ACTUATE

advanced training for safe ecodriving of electrically powered vehicles
– Hybrid bus –

www.actuate-ecodriving.eu

Co-funded by the Intelligent Energy Europe Programme of the European Union

actuate

ACTUATE

a project for the optimisation of driving behaviour to reduce energy consumption

As part of the ACTUATE project funded by the European Union, training programmes and general training measures for ecodriving electrically powered vehicles in local public transport were developed, tested and implemented successfully.

With the introduction of advanced training for ecodriving, potential energy savings in electrically powered vehicles such as trams, hybrid buses or trolley buses can be further optimised and hence the cost-effectiveness and utilisation of these types of vehicles be promoted.

The focus of the ACTUATE project is on the driver as the core operator for ecodriving. Accompanying motivation campaigns will ensure that drivers continue to apply what they learn in training courses.

A project for the optimisation of driving behaviour...

- for safe ecodriving of electrically powered vehicles in local public transport
- to increase the cost-effectiveness of electrically powered vehicles in local public transport through
  - development and testing of training programmes for safe ecodriving
  - motivation campaigns aimed at drivers of trams, trolley buses and hybrid buses

This training brochure was developed for the vehicle type hybrid bus for the ACTUATE project.

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1 Introduction

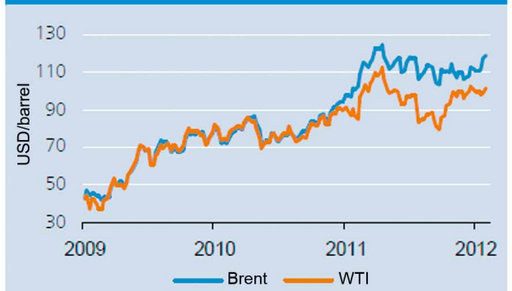
Studies have shown that driving behaviour can have a significant impact on the cost-effectiveness of vehicles. This, of course, also applies to electrically powered vehicles in local public transport, which basically offer better environmental performance due to their higher energy efficiency.

In this context the ACTUATE project partners are developing training concepts and general training measures for ecodriving of electrically powered vehicles in local public transport. The informational and training materials developed as well as motivation campaigns for ecodriving, which integrate the special requirements for clean bus and tram fleets, are provided to interested local public transport companies free of charge.

Why ecodriving?

If you look at the price for crude oil in recent years, one trend is apparent. Prices continue to rise. This fact is reflected in the costs to each local public transport company that operates vehicles running on diesel.

Crude oil prices continue to rise



Sources: Bloomberg, DekaBank

It is therefore a matter of urgency to consider the question of ecodriving. This applies also and especially to hybrid buses which comply with a concept for more environmental protection and cost-effectiveness in urban transport; this has been consistently focussed on saving fuel through the targeted development of drive technology, since ultimately fuel can only be saved through the corresponding driving behaviour.

In the future an increasing number of cities and local authorities in Europe will introduce environmental protection areas with corresponding threshold values.

eco-driving: Training programmes and general training measures improve ecodriving of electrically powered vehicles in local public transport.

If these thresholds are exceeded, a hefty fine can be expected. Here, too, the new trend towards ecodriving cannot be halted.

Directive 2003/59/EC of the European Commission on the initial qualification and periodic training of professional drivers specifies the aim of implementing improvements, especially in traffic safety and rational driving behaviour based on rules of safety and teaching special driver-oriented skills and knowledge.

This training brochure and the supplementary training materials, which can be found at www.actuate-ecodriving.eu, on initial and advanced training of (hybrid) bus drivers means ecodriving of hybrid buses can be taught within the scope of this European Directive.

Who benefits from ecodriving?

However, energy-saving does not only mean actual savings in fuel.

The driver

- The driver is more relaxed, not stressed
- Fewer sickness days, fewer accidents

The passenger

- The passenger feels safer because s/he senses the calmness of the driver through their driving behaviour

The vehicle

- There is less wear, the drive systems are treated with more care.

The environment

- Less emissions and particulate matter are produced.

The company

- Ecodriving with hybrid technology can realistically lead to an (additional and not technology-based) reduction in fuel con sumption of c. 5 per cent, based on the experience of the ACTUATE partner company Leipziger Verkehrsbetriebe (LVB, Germany). A model calculation for the LVB: With an annual consumption of around 4.5 million litres of fuel, savings of c. 225,000 litres of diesel fuel can be expected for the Leipzig bus fleet. In financial terms this would means savings of around € 280,000 per annum for the LVB.

Fuel consumption should be lowered by a minimum of 5 per cent with hybrid technology.

2 Relevant factors

Ecodriving is subject to several factors. There are external factors, such as the traffic situation, topography or weather conditions, that cannot be influenced by drivers. However, there are factors that can certainly be influenced by drivers. Ecodriving is one of them. Ecodriving means driving which is low in consumption and wear on materials as well as eco-friendly. It is largely dependent on

- the level of technical development, especially of software
- the level of maintenance
- design, traffic density and occupancy of the hybrid bus
- driving behaviour of the driver
- conscious use of auxiliary equipment, e.g. air-conditioning and heating

2.1 The human factor

Drivers must be aware that an energy or fuel-saving style of driving can only be achieved by them. Part of the energy can be recovered, especially by the retarder. In practice it is often not possible to apply this driving behaviour due to external factors (see above) outside the influence of drivers; however, it should be practised as often as possible so that drivers acquire permanent practice in this driving behaviour. For many drivers learning about ecodriving means changing their driving habits, something which is not achieved overnight.

In order to better evaluate the impact of eco-driving on fuel consumption, it is useful for suitable measuring devices to be available. These should be agreed with the bus manu-facturer if possible, in order to minimise measuring errors or inaccuracies. The installation of displays within the line of vision of the driver is useful in order to have an immediate impact on driving behaviour.

This results in the advantage that drivers can apply ecodriving independent of the line (topography) and time of day. If the driver is then in a position to view his/her personal readings and compare them with the results of others, this reinforces their motivation to actually apply the ecodriving style which they have learnt. Raising the level of success depends on the voluntary nature of and confidence by drivers that their data will be treated as confidential.

After evaluation of more than 200 practice runs during the practical part of training, it can be said that:

- accelerating as described in the instruction manual should not be done by flooring the accelerator but should be done swiftly
- the rolling phases should be as long as possible while adhering to the schedule
- unnecessary braking should be avoided
- wear-free brakes (with retarder) should be used to recover energy

2.2 The factors infrastructure and topography

Factors that cannot be influenced include the topographic features of the line. These include upgrades and down slopes as well as the special inner city area where scheduled buses run.

2.3 The speed factor

Speed and braking distance have an inseparable reciprocal effect on each other. When selecting speed, various other factors must be considered. For example, visibility, road and weather conditions as well as occupancy of the vehicle and the individual skills of the driver are of decisive importance. Stress in particular, caused by a shortage of time for scheduled services, has a negative effect on the personal skills and hence on the ecodriving behaviour of drivers. Braking distance is also strongly influenced by these factors.

There is a rule which says that the braking distance increases in a quadratic relationship to speed. Put simply, this means:

If you double speed,
you quadruple your braking distance.

Higher average speed is not achieved by individual speed peaks but by a smooth manner of driving.

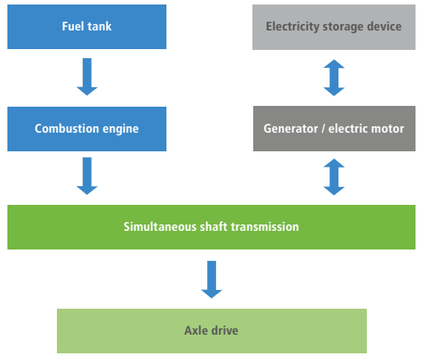
Hybrid: A system that combines two types of technology.

3 Basic technical principles and vehicle technology – hybrid bus

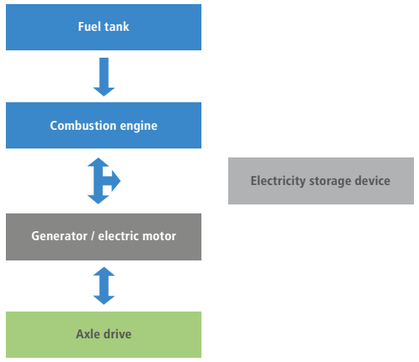
3.1 Basic technical principles

The word hybrid means "something which is combined, crossed or blended". It is derived from the Latin work "hybrida".

In technical terms hybrid means a system that combines two types of technology. In vehicle technology the term hybrid is applied to two types of energy or drives. The most prevalent hybrid variant is the combination of a combustion engine (i.e. diesel, petrol or liquefied gas) as the main energy source and an electric motor with storage in the form of an accumulator or double-layer capacitor. In practice this normally means the combination of a combustion engine with one or more electric motors in the same vehicle. A differentiation is made between parallel and serial hybrid drives.



With a parallel drive system the drive axle is driven by a combustion engine and one or more electric motors simultaneously. The standard power train is largely retained, therefore the vehicle can be powered by the combustion engine. The manual or automatic gearbox is disadvantageous. Furthermore, it is difficult to design a purely electric drive system. In contrast to the parallel drive system, with a serial hybrid system the vehicle is powered by only one or more electric motors. The combustion engine simply powers a generator to generate electricity. The positive features of the electric motors have proved advantageous for this drive concept.



This includes, above all, smooth starting off and storage of the recovered braking energy. Furthermore, it is easy to use other energy sources, such as fuel cells. The disadvantage is the high costs caused by the additional expense of installing the electronics.

3.2 Vehicle technology

First of all it must be ascertained what type of drive technology is used in the company. However, ultimately it is the electric motor that generates propulsion for all drive types. Furthermore, electric motors are characterised by the fact that when energy is supplied the full torque is available almost immediately over a greater rpm range in comparison with a diesel engine. Gearing mechanisms to utilise revolution speed can be dispensed with. Apart from the advantages listed above, start-stop management of the combustion engine, the smaller size of combustion engine needed for the base load (downsizing), high energy recovery performance by electric motors and less wear on brake pads also play a significant role.

When the electricity storage devices are full, the control electronics draws the required power from the storage device. If the storage device is drained to a pre-defined level, the combustion engine starts automatically. It generates electric energy which can then be supplied to the propulsion motors. If the vehicle is braked by the driver, the propulsion motors act as generators and generate electricity. The electricity replenishes the storage devices. This effect can be significantly boosted by the use of an electric rheostatic brake. If the system recognises that the vehicle is being braked or if the vehicle stands still for several seconds, the combustion engine is switched off automatically.

The generated electric energy is provided to the motors.

In addition to better utilisation of braking energy for acceleration, there is another advantage. On certain sections it is possible to drive using only electrical power if the storage devices have been replenished previously. The pollution from vehicle exhausts can be reduced to zero, especially at highly frequented stops.

The installation of "event points" is a further possibility. Event points are points marked via GPS which prescribe a certain type of operation for the propulsion system. For example, not only is the maximum speed defined for a bus line through a residential area, but the maximum rpm is also defined. Apart from saving fuel, the reason for this is to lower exhaust emissions and control noise.

4 Ecodriving in scheduled passenger services

The aim of driver training is to train drivers to become safe, responsible and environmentally conscious road users. However, many factors combine to push ecodriving in particular into the background time after time.

But ecodriving starts before starting the motor. The HVAC system can be adjusted manually by the driver. By selecting a sensible setting the driver can help to lower energy consumption. Furthermore, heating or cooling of the passenger section through open doors or windows should be avoided.

In order to make the timetable as efficient as possible, the intention is to offer as few routes as possible. Less routes mean lower costs. In order to achieve this, journey times and turning times at terminals must be kept as short as possible. But if road works or obstructions occur in the network, many drivers try to make up for lost time by driving faster. These drivers are taxing their nerves, they become hectic and nervous and so become prone to making further errors, thus impacting safety. These drivers are damaging their health and the vehicle technology is also put under a great strain. This results in higher wear on vehicles and of course in excess consumption of energy.

Passengers also notice this driving behaviour and are unlikely to feel at ease. That is why ecodriving is so important. You hardly need any extra time but you are more relaxed, healthier, there is less wear on the vehicle and on the infrastructure and you attract more passengers with safe, anticipatory driving behaviour. Ecodriving can, of course, be transferred not only to (hybrid) buses running on diesel, but also to other "clean" vehicles such as trams and light rail vehicles, underground railways, trolley buses and also to electric bus technology.

The principles for optimum driving behaviour must therefore be formulated as follows:

Safety
Safety is the first priority. Everything else is subject to safety! Safety, or security, is derived from the Latin word "securitas", which means "providence" or "without care". It describes a condition considered to be free of danger. Passengers should board a local passenger train "without care" and it should bring them to their destination in a "careful" manner. Ecodriving always means anticipating when driving, the be-all and end-all for safety in road traffic.

If an accident occurs, the traffic control division of the company must be informed. The fact that the vehicle is a hybrid type should be mentioned. If there is a suspicion that the high voltage network could be affected by an accident, special care must be taken. The electrical installations in hybrid vehicles are voltage class B, with voltages ▸ 60V DC and ▸ 25V AC. In the event of danger, the high-voltage on-board power system must be disconnected from the high-voltage traction energy storage device and powered down. It should be noted that there are still highly dangerous high voltages present despite the electricity storage device being switched off. Basically this means that orange coloured high voltage cables should not be severed; if they are damaged they can cause irreversible or life-threatening injuries or even death.

Cost-effectiveness
Cost-effectiveness is a general measure of efficiency and sensible use of resources. The aim is also to use as little energy as possible to get from A to B. Furthermore, a balanced, well thought out, energy-efficient mode of driving minimises wear on omnibuses or hybrid buses and on roads. Energy saved means money saved!

Punctuality
Customers expect punctuality from their public transport system. Services should never leave stops too early. Unfortunately, it is often not possible to avoid delays in journeys in the midst of individual means of transport. Punctuality should never be enforced at the expense of reduced safety (taking risks when driving). Imprudent driving at high speeds not only poses a risk to safety but also increases wear on vehicles and infrastructure. Economic and anticipatory driving is not synonymous with longer journey times, as proved by experience garnered in practical sessions of the training courses on ecodriving offered in partner cities in the ACTUATE project (e.g. in Leipzig for the hybrid bus or Salzburg, Austria, for trolley buses).

Customer orientation
Customer orientation is an important tool for transport companies when creating their public image. Customer orientation is often called customer service. In this special case it means satisfying customers' wishes regarding the "passenger transport" service. This is complemented by services such as helping passengers with limited mobility when boarding or exiting vehicles or providing information on the price of tickets, etc.

Customers want to deal with competent employees and not stressed, exhausted drivers who react to a question with a dour grumble. They want to feel safe and secure (see safety). A driver who uses a balanced, economic way of driving is less stressed and can respond better to customers (passengers). Drivers and passengers feel more at ease and more secure with a gentler, more economic way of driving.

An anticipatory, smooth style of driving is less stressful for driver and passengers. The less stressed everyone is, the friendlier they will be.

Drivers can extend their knowledge and skills regarding special drive technology in eight training units.

6 Training

The theory part of training is divided into eight training units with the following content (see also the training presentation at www.actuate-ecodriving.eu):

1. *Features of the various alternative drive systems*
- parallel drive
- serial drive
- different electricity storage devices (supercapacitors, capacitors, batteries)
- driving behaviour of hybrid vehicles (city bus) especially braking and cornering characteristics, focal points

2. *Knowledge of characteristics of electrical components*
- Definition of voltage, current rating, resistance, power, loss
- How can you recognise electrical components?
- What causes a loss of voltage or power?
- Generation of heat/cooling of components

3. *What is the difference between diesel and electric motors?*
- repetition of working principle of combustion engine
- design / working principle of electric motor
- performance chart for combustion engine/ electric motor
- impact on driving operations

4. *Where can the characteristics in power progression to be found?*
- difference to standard power progression
- serial and parallel drive system/mixed forms
- common elements of drive systems

5. *Knowledge of the ideal driving cycle and utilisation of topographical conditions*
- various means of charging storage devices
- utilisation of the electric brake
- utilisation of the service brake
- utilisation of topographical conditions

6. *What to do if a malfunction or accident occurs when hybrid vehicles are involved*
- How can a driver recognise high-voltage cables?
- What is high voltage?
- Risk of injury / electric shock
- Securing the vehicle
- Disconnection / powering down electric circuits
- Information for emergency services / fire brigade in relation to high voltage

7. *Knowledge of dangerous high voltage parts in vehicles*
- supercapacitors
- lithium-ion batteries
- high-voltage cables
- emergency switch
- rectifier

8. *What effect does ecodriving have on the environment?*
- environmental performance evaluation
- CO_2 emissions
- environmental compliance / areas
- fuel consumption

Documenting measurements allows for a before-after comparison.

In addition to theory, the practical part of driver training is especially important for drivers in relation to eco-driving. The practical part comprises practice runs with the hybrid bus under the supervision and instruction of the driving instructor, in a best-case scenario with a before-after comparison - related to theory with hints and instructions on ecodriving - of fuel consumption. Application of the (repeated) theory in practice will (hopefully!) result in a reduction of fuel consumption during the "after" practice run.

In order to demonstrate to drivers the success of training in "black and white", preparations should be made for measuring fuel consumption during training. Procurement of measuring systems and retrofitting buses can be a significant item of expenditure (especially installation or retrofitting).

However, careful planning will ensure that the measuring systems can continue to be used to monitor fuel consumption in order to provide long-term comparisons and reviews of the success of the learning process. Data protection requirements must be observed at all times. Further possibilities to consolidate training would include distributing reminders or the introduction of bonus systems to encourage saving energy.

Tips on the practical part of training

- Selection of a "real" route/line for the practical part and ensuring conditions are as realistic as possible (for example, driving behind a scheduled bus in order to simulate approaching, stopping and moving off from bus stops as close to reality as possible)
- Determination of a certain sequence of drivers
- Prepare energy measurements during driving
- Application of "normal driving behaviour" ("before" run)
- If possible the same route and sequence of drivers should be retained for the "after" run (with similarly realistic conditions if possible)
- Teach driving behaviour, including informa tion provided during the theory part, during the "after" run
- Repeat energy measurements for a comparison of possible reductions in energy compared to the "before" run

8 Concluding remarks

After completing the training programme, a reduction in energy or fuel consumption should be noted. However, it must be clear that this effect must be constantly worked on. In addition there will be fluctuations in drivers.

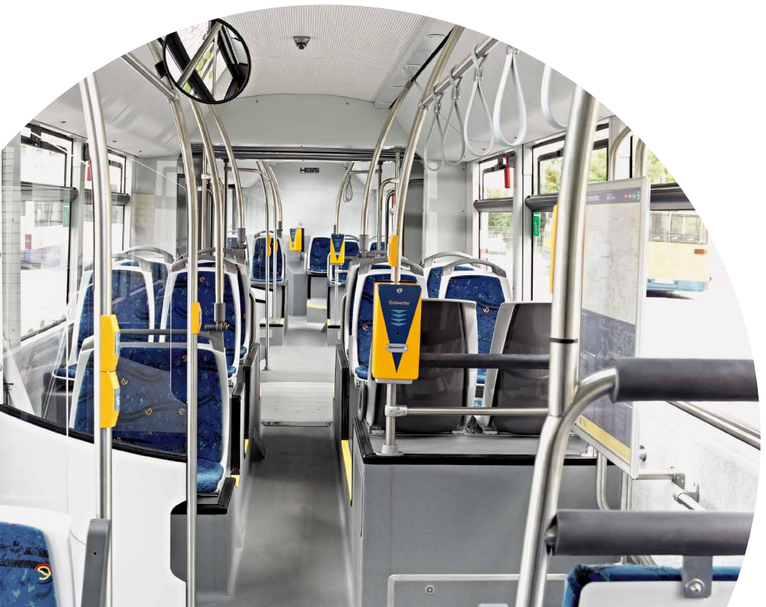
Therefore further training sessions will be necessary in order to remind drivers of the following "golden rules" for ecodriving of (hybrid) buses:

- Always stay calm.
- Never accelerate to the maximum but accelerate evenly until the required speed is reached.
- Make the best use of rolling.
- Brake evenly, remembering passengers, using regenerative brakes.
- Make sensible use of auxiliary equipment such as heating and air-conditioning.
- Concentrate and be aware when driving.

The potential offered for saving energy through ecodriving of hybrid buses is illustrated, for example, by the results of energy measurements taken in Leipzig (c. 5 %). Every single company that intends to save energy or fuel through well-trained drivers can utilise this training booklet, adapt it to the relevant city or local conditions and put the training concept into practice.

This training booklet, developed under the direction of Leipzig's project partners in the ACTUATE project, will help you to start to tackle the subject of saving energy through ecodriving hybrid buses in your company.

We wish you every success!



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The ACTUATE consortium comprises five local public transport companies from Salzburg (Salzburg AG, Austria), Brno (DPMB, Czech Republic), Parma (TEP S.p.A., Italy), Leipzig (LVB) and Eberswalde (BBG, both Germany) who are already operating electrically powered vehicles, Leipziger Aus- und Weiterbildungsbetriebe (LAB - Leipzig Training Institute), the Belgian bus manufacturer Van Hool and trolley:motion, the international association to promote e-bus systems with zero emissions (Austria). Rupprecht Consult GmbH (Germany) is responsible for project coordination.

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The six golden rules for eco-driving

1. Always stay calm.

2. Never accelerate to the maximum but accelerate evenly until the required speed is reached.

3. Make the best use of rolling.

4. Brake evenly, remembering passengers, using regenerative brakes.

5. Make sensible use of auxiliary equipment such as heating and air-conditioning.

6. Concentrate and be aware when driving.

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