

## Overall learning objectives

- To explore the challenges facing bus designers when producing a bus for an urban environment.
- To investigate how different solutions can be identified and evaluated.
- To collaborate to present recommendations for an effective solution.

## Overall learning outcomes

- To have investigated and summarised key features of alternatives.
- To have presented a well evidenced case for a solution.

## Curriculum learning objectives

Students should have the opportunity to:

## Maths

- Apply suitable mathematics accurately within the classroom and beyond.
- Select appropriate mathematical tools and methods, including ICT.
- Use existing mathematical knowledge to create solutions to unfamiliar problems.
- Understand that mathematics is used as a tool in a wide range of contexts.
- Identify the mathematical aspects of the situation or problem.
- Make accurate mathematical diagrams, graphs and constructions on paper and on screen.
- Engage in mathematical discussion of results.

## Science

- Describe how explanations of many phenomena can be developed using scientific theories, models and ideas.
- Recall, analyse, interpret, apply and question scientific information or ideas.
- Use both qualitative and quantitative approaches.
- Present information, develop an argument and draw a conclusion, using scientific, technical and mathematical language, conventions and symbols and ICT tools.
- Describe the use of contemporary scientific and technological developments and their benefits, drawbacks and risks.
- Consider how and why decisions about science and technology are made, including those that raise ethical issues, and about the social, economic and environmental effects of such decisions.
- Explain how energy transfers can be measured and their efficiency calculated, which is important in considering the economic costs and environmental effects of energy use.
- Describe how electrical power is readily transferred and controlled, and can be used in a range of different situations.

## Extended learning – Siemens Digital Badges

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Technology Challenger



On the Move Challenger

## Sequence of learning activities

### Introduction

This episode is designed to set the scene and place the topic in a social as well as technical context. The video clip introduces the bus as something which is essential to a wide range of people and is a real benefit. It also indicates how it is working in an urban environment and introduces the notion that the power system has been developed to reduce the environmental impact. The aim here is for students to understand the setting of the challenge.

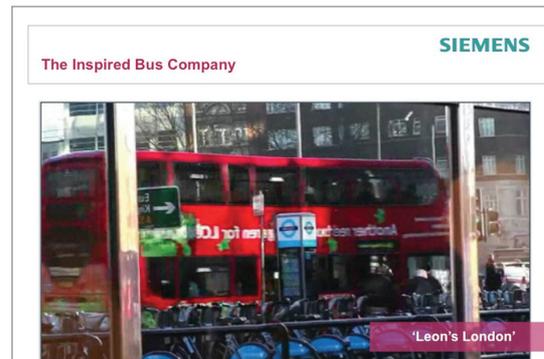
### Learning objectives

- To explore the key factors in the design of buses to operate in an urban environment.

### Learning activities

#### 1. Show video clip “Leon’s London” and ask students to work in groups to consider the following questions:

- Why are there different kinds of passenger at different times of the day?
- What impact does traffic congestion have on the bus journey?
- Why is traffic pollution an important factor in the design of the bus?
- What would be the problem in this context with using a bus that simply had a diesel engine driving the wheels?



#### 2. Take feedback and draw out the following points:

- Many people use the bus, including children, elderly people, people going to and from work, people going to and from hospital, etc. A number of these people would be particularly susceptible to the negative effects of pollution.
- The congestion will vary but could be significant at times, so the bus could be stationary in a queue or moving slowly.
- A bus could produce a significant amount of pollution, close to where people are.
- A diesel engine produces exhaust emissions which are released directly into the atmosphere. This is particularly noticeable at low speeds and in built-up areas.

### Outcomes

- Students will be able to describe the situation in which a bus, such as the one featured, is operating and will have identified why reducing pollution will be a key consideration in the design of such a vehicle.

## Students to investigate alternative fuel sources

### Introduction

In this episode students learn about various power sources; in doing so they need to acquire and manage factual information. They should be encouraged to identify what will be of use.

### Learning objectives

- Students will explore by various means different power sources for a bus and identify key characteristics.
- Students will share and consider these ideas.

### Learning activities

1. This episode could be organised in different ways. One strategy would be for students to work in groups, with some members researching each source and then reporting back to the rest of the group. This will develop the skills of collaboration, communication and identification of key features. The other way is for all the students to study all the sources and then to share ideas; this is more straightforward logistically.
2. Explain that to understand any power source it is useful to think about the transfer of energy, the total amount of energy (as this will determine the range of the vehicle), the environmental impact and the rate of transfer of energy (this is the power output).
3. **Source A: Battery.** Introduce this by means of a battery powered model vehicle and fact sheet 1. Ask students to read the information, investigate the model and then ask questions about the power source to check their understanding. Ask them to work in groups and discuss these questions:
  - a) How would the batteries be charged up in a full sized vehicle?
  - b) Identify where energy is being transferred from and to.
  - c) Describe the environmental impact of this power system.
  - d) What might affect the operating range of the vehicle?
  - e) Summarise the advantages and disadvantages of this source.
4. **Source B: Fuel cell.** Introduce this by means of (if possible) a demonstration set of equipment and fact sheet 2. Explain how the fuel cell works, ask students to read the information and then ask them questions about the power source to check their understanding. Ask them to work in groups and discuss these questions:
  - a) How would this work in a full sized vehicle?
  - b) Identify where energy is being transferred from and to.
  - c) Describe the environmental impact of this power system.
  - d) What might affect the operating range of the vehicle?
  - e) Summarise the advantages and disadvantages of this source.

**SIEMENS**

Where do the Savings come from?

Mainly from recuperation of braking energy 



**Further reasons for savings:**

- Start-stop function for combustion engine
- Optimized auxiliary concept based on electric motors
- Operate combustion engine in optimum point, reduce transients

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### Learning activities, cont'd

5. **Source C: Diesel engine.** Introduce this by means of (if possible) a demonstration of full sized vehicle or use of a video clip and fact sheet 3. Explain how the diesel engine works, ask students to read the information and then ask them questions about the power source to check their understanding. Ask them to work in groups and discuss these questions:
  - a) Identify where energy is being transferred from and to.
  - b) Describe the environmental impact of this power system.
  - c) What might affect the operating range of the vehicle?
  - d) Summarise the advantages and disadvantages of this source.
6. Students then need to work in groups to decide how best to record and display the key points about the significant features, advantages and disadvantages of each. This may need some support and discussion; this is worth investing time in as information management is a key skill.

### Outcomes

- Students will have investigated three different power sources for a bus and identified key features.
- Students will have produced an overall summary of their ideas.

## Teacher input on energy transfer when braking and raising question of how to demonstrate this in the classroom

### Introduction

This episode opens up a new aspect to the topic, which is that a bus could be made more energy efficient (and therefore less polluting) by utilising some of the energy otherwise wasted. Draw attention to the fact that in a busy urban environment the bus is likely to be accelerating and decelerating repeatedly and that in deceleration energy is lost.

### Learning objectives

- Students explain the energy transfers that take place when a vehicle is braking and consider how to investigate these.

### Learning activities

- Display photo of a racing car with glowing brake discs and ask students to work in groups to generate answers to these questions:

- Why is this happening?
- What is the energy transfer that is taking place?
- Why is this a challenge for the car designers?
- Why is this a problem in terms of energy efficiency?

- Take feedback and draw out these points:

- The discs are glowing because of the high temperatures caused by friction as the driver brakes.
- The energy is being transferred away from the car as it slows down. The kinetic energy of the car is being reduced and released as heat. The heat will escape from the car into the atmosphere.
- The designers need to make sure the brakes are cooled down. If they overheat they won't work as well.
- The energy is transferred away from the car in a way that cannot be used.

- Discussion question:

- Challenge students to suggest how the energy might be harnessed. It may be necessary to suggest that heat might not be the most useful form of energy.



### Outcomes

- Students will have developed an explanation for the energy losses that may take place when a vehicle brakes.

## Students to devise a way of demonstrating with a bicycle that energy is transferred to brakes as heat

### Introduction

This episode is designed to get students to think creatively and imaginatively about devising a way of showing how heat is produced. Emphasise that it is important not only to have ideas, but to be able to develop them and present them. Having devised a method, it can then be used to identify critical factors and produce useful information.

### Learning objectives

- Students develop and test ways of investigating heat dissipated during braking on a bicycle.
- Students use technique to explore how the amount of heat is affected by various factors.

### Learning activities

1. Ask students to recall from previous activity what happens to the energy that a moving vehicle has when the brakes are applied.
2. Ask students to work in groups to suggest how this could be demonstrated and measured using a bicycle and other equipment. Suggest that ideas are presented as labelled sketches and take feedback.
3. Take feedback and explore ideas. Select a realistic method and use. (There are several ways of doing this, but one of the best is to arrange for a bike to be supported so that the rear wheel is not in contact with the ground. There will need to be a way of recording and displaying the temperature; a good way of doing this is to use a temperature probe linked to a computer and displaying the temperature on a screen. This may involve adapting a brake pad; ensure this is rectified before using the bike again.)
4. Use the equipment to explore these questions:
  - a) What happens to the temperature of the brakes if the bike wheel is set in motion and the brakes applied?
  - b) What happens to the temperature of the brakes if the speed is increased? (If the bike has a speedometer this question can become "What happens to the temperature of the brakes if the speed is doubled?")
  - c) What happens to the temperature of the brakes if the speed is held for longer before braking?
  - d) Where does the energy go when the wheel has stopped?
  - e) How repeatable are these results?
  - f) Encourage some discussion about the results. Draw out points including that the brakes heat up, that they heat up more if the wheel was going faster but no more if the speed was held for longer. The energy is dissipated into the atmosphere. Some students may wish to consider whether there is a pattern in the results as the speed is increased. In fact a vehicle with twice the speed has four times the kinetic energy (which is why speed is so critical a factor in braking distances) but this doesn't mean you will get four times the temperature increase (for one thing temperature in °C isn't starting from zero in terms of energy level and for another the measuring system won't be able to track all of the energy).

### Outcomes

- Students will have designed a way of measuring the effect of braking on the temperature of brakes.
- Students will have used the method to determine the factors that affect the temperature.

## In this episode students will consider how energy dissipated when a vehicle brakes might be used

### Introduction

This episode is also about devising solutions but in this case is more open-ended and doesn't culminate in a practical demonstration. There is an emphasis upon students critically evaluating each other's ideas and identifying who has developed something of merit.

### Learning objectives

- Students will consider how kinetic energy that is being transferred away from a moving object could be utilised.

### Learning activities

1. Demonstrate a hand crank device such as radio or torch, showing how it is possible to use the crank to charge up the battery and then use the battery to power the device. Ask students to think about the energy transfers that are taking place, suggest ideas and summarise.
2. Remind students about bicycle braking and car braking, pointing out that in those cases significant amounts of energy were transferred but dissipated in the atmosphere.
3. Challenge students to suggest how bicycle braking might be done in such a way as to charge a battery. Ask students to work in groups to sketch and label how this might be done.
4. Ask students to display their work and then look at each other's work. Encourage positive feedback.
5. Take overall views on the kind of solution that might be effective.

### Outcomes

- Students will understand how energy being transferred from a moving object can be stored for future use.
- Students will have collaborated effectively to generate effective solutions.

## Evidence summarised graphically

### Introduction

This episode is based strongly on the understanding and application of information presented in a graph. The emphasis needs to be upon students understanding what is being shown and then applying this to various situations.

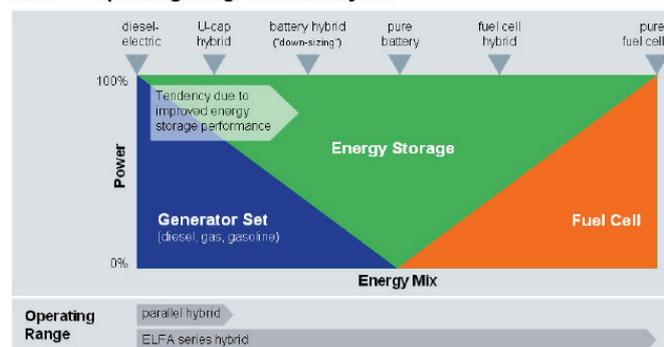
### Learning objectives

- Students will be able to interpret information presented graphically.
- Students will be able to relate the information to particular applications.
- Students will be able to use the information to relate applications to situations.

### Learning activities

1. Display a picture of a London bus and explain that the wheels are actually driven by electric motors. Say that the electricity could come from any of the power sources introduced earlier (diesel engine, battery or fuel cell). Explain that in practice a bus wouldn't have all three; it could have any one or a both a battery and either a diesel engine or a fuel cell.
2. Introduce the graph and explain what it shows. A particular vehicle is at any point on the horizontal axis depending upon the 'energy mix' it has. Explain that this means that the designer has a lot of flexibility when it comes to designing a bus for a particular application. Point out as well that this kind of graph is a powerful visual summary.
3. Check on students' understanding by asking questions such as "Whereabouts on this graph would you place an electric milk float?" (Half way along – the float is battery powered and the battery is charged up at the depot; it's range is significantly less than that of a bus.)
4. Then encourage students to use the graph to suggest the energy mix for various situations. These might include:
  - a) Transport around a railway station for passengers with limited mobility.
  - b) A farm tractor.
  - c) A lawn mower for a domestic garden.
  - d) A lawn mower for the school playing field.

ELFA® – Operating Range of Series Hybrid



### Outcomes

- Students will have shown how they can interpret the graph and draw useful data from it.
- Students will have applied this to various situations.

## Use video on Siemens ELFA drive system

### Introduction

This episode is based on students finding out about how a hybrid drive system works and why such a system is useful. Knowledge of the detailed operation is not appropriate, but it's what it does and why that's important rather than how it does it that is important here.

### Learning objectives

- Students will understand how the Siemens ELFA drive system is a logical solution to the challenge of alternative drive systems.
- Students will be able to explain how the system is applied.

### Learning activities

1. Explain that whereas having more than one drive system offers advantages, it needs to be controlled and managed automatically. Say that this is the kind of system that high tech engineers specialise in doing and the kind of project that well qualified engineers can earn a good income from being involved with.
2. Show the video.
3. Ask students to identify key points about the solution produced.



### Outcomes

- Students will be able to explain the advantages offered by the hybrid drive system.

## Students to work in teams to develop proposals and present solutions for fuel systems for buses for The Inspired Bus Company

### Introduction

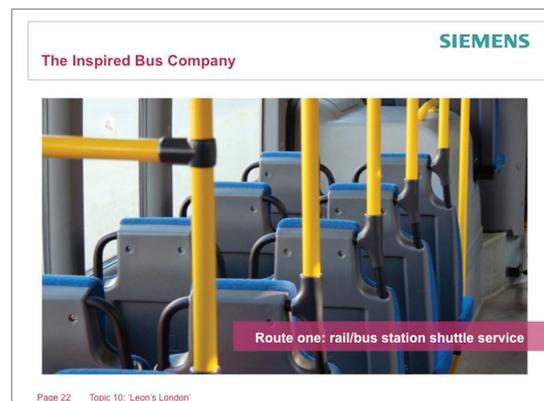
This is the episode where the topic comes together and students develop a considered response. The emphasis is upon not only what each group has decided but why it has been decided and how it is communicated.

### Learning objectives

- Students will be able to draw together ideas from this topic to justify decisions.
- Students will be able to present decisions in a clear and logical way.

### Learning activities

1. Students will work in groups to present a case for the power systems for a fleet of new buses. These buses will each be dedicated to a particular route; the routes to be covered are:
  - a) Route 1: shuttle service between rail and bus stations in city centre.
  - b) Route 2: 'inner circle' service around urban estates.
  - c) Route 3: airport bus service using urban motorways.
2. The presentation will need to explain how the team evaluated each kind of power system for each route and what their recommendations were.



### Outcomes

- Students will have considered for each route the advantages and disadvantages of different power systems and will have justified their final recommendations.