ACTUATE

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ACTUATE

“Advanced Training and Education for Safe Eco-driving of Clean Vehicles”

For more information go to http://www.actuate-ecodriving.eu/

- Project for the **optimisation of driving behaviour to reduce energy consumption**
  - Development of training programmes and general training measures for ecodriving electrically powered vehicles in local public transport.
  - The focus 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.

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ACTUATE Consortium

- 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
  - as well as the 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** (Germany) is responsible for project coordination.

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Basic qualification and advanced training

- **Basic qualification**

  for all professional drivers mandatory before starting work

- **Advanced training**

  proof of advanced training must be provided when working in this profession

- according to Directive 2003/59/EC, the structure of advanced training comprises
  - 35 hours of advanced training in 5 years
  - in most EU countries advanced training is provided in units of 7 hrs p.a.
- This advanced training material can be used for the advanced training unit “Ecodriving”.

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Structure of advanced training

- Introduction and working principle of the trolley bus system
- Driving practice - Part 1
- Ecodriving a trolley bus
- Driving practice - Part 2
- Safety aspects of trolley buses
- NB!

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Introduction

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Ecodriving in scheduled passenger services

- Ecodriving in scheduled passenger services means:
  - energy-efficient
  - low-wear and
  - eco-friendly driving.

- ecodriving helps
  - to preserve the environment
  - to provide a less stressful journey for passengers and drivers
  - to reduce energy and maintenance costs

3 rules of ecodriving

- **Rule of safety**

  All other rules are subordinate to the rule of safety

- **Rule of punctuality**

  Punctuality is essential for scheduled passenger services and means leaving a stop neither too soon nor too late

- **Rule of cost-effectiveness**

  Ecodriving means minimising energy consumption and lessening wear on the vehicle while complying with the rules of safety and punctuality

Energy source - e-mobility

- Utilisation of electric energy from renewable energy sources
- No loss during conversion in the production of renewable energy sources
  (in contrast to the refining process for petrol and diesel)
- Zero emissions locally
- Possibility of energy recovery during braking
- Efficiency factor of up to 99% for electric motors, but only up to 35% for diesel engines
  (lower for petrol and gas engines)

- **Electric drives are environmentally friendly and practically noiseless**

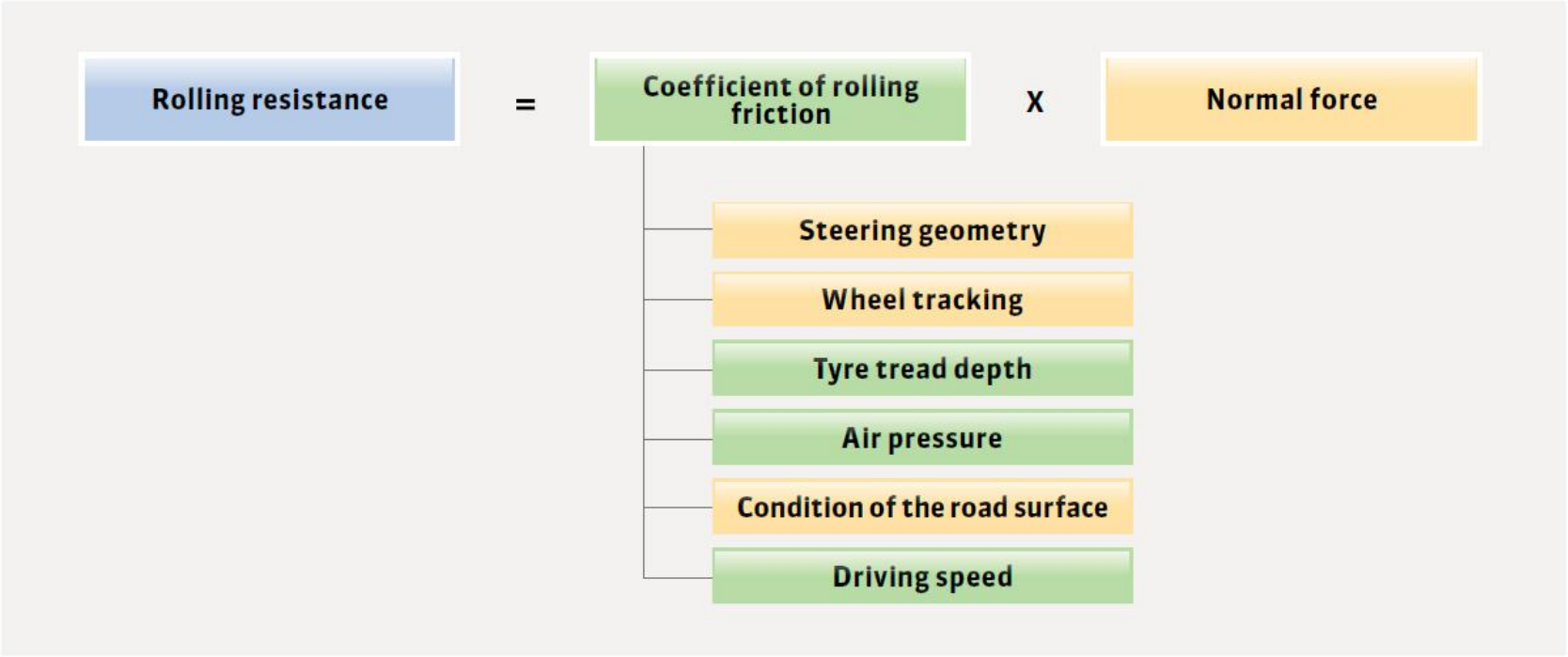
Running resistance and forces when a vehicle is in motion

- Running resistance acts permanently while a vehicle is in motion
- The resulting force acts in the opposite direction to movement and acts as a brake
- The driving force of the motor needed to overcome running resistance has a major impact on energy consumption.
- The following running resistance and forces act when a vehicle is in motion

Resistances and forces while driving			
Rolling resistance	Climbing resistance	Aerodynamic resistance	Acceleration resistance

Rolling resistance (1/3)

- Independent of adhesion force and normal force (weight of vehicle)



Rolling resistance (2/3)

- Factors influencing the rolling resistance coefficient depending on
  - tyre profile (normal tyres or snow tyres)

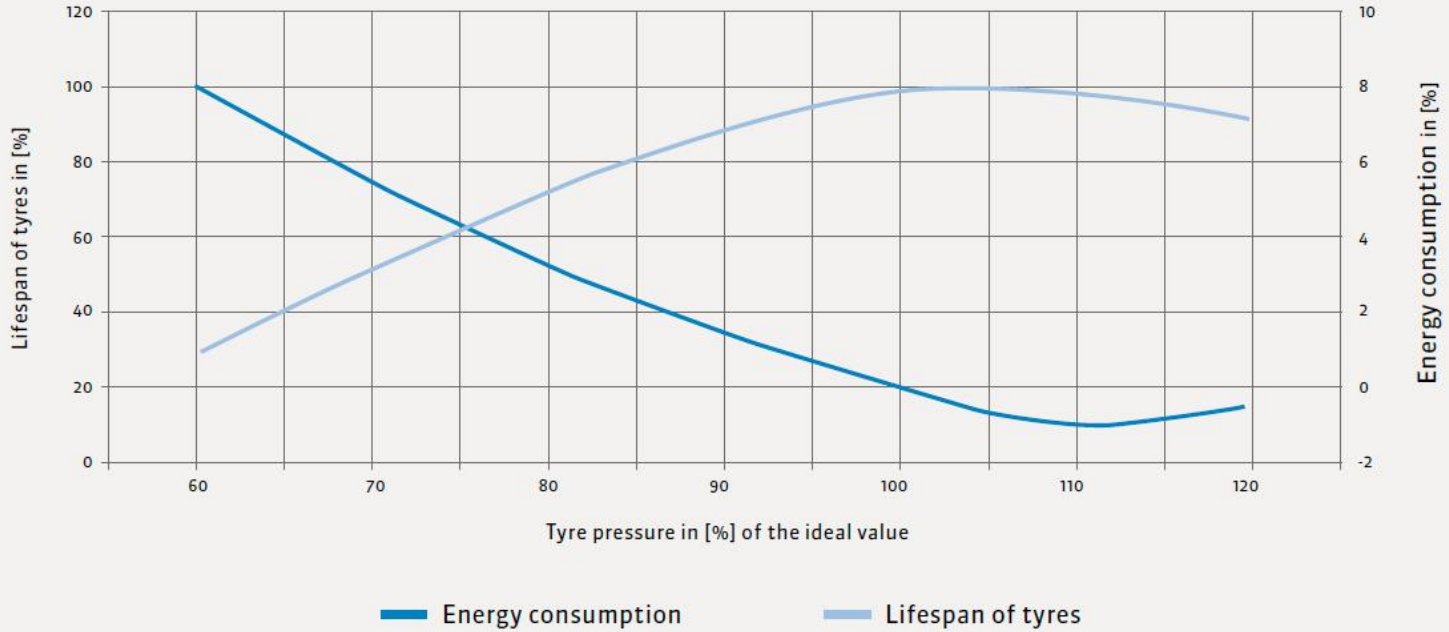
    Buses in Austria must be fitted with snow tyres from 1 November to 15 March
  - Tyre pressure

    Greater tyre pressure reduces rolling resistance, but has a negative effect on tyre adhesion and travelling comfort

    Lower tyre pressure results in greater rolling resistance and greater wear on tyres as well as the risk of tyres overheating
  - *Speed*

Rolling resistance (3/3)

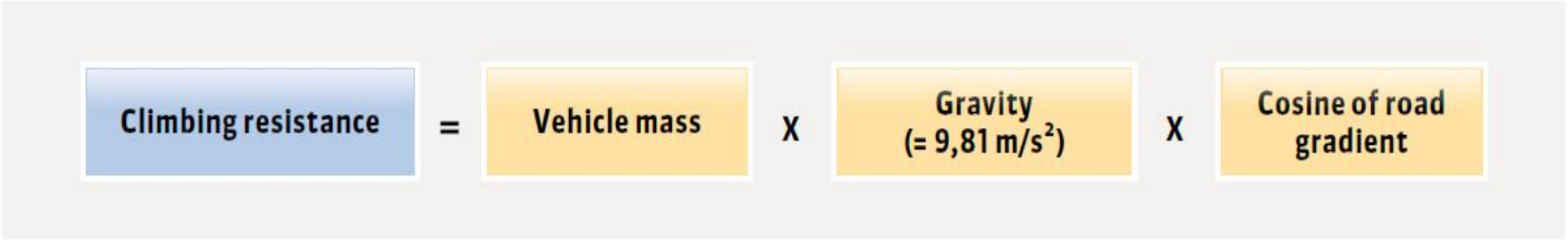
- Impact of tyre pressure on energy consumption and wear on tyres



Source: Eco-Training; Günter Meyer; Hubert Ebner Verlags GmbH

Gradient force

- this corresponds to the force required to overcome a difference in height upwards

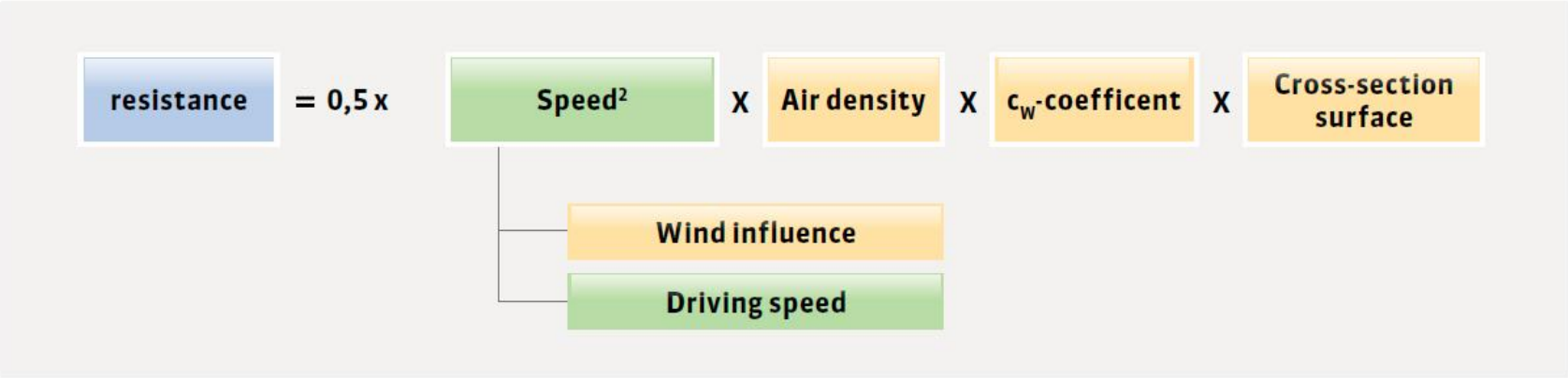


- the driver has no influence over grade resistance (except for selecting another route for non-scheduled services)

* Cosine: mathematical function, the greater the gradient, the greater this factor

Air resistance

- this is the force needed to displace air



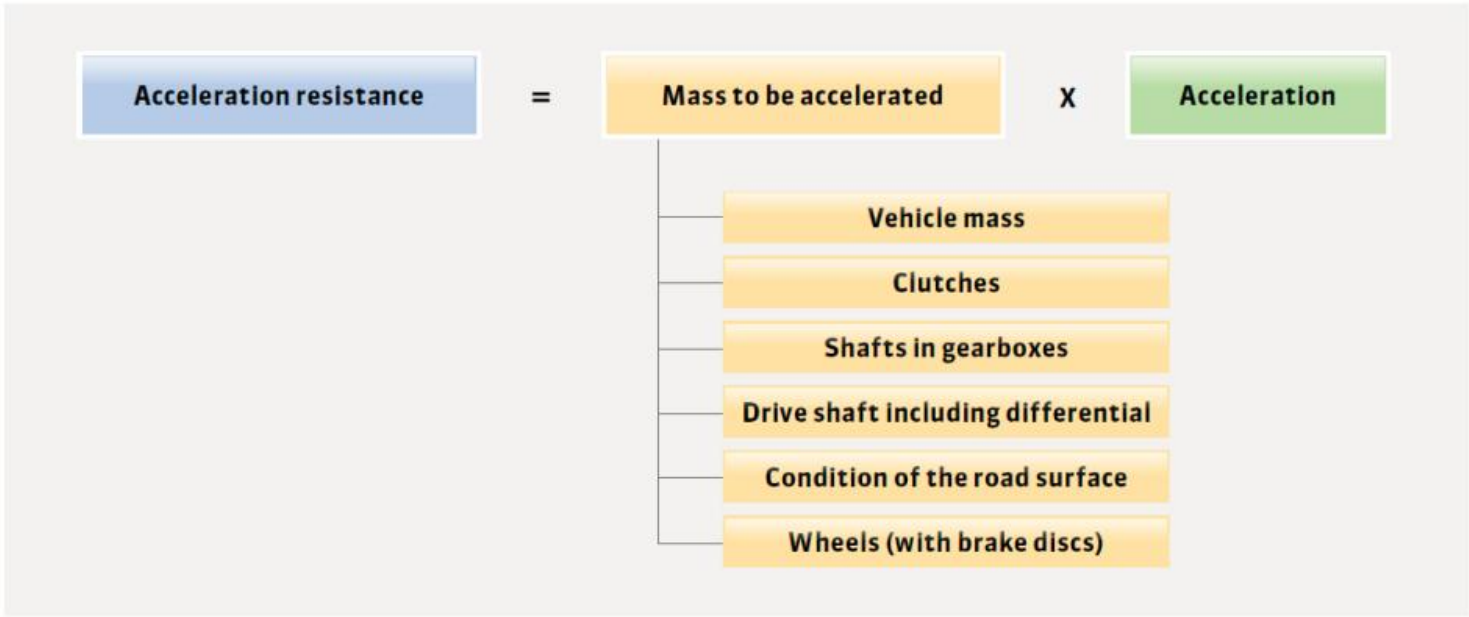
- quadratic relationship to speed

  double speed, fourfold air resistance

- also dependent on air density, vehicle shape (Cw value) and area cross-section of the vehicle

Inertia resistance to acceleration

- caused by the inertia of moveable parts installed in the vehicle
- The principle of inertia describes the tendency of a body to remain in a given condition unless acted on by a (driving) force



Significant factors

- Two significant factors for energy-efficient operation can be deduced from the correlations of the individual running resistance values

  - **before start of journey**

    inspection of the condition of the vehicle

  - **during the journey**

    conscious selection of speed

General use of trolley buses

- Zero emissions
  - Scarcely any use of non-regenerative energy
  - Low greenhouse gas emissions
- Quiet operation
- High performance, effortless acceleration/braking
- High level of travel comfort

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Working principle of the “trolley bus” system

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General information on the contact wire network

- Rectifier substations supply electricity

  These convert the electricity supplied by electricity suppliers to DC voltage and feed the electricity into the individual sectors

- Sectors separated by insulated overlaps

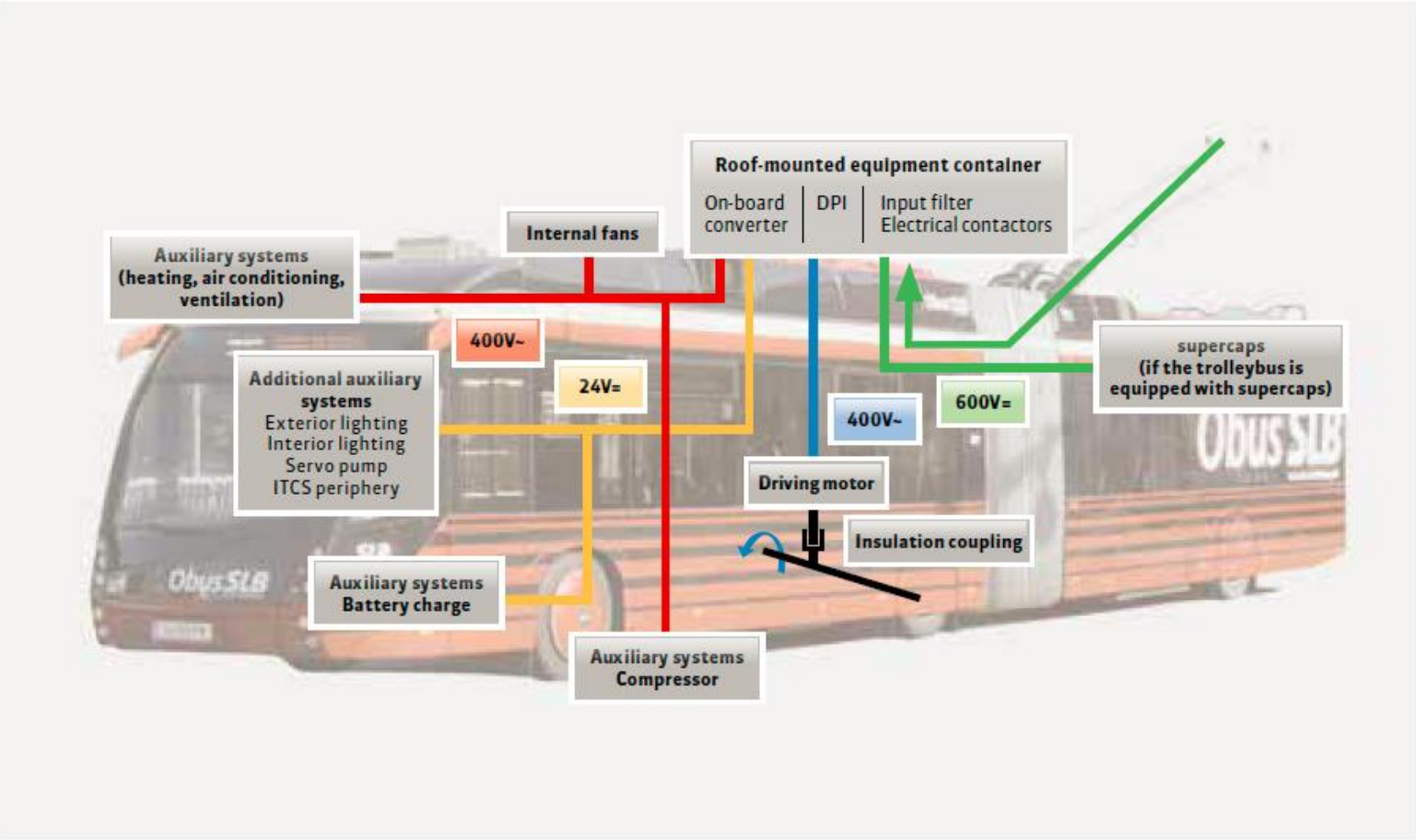
  Overlaps are crossed with switchgroup deactivated

- When the electric brake is applied the supercapacitors absorb the electricity recovered (and to an extent the lithium-ion battery) → When the supercapacitors are fully charged, the electricity is fed into the contact wire (however, another trolley bus must be in the same section to absorb the electricity)

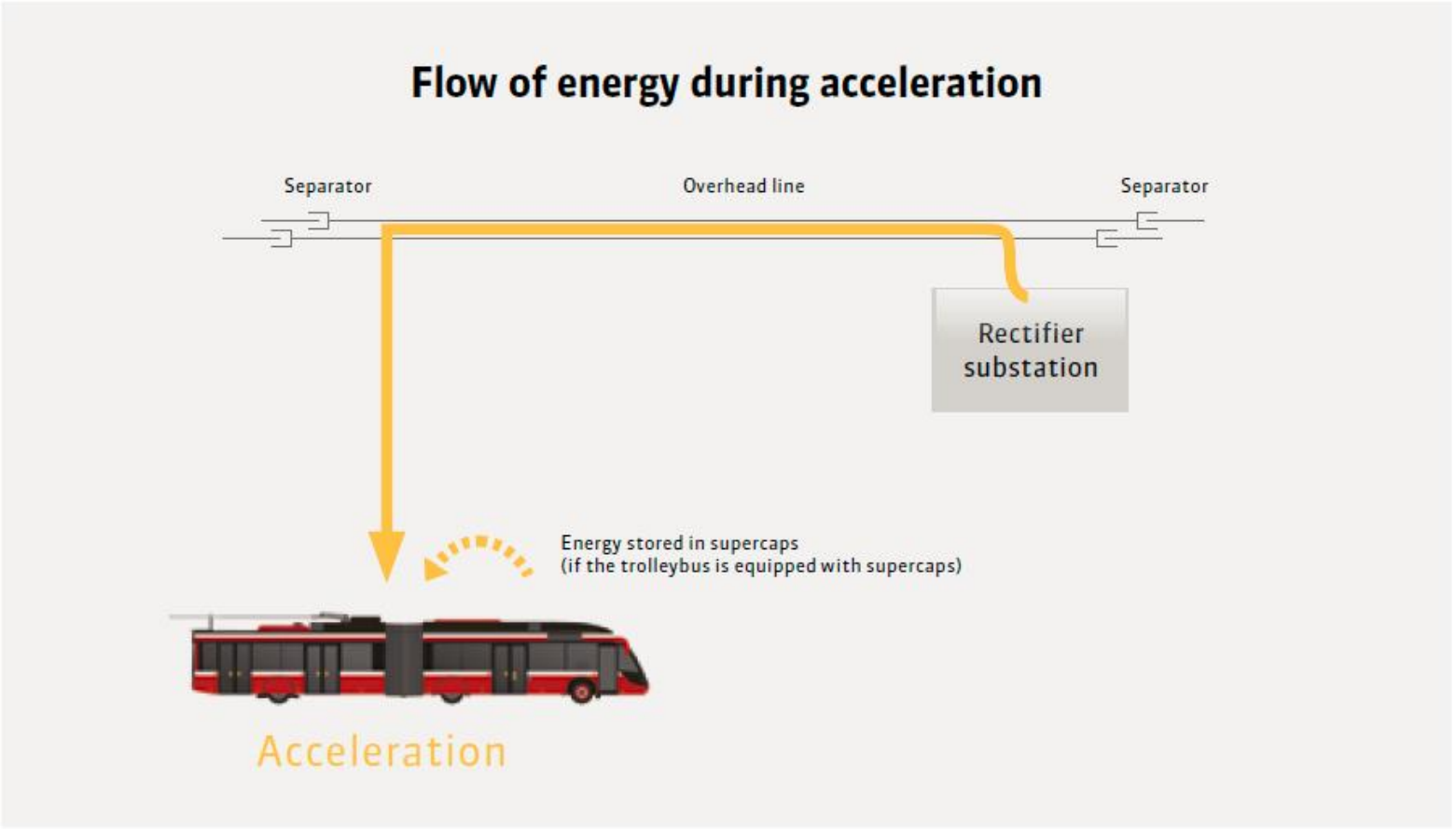
Electric brake

- Traction engine and electric resistance comply with statutory requirements as a drag brake
- **Energy recovery** during braking operations
- surplus energy not needed by the vehicle for auxiliary equipment is fed back into the contact wire
- the electric brake is **wear- and maintenance-free**

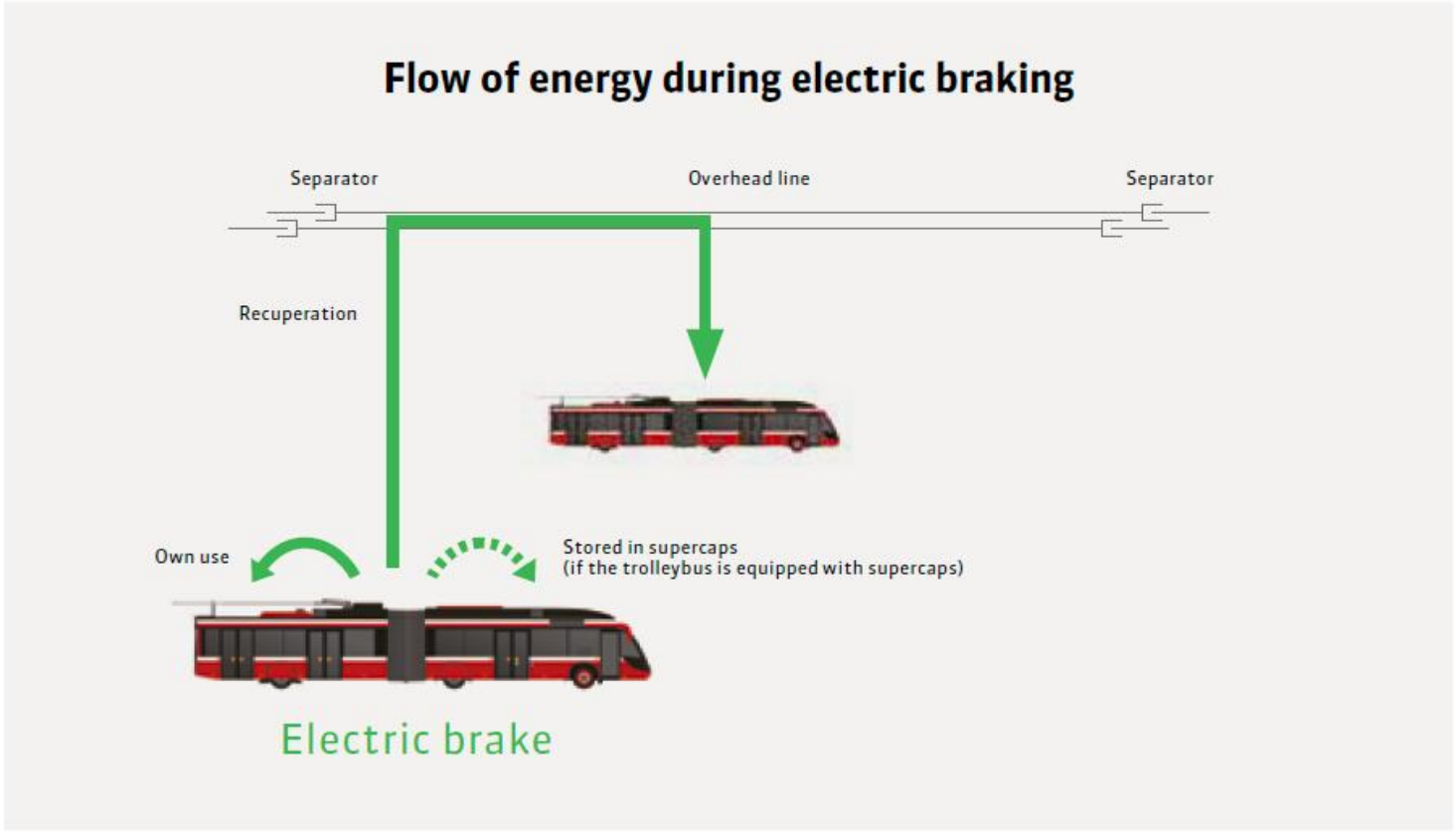
Energy flow in the trolley bus



Energy flow during acceleration



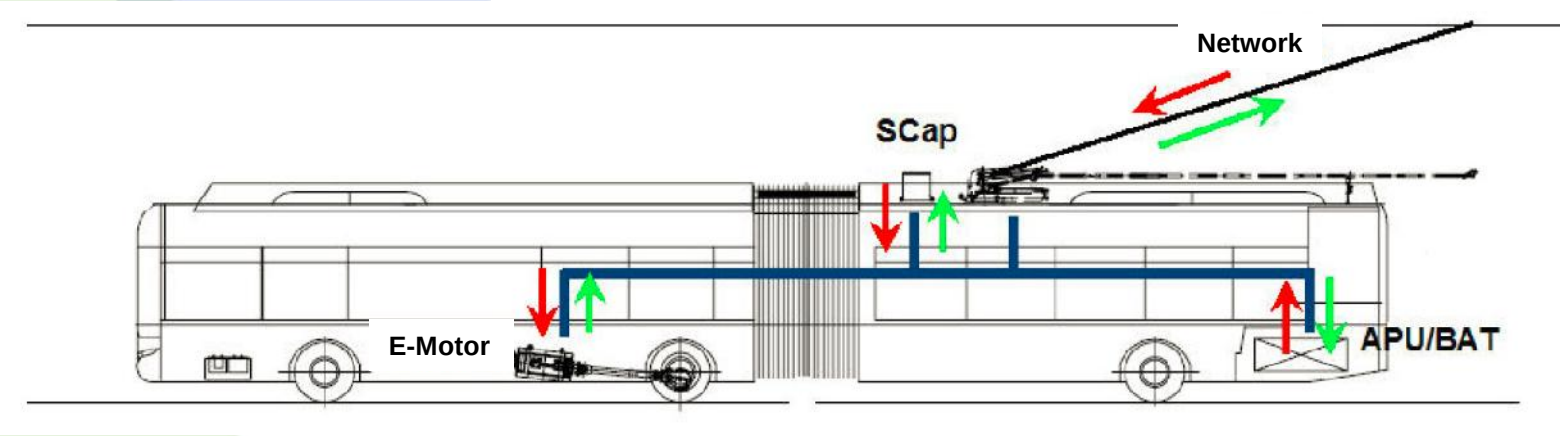
Energy flow during application of electric brake



Energy flow during acceleration and application of electric brake (with supercapacitors)

- During acceleration the trolley bus first uses electricity from the charged supercapacitors and then, when they are empty, from the contact wire.

- On application of the electric brake the recovered electricity is fed to the supercapacitors (and, where appropriate, to the battery also) for storage.

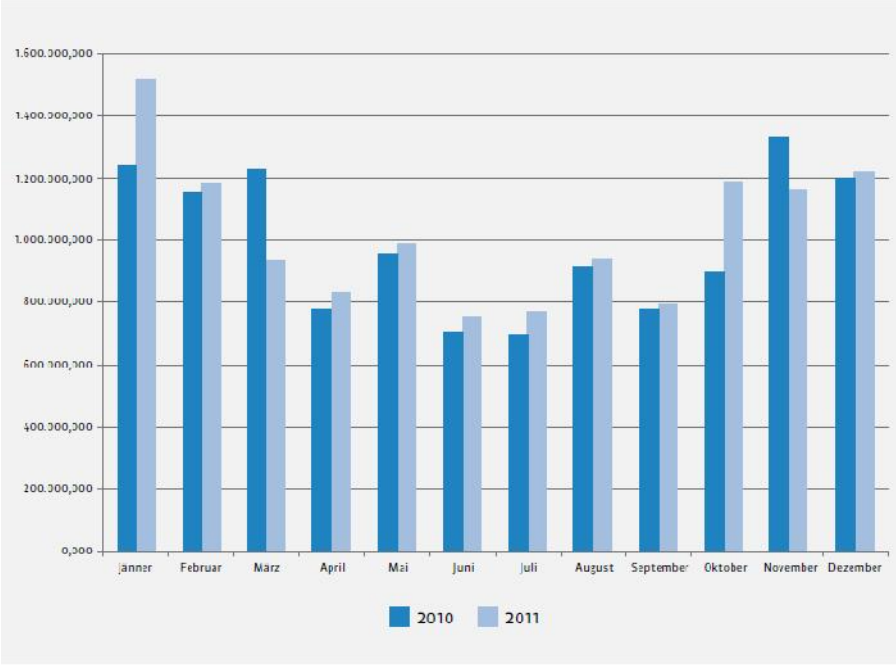


Energy consumption and influencing factors (example of Salzburg)

- fluctuating energy consumption due to varying utilisation of HVAC system according to variations in outside temperatures

- especially high energy consumption between November and February since the heating systems are in constant use

- at temperatures between -4°C and +4°C the average energy requirement for heating is 13.5 kW



Differences between trolley bus and diesel bus

- Energy conversion through combustion of diesel fuel
- Efficiency factor of diesel engines up to 35 % max.
- Power transmission through power train
  - friction connection with automatic transmission (hydraulic converter, friction disc, etc.)
  - non-slip with standard transmission (gear wheels)
- non-slip traction is loss-free; however, power train must be interrupted in order to change gear
- friction connection is lossy
- transmission in trolley buses is non-slip

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Driving practice - Part 1

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Tips on the practical part of Advanced Training I

- Selection of a “real” route/line
- Determination of a certain sequence of drivers
- Application of “normal driving behaviour”
- conditions 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)
- Prepare energy measurements during driving

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Ecodriving a trolley bus

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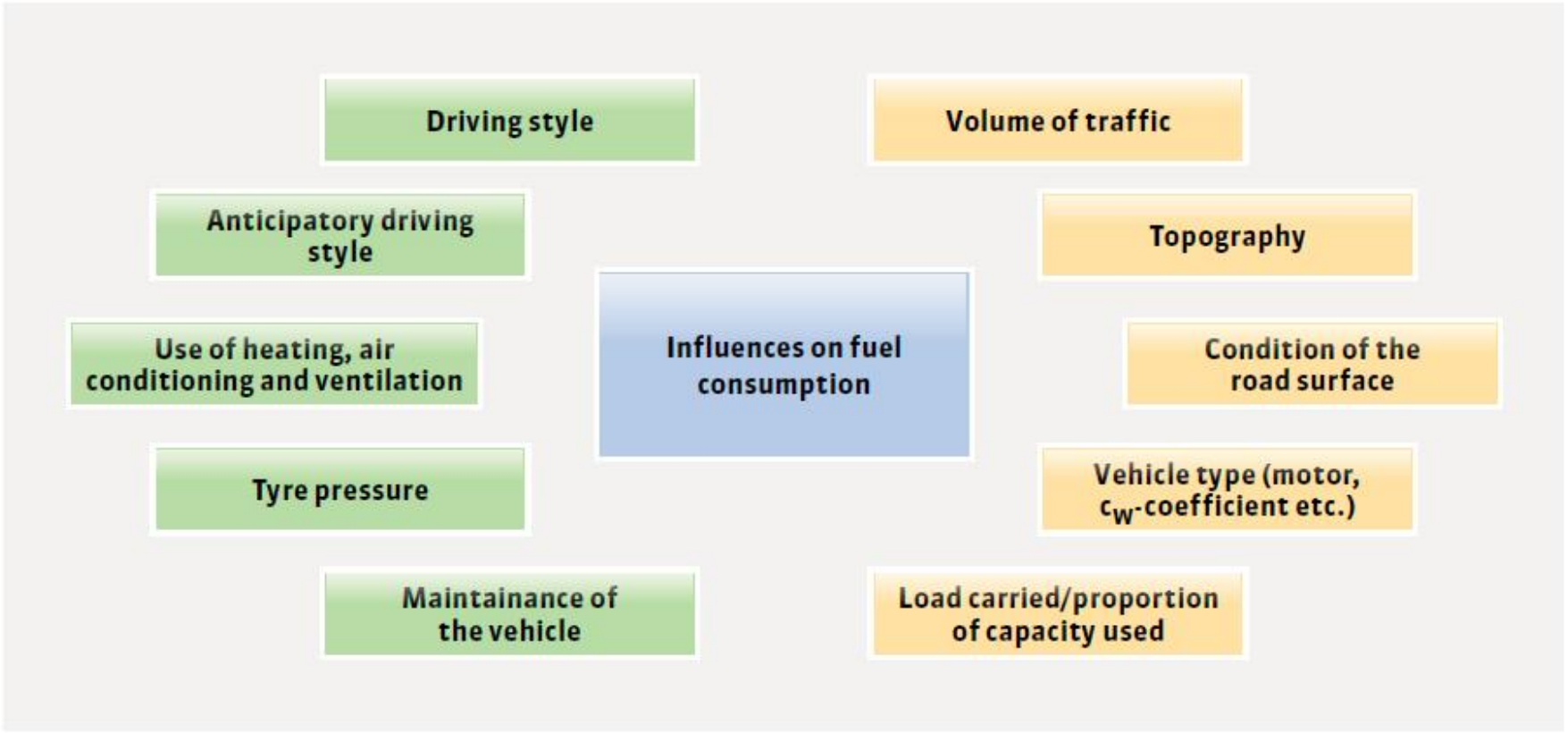
Factors influencing energy consumption



Controllable factors

- since traffic volume, routing and occupancy (weight) cannot be influenced for scheduled services, the factors
  - driving behaviour
  - anticipatory driving behaviour
  - adjustment of HVAC system

  become more important

- tyre pressure and condition of the trolley bus can be checked visually

Different driving conditions

- different driving conditions are possible when driving vehicles
- immediate connection between driving conditions and energy consumption
- 4 different driving conditions
  - Accelerating
  - constant velocity
  - rolling
  - braking

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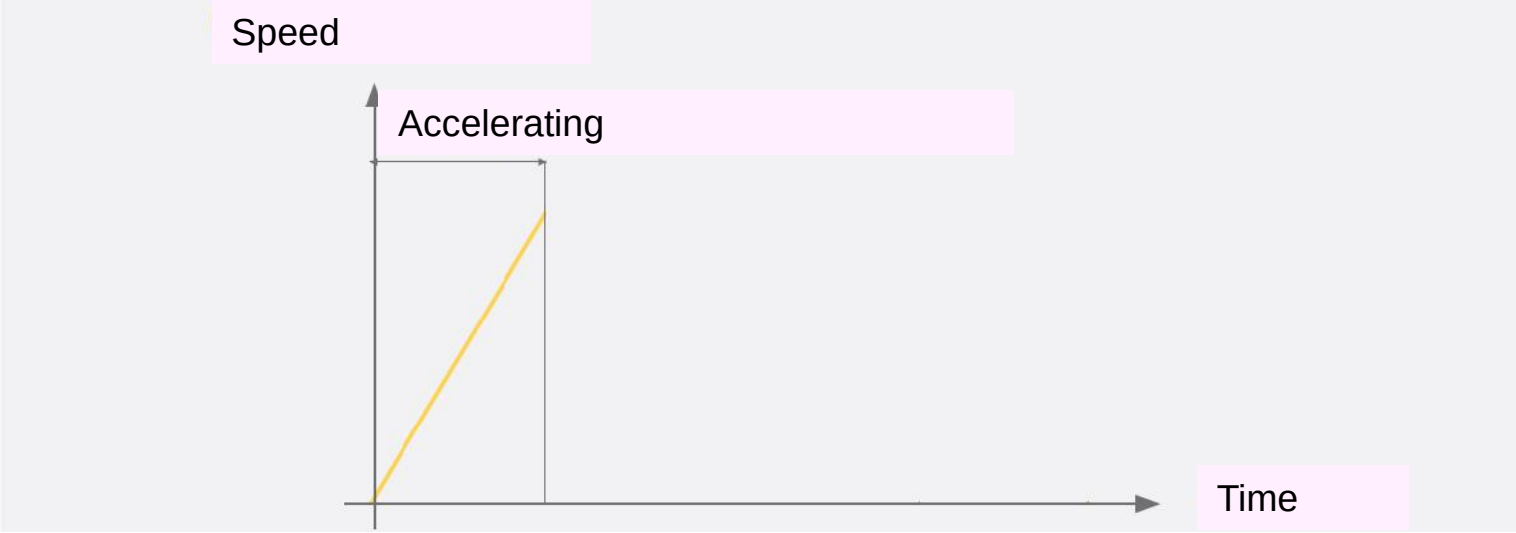
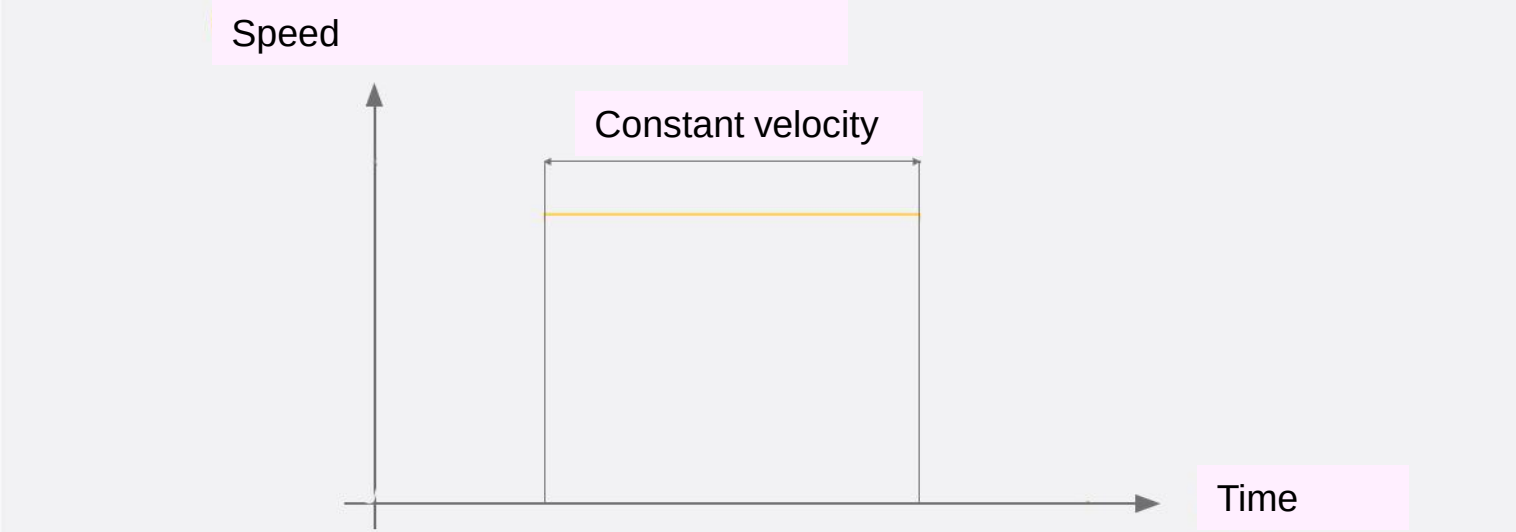
Accelerating

- means increasing speed by using energy
- the propulsive force of the trolley bus must be greater than the running resistance counter to the direction of travel



Constant velocity

- this means maintaining speed
- this means using exactly the amount of energy to match the running resistance counter to the direction of travel

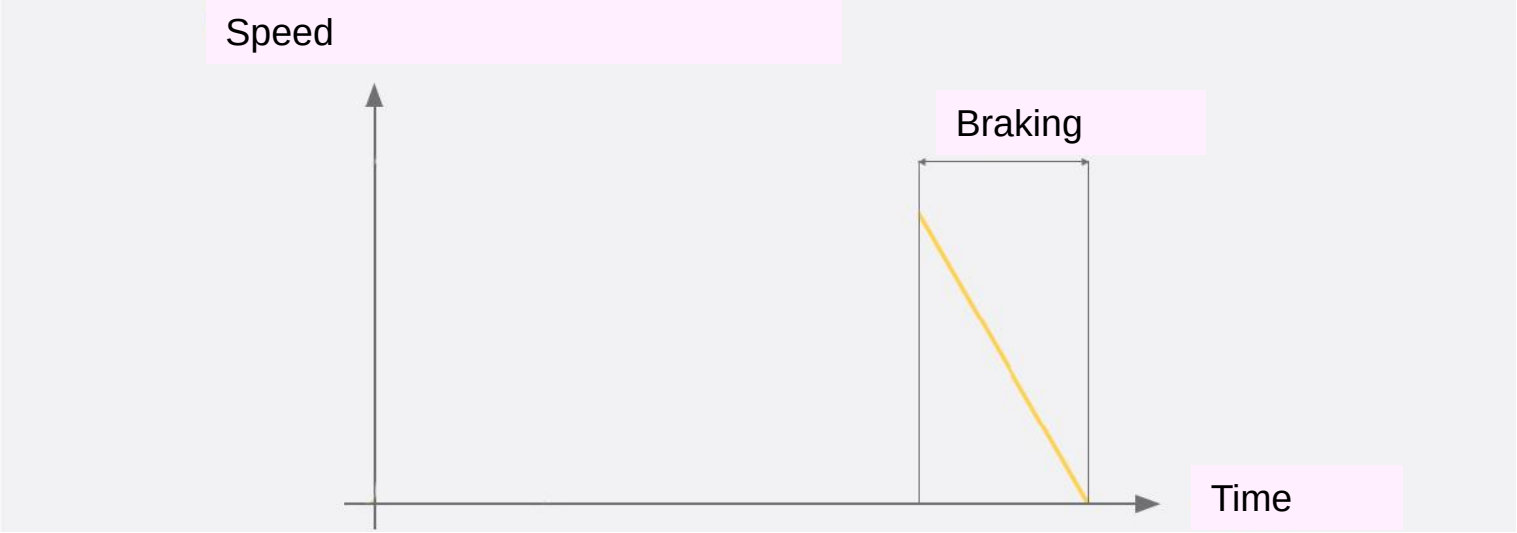


Rolling

- the accelerator pedal is not used when the vehicle is rolling and no energy is needed for it to move forwards
- Auxiliary equipment is supplied with power by self-excitation of the motor
- when the vehicle is rolling the speed drops due to the braking effect of running resistance

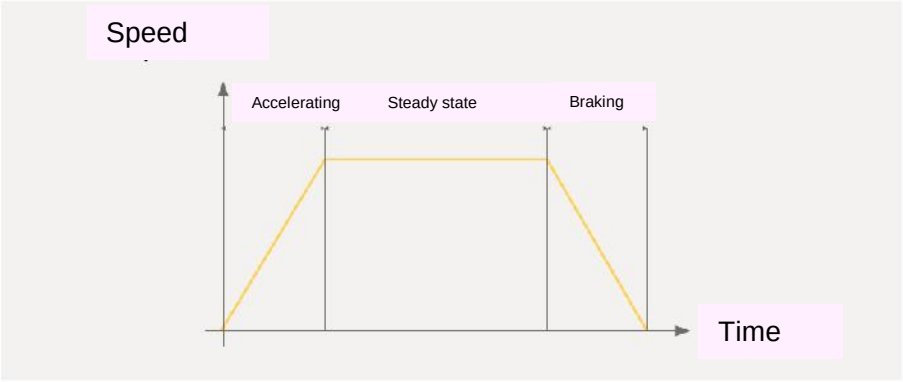
Braking

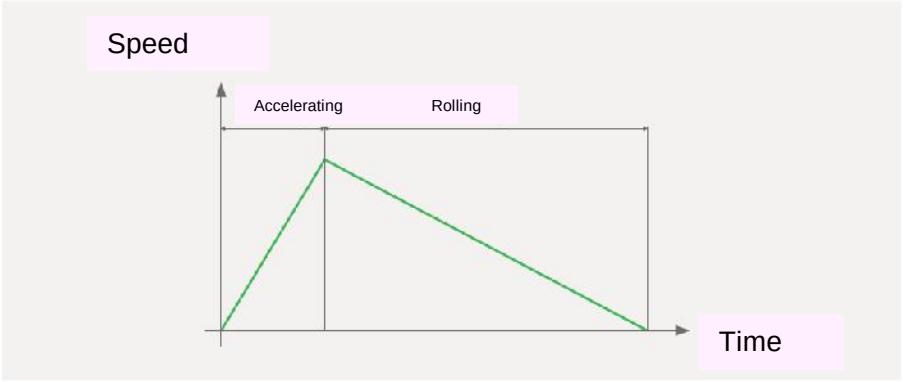
- braking means reducing speed
- energy recovery by application of the electric brake
- when braking with the pneumatic brake, all braking energy between brake disc and brake pad is converted to heat and is lost



Different driving cycles

- driving conditions when compounded result in driving cycles
- idealised representation of driving cycles with
  - section “constant velocity”
  - section “rolling”





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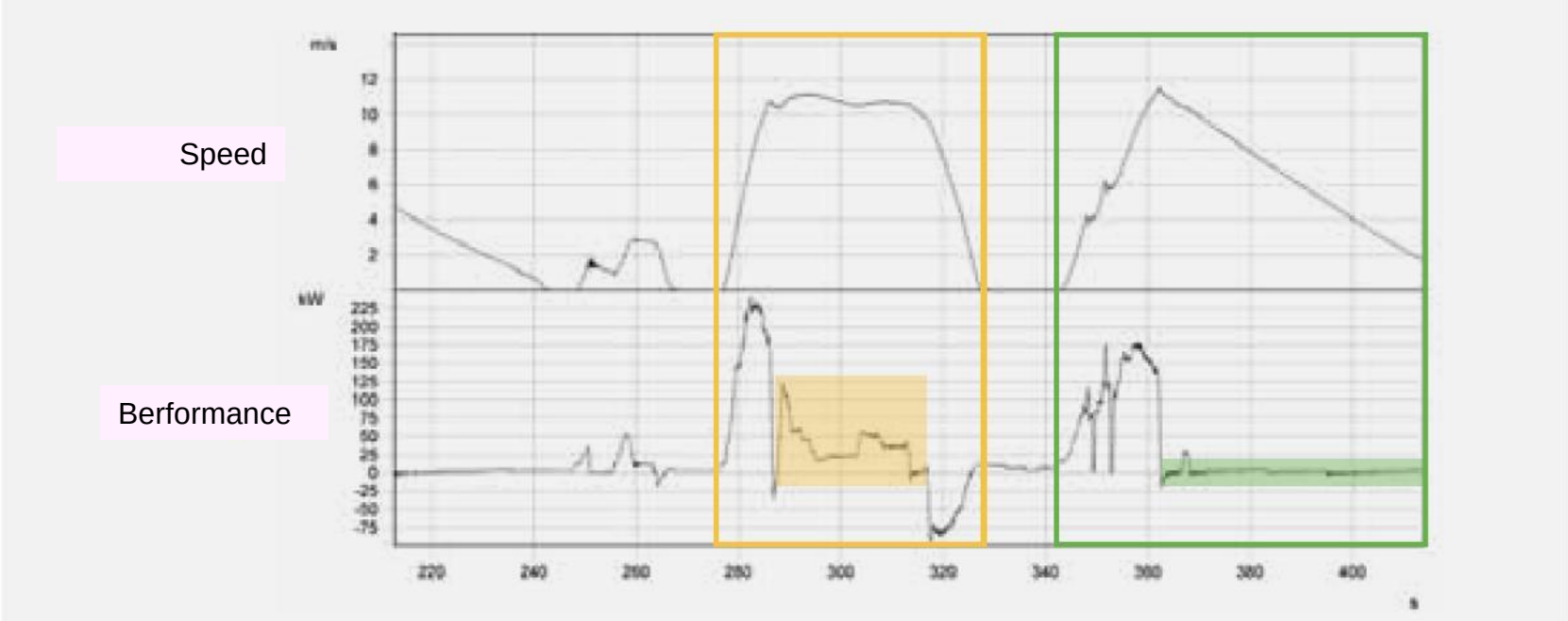
Actual driving cycles

- representation of energy consumption as area underneath the output curve
- higher energy consumption during constant velocity (yellow) than when rolling (green)



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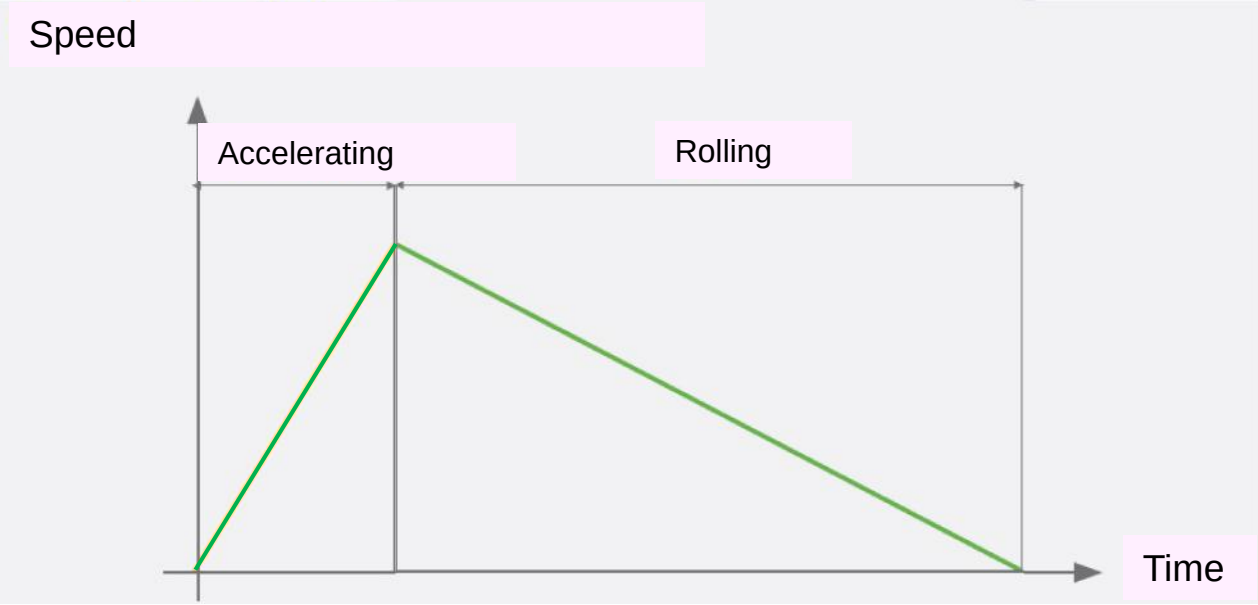
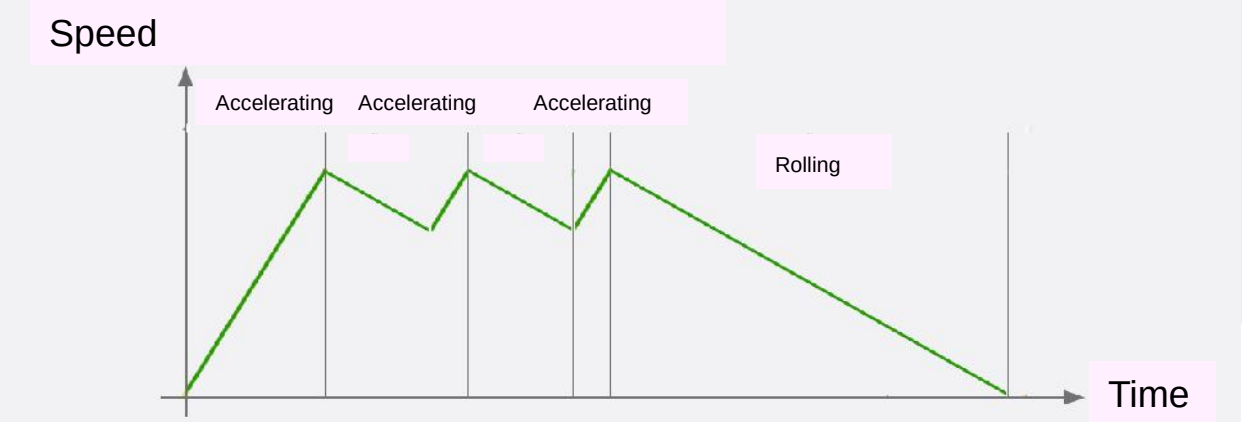
Ideal driving cycle

- in an ideal driving cycle acceleration is followed by a rolling section, coming to a standstill at the required stopping point
- this can be shown as a triangle in the speed-time chart



Driving behaviour for an ideal driving cycle

- accelerate as gently as possible but still quickly
- avoid a constant velocity altogether
- maintain speed in a sawtooth wave (acceleration - rolling)



- maximum rolling section while adhering to schedule
- brake ideally using the electric brake

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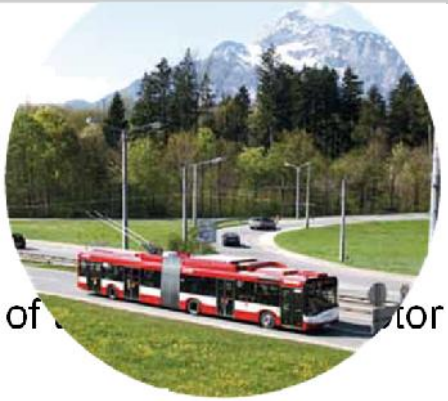
Impact on contact wire power

- each **acceleration** results in a **drop in the contact wire power** due to the energy needed

- each **application of the electric brake** results in a **rise in the contact wire power**

- **If supercapacitors are used, the drop or rise in power is significantly less**

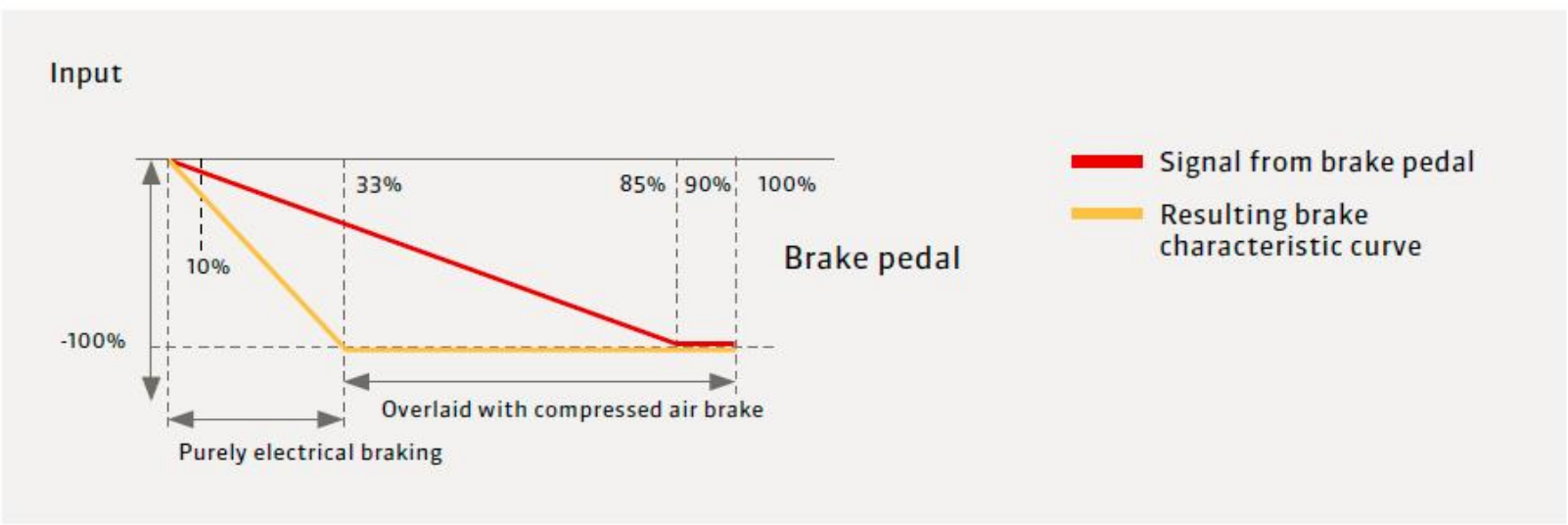
Advantages of rolling phases



- no energy is absorbed from the contact wire and
  auxiliary equipment is supplied with power through self-excitation of
- less wear on the mechanical pneumatic brake due to reduced approach speed to the next stopping point
- smooth driving style means greater travel comfort for passengers and driver
- **however, extended rolling sections are only possible with anticipatory driving behaviour and a well calculated distance to vehicle in front**

Advantages and function of the electric brake

- energy recovery during braking operations
- wear- and maintenance-free
- high level of travel comfort for driver and passengers
- the electric brake functions alone until the pedal is depressed c. 33 %



Conscious use of heating and air-conditioning

- avoid open windows and doors when heating or air-conditioning is on
- during longer stops and when turning, keep doors with door release closed or switch off heating or air-conditioning
- heating requires 13.5 kW at outside temperatures between -4ºC and +4ºC (example of Salzburg)
- new trolley buses have automatic heating and air-conditioning systems installed

Driving practice - Part 2

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Tips on the practical part of Advanced Training II

- same route as for Part 1
- same driver sequence as for Part 1
- make realistic conditions as similar as possible to Part 1 (if possible)
- driving behaviour, integrating information taught in the theory section
- repeat energy measurements in order to compare a potential reduction in energy consumption compared with 1st practical run

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Safety aspects of trolley buses

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Action if the pantograph is disconnected from the contact wire

- stop immediately, but with consideration for passengers
- put on hi-viz jacket before leaving the trolley bus
- a visual inspection must be made of pantograph and contact wire
- the following is prohibited
  - touching a trolley pole while the other is still connected
  - touching live parts of vehicle and contact wire
  - climbing onto the roof of the trolley bus
- before connecting the pantograph the main switch must be disconnected
- if a fault occurs, the control centre must be informed; wait for instructions from the control centre; a written report must be submitted

Action if the contact wire is damaged

- take special care if parts of the contact wire are hanging down!
- the driver of the first trolley bus to arrive on the scene is required to secure the area if there is a risk to other road users
- it is forbidden to touch hanging sections of the contact wire
- if a vehicle is in contact with hanging sections of the contact wire, the control centre must be requested to turn off the power immediately
- if necessary, the passengers must wait inside the vehicle until the emergency repair service arrives
- If a fire breaks out, the control centre must be requested to turn off the power immediately If this is not possible, the passengers must jump out of the trolley bus in order to avoid flash-arcs and the road surface must be isolated by laying down appropriate materials (e.g. dry clothing) when passengers exit the vehicle

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Failure and overload of the power supply

- if a power cut prevents the journey from being continued, utilise the speed of the vehicle, i.e. its momentum, and park the trolley bus so as not to obstruct traffic
- the parking brake must be applied to prevent the trolley bus from rolling away
- the pantographs should be disconnected
- trolley buses with an auxiliary drive should continue the journey using the alterative drive
- repeated power cuts within a very short space of time may mean the power supply is overloaded
- drive very carefully, avoid accelerating at the same time
- switch off the heating and air-conditioning systems
- comply with possible coordination of departures by the control centre

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3 rules of ecodriving

- **Rule of safety**

  All other rules are subordinate to the rule of safety

- **Rule of punctuality**

  Punctuality is essential for scheduled passenger services and means leaving a stop neither too soon nor too late

- **Rule of cost-effectiveness**

  Ecodriving means minimising energy consumption and lessening wear on the vehicle while complying with the rules of safety and punctuality

Energy-efficient driving behaviour with trolley buses

- 5 golden rules for ecodriving

(1) accelerate rapidly

(2) avoid a constant velocity altogether

(3) maximise rolling while adhering to the schedule

(4) avoid unnecessary braking and ideally use the wear-free electric brake for energy recovery

(5) conscious use of the HVAC system if it is not automatically set to optimum operation

Thank you for your attention

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