eGUTS

Electric, Electronic and Green Urban Transport Systems – eGUTS

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D4.2.5 DYI Conversion provides step-by-step instructions

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10 highlights of the study

- DIY plans exist in different forms (book, other "paper" formats, electronic, online). Apart from assembly plans of conversion kits manufacturers, DIY plans are not usually comprehensive.
- There are plenty of universal conversion kits available on the market, especially for bicycles, but also for other two-wheeled vehicles. Their conversion is simple.
- The conversion of passenger cars and light commercial vehicles (M1 and N1 categories) already requires expert knowledge and practical experience. Conversion kit offer exists for a few selected models (mostly historical).
- DIY rebuilding of modern cars is not recommended due to their more complex construction and complicated electronic systems.
- DIY construction of a brand new vehicle is considered for the L category, especially due to the demanding construction of other categories of vehicles, safety requirements, compliance with regulations and standards, the complexity of the approval process and costs.
- In DTP countries, standards for electric vehicles are not different from EN standards. Issue of conversion is not covered.
- There are seldome national legal documents available in DTP countries, dealing with the conversion of vehicles to EV: the Croatian Catalogue of changes (incl. conversions) and the Slovenian Decree on the approval of vehicles with battery electric drive. Furthermore it was recommended to investigate the German Electromobility: Regulations in the area of Automotive Engineering and Dangerous Goods.
- Financial support in DTP countries tends to focus on acquiring new vehicles and charging stations; only Austria, Croatia and Slovenia offer a subsidy focused also on conversion to EVs.
- National approving processes are easy to be met for single-track vehicles; in regard of the conversion, cars with a VIN have a more complicated but acceptable approving process; for cars with no VIN yet (incl. converted or constructed as DIY EVs) the approving process is complicated, long and expensive.
- In the FS5 international regulations and technical standards were collected and investigated. It was recommended to follow them, for purposes of the eGUTS standards to be developed.

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Glossary

ABS	Anti-lock Braking System
AC	Alternating Current
ACD	IEC stage code(http://www.iec.ch/standardsdev/resources/processes/stage_codes.htm)
ADR	European Agreement concerning the International Carriage of Dangerous Goods by Road
ADTS	IEC stage code (http://www.iec.ch/standardsdev/resources/processes/stage_codes.htm)
ATV	All Terrain Vehicle
ATVEA	All Terrain Vehicle Industry European Association
BMS	Battery Management System
CAN	Controller Area Network
CD	IEC stage code (http://www.iec.ch/standardsdev/resources/processes/stage_codes.htm)
CDM	IEC stage code (http://www.iec.ch/standardsdev/resources/processes/stage_codes.htm)
CEN	European Committee for Standardization
CFDIS	IEC stage code (http://www.iec.ch/standardsdev/resources/processes/stage_codes.htm)
CHAdeMO	Quick charging method for battery electric vehicles "CHArge de MOve"
COC	Certificate of Conformity
CVH	Vehicle Center of Croatia
DC	Direct Current
DIY	Do-It-Yourself
DTP	Danube Transnational Programme
EC	European Commission
ECE	Economic Commission for Europe
eGUTS	Electric, Electronic and Green Urban Transport System (Project acronym)
EMC	Electromagnetic compatibility
EN	European Standard
EPAC	European Partners against Corruption
EU	European Union
EV	Electric Vehicle
FS	Feasibility Study
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
ICE	Internal Combustion Engine
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
KFG	Kraftfahrgesetz (Motor Vehicles Act)
LCD	Liquid Crystal Display
LCO	Lithium Cobalt Oxide
LED	Light-Emitting Diode

LEV	Light Electric Vehicle
LFP	Lithium Iron Phosphate
Li-Ion	Lithium-ion Battery
LiFePO4	Lithium Iron Phosphate
LMO	Lithium Manganese Oxide
LUV	Light Utility Vehicle
L6e, L7e	Light quadricycles, heavy quadricycles (vehicle category)
MOT	Ministry of Transport
M1	Passenger cars (vehicle category)
NHK	National Transport Authority (Hungary)
NMC	Lithium Nickel Cobalt Manganese Oxide
NCA	Lithium Nickel Cobalt Aluminium Oxide
N1	Utility vehicle (vehicle category)
PC	Personal Computer
PRVC	IEC stage code (http://www.iec.ch/standardsdev/resources/processes/stage_codes.htm)
TOB	Technology Promotion Burgenland
UN	United Nations
USB	Universal Serial Bus
VIN	Vehicle Identification Number

Introduction

This document offers an overview of e-vehicle types, including their description, and the overview of plans for do-it-yourself (DIY) conversion to e-vehicle. Conversion kits and plans with step by step instructions are depicted. The document takes into account EU standards and DTP, as well as national specificities of each participating country. Global trends that support the implementation of e-mobility were taken into account. For purposes of this document the e-vehicles were categorized as previously non-motorized (bicycles and scooters) and previously motorized (motorbikes, cars, and others). In addition, less known transport means (i.e. boats) are defined, since they could be of interest.

Several options are available for procurement of e-vehicle:

a) Purchase of a brand new e-vehicle (beyond scope of this deliverable).
b) Purchase of a used e-vehicle, either produced or converted (beyond scope of this document).
c) Conversion from an existing vehicle with a internal combustion engine to an e-vehicle with engagement of professional service
d) Conversion of existing non-electric vehicle (powered by internal combustion engine or non-powered) using a conversion kit as do-it-yourself (scope of this document)
e) Construction of a brand new e-vehicle as do-it-yourself with use of available and proven plans, if possible with support of any forum or platform of users (scope of this document)

Firstly, before dealing with subjects of this study, it would be useful to mention some of motivations and things to be taken into account when hesitating between a conversion and buing a brand new EV. Indeed, it depends on reasons and expectations of an individual person: his/her wish to simly enjoy the conversion, financial (non)availability of buying a new EV, eco-friendly approach towards personal environmental footprint, use of a vehicle with an already inoperative conventional drive, school projects and company experiments or developments etc. Somebody can plan and then realize the conversion/building of an EV although it is not just time and costs efficient, but it is a challenge and pleasure to spent time in this way.

This feasibility study on the DIY e-vehicle conversion is divided into six chapters - the introduction presents the starting points and basic information. The second chapter includes an overview and a description of existing electric vehicles. The third chapter contains a review and analysis of existing DIY plans, necessary European and national conditions and requirements, and gathered information on conversion kits. The fourth chapter is a DIY step-by-step guide for converting a regular vehicle into an e-vehicle. The highly estimated demand for conversion is for bicycles. The fifth chapter provides tips and guidance for building another very much demanded electric vehicle, the passenger car. The final chapter is a short conclusion on findings reached during the work for this feasibility study. The Annex gives a list of technical standards and specifications, each of them with a link to certain status and abstract (the full standard has to be purchased).

1 Overview and a brief description of existing electric vehicles

The section covers an overview and description of existing types of electric vehicles (converted or built by self-construction, not manufactured).

1.1 Electric bicycles (pedelecs) and scooters

Following important issues need to be considered before purchase or conversion of bicycle to an e-bicycle:

- Types of electric bicycles: without or with accelerator (opportunity to move off without using treadles)
- Influence of centre of mass (battery location in all three axes: length, width, height) on driving control and riding safety
- Locking option for battery as an expensive part of a bike
- Derailleur for non-motorized operation; for the e-engine option with multi-stage assistance setting-up
- User needs: new e-bike characteristics in comparison with a common bike:
    - Total e-bike weight for handling and riding (alternatively, for longer trips including charging equipment)
    - Estimated ride range (depending on battery capacity) at given weight of an e-bike with a cyclist together, certain terrain type and altitude profile of a route
    - Type and placement of the battery (capacity and lifecycle mainly)
    - Charger type for the battery (charging time needed)
    - Investment and operation costs of an e-bike for the whole life cycle (battery as a significant cost)
- Type of trips: sport versus city riding (upright sitting, easy remounting/dismounting for seniors, carrier, fenders, shock-absorbers etc.)
- Costs and benefits investigation
- Suitability for a certain purpose and person
- Safety: lights and reflectors and retro-reflexive wear and equipment, helmet
- Options: a folding e-bike (fits into a car boot, for combination with long distances)

Bicycles were divided into the following categories for the needs of the study:

- City and trekking bicycles, (based on the frame) further divided into subcategories:
    - With fixed frame
    - With fixed lowered frame
    - Folding

        - Retro and lifestyle
- Mountain and cross bicycles
    - Cross bicycles
    - Mountain bicycles
        - With fixed frame
        - With full suspension frame
        - Downhill bikes
        - Freeride bicycles
        - Fatbikes
- Road bikes

Scooters were divided into the following categories:

- Folding
- Large

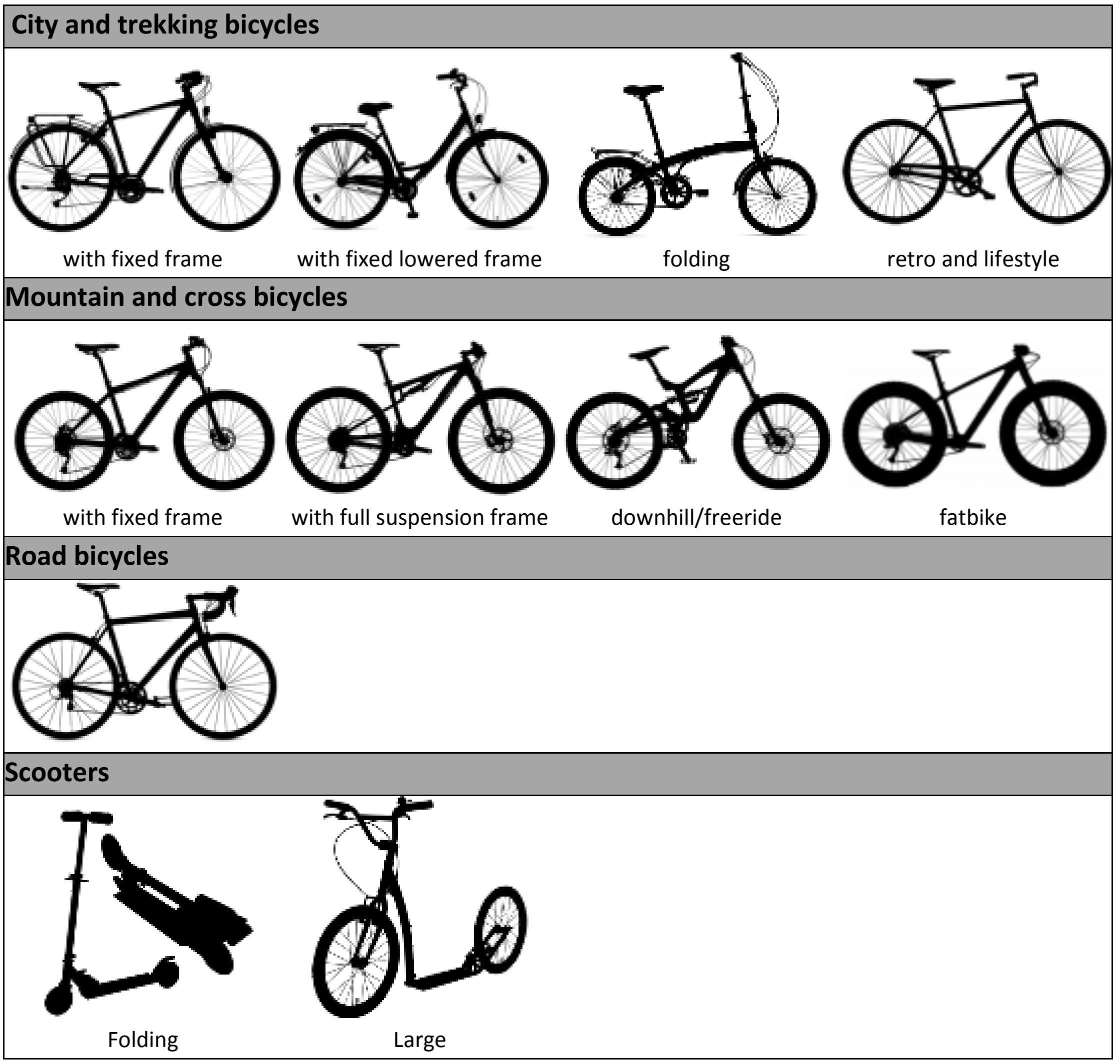


Fig. 2.1 Electric bikes (pedelecs) and scooters categories

There are conversion kits in the market available for the construction and conversion of bicycles. The kits offer various combinations of electric motor and battery placement. We distinguish kits for the rear wheel, front wheel, and kits with central electric motor. Batteries can be mounted on the frame or the rear holder.

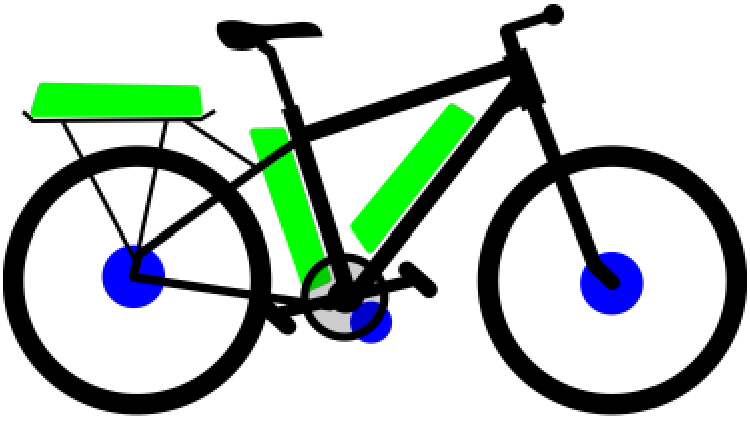


Fig. 2.2 Potential placement of electric motor and batteries

1.1.1 City and trekking bikes

City bikes, as the term suggests, are primarily designed for use in urban areas, although some allow riding in light terrain. They can be generally divided into two groups. Regarding the first group, the frame construction is designed for comfortable and frequent mounting. They often have no upper frame tube. In case they only have the lower frame tube, it is usually lowered. They can either have a fixed or a folding frame. The second group includes bicycles in a retro or designer style. In some cases the design effect prevails over functionality. The frame dimensions correspond with wheel dimensions. Bicycles with fixed frames usually use 26“ and 28“ wheels. Folding bicycles have 16“ or 20“ wheels. Retro and designer bicycles usually have 28“ wheels, women's bicycles sometimes have 26“ wheels. City bicycles are often equipped with accessories, such as chain covers, fenders, racks, etc. These accessories increase weight, but on the other hand they improve bicycle comfort and functional properties. A side effect of racks is their use for a battery placement. A battery can also be fixed to the frame or saddle tube. With occasional exceptions of retro or designer bicycles the city bicycles are equipped with transmissions. Transmissions are usually controlled by shifters, or can be a part of the rear hub. Hub transmissions typically include 3, 7 or 8 gears. Traditional transmissions usually include 6-9 gears. City bicycles typically include just one chainring, exceptionally two (multiply the number of gears). Typical weight parameters of city bicycles are summarized in Tab. 2.1. Table does not include retro and designer bicycles, where the conversion into electric bicycles is unlikely due to aesthetic reasons.

Tab. 2.1 Weight parameters for standard, currently available bicycles

	Weight excl. electric drive [kg]	Weight incl. electric drive [kg]
men’s bike with fixed frame	14-18	22-25
women’s bike with fixed frame	13-17	23-25
bike with fixed lowered frame	15-19	23-26
folding bike	10-13	18-24

Another group are bicycles in retro style or lifestyle. Retro bicycles are mainly produced hand made by traditional procedures and from traditional materials (steel, leather, wood, etc.). There is an effort to maintain the original design. In contrast, lifestyle bicycles are typical for their lightweight construction and particularly modern minimalistic design. Conversions into electric bicycles are not expected for these two categories, since the bicycles would lose their unique character.

1.1.2 Mountain and cross bikes

Except city and trekking bicycles, mountain bikes are another group suitable for conversion into electric bicycles. Regarding the frame geometry, battery is in most cases expected to be fixed to the lower frame tube. In the case that the bicycle has increased wheelbase and unsuspended rear frame, compact batteries can be fixed to the saddle tube. Racks are unusual on this type of bicycles. Gears are exclusively changed by derailleurs. There are 8-10 gears which are typically multiplied by 3 chainrings. Two chainrings are supplied to lightweight (race) bicycles with carbon fibres or aluminium alloys. There can be a single chainring, particularly for mass produced electric bicycles. The electric motor is often placed in the central hub or rear wheel hub.

Apart from traditional mountain bikes, this category includes a group of specially designed bicycles, such as downhill bikes, freeride bicycles a fatbikes. Regarding these groups, no conversions into electric bicycles are expected, with the exception of fatbikes. Typical weight parameters of terrain bicycles are summarized in Tab. 2.2. There are no substantial differences between the men’s and women’s bikes in weight (similar frame construction). Cross bikes can be a little lighter, unless they have a suspension fork.

Tab. 2.2 Weight parameters of standard, currently available bicycles

	Weight excl. electric drive [kg]	Weight incl. electric drive [kg]
mountain bike	13-15	20-23
cross bike	12-15	20-23
fat bike	14-16	21-24

1.1.3 Road bicycles

Road bicycles are primarily designed for sport race rides for long distances. There is an effort to reach as low weight and aerodynamic resistance as possible. The frames are currently made mainly from aluminium alloys or with the use of carbon fibres materials. The effort to reach the lowest aerodynamic resistance requires a compact and very narrow bicycle design. Therefore, road bicycles are unsuitable for conversion into electric bicycles. That would contradict their purpose.

1.1.4 Scooters

Scooters are suitable means of transport for all people, regardless of age. Once a children's toy, it has recently become a practical means of transport, particularly in urban areas. Their construction allows easy mounting and dismounting. Low centre of mass takes minimum requirements for balancing. Based on the type, they can be suitable for long distances. They can also be used for fast trips in large company premises.

Folding scooters are suitable for short trips, potentially in combination with other transport modes. Thanks to their low weight and compact dimensions, they are easily portable. A certain drawback is the size of wheels, which need a high quality surface for the ride. The weight of folding scooters (without electric drive) usually ranges between 2.7 and 4.7 kg for the maximum load of 100 kg. Regarding large-scale produced scooters with an electric drive, the weight ranges between 12.5 and 15 kg. Based on the ambient conditions and configuration, the riding range can reach 20-30 km. The electrification of folding scooters is complicated. Conversion kits are not easily available and are usually of Chinese production. The placement of batteries is problematic, since there is not enough space on folding scooters. Some of the conversion kits do not include batteries as standard supply.

Bigger scooters allow rides for longer distance and in terrain. They are readily available with a steel frame, fork, and handlebars from aluminium alloys. The frames can be produced from lightweight aluminium alloys, and sometimes from carbon composites, for sport purposes. Brakes can be foot brakes, V-brakes, or disc brakes. The weight of a big scooter, excl. electric drive, ranges usually between 7.4 and 9.2 kg. The weight of large-scale produced scooters with an electric drive usually ranges between 19.5 and 25 kg. In contrast to folding scooters, the conversion of big scooters is easy. It is performed with the use of conversion kits for bicycles with the motor placed in the front or rear wheel. The battery is usually fixed to the frame. A typical riding range of the electric drive is 30-70 km, based on battery capacity (typically 8-15 Ah) and operation conditions.

1.2 Electric cars

Electric cars included in this category are four or more wheel vehicles designed for transport of passengers or goods. Electric cars were divided into four categories for the needs of this study:

- Light quadricycles and quadricycles (categories L6e and L7e)
- Passenger vehicles (category M1)
- Light utility vehicles (category N1)

Medium heavy and heavy utility vehicles and buses are not subjects of this feasibility study, moreover DIY conversions is not normal practice for this category, typically professional conversions are done.

1.2.1 Light quadricycles and quadricycles

In Directive 2002/24/EC light quadricycles are defined as four-wheel vehicles with the maximum weight of 350 kg (without batteries), the maximum net power and the maximum rated power of 4 kW and speed up to 45 km/h (category L6e). Quadricycles are limited by the maximum weight without batteries to 400 kg, or 550 kg respectively for freight ones, with net power not exceeding 15 kW (category L7e).

Vehicles of these categories are often equipped with the electric drive from production, particularly in cases of utility variants. Therefore, the choice of vehicles for conversion is rather limited. On the other hand, the conversion is not as complicated as for vehicles of M1 and N1 categories, thanks to their simple construction. Apart from the conversion kits, the whole assembly units are available on the market. They concern rear axles with a final drive and motor. The extensive offer of drive components, together with a simple approval procedure, allows building the whole vehicle, not only doing the conversion.

1.2.2 Passenger vehicles

In Directive 2007/46/EC passenger vehicles of M1 category are defined as motorised vehicles with at least four wheels and maximum weight up to 3.5 tonnes, designed and produced for transport of passengers with the maximum of 8 seats, excl. driver’s seat. In general, any car can be equipped with an electric drive, but the conversions mostly occur in the so-called cult cars (e.g. Volkswagen Beatle, Austin Mini, Citroen 2CV, Renault 4, etc.) and sports cars from the 1960s – 1980s. They are often cars with higher or high purchase price if they are in good technicaland/or operational condition. Vehicles with non-functional, incomplete, or missing combustion engine are those which are usually used for conversions into electric drive. The advantage of the conversion of older vehicles is an absence of complicated electronic systems and simple construction. The design and image of these vehicles is a bonus. The drawback of old vehicles is their condition of bodywork, or bearing bodywork parts, and frames, due to corrosion. Another frequent problem is the condition of the interior and upholstery. In these cases extensive bodywork repairs, and sometimes a complete renovation of the vehicle, is necessary. Due to complicated electronics and wiring, the conversion of modern vehicles cannot be done by owners themselves. In those cases the conversion is performed by a team of experts. The conversions are usually performed in specialist companies offering professional conversions or at universities/research centres.

1.2.3 Light utility vehicles

There is a relatively wide offer of serial produced electric vans in the weight category up to 3.5 tonnes. They particularly concern small Renault, Peugeot, Citroën, Nissan vans and large Iveco vans. Medium and large Renault and Volkswagen vans are being prepared to production in 2017. In addition, there are several companies offering professional conversions of utility vehicles on the market e.g. Smith Electric Vehicles, EVC, etc. Based on the above mentioned reasons and regarding the significantly lower number of registered vehicles, self-performed conversions in the category of light utility vehicles are less frequent than in passenger vehicles.

The conversions can be most frequently seen among private owners, or in small businesses. Similarly to passenger vehicles, the conversions mostly include older vehicles. VW Transporter vans T1, T2 and T3, produced in 1950-1990, are particularly popular. The first three generations of VW Transporter had the motor placed at the rear driven axle and had a raised floor at the rear of the vehicle. This design allows easier integration of both the motor and the battery sets without more complicated bodywork construction changes. Older Japanese vans with motors under the floor in the middle of the vehicle or at the rear axle are similarly popular. The conversions of modern utility vehicles are predominantly performed by professional companies, similarly to passenger vehicles.

1.3 Other types of means of transport

1.3.1 Mopeds and e-bikes

Despite the fact that these categories of vehicles are driven by a motor, they are also equipped with pedals. E-bikes are bicycles equipped with an auxiliary electric motor that can drive the bike. The cyclist is not necessarily required to pedal. Pedal assisted bicycles with the power exceeding 250 W and e-bikes that can be exclusively driven by a motor in accordance with Directive 2002/24/EC, are included in the category of low-performance mopeds. Vehicles in this category are defined in the Directive as vehicles with pedals, with an auxiliary engine not exceeding 1 kW and a maximum design speed not exceeding 25 km/h. These vehicles are subjected to type-approval, but they need not meet all requirements (see Annex I of the Directive). Pedal assisted bicycles with motor assistance exceeding 25 km/h and e-bikes with maximum speed higher than 25 km/h are included in the category of mopeds and are subjected to type-approval. In those cases helmets must be used, the vehicle must be insured and there is an age-limit for its use. In some cases, a registration plate and driver’s licence are required.

The conversion of bicycles to e-bikes is very easy and very similar to the conversion of pedelecs. In addition, conversion kits are similar. The difference is particularly in the parameters of individual components. There are conversion kits for the bottom bracket as well as for wheel hubs. Conversion kits for central hubs are more suitable for terrain bikes, if the motor is placed in front of the central tube (not under). Typical motor power is of 350, 500, 750 and 1000 W. The riding range of 55-100 km is based on the battery capacity and ambient conditions. The weight ranges between 6.5 and 9.5 kg. Regarding the transferred power and particularly higher speeds, the conversion should also include brake enhancement, i.e. potential replacement of V-brakes with disc brakes, or an upgrade of disc brakes.

The electrification of mopeds can be made with more methods. One of the ways is to keep the original drive conception, where the difference is only visible in the replacement of ICE for an electric motor. This type of conversion is used in case the owner refuses to use the available conversion kits, or when there is an effort to keep the original moped design (oldtimer, youngtimer, etc.). Another method is to simplify the drive, and use conversion kits with a rear hub motor designed pro e-bikes.

1.3.2 Motor scooter

A specific feature of scooters is the fact that the motor is a part of the rear fork. In this case, there are different approaches to conversions. One of the methods is to keep the original arrangement of the drive with the ventilator and the motor. This solution is demanding in terms of the fork construction as well as of the drive regulation itself. Therefore, the offer of serial produced conversion kits is very limited. The Asian production occasionally includes complete kits which contain a new fork. Another, simpler, solution is the use of conversion kits with a rear hub motor, which are offered together with spokes of the 10-14“ diameter. The power of motors ranges between 0.5 kW and 5 kW. The weight of the set with a disc ranges between 10 and 22 kg, based on the diameter and used material.

1.3.3 Motorbike

Motorbike conversion can be performed in two ways. The motor can be placed in the central frame and the drive can use a chain (majority of reported DIY conversions), or it can be a part of the rear hub. Conversion kits are available for both variants. The advantage of the first variant is a better distribution of weight with substantially lower mass on the rear wheel. Air or water cooled motors usually have the rated power of 0.5-10 kW at the rated voltage of 48, 72, 96, or 120 V. The advantage of variants with rear hub motors is a simple conversion. Hub motors are air cooled only and their power is in a similar range. Based on motorbike riding properties, it is necessary to keep the optimum ratio between the riding range and the weight of battery sets. It is also necessary to pay attention to suitable placement of batteries, so that the centre of mass is not increased and manoeuvrability of a motorbike is not reduced.

1.3.4 ATV

All Terrain Vehicle Industry European Association (ATVEA) defines ATV (also called quad) as any motorised vehicle designed to travel on four low pressure tyres on unpaved surfaces, with a seat designed to be straddled by an operator and handlebars for steering control. ATVs can have 2 or 4 driven wheels. ATV combustion motors are derived from motorcycle motors. The same holds for electric motors as well as for conversion kits. The kits, usually of Asian production, are supplied with air or water cooled motors with rated power of 0.8-8.6 kW at the rated voltage of 48, 60 and 72 V. Simpler and more frequent conversions are made for sports ATVs, with the chain driven rear axle. Conversions of 4-wheel drive ATVs can be particularly seen at universities within development projects, where technological know-how and machinery equipment can be fully used.

1.3.5 Boats

4 basic types of drives for boats are considered:

- Outboard engines – a portable, self-contained package of an engine, gear case, and propeller that is attached to the rear part of a boat
- Inboard engines – an automotive engine (adapted for marine use) is mounted inside, drive shaft runs through the bottom of the hull and is attached to a propeller at the other end
- Stern drives – an automotive engine (adapted for marine use) is attached through the transom to a drive unit that is essentially the lower unit of an outboard engine
- Jet drives – use of an engine to power a strong water pump which sucks up water and then forces the water out of the back to thrust the vessel forward. There are two versions: inboard jets and outboard jets

Boats with outboard engines allow easy conversion into electric drive. Complete outboard motors are readily available on the market. These motors are often driven by separate lead traction batteries installed in waterproof casings. Sometimes, there are lithium-manganese batteries installed in the drive unit. More expensive motors are equipped with a continuous regulation, the cheaper ones with a step regulation. Majority of small light boats use 12 V motors based on the battery weight (Řezáč, 2010). Bigger motors use 24, 36 or 48 volts. The power is usually stated in pounds and ranges between 12 and 80 lb for 12 V engines.

Apart from a complete drive purchase, a conversion of the original drive is possible. The available conversion kits are universally usable for all 4 types of drives. Motor power ranges between 1.5 and 22 kW at the voltage of 36, 48, 60 or 72 V. Stronger variants use water cooled motors, and a water pump is included in the kit.

2 Review of existing DIY plans

Befor starting DIY conversion of any type of vehicle it is important to find a suitable DIY plan. It is a plan that is easily understandable and easy to be realized. Several forms of DIY plans exist:

- Book form
- Another “paper” form
- Electronic form
- Online form

Regarding the content, one should consider:

- General Schoolbooks
- Textbooks and/or training prints for professionals
- Training prints and/or guidelines for non-professionals
- Guidelines or manuals for specific conversion kits in the market

Anything not available online can be found in public, technical, company, university, or high and higher school libraries.

Photo documentation is very welcome. The electronic and online forms have an advantage of video sequences availability. The online form has got an opportunity to create a platform for experience sharing and frequently asked questions providing; this is even better than pictures. For conversion kit sellers, it can be a high advantage to offer a call centre, a phone number or an e-mail link.

Combination of text, photos and videos, or consultation should provide answers to following questions to be considered:

- Is this plan suitable for my vehicle to be converted in an e-vehicle?
- If yes, than it is useful to prepare in advance:
- Shopping list
- What to prepare:
    - Materials
    - Components
    - Tools
    - Garage/workshop equipment
    - Other possible conditions and requirements

The plan should also give an estimate of time needed for the conversion.

Calculators available on the Internet can be used as a tool for designing the basic parameters of electric vehicles (range, battery capacity, engine power, etc.). The disadvantage of Internet resources is their instability in time (termination, moving, content changing). Therefore, it is advisable to make an own search of existing calculators before starting of the EV construction and choose the most suitable one for the purpose.

Currently, the following calculators can be found online:

- for ebikes:
  - *http://www.electricbikesimulator.com/* – calculates minimum parameters of drive and battery,
  - *https://www.bosch-ebike.com/en/service/range-assistant/* – for BOSCH eBike System
  - *http://www.electricbikerange.info/Electric_bike_range.html* – too much parameters, simulation of the particular trip (with Google Maps)
  - *https://www.evbike.cz/index.php?* – a simple calculator of EV range (4 parameters only); in Czech
- for ecars:
  - *http://www.evconvert.com/tools/evcalc/* – for selected vehicle types and components
  - *http://www.evdl.org/uve/ev.html* – for selected vehicle types and components

More sophisticated calculations of electric vehicle parameters can usually be found in book forms of plans. These are especially suitable for ecars. Simple calculators, that are available online, are sufficient for ebikes.

2.1 Review and description of DIY plans

2.1.1 Review and description of DIY plans for conversion

DIY plans for (non-motorized) bicycles and scooters

DIY conversion is an alternative to purchase of a completed electro bicycle/scooter or enagging a conversion from a professional service.

Conversion of a bicycle for use of electric drive is the easiest type of vehicle conversion. If one dares to take this challenge either himself or with support of a close person, it is a good way to save costs for a professional service and to invest own free time.

If the bike to be converted is already close to end its lifecycle or if any larger adjustments were still be necessary before the conversion, it would be better to consider buying a brand new or used electric bicycle (with no conversion needed).

If the involved person does not have enough experience or time, it is suitable to ask a professional workroom/shop providing the conversion service. The conversion service is often offered by the same shop/service, where DIY conversion kits are offered.

It is recommended that DIY is attempted by an experienced bicyclist, for whom common maintenance and smaller repairs are no problem (without a specific equipment of the professional workshop). If he/she is even looking forward to the conversion as to enjoy his/her leisure time, it is the ideal option.

2.1.2 Review and description of DIY plans for construction

Construction of an e-vehicle (e.g. electric passenger car) from zero means to plan, design, construct and have the e-vehicle officially approved. As this is rather demanding this approach is more suitable for professionals than for common e-vehicle fans.

From the administration viewpoint, the difference between conversion and construction is that if there is an already existing car for conversion, it usually has its unique VIN code (vehicle identification number) what allows an easier way to succeed within an approval process.

Existing cars without the VIN or brand new cars built yourself need to go through a very difficult process that requires relatively high efforts and costs, and after all it is not sure if the car will be approved for use on public road network.

Construction of the whole passenger car with an electric motor is not a part of the chapter 3 “Review of existing DIY plans”, because the detailed plans for building of e-cars are not commonly available. Case apart are plans in form of a book.

2.2 Analysis and assessment of DIY plans

DIY plans analysis serves for assessment of the state-of-the-art in the area of DIY plans. This supports understanding of good practices, experience learned and gaps at DIY to be filled. Results of the analysis are aimed on later eGUTS standards creation. The assessment will allow an ideal DIY plan suggestion in regard of form and content.

2.2.1 Methodology of the DIY plans assessment

For gaining a suitable sample of DIY plans experience, a questionnaire was disseminated among the eGUTS partners for their work on national level, to map the circumstances. The questions were following:

1) Are there standards in your country for an electric vehicle that are different from EN standards? If they cover the rebuilding/conversion issue, please write a brief abstract about the relevant sections of the standards.
2) Are there any local legislative documents, in your country, dealing with the conversion of vehicles to EV? If yes, please write brief information about what parts of the issue they are dealing with.
3) Is there a subsidy for converting vehicles to EV in your country? If yes, please write brief information how they are set up.
4) Describe the type approving process for the converted vehicle or a built-in EV (DIY) in your country.

For responses on the first four qestions and their analyse, see chapter 3.4.

5) Is there a conversion kit manufacturer in your country? If so, please send the technical specifications in English and link to the manufacturer's website. (see chapter 3.5)

6) Analysis of DIY plans available in your country. Please, fill in the enclosed template. You can find the instructions for filling in the first sheet of the file. You will find the sample in the second attached file (note: finding a plan according to our experience takes more time than its analysis and fill in the template). (See chapter 3.2.2 and Annex B)

A template with various categories and their specifications was prepared including an example of the DIY plan as reference for better understanding of the issue. The items required for various DIY plans were:

- Plan subject
    - Universal plan
    - Vehicle type from non-motorised
    - Vehicle type from motorised
- Plan description
    - Form
    - Included
    - Specific content
- Necessary equipment
    - Information on resources
- Technical details
- Safety
    - Safety instructions
    - Authorization/qualification
- Environment
    - Recyclation
- Testing
    - Testing conditions
- Approving
    - Specification
- Plan Information
    - Source
    - Consultation/support/call centre
    - Language
    - Plan understandability
    - Completed by eGUTS partner:
    - Comments

The template was used by eGUTS partners to give an international overview of availability, quality and understandability of the plans.

2.2.2 Advantages and disadvantages of gathered DIY plans

A sample of DIY plans was gathered during FS5 activities, totally 21 plans from various countries, mainly from the Danube region, further also from other EU countries and non-European countries.

Two main issues were investigated: A) targeted vehicle type and B) content/technical specifications of the plan. Also, C) a form of the plan was considered, to see the capabilities of this area. More details to these three parts see below.

A) Targeted vehicle types in the DIY conversion plans sample

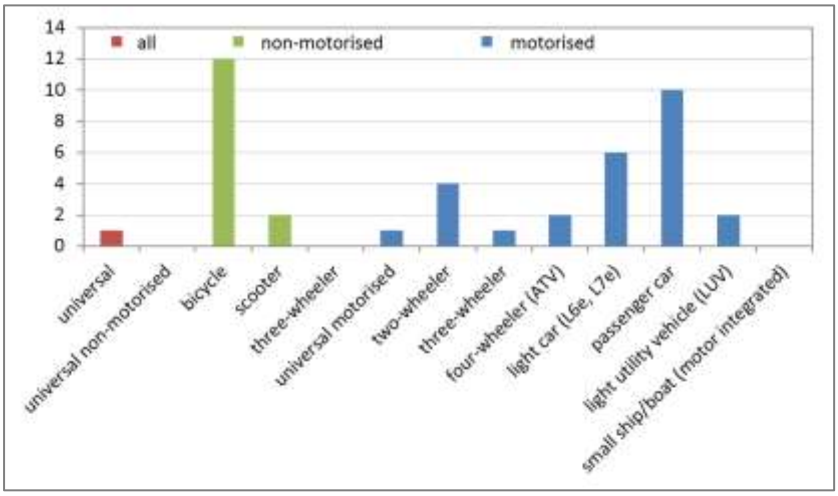


Fig. 3.1 Results of targeted vehicle types in the conversion plans sample

Some important types of information do not occur in the analysed sample:

- A universal conversion plan for all non-motorised vehicles
- A specific conversion plan for non-motorised three-wheelers
- A specific conversion plan for a boat or a small ship

Nevertheless, independently on the gaps in the gathered plans, the considered vehicle types are described in Chapter 2, and available conversion kits in Chapter 3.5, of this document.

Some important information is included in the sample of the DIY conversion plans, but only ocassionally:

- One universal conversion plan for both non-motorised and motorised vehicles, as introduction to this wide task
- Two plans include technical details on calculation of parameters
- Two plans include information on specification of an approving process
- Two plans include information on specification of approving authority
- Only in two conversion plans, there is no contact to get information support or consultations

B) Technical specifications in the DIY conversion plans sample

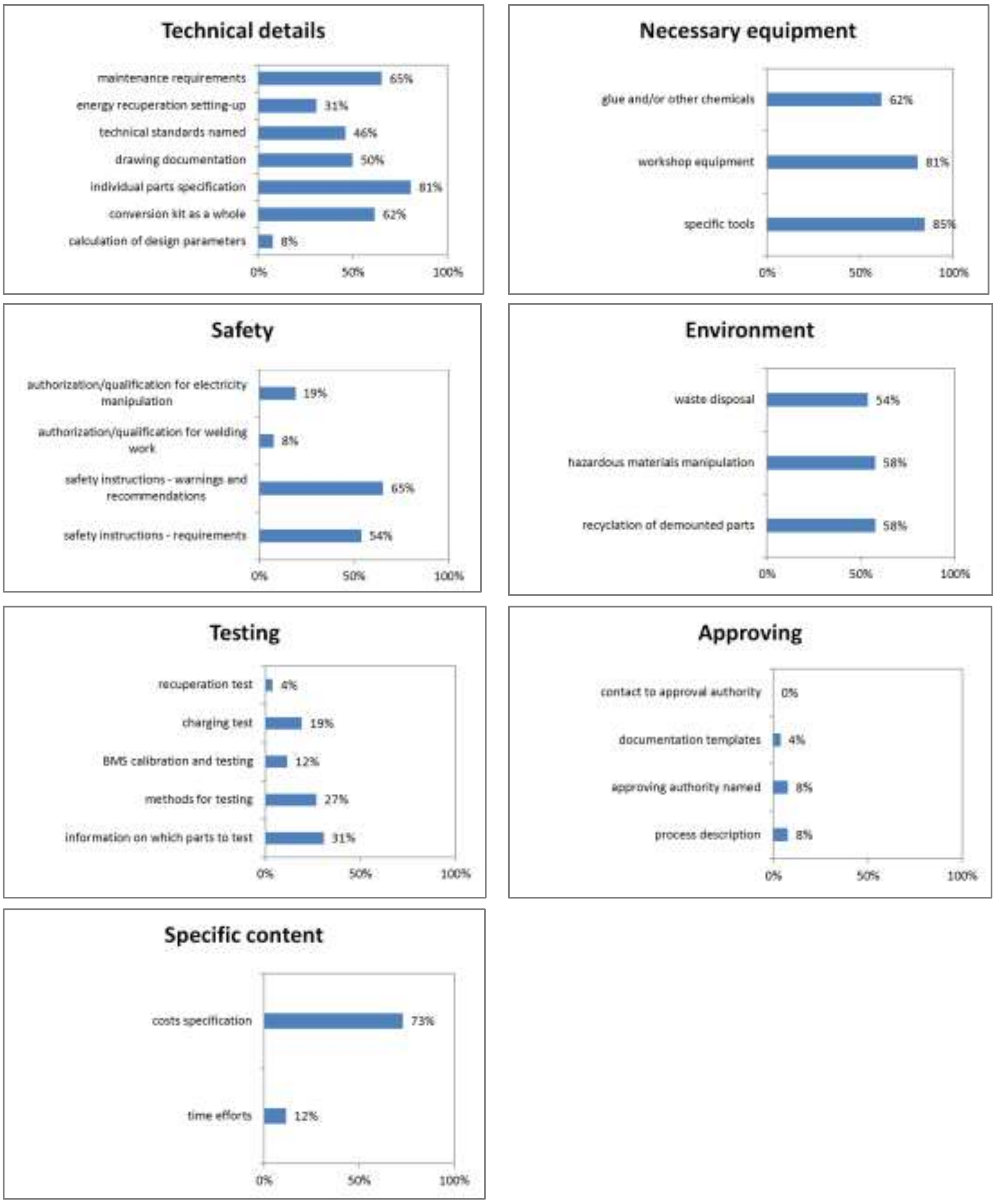


Fig. 3.2 Results of technical specifications in the conversion plans sample

As visible from the graphs above, there is seldome information on:

- Time efforts
- Calculation parametres
- Energy recuperation
- All testing aspects
- All approving aspects

C) Forms of the DIY conversion plans sample

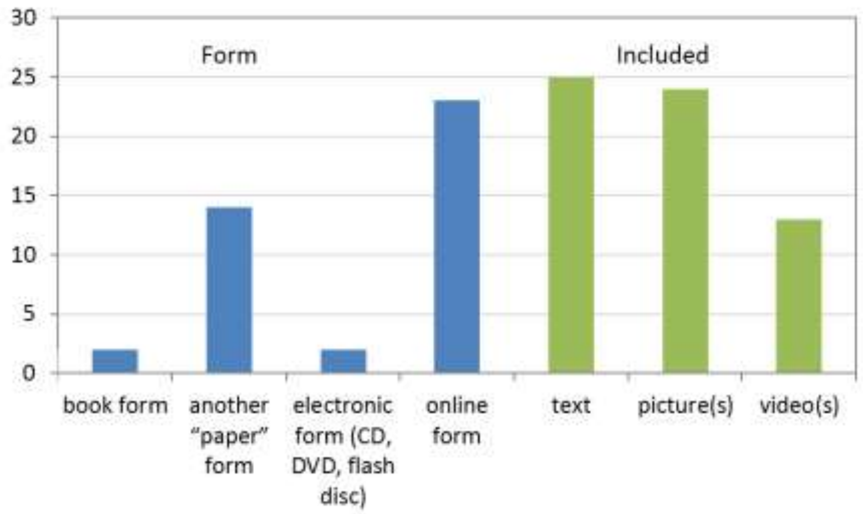


Fig. 3.3 Resulsts of forms of the conversion plans sample

In regard of the form of the DIY conversion plans, the grafph shows the following specific features:

- Except one plan, all others include text
- Two plans do not contain pictures
- Only two plans are in a form of a book

For more details, see the linked excel file, named as FS5_Questionnaire_aggregated, with all gathered DIY plans. For recommendations based on these findings, see Chapter 6 Conclusions.

2.3 Compliance with European regulations and standards

The DIY plans have to meet:

- EU and national legislation
- Regulation in a form of technical standards and specifications
- Globally accepted regulations

EU directives are mandatory in all EU member states. CEN technical standards and specifications are being published as mandatory in EU member states, nevertheless, the technical standards are optional from their status, if not enshrined in legislation. Also, there are more international bodies as ISO, IEC, United Nations etc. who give internationally accepted requirements. The requirements are as follows:

2.3.1 Legislation generally

Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast)

Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles

Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure

Directive 2008/68/EC of the European Parliament and of the Council of 24 September 2008 on the inland transport of dangerous goods

Dangerous goods regulations for transport by road (ADR) and by air (IATA & ICAO) is applicable for Li-Ion batteries transportation.

2.3.2 Main rules for e-bicycles

Directive 2002/24/EC of the European Parliament and of the Council of 18 March 2002 relating to the type-approval of two or three-wheel motor vehicles and repealing Council.

European Technical standard EN 15194 + A1 Cycles – Electrically power assisted cycles – EPAC Bicycles.

2.3.3 Main rules for e-vehicles

For motor vehicles, the UN Vehicle Regulations - 1958 Agreement, Addenda to the 1958, concerning the adoption of uniform conditions of approval and reciprocal recognition of approval for motor vehicle equipment and parts, done at Geneva on 20 March 1958, as amended.

For more technical standards and specifications, see the Annex A below.

2.4 National framework in eGUTS partners´ countries

As explained in the methodology (see 3.2.1), investigation on a national level among partners was very important for later creating of eGUTS standards. Collated responses to first four of six questions by partners (countries alfabetically) are in following paragraphs.

2.4.1 National standards

Question 1: Are there standards in your country for an electric vehicle that are different from EN standards? If they cover the rebuilding/conversion issue, please write a brief abstract about the relevant sections of the standars.

Austria

Electro mobility is seen in Austria as a base for a modern and efficient overall transport system. This is more than replacing the internal combustion engine with an electric motor. Electro mobility should help to make traffic more efficient and environmentally friendly:

- As part of a combined use of public transport and environmentally friendly vehicles in private transport

- In conjunction with efficient and renewable energy sources
- Embedded in an intelligent and intermodal overall transport system

With the interministerial implementation plan for electro mobility decided by the federal government in 2012, the Austrian transport policy wants to help breakthroughs in technology for electro mobility. The electro mobility plan, which is defined by the Council of Ministers, which defines 65 measures, describes, for example, the steps towards launching the market and the establishment of an incentive system to create awareness of new mobility solutions and maximize positive environmental effects.

The aim is to create an integrated energy and climate strategy, which should provide a framework for the future orientation of the Austrian energy and climate policy. The objectives are derived from the corresponding EU guidelines, in particular the future burden distribution in the non-emissions trading (Effort Sharing). At the beginning of the process, a Green Paper was drawn up to provide the basis for an informed and factual discussion on an integrated energy and climate strategy. It analyzes the existing situation in terms of CO_2 emissions, energy consumption in general and energy consumption in Austria specifically, and compares existing scenarios for future development. A consultation process on the Green Paper on the broad involvement of all stakeholders is still ongoing.

Current legal measures for the promotion of alternative fuels in transport or the construction of the relevant infrastructure are largely concerned with building law, which falls within the competence of the counties in Austria. In the construction law, for example, provisions can be made for empty piping for the future market boom of electro mobility. The licensing requirement for loading infrastructure is regulated in these legal systems or can be derived from similar regulations.

In the course of the implementation process to Directive 2014/94/EU, a guideline for the authorization process for the construction of a loading infrastructure has been developed.

In the course of the past year, the federal states have implemented some relief. In Lower Austria, for example, the approval procedure was simplified in April 2016. Charging stations are only required to report, no longer subject to notification (LGBl. No. 37/2016). In Vienna, in February 2016, it was clarified that no special exhaust air-conditioning systems should be installed in garages if E-charging stations were installed there. In Styria, a decree from 15 September 2015 stipulated that commercial e-loading stations are subject to commercial law, but are not per se installations which are subject to approval.

Burgenland in particular does not have an electro mobility strategy, but the goal of the new government in 2015 is to increase e-mobility throughout Burgenland. The energy strategy Burgenland 2020 (2013) sees the switch to electro mobility as essential. The country's overall transport strategy (2014) also provides greater consideration.

Croatia

There are no standards for electric vehicles in Croatia different from EN standards. All the existing standards are taken in the original and accepted from foreign standards (ISO, EN);

standards like HRN ISO 6469-1:2012, HRN ISO 6469-2:2012, HRN ISO 6469-3:2014, HRN EN ISO 17409:2017. Issue of rebuilding/conversion is not covered.

Czech Republic

There are no specific standards in the Czech Republic that would differ from the existing EN standards.

Hungary

Unfortunatelly, e-mobility is in its infancy. The first national plan, was approved in 2015, deals with questions and future of e-mobility. It was the first document that determines directives for the future. Thus, in Hungary, there are no national standards for the conversions. The Hungarian state administration has just dealt with these issues in the past few years. Therefore, there is neither legal nor system background.

Montenegro

The standards in Montenegro for electric vehicles do not differ from EN standards, yet national rules do not cover rebuilding / conversion issues.

Romania

There are no specific Romanian standards.

Serbia

There are no specific standards in the Republic of Serbia regarding electric vehicles. EU standards and directives are applied. Those define the minimum conditions that must be met by electric vehicles and components that are built into them.

Slovakia

In Slovakia there are no specific standards defined for electric vehicles differing from EU standards. Slovakia therefore sells the same electric vehicles as they are on the European market, e.g. Volkswagen e-Golf, Nissan LEAF, Citroën C-Zero, Kia Soul EV and others.

Slovenia

In Slovenia there are no specific standards that would differ from the existing EN standards.

Tab. 3.1 Summarization of Question 1: National standards

Summarization of Question 1: National standards	
Question 1: Are there standards in your country for an electric vehicle that are different from EN standards? If they cover the rebuilding/conversion issue, please write a brief abstract about the relevant sections of the standards.	
Austria	

Summarization of Question 1: National standards	
Croatia	No specific national technical standards differing from the EN standards.
Czech Republic	
Hungary	
Montenegro	
Romania	
Serbia	
Slovakia	
Slovenia	
Note:	*European technical EN standards are as mandatory in EU countries, optional in further European countries.*
Conclusion:	**No differing from the EN technical standards found at eGUTS partners.** **EN technical standards are to be investigated and followed.**

2.4.2 National legislation

Question 2: Are there any local legislative documents, in your country, dealing with the conversion of vehicles to EV?

Austria

According to the current legal electromobility document there are no legal documents available or fixed in Austria or in Burgenland.

TOB recommends the German Nationale Plattform Elektromobilitaet that has created a guideline Electromobility: Regulations in the area of Automotive Engineering and Dangerous Goods.

Croatia

The most important document that has to be taken into account when dealing with the conversion of conventional vehicles to electric vehicles is the Rulebook on vehicle testing (Official gazette no. 152/09 and 8/15). The rulebook lists all important elements that have to be taken into account when converting. An essential part of the Rulebook is the Catalogue of Changes, which is listing all the elements that have to be tested when a change on specific vehicles is made. Regarding electric vehicles, the most important change is the change on the power train system and the battery pack.

Czech Republic

There are no local legislative document dealing with conversion to EV in the Czech Republic.

Hungary

Having no standardized system, Hungary has neither national nor local legislative documentation.

Montenegro

There are no local legislative documents, that deal with conversion to EV.

Romania

No Romanian documents on this topic available.

Serbia

There is no national legal framework regulating the conversion of vehicles to EV.

Slovakia

In Slovakia, it is only allowed to reconstruct registered vehicles. The reconstruction is subject to an entire set of tests and approval acts by an authorized technical service and by a competent transport authority. The conditions for the conversion of vehicles with a conventional drive to electric vehicles are laid down by Act No. 725/2004 on the conditions for the operation of vehicles in the road traffic and are mainly related to administrative acts.

Under the Act, the conversion of a single vehicle is considered to be a conversion of a maximum of five vehicles of the same type. A natural person or a legal person is obliged to apply to the District Authority in advance for permission to rebuild a vehicle. The applicant is obliged to ensure that the tests and control specified by the district authority are carried out at his own expense. An attachment of the application is a detailed description of the vehicle rebuilding, the technical description and the design documentation of the system. The application must also include the manufacturer's authorization or a representative of the vehicle manufacturer.

In the interest of the development of electromobility in Slovakia, in the framework of approval processes, efforts are being made to remove the statutory obligation to get an aproval from the original car manufacturer.

Slovenia

Decree on the approval of vehicles with battery electric drive:

This decree applies to safety requirements for all road vehicles of categories M and N, with a maximum design speed exceeding 25 km/h and with an electric drive. Design requirements regarding the electric battery, protection against electric shock and operational safety of electric vehicles are regulated by this decree. Homologation and roadworthiness testing of electric vehicles are also mentioned in the decree.

Tab. 3.2 Summarization of Question 2: National legislation

Summarization of Question 2: National legislation	
Question 2: Are there any local legislative documents, in your country, dealing with the conversion of vehicles to EV?	
Austria	Documents not available, yet.
Croatia	Rulebook on vehicle testing. It includes the Catalogue of Changes, which is listing all the elements that have to be tested, incl. changes like EV conversion.
Czech Republic	Documents do not exist, yet.
Hungary	Documents do not exist, yet.
Montenegro	Documents do not exist, yet.
Romania	Documents not available, yet.
Serbia	Documents do not exist, yet.
Slovakia	It is allowed to reconstruct/converse only registered vehicles. ... to apply to the District Authority in advance for permission to rebuild a vehicle... Efforts are being made to remove the statutory obligation to get an aproval from the original car manufacturer.
Slovenia	Decree on the approval of vehicles with the battery electric drive. It includes homologation and roadworthiness testing rules.
Note:	*Austrian recommendation to accept as reference also the following:* *German Nationale Plattform Elektromobilitaet: Electromobility: Regulations in the area of Automotive Engineering and Dangerous Goods.*
Conclusion:	**To investigate following documents:** • **the Croatian Catalogue of Changes** • **the Slovenian Decree on the approval of vehicles with battery electric drive** • **the German Electromobility: Regulations in the area of Automotive Engineering and Dangerous Goods**

2.4.3 National subsidies

Question 3: Is there a subsidy for converting vehicles to EV in your country?

Austria

No, at least it hasn't been found no similar subsidy, which offers such conversion promotions. In Burgenland, only vehicle acquisitions are promoted. Alternative mobility promotions in Burgenland samples:

Acquisition of electric vehicles by the granting of non - repayable subsidies for:

- New purchase of electric scooters for pensioners and disabled persons with 30% of the acquisition costs or a maximum of EUR 250
- New purchase of electric mopeds and electric motorcycles with 30% of the acquisition costs or max. EUR 350
- New purchase or conversion to full electric operation of cars with 30% of the acquisition costs or max. EUR 750
- New acquisition or conversion to natural gas or biogas operation of cars with 30% of the acquisition costs or max. EUR 750

Incetives conversions Burgenland (Burgenland County – regional government of Burgenland):

In Burgenland the aim of the promotion is to use effective incentives in the interest of energy efficiency and climate and environmental protection to focus on energy and other elementary resources as efficiently as possible in the field of mobility and is now administered directly by the county of Burgenland. A further objective of this Directive is the promotion of new electrically-powered passenger cars, the conversion of passenger cars to demonstrable complete electrical operation, new electrically operated single track motor vehicles (such as e-mopeds and e-motorbikes) including two-track electric coders for pensioners and disabled persons, new cars or cars powered by natural gas or biogas, which can be operated with natural gas or biogas after conversion. This funding is intended to contribute to the reduction of emissions in the transport sector and also to draw attention to alternative drives.

The purpose of the grants under these Directives is the grant of Non - repayable grants for:

1.2.1 Officially approved new electrically operated passenger cars as well as the conversion of passenger cars on proven complete electrical operation.
1.2.2 New electrically operated single-track motor vehicles (e-moped and e-motorbikes).
1.2.3 New two-track electric scooters for pensioners and persons with disabilities design speed of max. 25 km/h and max. 600 W (§1, subsection 2a and 2b of KFG), with the exception of vehicle-like children's toys and similar vehicles with design speed of max. 5 km/h and diameter of max. 12 inches.
1.2.4 Authorized new cars which are operated with natural gas or biogas, as well as the conversion of cars, which after the conversion proved to be using natural gas or biogas which can be used to reduce CO emissions in motor vehicles.

Grants may only be awarded if the conditions laid down in this Directive are met and in accordance with Burgenland's financial resources. There is no legal right to award a grant.

Croatia

On 28 April 2015, the Croatian fund for energy efficiency and environmental protection has launched a call for co-financing acquisition of other means of electrically powered transport means and the appropriate infrastructure. The call had eight measures in total, among which the conversion of conventional vehicles into electric vehicles, regardless of the vehicles type and category. The users of the call were private persons, companies and public authorities that were based in Croatia, had no debts to the Croatian state and had no financial difficulties in everyday operations. Public authorities could apply for all measures in the call, while companies and private persons could apply for half of the measures (mostly non-infrastructural).

The amount of co-financing depended on the level of development where the subject was located, ranging from 40% in more developed regions to 80% in less developed regions. The maximum amount of funds that the Fund could co-finance per project was HRK 200,000.00 (EUR 26,666.67). After the approval of the project, the beneficiary had a maximum of 12 months to realize the project.

In addition, there was a possibility before the call for the purchase of other means of electrically powered transport means and the appropriate infrastructure that interested entities could directly approach the Croatian fund for energy efficiency and environmental protection with specific project ideas and ask for funding of the project.

Czech Republic

There is no subsidy for additional converting of vehicles to EV in the Czech Republic.

Hungary

In Hungary, there are no subsidies for converting vehicles to EV.

Montenegro

There is no subsidy for converting vehicles to EV in our country.

Romania

No subsidy for converting vehicles in Romania.

Serbia

There are no systematic measures to subsidize conversion of vehicles to EV.

Slovakia

In Slovakia there is no subsidy for converting vehicles to EV. The subsidy is granted only for a purchase of new electric vehicles and it is only valid nowadays for the period from 11 November 2016 to 31 December 2017 in the amount of EUR 5000 per a new electric car. The total amount of the state contribution amounts to EUR 5.2 million.

Slovenia

Incentives for the development of e-mobility in Slovenia are founded through the Slovenian environmental public found – Eco Fund. Different incentives for purchase of electric vehicles or development of the network of charging stations are intended for three categories of final consumers – citizens, legal entities and local government.
There are two types of incentives in the form of grants and loans:

1) Public tender 45SUB-EVOB16 is a about non-refundable financial incentives to individuals for purchase or investment into electric vehicles. An individual is eligible for a grant:

- in case of purchase of a new electric vehicle
- in case of purchase of a new hybrid vehicle
- in case of purchase of a new electric vehicle with a range extender or
- in case of converting a vehicle with internal combustion engine into an electric vehicle

Grants may be awarded for the purchase of vehicles in categories L7e, L6e, N1 and M1 with electric propulsion without CO_2 emissions. Incentives can also be granted for purchase of hybrid vehicles and vehicles with a range extender, however, CO_2 emissions must not exceed 50 g of CO_2 emissions per km.

The amount of the financial incentive is:

- EUR 7.500 for a new or a processed electric vehicle without CO_2 emissions in category M1
- EUR 4.500 for a new or a processed electric vehicle without CO_2 emissions in category L7e
- EUR 4.500 for a new hybrid vehicle or an electric vehicle with a range extender with CO_2 emissions lower than 50 g of CO_2 emissions per km
- EUR 3.000 for a new or a processed electric vehicle without CO_2 emissions in category L6e

Each natural person that has permanent residence in Slovenia is entitled to the mentioned financial incentive.

2) Public tender 38SUB-EVPO16 is almost identical to the one mentioned above, with the difference that it is meant for legal entities.

Tab. 3.3 Summarization of Question 3: National subsidies

Summarization of Question 3: National subsidies	
Question 3: Is there a subsidy for converting vehicles to EV in your country?	
Austria	No subsidy for converting of vehicles to EV national wide. Burgenland County: subsidy for purchasing of new electric vehicles; for passenger cars, there is also limited costs subsidy in regard of conversion.
Croatia	Subsidy for converting of vehicles to EV, among others.

Summarization of Question 3: National subsidies	
	It includes infrastructural measures, too.
Czech Republic	No subsidy for converting of vehicles to EV.
Hungary	No subsidy for converting of vehicles to EV.
Montenegro	No subsidy for converting of vehicles to EV.
Romania	No subsidy for converting of vehicles to EV.
Serbia	No subsidy for converting of vehicles to EV.
Slovakia	No subsidy for converting of vehicles to EV. Subsidy for purchasing of new electric vehicles.
Slovenia	Subsidy for converting of vehicles to EV, among others. Subsidy for purchasing of electric vehicles or charging stations.
Conclusion:	**Subsidies to be taken into account for conversions to EVs at the eGUTS partners occur in: Austria, Croatia and Slovenia.**

2.4.4 National approving processes

Question 4: Describe the type approving process for the converted vehicle or a built-in EV (DIY) in your country.

Austria

It is more a do it yourself or look for appropriate manufacturers mentality in Austria.

Therefore, there are no incentives, promotions or restrictions from the political/legal point of view.

Croatia

If a vehicle has been converted from a conventional one to an electric powered vehicle, in order to participate in regular traffic, a certification of the vehicle has to be done. The certification process and the final certificate is issue of the Croatian centre for vehicles (Centar za vozila Hrvatske – CVH). The manufacturer of the converted vehicles has to prepare the vehicle according to the current regulations and the specific demands for electric vehicles. The most important specifications are as follows:

- If voltage of the installation is higher than 50 V, it is necessary to mark the installation in orange

Fig. 3.4 Over 50V installation marked orange, source: www.e-auto.guru

- An installation with voltage higher than 50 V has to be protected from direct impact – therefore, a protection box with a minimum level of protection IP55 has to be installed, i.e. the contact has to be enable only by the use of tools
- An extra battery has to be ensured in order to power turn signals and position lights when the main battery is empty
- An electric heater has to be installed in order to defrost/heat the windshield
- An emergency mushroom pushbutton has to be installed in order to enable emergency shutdown of the electrical system
- If there are servo breaks in a vehicle, a vacuum has to be ensured – vacuum pump and vacuum tank
- The wheel axle of the electric vehicle has to carry at least the third of the weight of the vehicle
- The AC engine has to have at least 3kW per 1 tone of the vehicle

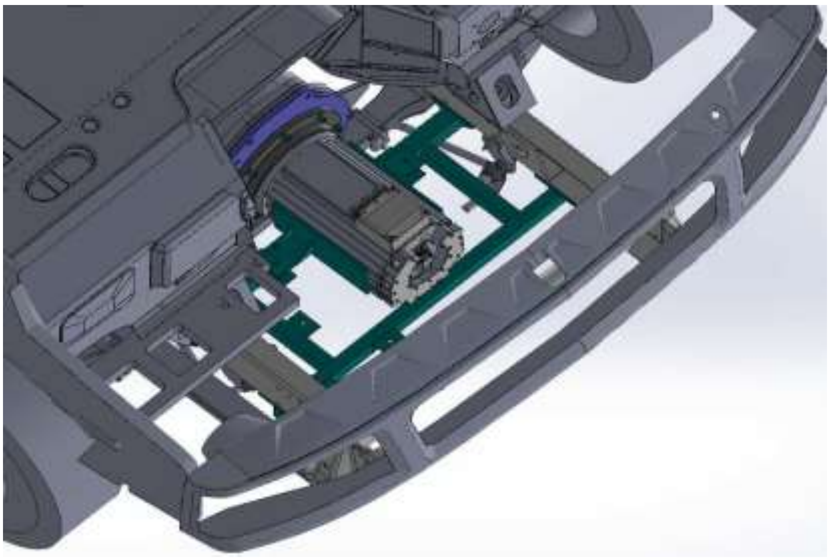


Fig. 3.5 Example of an AC motor in a conversion, source: www.dok-ing.hr

It is recommended to produce a study on the process of conversion in order to speed up the process of certification.

Czech Republic

The standard procedure is to apply for permission in the Transport Department of a relevant Municipal Authority before the vehicle conversion. However, the permission for conversion is valid between 2 months and a half a year, which is sufficient for the conversion to a gas drive. Regarding the conversion to an electric vehicle, it is probable that the conversion and homologation will not be managed in time. Therefore, the permission for conversion or construction (individually builded vehicle) from homologated parts is applied for as late as in the phase of testing rides.

In case the construction is concerned, i.e. original documents are unavailable for the vehicle, the Transport department issues a new VIN. New aluminium tables must be produced with this VIN, where VIN is shown with maximum weight per axle including the load. In case there is still an invalid VIN on a bodywork bearing element, it needs to be re-stamped by a certified company and had a statement issued of the re-stamping.

A basic vehicle inspection should be made in the Czech Republic before the homologation process. The inspection checks brakes, axles, steering pins, lights, electrical system, safety belts and equipment, etc. As a vehicle inspection company can not judge a number of parameters, it will pass the vehicle to specialized testing companies.

These missing parameters for approval are certified in the Czech Republic by specialized companies (homologation testing company), such as TÜV SÜD Czech or Dekra Czech. Apart from vehicle testing company, the vehicle must be checked in terms of execution and electrical safety. One of the companies in the Czech Republic is Electrotechnical Testing Institute in Prague. The measurements of electromagnetic compatibility, i.e. resistance against strong electromagnetic radiation and low own interference of other devices is performed in, for example, in TÜV SÜD Czech, Institute for Testing and Certification, and in the Military Technical Institute of Ground Forces. In the end, energy consumption in a standard measuring cycle on vehicle dynamometer is performed in a vehicle testing company. A final vehicle inspection is made at the end of the approval process (in a vehicle inspection company).

It is necessary to produce a detailed operational manual during the homologation. Inspiration for the manual can be found at the manual of the converted vehicle, but many aspects regarding steering, charging, transmissions, heating, and air-conditioning will change. If the vehicle weight is changed, it may have an impact for example on the recommended tyre pressure. The manual should also contain safety instructions for injuries caused by electricity.

Apart from the manual, it is necessary to create a COC sheet with vehicle and motor technical parameters after the conversion. This sheet, together with the manual, homologation certificate, is included in the application for issuing Registration Certificate and registration plate.

Hungary

If we need to make our conversion offical, it is very difficult to obtain the licence.

The steps of the approval process are as follows:

1) Documentation of the conversion of vehicles: We need to find a certified Vehicle Mechanical Engineer, who prepares the documentation and submit it to the NKH (National Transport Authority). There is a fee, which depends on the vehicle.
2) Conversion fee: The certification fee has to be paid. The licence is valid for 1 year. Therefore, there is one year for the conversion of a vehicle.
3) MOT test/Road worthiness test: It can be performed at the place of NKH (National Transport Authority). It has a fee, which is higher than the common fee.
4) Environmental certification: Not necessary for a 100% e-vehicle.
5) Registration fee: The customs office must be informed about the conversion activity with the current and the future status. It will be certified by the customs office. After the conversion and a successful MOT test, we have to submit a “Registration fee declaration”, which contains (in one copy) description of the prior status with proving documentation about paid registration fee and which includes (two copies) specification of the post-status. After the payment of the registration fee, the customs office provides a Certificate.
6) Authentication: Not necessary for a 100% e-vehicle.
7) Third party liability insurance: Compulsory (otherwise, it is compulsory for every vehicle)
8) Tax: Compulsory, but lower for e-vehicles, than the average rate.

Montenegro

National legislation states that any type of new vehicles that did not enter Montenegro in an earlier period (in our case electric, hybrid) will undergo a homologation process, e.g. type approval. But in the national official gazette, there is no mention of vehicle conversion rules, so that in the case of conversion, European standards should be applied.

Romania

No documents for approving process or for converting vehicle or a built-in EV (DIY) in Romania.

Serbia

Owners of converted vehicles must complete the procedures of homologation of changes made to the base model (basic model of the vehicle on which the conversion was made). The process is extremely complicated. Firstly, it requires the manufacturers' consent for conversion of vehicles to EVs. The next step is to provide a very comprehensive technical documentation. Only after the completion of the homologation procedure, it is possible to make a temporary registration for the considered EV. This is one of the reasons why owners give up the conversion of vehicles to EVs.

The procedure of homolgation is based on the application of a part of the EU legislation and homologation regulations.

The Automobile and Motorcycle Association of Serbia (AMSS) - Vehicle institute has converted the classic FIAT Punto to an EV. Final vehicle testing and licensing procedures are still under way (summer 2017).

Slovakia

In accordance with the Act No. 725/2004, a natural person or a legal entity submits an application for permission to rebuild a vehicle to the district authority.

The application must include identification details of the applicant and the vehicle, including the purpose for which the vehicle is to be used after the conversion. The annex to the application contains a detailed description of the vehicle conversion, technical description and drawings of the system, component or separate technical unit if it has not been type-approved, including the aproval of the vehicle manufacturer.

The district authority may require the submission of opinions or expert opinions from relevant authorities of fire protection, occupational safety, regional public health and other authorities. If the applicant has fulfilled all legal conditions, the district office will permit the conversion if it complies with the technical requirements and the vehicle does not endanger the safety of traffic, the passengers or the environment after the rebuilding. The decision to authorize the rebuilding of a vehicle is issued for one year. In the decision, the district office may require the applicant to carry out the tests after the rebuilding or inspection of the assembly in the authorized technical service for vehicle verification which the applicant is obliged to obtain at his own expense.

The approval of the rebuilding at the written request of a natural person or a legal person is decided by the district authority which decided to authorize the rebuilding of the vehicle. The application must include basic identification data for the applicant and the vehicle, including the number and date of the decision to authorize the rebuilding of the vehicle. Attached to the application is an expert opinion on originality check, a test report for the vehicle after the rebuilding in order to meet the technical requirements, a draft of the basic technical description of the vehicle issued by an authorized technical service of the vehicle verification and the design of the manufacturer's additional label. The district authority may require a submission of expert opinions from the competent fire protection authorities, labour safety, regional public health authorities and other bodies.

At the time of approval of the individual vehicle conversion, the converted vehicle shall meet the same technical requirements as laid down in the type-approval or the EC type-approval.

If the applicant complies with all the requirements, the district office will issue a decision on the approval of the vehicle rebuilding and will issue a basic technical description of the vehicle. The district office shall record the vehicle rebuilding data in the registration certificate or issue a new certificate of registration.

Slovenia

Roadworthiness test and homologation:

In Slovenia there are no specific regulations that would differ from the existing regulations from ECE R 100.00. See the context of Decree on the approval in Section 3.4.2 on national legislation.

Tab. 3.4 Summarization of Question 4: National approving processes

Summarization of Question 4: National approving processes	
Question 4: Describe the type of an approving process for the converted vehicle or a built-in EV (DIY) in your country.	
Austria	No incentives, promotions or restrictions from the political/legal point of view.
Croatia	Rules given in the national regulation, following the international regulation.
Czech Republic	Rules given in the national regulation, following the international regulation.
Hungary	Rules given in the national regulation, following the international regulation.
Montenegro	Regulation documents do not exist, yet.
Romania	Regulation documents do not exist, yet.
Serbia	Rules given in the national regulation, following the international regulation.
Slovakia	Rules given in the national regulation, following the international regulation.
Slovenia	Rules given in the national regulation, following the international regulation.
Note:	*United Nations ECE R 100.00 regulation »Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train, as amended« is mandatory in the UN countries.*

Summarization of Question 4: National approving processes	
Conclusion:	**For participation in the regular road traffic, an approval for the (converted or newly DIY constructed) vehicle has to be obtained from designated authorities.** **To meet requirements of the ECE R 100.00 regulation.** **Vehicles with the VIN identificator (allocated at a manufacturer) expected to easier succeed in the approval process.**

2.5 Description of available conversion kits

It is often difficult to know, according to the available information, whether the set is produced or sold by a commercial entity. Therefore, the analysis of available kits is not more extensive and can not be considered as exhaustive. But the analysis is sufficient for getting an idea from which components of the kits are most often composed and what their usual parameters are.

2.5.1 Conversion kits for pedelecs

Conversion kits for pedelecs are among the most available groups of kits on European market, on the market in the Danube region, respectively. Depending on the location of the motor, the mid drive kits, front and rear wheel kits are distinguished. The pedelecs kits have a limited power of 250 W. They allow pedalless riding at a maximum speed of 25 km/h.

Mid drive motor kits

An analysis of the composition and technical specifications of the kits was made with the conversion kits of 4 dealers/manufacturers operating in the Danube market and kits available on the Internet from a Chinese dealer. The base of all kits is a motor with chainring and cover, cranks, speed or pedal sensor, control display with separate or integrated controller, cabling, battery and charger. The kits may also include other parts such as thumb throttle, a special tool for mounting, etc. Some dealers allow ordering additional parts, such as brake levers, etc. Kits from China have similar basic composition as the European ones, but do not contain batteries and chargers. For more detailed overview of the composition of conversion kits and their technical specifications, see Table 3.5.

Selected dealers/manufacturers:

1. Apache (CZ) https://apache-bike.cz/cs/elektrosada-se-stredovym-motorem
2. Elektrosport (CZ) http://elektrosport.cz/prestavby-kol/stredovy-pohon
3. Elektrosport (CZ) http://elektrosport.cz/prestavby-kol/stredovy-pohon
4. EVBike (CZ) https://www.evbike.cz/EVBIKE-Stredove-pohony/Kompletni-sady/
5. L-faster (China) http://www.l-faster.com/mid-mounted-motor-kit/

Tab. 3.5 Overview of mid drive motor conversion kits

No.	Composition	Specifications
1	Mid drive motor (with chainring and cover) Cranks (left + right), bolts Display with separated controller Speed sensor, magnet Fixing plate Locknut M33 Security part for frame, bolt Mounting parts (bolts , washers etc.) Tool for locknut mounting Rack battery, carrier, extension cord / Frame battery, battery holder Optional: Brake levers	Motor power: 250W Voltage: 36V Battery type: Li-Ion Battery capacity: 10.4/13/14.5 Ah Battery weight: 2.3/2.8/2.8 kg Range: 50-80/70-110/80-130 km Axis length: 68-73 mm Chainring: 42/44/46/48 cogs
2	Mid drive motor (with chainring and cover) Display with integrated controller Pedal sensor Cabling Frame battery + battery holder Charger	Motor power: 250 W Voltage: 36 V 10.4/11.6 Ah Battery weight: 2.8 kg Motor weight: 4.2 kg Range: up to 100 km
3	Mid drive motor (with chainring and cover) Cranks (left + right) Display with separated controller Speed sensor + magnet Brake levers Cabling Rack battery, carrier, extension cord / Frame battery, battery holder Charger	Motor power: 250 W Voltage: 36 V Battery type: Li-Ion Frame battery capacity: 11.4/11.6/17.4/20.1 Ah Rack battery capacity: 11.6/17.4 Ah Frame battery weight: 2.8/2.4/3.7/3.8 kg Rack battery weight: 3.1/4 kg (+1.2 kg carrier) Motor weight: 3.7 kg Range (frame battery): -/-/140/160 km Range (rack battery): -/150 km Chainring: 46 cogs
4	Mid drive motor (with chainring and cover) and main controller, Cranks (left and right), Assembly accessories (screws, washers, nuts), Control LCD display and button panel for handlebar installation, Brake lever with connection to motor for switch off during braking, Thumb throttle, Speed sensor and magnet, Cable to cennect display, throtle and brake lever. Frame battery, battery holder Chrger	Motor power: 250 W Voltage: 36 A Battery type: Li-Ion Battery capacity: 13 Ah Battery weight: 4 kg Motor weight: 3.7 kg Range: 140 km Axis length: 68-72 mm Chainring: 46 cogs
5	Mid drive (brush) motor & motor bracket Chainring Cranks (left side and right side) 68mm Bottom bracket Throttle (with battery indicator & key switch) Controller LED lens light Light switch	Motor power: 250 W Voltage: 24/36 V

No.	Composition	Specifications
	Brake lever	

Front and rear motor kits

In principle, kits for the front and rear motor are similar. An analysis of the composition and technical specifications of the kits was made with the conversion kits of 4 dealers/ manufacturers operating in the Danube market and kits available on the Internet from a Chinese dealer. The base of all analysed European kits is a complete front or rear wheel (hub motor with rim), control unit, pedal sensor, control display, cabling, battery and charger. Kits from China do not contain the rim, battery and charger. In addition, they sometimes include brake levers and thumb accelerator. A unique set was developed in Slovenia. Smart Wheel, as it is called, is designed in a way that makes installation as easy as possible. The motor and all the other components are packed inside a robust case. There are no wires or other gadgets to install. Only the rear wheel is replaced with the Smart Wheel, which comes in many different standardized sizes. Top speed of the Smart Wheel is 25 km/h for 50 km range. The Smart Wheel weighs only 4 kg. The Smart Wheel is pedal assisted and can be monitored and controlled with the FlyKly smart phone app. This app has many other interesting features like remote locking of the bike, tracking the bike if stolen and the app also studies bikers cycling habits and suggests the most time-efficient, the safest or the most attractive routes. For more detailed overview of the composition of conversion kits and their technical specifications, see Tables 3.6 and 3.7.

Selected dealers/manufacturers:

1. Apache (CZ) https://apache-bike.cz/cs/elektrosada-se-zapletenym-motorem
2. Elektrosport (CZ) http://elektrosport.cz/prestavby-kol
3. Eco electrik (RO) http://ecoelectrik.ro/Biciclete_electrice.html
4. L-faster (China) http://www.l-faster.com/hub-motor-kit/
5. FlyKly (SLO) https://www.kickstarter.com/projects/flykly/flykly-smart-wheel/faqs

Tab. 3.6 Overview of front hub motor conversion kits

No.	Composition	Specifications
1	Front hub motor Rim for V-brake Control LED panel Control unit Pedal sensor Cabling Rack battery, carrier/ Frame battery, battery holder Charger Optional: USB plug Brake lever with sensor/Brake sensor Display with separated controller	Motor power: 250 W Voltage: 36 V Battery type: Li-Ion Battery capacity: 10.4/13/14.5 Ah Battery weight: 2.3/2.8/2.8 kg Range: 50-80/70-110/80-130 km
2	Front hub motor (brushless) Rim for V-brake/disc-brake Control LED/LCD panel	Motor power: 250 W Voltage: 36 V Battery type: Li-Ion

No.	Composition	Specifications
	Control unit Pedal sensor Cabling Rack battery, carrier Charger	Battery capacity: 11.6/17.4 Ah Range: 80-120 km
4	Front hub motor (brushless) Motor controller Thumb accelerator Brake lever Pedal assist sensor Cabling	Motor power: 250 W Voltage: 24/36/48 V Motor weight: 2.8 kg motor Axis pitch: 100 mm

Tab. 3.7 Overview of rear hub motor conversion kits

No.	Composition	Specifications
1	Rear hub motor (freewheels for threaded hub/cassette) Rim for V-brake Control LED panel Control unit Pedal sensors Cabling Rack battery, carrier/ Frame battery, battery holder Charger Optional: USB plug Brake lever with sensor/Brake sensor Display with separated controller	Motor power: 250 W Voltage: 36 V Battery type: Li-Ion Battery capacity: 10.4/13/14.5 Ah Battery weight: 2.3/2.8/2.8 kg Range: 50-80/70-110/80-130 km Axis pitch: 135 mm
2	Rear hub motor Rim for V-brake/disc brake Control LCD panel Control unit Pedal sensors Brake sensor Cabling Frame battery, battery holder Charger	Motor power: 250 W Voltage: 36 V Battery capacity: 10.4/11.6 Ah Battery weight: 2.8kg (with control unit) Motor weight: 4.8 kg (with other part of kit) Range: up to 120 km
3	Rear hub motor Rim Controller Accelerator control Brake levers Electric instalation Optional: Frame battery, battery holder Charger Control LCD panel Data cable with PC software	Motor power: 200/250 W Voltage: 24/36/48 V Battery type: Li/ Li Ion Battery capacity: 8 Ah (36 V)/10 Ah (48 V) Battery weight: 2.5 kg/-
4	Rear hub motor (brushless) Motor controller	Motor power: 250 W Voltage: 36/48 V

No.	Composition	Specifications
	Thumb accelerator Brake levers Pedal assist sensor Cabling	Motor weight: 2.8 kg motor Axis pitch: 135 mm
5	Rear hub kit Control app for smartphone	Motor power: 250 W Voltage: 36 V Hub weight: 4 kg Wheel size: 20/26/28“

2.5.2 Conversion kits for scooters

Conversion kits for large scooters are usually the same as for pedelecs with front or rear hub motor, see Chapter 3.5.1. Therefore, the analysis was mainly focused on folding scooters. However, no conversion kits have been found among European dealers for this category of vehicles. Two types of conversion kits have been found among Chinese dealers (GS-Vehicle Accessory Co., Ltd.). The basis of the typical kits (labeled as No. 2) is the electric hub motor. Regarding the other types (No. 2), the rear wheel is driven by a short cogged belt. But this kit is for the drive device only, it does not contain a controller, an accelerator and a battery. For a more detailed overview of the composition of conversion kits and their technical specifications, see Table 3.8.

Selected dealers/manufacturers:

1., 2. L-faster (China) http://www.l-faster.com/e-scooter-motor-kit/

Tab. 3.8 Overview of scooter conversion kits

No.	Composition	Specifications
1	Motor (brushless) drive device with bracket and small pulley 8 inch pneumatic wheel Big pulley with bracket and screws Belt	Motor power: 1650 W Kit weight: 0.5 kg Wheel diameter: 8 inch
2	Hub motor (brushless) Motor controller Brake+cruise switch/Brake thumb throttle Thumb accelerator Battery bag (just a bag, not battery) Cable pipe & ribbon -/LCD display	Motor power: 180/250 W Voltage: 24/36/48 V Kit weight: 3/2.5 kg Axis pitch: 58/45 mm Wheel diameter: 8 inch

2.5.3 Conversion kits for e-bikes

Conversion kits for e-bikes, just as a kits for pedelecs, are the most widely used on the European market, respectively on the market in the Danube region. Depending on the location of the motor, the mid drive kits, front and rear wheel kits are distinguished. The pedelecs kits have power higher than 250 W.

Mid drive motor kits

An analysis of the composition and technical specifications of the kits was made with the conversion kits of 4 dealers/manufacturers operating in the Danube market and kits available on the Internet from a Chinese dealer. The base of standard kits (marked Nos. 1-3) is a motor with a chainring and cover, cranks, brake levers, speed or pedal sensor, control display with a separate controller, cabling, battery and charger. The kits may also include other parts such as mounting parts, special tool for mounting etc. Kits from an Austrian manufacturer (marked No. 4) are different from the others. They are intended for heavy terrain biking. The manufacturer offers three mounting systems depending on the type of a bike frame. The kits can be mounted on the inner bearing, on suspension rocker or on the frame. The last system requires a modification of the frame. The kits from China (marked No. 5) have a complicated construction and do not contain batteries and chargers. For a more detailed overview of the composition of conversion kits and their technical specifications, see Table 3.9.

Selected dealers/manufacturers:

1. Apache (CZ) http://bplumen.cz/konfigurator.html
2. Elektrosport (CZ) http://elektrosport.cz/prestavby-kol/stredovy-pohon
3. EVBike (CZ) https://www.evbike.cz/EVBIKE-Stredove-pohony/Kompletni-sady/
4. Ego (AT) https://www.ego-kits.com/en/produkte/ego-kits/
5. L-faster (China) http://www.l-faster.com/mid-mounted-motor-kit/

Tab. 3.9 Overview of mid drive motor conversion kits

No.	Composition	Specifications
1	Mid drive motor (with chainring and cover) Cranks (left + right), bolts Display with separated controller Speed sensor, magnet Brake levers Fixing plate Locknut M33 Security part for frame, bolt Mounting parts (bolts , washers etc.) Tool for locknut mounting Rack battery, carrier, extension cord / Frame battery, battery holder Charger	Motor power: 350 W Voltage: 36 V Battery capacity: 10.4/13/14.5 Ah
2	Mid drive motor (with chainring and cover) Cranks (left + right) Display with separated controller Speed sensor, magnet Motor holder Brake levers Cabling Rack battery, carrier, extension cord / Frame battery, battery holder Charger	Motor power: 350 W Voltage: 36 V Battery type: Li-Ion Frame battery capacity: 11.4/11.6/17.4/20.1 Ah Rack battery capacity: 11.6/17.4 Ah Frame battery weight: 2.8/2.4/3.7/3.8 kg Rack battery weight: 3.1/4 kg (+1.2 kg carrier) Motor weight: 3.7 kg Range (frame battery): -/-/140/160 km Range (rack battery): -/150 km Chainring: 46 cogs
3	Mid drive motor and main controller, Cranks (left + right), bolts	Motor power: 750/1000 W Voltage: 48 V

No.	Composition	Specifications
	Chainring and plastic cover Assembly accessories (screws, washers, nuts), Control LCD display and button panel for handlebar installation, Brake lever with connection to motor for switch off during braking, Thumb throttle, Speed sensor and magnet, Cable to cennect display, throtle and brake lever. Frame battery, battery holder Charger (2 A) Optional: senzor řazení (1000 W motor) Battery in bag (1000 W motor) Fast charger (5 A)(1000 W motor)	Battery type: Li-Ion Frame battery capacity: 9/13 Ah Battery weight: 4/3.4 kg Motor weight: 3.8/4.8 kg Axis pitch: 68-72 mm Range: 100/70-100 km Chainring: 46 cogs
4	Engine + epicyclic gear set Adapter to enable engine mounting Freewheel crank + chainring + inner bearing + chain Controller + bracket Twist grip with load display Battery + wiring 7 amper rapid charger	Motor power: 2400 W/1200 W nominal Voltage: 48 V Battery type: LiMn Battery capacity: 48 V/12.5 Ah Battery weight: 4.9 kg Motor weight: 3.2 kg (5.5 kg with accessories) Range: 40 km Motor power: 3400 W/1700 W nominal Battery type: LiMn Battery capacity: 54 V/17.5 Ah Battery weight: 6.9 kg Motor weight: 3.2 kg (5.5 kg with accessories) Range: 40 km
5	Mid drive (brush) motor 350 W, (brushless) motor 350/450/500/650 W Motor bracket & bolts Chain wheel Crank (left and right) Bottom bracket Throttle (with battery indicator & key switch) Chain Controller Guide wheel LED lens light (for brush motor kit) Light switch (for brush motor kit) Idler pulley (for brushless motor kits) Brake lever (for brush motor kit)	Motor power: 350/450/500/650 W Voltage: 36/48/48/60 V

Front and rear motor kits

In principle, the kits for the front and rear motor are similar. An analysis of the composition and technical specifications of the kits was made with the conversion kits from 4 dealers/manufacturers (one for both hub motor sets and three for the rear hub motor set) operating in the Danube market. The base of all analysed kits is a complete front or rear wheel (hub motor with a rim), a control unit, a pedal sensor, a control display, and cabling. Most of them contain a battery and a charger. In addition, some of them include brake levers or a brake sensor, an accelerator or throttle lever. For a more detailed overview of the composition of conversion kits and their technical specifications, see Tables 3.10 and 3.11.

Selected dealers/manufacturers:

1. EVBike (CZ) https://www.evbike.cz/EVBIKE-Prime-pohony/Kompletni-sady/
2. Apache (CZ) http://bplumen.cz/konfigurator.html
3. Elektrosport (CZ) http://elektrosport.cz/prestavby-kol/pohon-v-zadnim-kole
4., 5. Eco electrik (RO) http://ecoelectrik.ro/Biciclete_electrice.html

Tab. 3.10 Overview of front hub motor conversion kits

No.	Composition	Specifications
1	Front hub motor Rim 28“ Controll unit Assembly accessories (screws, washers, nuts) Control LCD display and button panel for handlebar installation Brake lever with connection to control unit for switch off during braking Accelerator Pedal assistant Cabling Rack battery, carrier Charger	Motor power: 500/700 W Voltage: 36/48 V Battery capacity: 36V/13 Ah Battery weight: 5.6 Motor weight: 6.6 kg Range: 70 km

Tab. 3.11 Overview of rear hub motor conversion kits

No.	Composition	Specifications
1	Rear hub motor Rim 26“ Controll unit Assembly accessories (screws, washers, nuts) Control LCD display and button panel for handlebar installation Brake lever with connection to control unit for switch off during braking Accelerator Pedal assistant Cabling Rack battery, carrier Charger	Motor power: 750 W Voltage: 36/48 V Battery capacity: 48V/9 Ah Battery weight: 5.6 kg Motor weight: 6.6 kg Range:70km
2	Rear hub motor (freewheels for threaded hub/cassette) Rim for disc brake Control LED panel Control unit Enclosed bottom bracket axle with torque pedal sensor Cranks (left and right), chainring, cover Cabling	Motor power: 350 W Voltage: 36 V Battery weight: 4 kg Motor weight: 3.5 kg Axis pitch: 135 mm Chainring: 38 cogs

No.	Composition	Specifications
	Optional: Rack battery, carrier/ Frame battery, battery holder Charger Throttle lever	
3	Rear hub motor Rim for V-brake/disc brake Control LCD panel Control unit Pedal sensor Brake sensor Cabling Frame battery, battery holder Charger Optional: Rear hub motor without gears Controller by grip Display dot matrix Battery 9 Ah	Motor power: 350 W Voltage: 36 V Battery capacity: 10.4/11.6 Ah Battery weight: 2.8 kg (with control unit) Motor weight: 5.9 kg (motor and other parts) Range: up to 95 km
4	Rear hub motor Rim Controller Accelerator control Brake levers Electric instalation Optional: Frame battery, battery holder Charger Control LCD panel Data cable with PC software	Motor power: 200-400/250-1000 W Voltage: 24/36/48 V Battery type: Li/ Li Ion Battery capacity: 8 Ah (36 V)/10 Ah (48 V) Battery weight: 2.5 kg/-
5	Rear hub motor Rim Controller Control LCD panel Accelerator Brake levers with switches Pedal sensor Electric instalation Optional: Frame battery, battery holder Charger	Motor power: 1000 W Voltage: 48 V Battery type: Li Ion Battery capacity: 48 V/10 Ah

2.5.4 Conversion kits for motor scooters

The use of the rear hub engine, which is available together with 10-14 inch diameter rims, is a solution for converting scooters. The power of motors ranges from 0.5 kW to 5 kW. The weight of the kit with the disc is approximately in the range of 10 to 22 kg depending on the diameter and the material used. However, there are only separate motors of a Chinese manufacturer. An offer of complete kits on the European market has not been found.

2.5.5 Conversion kits for motorbikes

The offer of conversion kits for motorbikes is very limited on the European market. Only one dealer was found. The base of the analysed kits is a motor, a controller, a speed throttle, a DC contactor, brake levers and a programming cable. For a more detailed overview of the composition of conversion kits and their technical specifications, see Table 3.12.

Selected dealers/manufacturers:

1. Miromax (LT) https://www.miromax.lt/en/m-6/c-26/c-50-electric_motorcycle_conversion_kits#to_products

Tab. 3.12 Overview of motorbike conversion kits

No.	Composition	Specifications
1	Motor (brushless DC) Controller Speed throttle with ignition switch DC Contactor Brake levers Programming cable	Motor power: 3-5/5-8.6/8.6/10-13/13 kW Voltage: 48/90/72/96 V Air/liquid cooling

2.5.6 Conversion kits for ATV

The offer of conversion kits for ATVs is very limited on the European market. Only one dealer was found. The base of the analysed kits is a motor, a controller, a speed throttle, a DC contactor and a programming cable. Except the lowest option, they also include brake levers. For a more detailed overview of the composition of conversion kits and their technical specifications, see Table 3.13.

Selected dealers/manufacturers:

1., 2. Miromax (LT) https://www.miromax.lt/en/m-6/c-26/c-48-electric_quadrocycle_conversion_kits#to_products

Tab. 3.13 Overview of ATV conversion kits

No.	Composition	Specifications
1	Motor (brushless DC) Controller Speed throttle DC Contactor Programming cable	Motor power: 0.8 kW Voltage: 48 V Air cooling
2	Motor (brushless DC) Controller Speed throttle with ignition switch DC Contactor Brake levers	Motor power: 1.5/3/5/8.6 kW Voltage: 48/60/72 V Air/liquid cooling

No.	Composition	Specifications
	Programming cable	

2.5.7 Conversion kits for cars

Similarly, the offer of conversion kits for cars is very limited on the European market. Only three dealers / producers were found. The first one offers 2 basic types of kits (Nos. 1 and 2). One is similar to those for motorcycles and includes a motor, a controller, a foot throttle, a DC contactor and a programming cable. The other one is different from the used motors. It covers two hub motors, each with its own controller.

The other dealer offers two types of kits (Nos. 3 and 4). Kit No. 3 is designed for vehicles with laden weights up to 1000/1250/1400 kg either with gearboxes or slower vehicles with fixed ratio drives. Kit No. 4 is a high torque kit and is designed for larger fast vehicles with gearboxes such as vans, 4x4s and pickups or larger slower vehicles with fixed ratio drives such as delivery trucks etc.

The third one offers conversion kits mainly for small cars (No. 5). Simple kits have similar composition to kit No. 1. The main difference is in the vacuum pump and indicator of battery capacity in kits No. 5.

For a more detailed overview of the composition of conversion kits and their technical specifications, see Table 3.14.

Selected dealers/manufacturers:

1., 2. Miromax (LT) https://www.miromax.lt/en/m-6/c-26/c-49-electric_car_conversion_kits#to_products
3., 4. Everything-EV.com (GB) http://www.everything-ev.com/index.php?main_page=index&cPath=66_117
5. Eco electrik (RO) http://ecoelectrik.ro/Autovehicule_electrice.html

Tab. 3.14 Overview of conversion kits for cars

No.	Composition	Specifications
1	Motor (brushless DC) Controller Foot throttle for car DC Contactor Programming cable	Motor power: 3/5/8.6/10/13/20 kW Voltage: 36/48/60/72/96 V
2	2x Hub motor (brushless DC) 2x Controller Foot throttle for car DC Contactor Programming cable	Motor power: 2x7 kW Voltage: 72 V Air/liquid cooling
3	Low Speed AC Induction Motor - 7.5 kW/14 kW or High Speed AC Induction Motor - 7.5/25 kW or 15 kW/30 kW Controller – 96 V 450/450/550 A AC Regenerative Braking Motor Controller Package including: Throttle potentiometer Control loom materials Contactor	Motor power: 7.5/15 kW Voltage: 96 V

No.	Composition	Specifications
	Cut-off switch Charger - 96 V 22 A High Frequency Charger - for onboard use Relay - for key switch input Power Cable - 50 mm^2/10 metres approx Power Terminals - Power Cable Terminal Eyelets 50 mm^2 mixed sizes x 30 m Heatshrink 3:1 sleeving to suit above - 1 m Control wiring cables - mixed sizes and lengths Sleeving - mixed sizes and lengths Control wiring terminals - mixed sizes	
4	High Speed AC Induction Motor (built to order) - 20 kW/40 kW Controller - 96 V 650 A AC Regenerative Braking Motor Controller Package (built to order) including: Throttle potentiometer Control loom materials Contactor Cut-off switch Charger - 96 V circa 22 A High Frequency Charger - for onboard use DC-DC Converter – 96 V/12 V Nominal Relay - for key switch input Power Cable - 50 mm^2/10 metres approx Power Terminals - Power Cable Terminal Eyelets 50 mm^2 mixed sizes x 30 m Heatshrink 3:1 sleeving to suit above - 1m Control wiring cables - mixed sizes and lengths Sleeving - mixed sizes and lengths Control wiring terminals - mixed sizes	Motor power: 20 kW Voltage: 96 V
5	Motor (brushless DC) Controller Foot throttle for car Vacuum pump Indicator of battery capacity Battery pack in metal case Charger	Motor power: 3-7.5/8-20 kW Voltage: 48/96 V air cooling Controller: 48 V 5 kW/96 V 10 kW Battery type: LiFePO4 Battery capacity: 48 V/30 Ah Battery weight: 18 kg Motor weight: 11/17kg

2.5.8 Conversion kits for boats

As mentioned in Chapter 2, the conversion of boats can be easily dealt with replacing the complete drive. Since no conversion kit is used, in this case, this option is not analysed in more detail. Even for rebuilding boats, the offer of kits on the European market is very limited. The base of the kit is a motor, a controller, a speed throttle and a programing cable. If the motor is liquid-cooled, a water pump is included. For a more detailed overview of the composition of conversion kits and their technical specifications, see Table 3.15.

Selected dealers/manufacturers:

1. Miromax (LT) https://www.miromax.lt/en/m-6/c-26/c-51-electric_boat_conversion_kit#to_products

Tab. 3.15 Overview of conversion kits for boats

No.	Composition	Specifications
1	Motor (brushless DC) Controller Speed throttle Cooling pump (not for air cooled motor) Programming cable Optional: Remote speed control joystick set with forward/reverse and power switch Teleflex cabling set variable lenght Custom–made battery pack	Motor power: 1.5-3/3-5/5-8.6/10-13/20-22 kW Voltage: 36/48/60/72 V

3 DIY – converting to electric drive

This chapter describes in detail the process of conversion of a mountain bike to a bike with an electric drive. The conversion is shown on an example of a mid drive motor kit and a frame type of a battery. Illustrative photographs and instructions below are used by courtesy of the EVBike company (CZ). According to the provided step-by-step plan, the kits allow a fast assembly within 90 minutes.

Content of a model kit (a package content):

- Motor and main controller
- Left and right crankarm
- Chainring
- Plastic cover of chainring
- Assembly accessories (screws, washers, nuts)
- Control LCD display and button panel for handlebar installation
- Brake lever with connection to motor for switch off during braking
- Thumb throttle
- Speed sensor and magnet
- One cable to connect display, throtle and brake lever
- Frame battery with holder
- Tools required for the assembly are:
- Standard tools (eg. gola tool set, screwdrivers, hex key set, pliers, cutting pliers, adjustable spanner etc.)
- Spanner for lock ring of bottom bracket axle
- Crank puller
- Tightening belts

3.1 Step 1: Motor assembly

Using bolts (five in this case), screw the chainring with the motor. Use adequate power to tighten the bolts. Then, install the plastic cover on the chainring (using small bolts). After that the motor is complete and prepared for installation to the bike frame.


First remove the original chainring with right crankarm and left crankarm with a pedal. Use a special puller and be careful to prevent damage to the central axis inner thread. Remove the central axis with using the other special puller. Remove the tray from the other side too.

Turn the bike for easier access. Remove the front derailleur.

Remove any obstacle from the area of the middle pedal axis.

Carefully insert the motor on the axis. Motor is fixed with the use of a spiked washer. The spikes must face the frame of the bike, the spikes prevent any movement of the motor during use.

Screw the locknut. Make sure the brake and gear strings are free.

Install the bolts to the fixing washer. If your bike has the central pedal hub longer than 68 mm, the additional underlay should be used under the washer to prevent any free movement of parts.

Using a special spanner, tighten the main nut. If there is no free space to install a counter nut, using special glue for screws is recommended.

The screw which prevented the motor installation can be tightened now.

Install crankarms, pay attention to their correct position using symbols for left and right side.

The pedals need to be installed correctly as well (L – Left side, R – Right side). Secure the crankarms with screws and remember to tighten the pedals. Checking the tightening after a kilometer of riding is recommended.

3.2 Step 2: Installation of handlebar controls

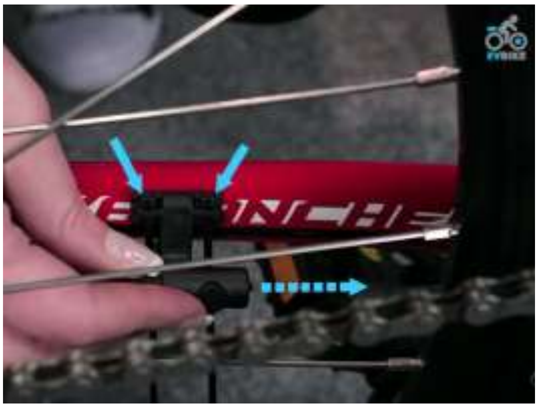

Remove accessories from the left side of handlerbars.


First install LCD panel controls, keep in mind the correct position of turn on/off symbol from the rider‘s view. Fix the LCD panel to handlebars. If necessary, use the provided distance rings. Place the panel to be easily readable by the rider. (LCD display can be placed on the right side)

Install the throttle and brake lever. Choose the position of parts as you see fit. Once all parts are on their place, tighten everything.

Install the brake lever cable.

3.3 Step 3: Installation of a speed sensor



Place the sensor using tightening belts. The sensor is installed on the rear wheel. For correct function, the sensor must be on left side of the bike frame and the signal LED in the direction to the rim.

Place a magnet on a spoke close to the rim. Direct the magnet towards the sensor body. Keep the distance of the magnet and sensor within 5 mm.
If there is a signal LED, check the correct installation by LED blinking each passing of the magnet. Tighten the magnet.

Connect the cable from the motor and secure it.

Fix the cables to the bike frame (using tightening belts or an adhesive tape).

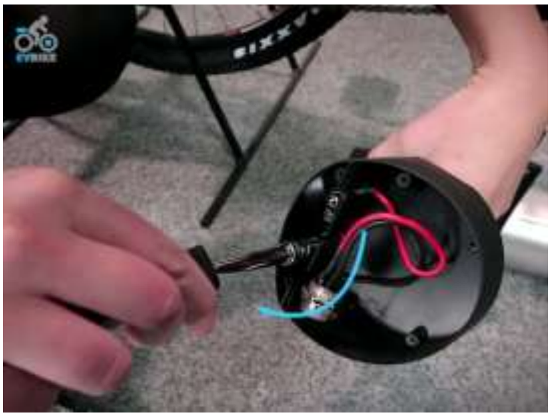
Connect the connectors with care, check for guiding arrows indicating the correct position, if there are any. The connectors of the controller are usually colour matched.
Make sure that cables are out of range from any moving parts and are not interfering during ride.
Should they not fit, make sure the pins are straight, not bent or curved.

Place the redundant cable to a hidden place (e.g. under the LCD control panel).

3.4 Step 4: Installation of battery

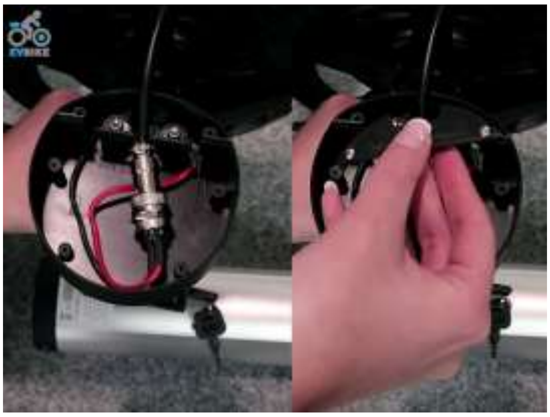
First remove the cover of battery contacts.

Power is distributed by two terminals, these are usually not tightened! Final tightening is made by a person who installs the battery.



Use pliers to prevent movement of terminals. Using a spanner to tighten the nut inside. Caution, do not use brutal force as it may damage the contact.

Connect the cable from the motor.



Put the connector from the motor under the battery cover and attach the cover back. During the assembly, prevent squeezing of the cable between the cover and the holder.

Install the holder on the bike frame instead of a bottle holder and tighten screws.

Slide the battery to holder.

4 DIY – building of electric vehicle

Before commencing the project work it is necessary to decide whether to acquire a new electric vehicle or convert an existing vehicle into an electric one. A new vehicle is very demanding in terms of designing, construction and hand-made production of parts. After completion it is difficult to perform the vehicle homologation. Therefore, it is easier to convert a vehicle with an internal combustion engine.

The difficulty of legislation aspects of the conversion is based on the vehicle manufacturer's approval. Some producers are reluctant to grant approval for the conversion into an electric vehicle even to universities. In case the manufacturer's consent cannot be obtained, it is necessary to obtain at least a list of technical requirements that need to be met. The list of requirements can already be verified by a certified body and can be used for subsequent homologation.

Unless the vehicle has Registration certificate, the construction must be made from homologated parts. The approval consists of the homologation by a certified body, tests based on EHK100 standards, aptitude and safety tests of electrical system, and electromagnetic compatibility tests. They are based on measurements of electromagnetic radiation of the vehicle on different frequencies and on measurements of resistance against strong external electromagnetic radiation.

Crash tests when the vehicle is deliberately damaged are not performed in the individual approval procedure. What is required is an assessment whether the conversion has no negative effect on safety, airbag operation, deformation zones, passive and active safety elements, and whether axles are not overloaded.

Conversion procedure is explained in the following steps.

4.1 Step 1: User's requirements

First, it is necessary to consider what type of vehicle is to be constructed – family, urban, sport vehicle, or a van. Manual skills, expert knowledge, technical equipment, together with financial means and time constraints need to be taken into account. Based on the above mentioned, we can decide whether to perform a simpler conversion of an older, less complicated vehicle in terms of construction, or whether to perform a conversion of a modern vehicle equipped with extensive electronic and electric system.

Based on driving and practical properties, we need to make a decision which axles are to be powered, what is to be the maximum load, number of passengers, luggage compartment size, etc. Furthermore, the conversion depends on the available versions and feature packages, documents existence, and technical condition. The most suitable models are those equipped with an electric brake booster, or with electric pre-heating, which is usually used until the cooling liquid is sufficiently heated.

In addition, we need to obtain the project documentation, mechanical schemes, 3D models of parts from the manufacturer and distributor, information on strength and maximum load of bodywork parts, on bearing points, electric schemes, control unit software, etc.

4.2 Step 2: Electric vehicle designing

The main step for the conversion planning is the intended or required driving range. Nowadays, it is technologically possible to reach the driving range between 100 km and 1000 km. The longer driving range increases the vehicle weight and reduces its loading capacity. The price for batteries, which grows with loading capacity, is the highest cost item in the vehicle conversion.

Furthermore, batteries, electrochemical cells, their price, duration, energetic density and shape need to be determined and selected. The existing options are box batteries, pouch cells, or cylindrical cells, e.g. 18650 welded in blocks. Individual cells are assembled in series, or in series and parallel configuration, in case it is necessary to reach higher capacity of cells.

Battery weight distribution needs to be designed so that both axles are equally and correctly loaded, as close to the original axle load as possible, while taking into account the expected load by passengers and payload. The connected batteries are placed in so-called battery boxes. They protect battery cells against mechanical damage, dusting and cold.

Another designing step is the selection of the drive architecture. There are the following options:

- 1 central motor replacing the dismantled internal combustion motor
- 2 motors on axles, in case 4x4 drive is required
- 2 motors in wheels on a single axle
- 4 motors in 4 wheels (requires linked or dual frequency converters for the regulation of both wheels for safety reasons).

It is necessary to select the electric motor type with regard to the drive architecture. The following can be used:

- A synchronous electric motor with permanent magnets, which is used by the majority of types of electric vehicles. An advantage of this motor type is high torque from zero revolutions, theoretical lower electricity consumption under constant load. Drawbacks include higher price (permanent magnets are made from rare earth elements), lower overload capacity based on the magnet attachments, and theoretical lower duration, even though considerably higher than of internal combustion engines.
- A squirrel cage induction motor – are currently used only by Tesla, Mercedes-Benz, and SuperEL (conversion of Skoda Superb II, CZ). A drawback is relatively low power during move-off. Tesla Motors compensates this low move-off power with a fixed transmission decreasing revolutions and a high-torque motor with excellent internal aerodynamics. Advantages include high overload capacity, cheap production, and electricity savings in real traffic when no power is necessary in downhills.

The presented vehicle with an ICE engine is usually equipped with a manual transmission, which can be kept or dismantled. Keeping an automatic transmission is not recommended due to the different characteristics of the motor. Electric motors have a broad torque range and need no transmission. Nevertheless, changing gears can lead to electricity savings, since excessively high revolutions cause higher current losses in the motor. Tesla Motors deals with this issue and is dealt by using two electric motors. The rear electric motor has fixed transmission with fixed gear for lower speeds. It means that higher torque is transferred to rear wheels, which are loaded more during vehicle move-off. The front electric motor has fixed transmission for high speeds so that it could reach ideal revolutions, e.g. on motorways.

Another designing step concerns the selection of electric motor voltage. Conversions usually need to consider the existing supply of electric motors on the market, although there are companies which can wind a water-cooled electric motor to any voltage. Higher input voltage of electric motor is more effective, since the conductor diameter can be lower, which reduces price, weight of conductors, amperage for power semiconductors, and required cooling power. The basic voltage around 400 V DC is ideal, so that the whole vehicle voltage was compatible with DC chargers CHAdeMO and Combo2. However, higher voltage is more financial demanding in terms of either purchase price or a construction of a revolution regulator, i.e. a frequency converter. Air-cooled electric motors are very noisy, particularly at higher revolutions, and the cooling is not very effective at low speeds.

The selection of an electric motor is related to the selection of a frequency converter, i.e. revolution regulator. Vector regulation is usually used. Common frequency converters cannot be usually used for machinery drives, since they cannot be regulated with sufficient accuracy during recuperation. In general, water cooling, resistance against shocks and impurities in vehicle are required. Some regulators are able to use power elements for charging batteries from the electric grid, which is connected instead of the recuperating motor. Some converters are able to supply 3-phase current 50Hz from the batteries back to the electric network of a company or household.

The selection of battery voltage is based on the requirements for the charging voltage of the regulator, i.e. frequency converter. Based on the battery chemistry we need to take into account a certain voltage range between discharged and charged cell states. The voltage may range between 4.2 V and 2.0 V. Based on the series parallel connection of cells, it is necessary to choose current limits and cable diameters. When designing the physical layout of components, the ideal is to reduce the distance between the battery, converter and electric motor to minimum, in order to reach savings in power cables.

The selection of battery electrochemistry is based on price and market availability. Various types of lithium cells are available, e.g. Nissan and Renault use LMO, LCO is available in electronics and home tools, LFP or $LiFePO_4$ is used for storing of photovoltaic panel energy. LFP is the most readily available with good resistance and duration, but allows to store just 100 kWh/tonne. NMC cells are also well accessible (used by BMW, VW, SOR, EVC and other manufacturers), and usually come in cylinder type 18650. This size is also used for Tesla vehicles with electrochemistry NCA. In addition, cells from crashed Tesla vehicles are a popular and affordable source of accumulators for conversions. Lithium-Sulphur accumulators are expected to be used in the future.

In order to secure safe operation of the battery it is necessary to use battery management system – BMS. This system monitors every parallel connection of cells, balances them so that all cells are charged equally, and protects them from low and high voltage, from low and high temperatures. Balancers must measure temperature at every cell so that it would be possible to detect potential overheating due to a manufacturing defect and immediately limit currents, thus protecting the battery from damage.

Vehicle conversion design must include a basic electric drive scheme. Power parts must be equipped with circuit breakers, electrical fuses at both poles, vacuum contactors with charger disconnection.

Before the conversion work, it is necessary to create at least a basic 3D model of the device power part and conductors for the calculation of power cables length, prevention of interference, and allocation of safe spots to add conductors. It is not recommended to lead positive and negative power conductors around the vehicle at different sides of the vehicle – it may lead to occurrence of large magnetic fields at short-term high currents. Three-phase or more-phase wiring must be shielded from data cables as well, or has to be as short as possible.

4.3 Step 3: Vehicle acquisition

Before acquiring the vehicle for conversion, it is necessary to obtain manufacturer permission or a list of technical requirements from the manufacturer, if possible.

Vehicle bodywork, chassis and the existing wiring need to be thoroughly checked before the vehicle is purchased.

It is recommended to keep a project logbook during conversion works where all important measurement values, events, and performed work are recorded. The first measurement to be recorded in the logbook is the precise weight of the vehicle, calculation of weight with full tank excl. people and load, recorded loading of individual axles. Mileage should also be recorded in the logbook.

Detailed photo documentation of the vehicle should be made and continued with every uncovering of vehicle parts.

4.4 Step 4: Material acquisition

Particular attention needs to be paid to acquiring suitable material and devices based on the conversion design:

a) Acquisition of suitable converter based on the project plan,
b) Power cables with corresponding conductors must be self-extinguishable and in orange colour. In case black self-extinguishable cables are applied, orange fire-proof insulation tube or “gooseneck” needs to be used.
c) Hooks and connectors have to be used for safe connecting of conductors without soldering.
d) Self-extinguishable data and signal cables
e) Charger, unless integrated with converter. Ideally single-phase 230 V 16 A or three-phase 400 V 32 A, which can handle charging to required battery voltage, controlled through a CAN bus with the use of BMS.

f) Three-phase charging connector "mennekes" according to standard, or Combo2 or CHAdeMO, respectively.
g) Acquisition of 1 or 2 (for 4x4) suitable gearbox with fixed gear ratio. It is also possible to use the existing gearboxes for selected gears, while some gears can be dismantled to save weight.
h) Acquisition of one or more electric motors, usually water cooled ones.
i) Acquisition of current sensors, vacuum contactors, control units
j) Acquisition of vacuum pumps for the brake system
k) Acquisition of electric heating
l) Acquisition of electric air-conditioning compressor
m) Acquisition of BMS and balancers
n) Acquisition of alternative sensor of acceleration pedal, in case the existing one cannot be used.
o) Acquisition of brake pedal sensor.
p) Acquisition of DC/DC convertor. Minimum 1000W if seat heating is installed, so that power steering worked. Acquisition of charging status of a 12 V battery and potentially automatically restart DC/DC, so that the battery can be charged.

4.5 Step 5: Vehicle reverse engineering

Unless we have the complete documentation of the converted vehicle, we need to obtain some information by measuring, monitoring of buses, or another reverse engineering method.

The following are particularly mentioned – connection of the CAN analyser to control unit buses of the vehicle comfort, and the motor control unit. Even before the disassembly of the combustion motor, we need to monitor the course of communication between the combustion engine and the control unit, e.g. during activating and starting the motor, recording individual tasks on the bus during vehicle during the start-up phase, starting, changing gears, move-off, engine switch-off, steering wheel turning, comfort elements control, different driving modes (with cold, heated motor), use of air-conditioning, heating, etc. Apart from data recording, it is useful to make a video recording to determine connection between bus signals and performed control activities.

This information will be later used for producing a device and its software, and a specialized control unit (e-gateway). This unit replaces the combustion engine control unit so that the vehicle control unit, broadly speaking, still received meaningful information from the non-existent combustion engine.

4.6 Step 6: Dismantling

From safety reasons dismantling should always start with disconnection and dismantling of an on-board 12V battery. Subsequently, it is necessary to professionally remove dangerous gas from the air-conditioning system, drain oil from the motor and gearbox, drain fuel from the fuel tank, fuel pump, cooling liquid, potentially drain a separate heating unit and AdBlue liquid containers. The vehicle is weighed as a whole after every modification.

In the next phase it is necessary to dismantle exhaust piping, oil filter, fuel filter and the catalytic converter. Then the fuel tank and the whole fuel system are dismantled. Some of the parts, e.g. fuel tank locking system can be reused.

Then motor cooling system and heating dismantling follows – some pipes and cooler can be probably reused. The dismantled air-conditioning system can be assembled again, but the drive itself or the drive including a compressor will be replaced with electric drive with its own frequency converter from traction voltage.

The main goal of this phase is the disconnection and dismantling of the internal combustion engine and the weighing of the engine. The engine can usually be sold as a whole or in parts. Another step is the dismantling of the clutch and gearbox. In the end the vehicle is weighed again.

4.7 Step 7: Designing continues

The values obtained through weighing will then be used for further designing work. Based on the dismantled weight on axles, it is necessary to calculate and design the weight distribution of batteries on the front and rear axle. Therefore, it is necessary to find the loading capacity of mountings on the bodywork itself and to define the room for batteries. The potential place is the emptied room after the removed internal combustion engine, room after the fuel tank, or potentially the room after the reserve wheel, the room after the drive shaft and central differential, as well as the room after the gearbox. In order to maintain the practical properties, it is preferable not to modify the luggage compartment.

The distribution of battery mass is preliminarily calculated for the centres of mass of mountings. Based on the distance from the axles, load on individual axles, which should stay within the chassis bearing capacity, is calculated.

In case it is not within the acquired chassis bearing capacity, it is required to change the system spring-damper, and if necessary to strengthen the platform, or to lighten a part of the bodywork.

Subsequently, battery boxes are designed based on the type, size, and battery connection, while taking into account their insulation, damage protection, heat (water cooling) and cold (electric or water heating) protection. In addition, boxes ventilation, moisture drainage, insulation against splashing water, etc. needs to be designed. Most commonly used material for battery boxes are plastic composite, laminate, aluminium, stainless steel and carbon composites.

In addition, mechanical connections of power train need to be designed (electric motor-shaft connector-adapter plate-coupler-gearbox-differential-power shafts). An adapter plate drilled on one side, based on the gearbox, and on the side, based on the electric motor, and sealed with high-temperature silicon is usually sufficient.

4.8 Step 8: Production of parts and construction blocks

The designed parts must be produced in appropriate quality before the construction. This concerns the production of battery boxes with welding, gluing of carbon, plastic, and 3D print, particularly of connection parts.

In case we use small cells, e.g. type 18650, for batteries, we need to pack them in the so-called battery packs. An interesting phase includes welding of connectors of batteries type 18650 or merging of larger battery connectors. CuAl washers are usually used for connecting of aluminium and copper.

Every parallel connected battery must be mounted with balancers including temperature sensors for every cell, and balancers data conductors and battery power conductors must be connected.

Before the traction battery is installed in the vehicle, initial cycling must be performed, i.e. discharging and charging of batteries out of the vehicle, including the measurements of key operation parameters. In this phase the measured parameters, battery quality checks, cells temperature monitoring, connection temperature (monitored by thermal camera during fast discharge and charging) monitoring, charging and discharging characteristics monitoring are all recorded in the logbook. All that need to be performed and monitored for several days.

During that time engineering production of the adapter plate or shaft connector between the electric motor and gearbox, or the connector or adapter plate between the gearbox and the differential can be underway. In case the vehicle is equipped with four wheel drive, the same holds for the other axle.

4.9 Step 9: Drive installation

The electric drive installation usually starts with the installation of gearbox and adapter plate. A pre-produced drive holder is mounted with rubber silent blocks – usually different than combustion motor. Electric motor is installed on the adapter plate.

The mounted electric motor can be tested by connecting it to charged external batteries with a frequency converter. The drive test is at first performed on a lift with free wheels and then on vehicle dynamometer including recuperation.

The measurements are recorded in a logbook and the drive is tuned without load. It is necessary to pay particularly attention to drive coaxiality, vibration, and heating. Potential repeated assemblies and disassemblies are recorded in the logbook. The vehicle fixed on dynamometer can be used for the measurement and tuning of the motor with load and simulated recuperation.

When the motor works, an external board battery 12V can be installed in the vehicle and the charging is connected to the DC/DC converter, which replaced the dismantled alternator.

In case an older type of vehicle is concerned, which is not equipped with electric brake booster, it is necessary to install an electric vacuum pump.

4.10 Step 10: Mounting of batteries

If the battery boxes are designed for sizes and weights that can be easily handled, they can be installed in a vehicle already equipped with batteries and BMS balancers. Particular attention needs to be paid to fastening connections that hold the battery in the vehicle. If the battery boxes can be opened and are large, they can be installed empty and the batteries can be inserted afterwards. In the end individual axles need to be weighed to determine whether expected and maximum axle load is reached.

Individual battery boxes are interconnected and linked to vacuum contactors. Hall effect sensors are attached to direct traction conductors to measure current. Power fuses are installed in both poles of every battery box. Corresponding pipes and tubes are connected in case the battery box is cooled and heated with water.

Furthermore, frequency converter and its water cooling are installed in the vehicle. The converter must be placed in the vehicle in a safe place so that it is not damaged in potential accident. In the end the acceleration pedal is installed. The sensor of a common acceleration pedal usually has 2 sensor elements working opposite to each other for safety reasons. Its output values cannot often be connected directly to the frequency converter and it is usually necessary to make a signal converter.

4.11 Step 11: First ride

The testing of the drive on a vehicle lift or on a vehicle dynamometer should take place before the first ride. It is recommended to make a video recording of the first ride. In order to guarantee safety, it is advised to install a mechanical disconnection of the main vacuum contactor power supply in the traction drive, so that it was possible to stop safely even when everything else failed.

It is necessary to make a short test of a moving off, driving on flat, uphill, moving off over a kerb, recuperation, etc. During further test rides it is recommended to monitor buses, measure currents, measure energy consumption, monitor converter and electric motor temperature, and visualize voltage in individual battery cells.

4.12 Step 12: Construction continues

The first rides cannot be long in order to prevent dangerous battery discharge. In case BMS is not installed, it should be installed and connect it in this phase at the latest. There must be a signal between the frequency converter and BMS which allows driving, provided that batteries are sufficiently charged and within an acceptable temperature range.

Furthermore, charger needs to be installed, its CAN signals which allow charging from BMS need to be checked. In addition, a brake pedal pushing sensor will be installed and connected to the frequency converter to activate recuperation. The recuperation effect should ideally grow linearly depending on the pedal pushing distance. Subsequently, the starting key should be connected through a relay to the frequency converter and vacuum contactors.

In order to guarantee comfort elements, i.e. window rolling, additional electric heating, heating and setting of seats, and power steering in some vehicles, it is necessary to install a simulation control unit, which can substitute the dismantled combustion engine control unit and generate the same or similar CAN signals, like during correctly running combustion engine.

In addition, the ABS control unit and the chassis stabilization should be connected to the frequency converter, so that it could switch off inappropriate recuperation in case of an ABS intervention during hard breaking.

Then traction batteries charger needs to be connected to the installed vehicle connector for external direct charging and alternate charging. In case the charger is not equipped with this function, it has to be completed with a control unit to control charging on the basis of a protocol CHAdeMO or Combo2.

Eventually, usual weighing and recording of works to the logbook should be made.

4.13 Step 13: Testing rides

After the construction is completed, the phase of testing rides comes. At first they take place outside of the road. Driving with a prototype on the road requires a permission, vehicle inspection of brakes and other safety elements, issuing a testing registration plate (they start with F in the Czech Republic), and driving by trained driver.

Apart from the above mentioned measurements (see Step 11) during the rides, automatic calibration and tuning of frequency converter, and monitoring of battery boundary conditions is performed, i.e. complete discharging; recuperation behaviour at complete charging; monitoring of consumption, temperature, acceleration, load towing, drive cooling in summer and heating in winter, etc. In addition, charging processes between rides are monitored.

Moreover, interference in the radio spectrum is tested. Besides, it is recommended to test the vehicle resistance against electromagnetic interference by radiation with the use of antennas for wireless connections.

4.14 Step 14: Omologation

A vehicle cannot be allowed to be operated on roads without omologation. The approval process may differ in individual countries. It is described in Chapter 3.4.4 in more details.

5 Conclusions

Necessary information, such as input for the eGUTS standards, is included in this document, the eGUTS Feasibility Study 5.

Recommendation/requirements on rules and standards

- Meet EU and national legislation
- Meet EU and national regulations
- Meet UNECE regulation
- Follow EU and national technical standards and technical specifications
- Respect national habits and best practices in conversion to e-vehicles, if available

For details linked with this recommendation, see Annex A.

Recommendation on content for eGUTS standards

- To include a general part as introduction for both:
  - Non-motorised and
  - Motorised vehicles to be converted.
- To specify all possible types of vehicles suitable for conversion:
  - Bicycle,
  - Scooter,
  - Three-wheeler,
  - Motorised two-wheeler,
  - Motorised three-wheeler,
  - Motorised four-wheeler (ATV),
  - Light car (L6e, L7e),
  - Passenger car,
  - Light utility vehicle (LUV),
  - Small ship/boat (with an integrated motor).
- To consider both work processes:
  - Using the available conversion kits or
  - Own construction of the e-vehicle.
- To offer costs and time linked with the work.
- Parts specification, a conversion kit description, tools and workroom/workshop equipment, and chemicals such as glue, etc, which are commonly used.
- To avoid gaps in the plans content in this study, it is important to add all the technical details:
  - Calculation of design parameters, or a link to an Internet calculator.
  - Drawing documentation, including an electro assembly scheme.
  - Technical standards shall be quoted for certain work.
  - Capability of energy recuperation setting-up to be offered, where suitable.
  - E-vehicle maintenance requirements and timeplan.
- It is very demanding to complete information on testing and approving, because all the parts of these two processes were identified as underestimated and very seldome used in the plans.

- To avoid injuries, let us provide warning of:
    - Common safety instruction for work.
    - Specific safety instruction for assembling, welding and electrical cables parameters and manipulation, etc.
- To avoid impacts on the environment and to optimise resources:
    - To use, at least some, already used parts or even a second-hand bought car (usually with conventional engine out of operation).
    - No more used and removed parts of the original vehicle to offer for sale or to put to the recycling yard.
- Do not forget to use any suitable link to Internet available information.
- To add information to a national contact person for consultancy for eGUTS conversions and plans and/or a web tool for support via Internet.

Recommendation on form for the eGUTS standards

- The DIY conversion plan should be, first of all, understandable and user friendly.
- It seems that the mother tongue would be the best way to support dissemination of the eGUTS standards in the partners´countries.
- It would also be great to offer an English version of the eGUTS standards for wider sharing in the Danube region, further European Union members and EU membership candidate countries.
- The step by step plan should consist of a textual part and pictures and/or videos: the video is useful to watch mainly before the work in a workshop; the pictures (and the text as well) can be printed for an easy overview during the work**.**

6 Information sources

CEN CENELEC. Focus Group on European Electro-Mobility Standardization for road vehicles and associated infrastructure. Report in response to Commission Mandate M/468 concerning the charging of electric vehicles. October 2011.

Directive 2002/24/EC of the European Parliament and of the Council of 18 March 2002 relating to the type-approval of two or three-wheel motor vehicles and repealing Council Directive 92/61/EEC

Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast)

Directive 2008/68/EC of the European Parliament and of the Council of 24 September 2008 on the inland transport of dangerous goods

Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure

Questionnaires on national conditions, completed by eGUTS partners.

Řezáč, Petr. Testy elektrických lodních motorů. In: ITest [online]. Praha: Internet Test, 2010. Available on (April 2017): http://www.itest.cz/old/lode/lode2.htm

UNECE. Regulation No. 100. Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train. Date of entry into force: 15 July 2013. Available on (April 2017): https://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/2013/R100r2e.pdf

Other sources:

https://www.cen.eu

http://www.din.de

http://www.iec.ch

http://www.interreg-danube.eu/

http://www.unece.org

http://www.unmz.cz

https://www.iso.org

Annex A: List of related technical standards

Status in April 2017:

EN ISO 15118-1 Road vehicles – Vehicle to grid communication interface – Part 1: General information and use-case definition

EN 15194 + A1 Cycles – Electrically power assisted cycles – EPAC Bicycles

EN ISO 18246 Electrically propelled mopeds and motorcycles – Safety requirements for conductive connection to an external electric power supply

EN 50272-1 Safety requirements for secondary batteries and battery installations – Part 1: General safety information

EN 50272-4 Safety requirements for secondary batteries and battery installations – Part 4: Batteries for use in portable appliances

EN 60529 / IEC 60529:1989+AMD1:1999+AMD2:2013 CSV Degrees of protection provided by enclosures (IP Code)

EN 60071 / IEC 60071:2014 SER Insulation co-ordination – All parts

IEC 60364-4-41:2005+AMD1:2017 CSV Low voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock

IEC TS 60479-1:2005+AMD1:2016 CSV Effects of current on human beings and livestock – Part 1: General aspects

EN 61000-3-2 / IEC 61000-3-2 Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)

EN 61000-3-3 / IEC 61000-3-3 RLV Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection

EN 61140 / IEC 61140:2016 RLV Protection against electric shock – Common aspects for installations and equipment

IEC TR 61439-0 Low-voltage switchgear and controlgear assemblies – Part 0: Guidance to specifying assemblies

EN 61439-1 / IEC 61439-1 Low-voltage switchgear and controlgear assemblies – Part 1: General rules

EN 61439-2 / IEC 61439-2 Low-voltage switchgear and controlgear assemblies – Part 2: Power switchgear and controlgear assemblies

IEC 61851-1 Electric vehicle conductive charging system – Part 1: General requirements, with merged fragment of IEC 61851-1/FRAGf ED1

Not published yet, now in the CDM phase (2017-05): IEC TS 61851-3-1 Electric Vehicles conductive power supply system – Part 3-1: General Requirements for Light Electric Vehicles (LEV) a.c. and d.c. conductive power supply systems

Not published yet, now in the CDM phase (2017-05): IEC TS 61851-3-2 Electric Vehicles conductive power supply system – Part 3-2: Requirements for Light Electric Vehicles (LEV) DC off-board conductive power supply systems

Not published yet, now in the CD phase (2017-05): IEC TS 61851-3-3 Electric Vehicles conductive power supply system – Part 3-3: Requirements for Light Electric Vehicles (LEV) battery swap systems

Not published yet, now in the CDM phase (2017-05): IEC TS 61851-3-4 Electric Vehicles conductive power supply system – Part 3-4: Requirements for Light Electric Vehicles (LEV) communication

Not published yet, now in the ADTS phase (2017-05): IEC TS 61851-3-5 Electric vehicles conductive power supply system – Part 3-5: Requirements for Light Electric Vehicles communication – Pre-defined communication parameters

Not published yet, now in the ADTS phase (2017-05): IEC TS 61851-3-6 Electric vehicles conductive power supply system – Part 3-6: Requirements for Light Electric Vehicles communication – Voltage converter unit

Not published yet, now in the ADTS phase (2017-05): IEC TS 61851-3-7 Electric vehicles conductive power supply system – Part 3-7: Requirements for Light Electric Vehicles communication – Battery system

Not published yet, now in the CFDIS phase (2017-05): IEC 61851-21 -1 Electric vehicle conductive charging system – Part 21-1: Electric vehicle on-board charger EMC requirements for conductive connection to AC/DC supply

Not published yet, now in the PRVC phase (2017-05): IEC 61851-21-2 Electric vehicle conductive charging system – Part 21-2: EMC requirements for OFF board electric vehicle charging systems

IEC 61851-23 Electric vehicle conductive charging system – Part 23: DC electric vehicle charging station, with IEC 61851-23:2014/COR1:2016 Corrigendum 1

Not published yet, now in the CD phase (2017-05): IEC 61851-23-1 Electric vehicle conductive charging system – Part 23-1: DC Charging with an automatic connection system

Not published yet, now in the ACD phase (2017-05): IEC 61851-23-2 Electric vehicle conductive charging system – Part 23-2: DC charging system for small energy capacity

IEC 61851-24 Electric vehicle conductive charging system – Part 24: Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging, with IEC 61851-24:2014/COR1 Corrigendum 1

EN 61951-1 / IEC 61951-1 Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary sealed cells and batteries for portable applications – Part 1: Nickel-Cadmium

EN 61951-2 / IEC 61951-2 Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary sealed cells and batteries for portable applications – Part 2: Nickel-metal hydride

EN 61960-3 / IEC 61960-3 Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for portable applications – Part 3: Prismatic and cylindrical lithium secondary cells and batteries made from them

EN 62133-1 / IEC 62133-1 Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells and for batteries made from them, for use in portable applications – Part 1: Nickel systems

EN 62133-2 / IEC 62133-2 Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells and for batteries made from them, for use in portable applications – Part 2: Lithium systems

EN 62133-3 / IEC 62133-3 Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells and for batteries made from them, for use in portable applications – Part 3: Part 3: Prismatic and cylindrical lithium secondary cells and batteries made from them

EN 62281 / IEC 62281 RLV Safety of primary and secondary lithium cells and batteries during transport

ISO 2575 Road vehicles – Symbols for controls, indicators and tell-tales; plus its revision under development to be watched

ISO 11452-1 Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 1: General principles and terminology

ISO 11452-2 Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 2: Absorber-lined shielded enclosure; plus its revision under development to be watched

ISO 11452-3 Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 3: Transverse electromagnetic (TEM) cell

ISO 11452-4 Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 4: Harness excitation methods

ISO 11452-5 Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 5: Stripline

ISO 11898-1 Road vehicles – Controller area network (CAN) – Part 1: Data link layer and physical signalling

ISO/TR 22411 Ergonomics data and guidelines for the application of ISO/IEC Guide 71 to products and services to address the needs of older persons and persons with disabilities

DIN SPEC 70121 Electromobility – Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging in the Combined Charging System

Annex B: Questionnaire: Review of e-vehicle DIY conversion plans among partners

For more details, see the attached excel file, named as ***FS5_Questionnaire_aggregated***