electricity equaling one gallon of gasoline,

Nickel Metal Hybride (NiMH) – a less reliable rechargeable battery,

Off peak charging – charging your electrical vehicle at certain lowest cost off-peak hours,

Oil – a slippery or viscous liquid or liquefiable substance not miscible with water,

Plug-in hybrid electric vehicle (PHEV) – a car with a combination of a traditional internal combustion engine and a rechargeable battery, allowing for either pure electric-powered driving or extended range from a combination of the petrol engine and electric motor; examples would be the Ford Fusion Energi®, Toyota Prius® Plug-in Hybrid Electric Vehicle, even the Chevy® Volt and Cadillac® ELR, though these latter are also EREVs (extended-range electric vehicles),

Plug-in vehicle (PiV) – a blanket term for any vehicle with a plug socket, including BEVs and PHEVs,

Powered – often used in combination, having or using or propelled by means of power or power of a specific kind,

Range-extended EV (REx) – an EV that has only an electric drivetrain, but a small petrol generator to charge the battery when range is depleted for longer trips, often considered a type of PHEV; also this refers to an EV with a small gasoline engine that kicks in to run a generator that, in turn, operates the motor once the battery becomes depleted, at that point the vehicle's operating range is limited only by the amount of gas in the tank; this effectively eliminates worry over being stranded at the side of the road with a dead battery, which is often called "range anxiety",

Regenerative braking – a system used in EVs (and hybrid-powered cars) that recovers energy otherwise lost during deceleration and braking and sends it back to the battery pack to help maintain a charge; some EVs, like the Chevrolet® Bolt EV and Nissan® Leaf, can maximize the regenerative braking effect to slow down – and even bring the vehicle to a stop – without using the brakes, this is commonly called "one pedal" driving,

Refilling – refilling an electric car's battery with electricity,

SAE J1772 – the standard North American electrical connection for Electric Vehicles. Generally works with Level 1 and Level 2 systems,

State of charge (SOC) – it refers to the meter on an EV's instrument panel that displays the current battery level as a percentage,

Technology – the practical application of science to commerce or industry,

Torque – torque is officially defined as the twisting force that causes rotation, it's the force you feel when you're pressed into your seat as a vehicle accelerates aggressively; electric motors deliver 100% of their available torque instantaneously, which enables fast launches and strong passing abilities, having a higher torque rating otherwise makes an engine or motor with limited horsepower feel quicker,

Ultra Low Emission Vehicle (ULEV) – a car that has official tailpipe carbon dioxide emissions of less than 75g/km, and is therefore eligible for grants and benefits from the UK government,

Vehicle to grid (V2G) – a system that allows Electric Vehicles to communicate with the power grid to manage the flow of electricity in either direction,

Volt – a unit of potential equal to the potential difference between two points on a conductor carrying a current of 1 ampere when the power dissipated between the two points is 1 watt; equivalent to the potential difference across a resistance of 1 ohm when 1 ampere of current flows through it,

Zero emission vehicle (ZEV) – this abbreviation stands for "zero emissions vehicle," which means it produces no tailpipe emissions, all pure electric vehicles are of the ZEV variety.

7 A GLOSSARY OF TERMS RELATED TO ELECTRIC VEHICLE/EV CHARGING: from connector types, key concepts, types of charging to measures of electric range and efficiency

7.1 EV charging connector types

Type 1 – A five pin plug that also features a clip, this connector is common in the US and is typically found on EVs manufactured by Asian and US brands (e.g. Nissan, Mitsubishi and GM/Vauxhall/Opel). However its prominence is fading as Nissan have moved to Type 2.

Type 2 – A seven pin plug with one flat edge, this connector was originally favoured by European brands e.g. BMW, VW group, but is now becoming the most popular on all cars. Can carry three-phase power and locks into the socket of a charging point.

CHAdeMO – A round four pin plug, this connector is only used for rapid charging points and is typically compatible with EVs manufactured by Asian brands e.g. Mitsubishi and Nissan. Can offer Vehicle to Grid (V2G) but has less power than CCS and requires two separate sockets.

CCS/Combined Charging System – Standardised by the EU, this connector combines two DC pins arranged below the Type 2 AC connector and uses 3 of the Type 2s pins. Found on most Type 2 BEVs.

UK 3 pin – The plug for a standard UK electrical outlet. This connector can be used to charge some EVs in an emergency but lacks the safety, speed and security features of a dedicated chargepoint.

7.2 KEY concepts

Top Up charging – The practice of plugging in your electric vehicle whenever you park while out and about, making use of the time your car is not in use to add charge to your battery. This helps avoid range anxiety and means you will rarely find yourself waiting for your car to charge. Public Pod Points are ideal for top up charging and can be found using by the mobile application (free for use).

Home charging – Plugging your electric car in to charge while it is parked at home, typically overnight. A dedicated home charging point is the best and safest way of doing this.

En-route charging – En route charging typically requires high powered rapid chargers, that put >100 miles into your electric car in the time it takes to grab a coffee, a snack and use the facilities. This enables you to take long-distance trips in your electric car, but is not needed day-to-day.

ICEd – When a chargepoint is occupied by a vehicle with an internal combustion engine (ICE) , preventing an EV from charging. A polite note left on their windscreen with your phone number is generally the best response.

RFID Cards – Using the same technology used in public transport travel cards, these cards are used by many older chargepoints to allow access to EV charging.

The Pod Point Network – On the Pod Point Network you can charge your EV without RFID cards or membership. Simply use the Pod Point app to find a chargepoint and start your charge. Alternatively, some Pod Point rapid chargers can be used with just the tap of your contactless bank card.

Contactless Payment – Available on some rapid chargers, it is possible to start and pay for your charging session with the tap of your contactless credit/debit card.

Range Anxiety – The term given to a fear of running out of charge while driving a plug-in electric vehicle. This fear can be avoided by top-up charging wherever you park throughout the day and en-route charging on longer journeys.

Range per hour (RPH) – Miles of range per hour of charge.

Kilowatt hour (kWh) – A unit of energy equivalent to the energy transferred in one hour by one thousand watts of power. Electric car batteries are typically measured in kilowatt hours. 1 kilowatt hour is typically 3-4 miles of range in a BEV.

Smart charging – A catch-all term for a series of functions that a Wi-Fi connected chargepoint can perform. Typically this refers to things like load balancing, energy monitoring and “managed charging”, i.e. shifting charging periods away from periods of high grid demand and/or low grid supply and to periods of low grid demand and/or high grid supply.

Vehicle to Grid (V2G) – The concept of using your electric car battery to release power back through the charger either for use in the local building or back into the grid at large during time of high grid demand.

Single-phase Power – Typically found in most UK homes and some businesses, this is what all standard 3 pin plug sockets provide. A single-phase electricity supply can power a dedicated chargepoint up to 7kW.

Three-phase Power – Often found on commercial and industrial sites, this provides three alternating currents and allows for 22kW AC charging. Significant three-phase power availability is also a prerequisite for DC rapid charger installation.

The Rapid Charge Paradox – The counter-intuitive realisation that it is only at the fastest chargers where EV drivers typically spend time waiting to charge. This is because most charging is done at slower chargepoints that charge the car while the driver is otherwise occupied.

7.3 Types of charging

Trickle Charging – The slowest type of charging, this is best reserved for long overnight charges at home and is either provided safely by de-rated dedicated chargepoints, or through a standard 3 pin plug, which lacks certain safety features.

Slow Charging – A better option for home charging, this allows for both top up and overnight charging through a dedicated chargepoint. The 3.7kW Pod Point Solo is a good example of this type of charging point and provides faster charging times than a 3 pin socket.

Fast Charging – Ideal for top up charging, most fast chargepoints offer 7kW, ideal for keeping you going while out and about. Typically found in homes, workplaces and in public car parks where people typically spend circa 40 mins or more.

Rapid Charging – Typically used for en-route charging on long distance journeys, rapid chargers can also be used as occasional "caught short" chargers, particularly if available somewhere convenient, e.g. a supermarket. Rapid charging takes place from 43kW power and above.

7.4 Measures of electric range and efficiency

Manufacturer’s Claimed Range and Efficiency – This has traditionally been the most optimistic measure, achievable in specific circumstances. Often the manufacturers would use numbers derived from the “NEDC” cycle.

NEDC – A cautionary tale in use of the word “new”, the New European Driving Cycle (NEDC), last updated in 1997, was designed to assess the emission levels of car engines and fuel economy in passenger cars. It has fallen out of favour as manufacturers were configuring their cars’ performance for the NEDC test, rather than the NEDC measuring their cars’ real world performance. When it comes to electric vehicles, the NEDC gives quite a generous assessment of range.

WLTP – The Worldwide harmonized Light vehicles Test Procedure (WLTP) is the more thorough emissions and efficiency testing regime that has broadly superseded the NEDC. The test provides a less optimistic verdict on real world electric range, but it is arguably still more optimistic than a vehicle’s actual real world range.

EPA – The USA’s Environmental Protection Agency (EPA) has established its own testing methodology for electric range which is arguably the toughest, and thus closest to real world performance of the available metrics.

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