CONNECTING
CLASSROOMS

AFFORDABLE, CLEAN ENERGY FOR ALL

Understanding the opportunities for inclusive solar electricity through creativity, imagination and citizenship

BRITISH COUNCIL

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WHAT YOU WILL FIND HERE

This resource supports you in developing students' core skills through the study of solar electricity. It is also designed to explore the United Nations' Sustainable Development Goals, in particular Goal 7 which is to ensure access to affordable, reliable, sustainable and modern energy for all.

You can do this in the context of maths, English, citizenship, science, geography, design technology, or other subjects. The materials can be used with or without an international partner school and instructions are provided on how to best use the resources.

On P5 you will find a planning template which will support you in adapting the materials and help you in evaluating the project if you are working with a partner school.

OVERVIEW

Sustainable Development Goal 7 aims to ensure access to affordable and clean energy for all by 2030. As the world population rises and many millions continue to move to urban areas, there is a huge increase in the demand for cost effective and reliable modern energy.

Our reliance on fossil fuels, which are major contributors to greenhouse gas emissions, is making drastic changes to our climate. Nevertheless, renewable energy is receiving more and more investment and is becoming increasingly cost effective, particularly in remote areas.

Two thirds of the population of Sub-Saharan Africa do not have access to electricity, and those that do often pay very high prices for an unreliable supply. Many people living in the region's most remote areas are unlikely to be connected to a grid system for decades yet. However, the high level of sunshine, fall in the price of photovoltaic cells, together with more efficient appliances (such as LED lights) mean that there is great potential for affordable, reliable, sustainable and modern energy that is accessible to everyone across the region.

The UK's Energy Africa access campaign aims to accelerate the delivery of off-grid solar energy to households across Africa. The campaign, funded and managed by the UK government, was launched in 2015 to help Africa achieve universal access to energy by 2030. It will do this by helping countries to overcome financial hurdles and policy barriers, as well as make the most of the exciting developments in research and innovation to improve the market for solar energy across Africa. The campaign will involve key stakeholders, including African governments, donors, investors and lenders, industry, NGOs and the public.

One of the creative capacities of the Connecting Classrooms core skills course, creativity and imagination, is 'envisaging what might be'. The topic of off-grid solar energy offers great potential for students to visualize and design alternative solutions to a range of challenges. Similarly, the core skills citizenship course includes a session on 'sustainable development and sustainable living'. Understanding how photovoltaic cells pay for themselves, not only financially but in energy terms, will help to raise students' awareness of one possibility for tackling climate change. Finally, the core skills course on critical thinking and problem solving includes 'evaluating evidence for and against different positions' as one of its four key features. Considering different energy options provides an opportunity to practice this skill.

The learning materials that have been created may be adapted to the context of each school and the needs of specific students. Some learning activities can be left out in order to enable deeper learning through other activities. Although it is an advantage to have access to ICT and the internet in the classroom, this is not essential.

AGE RANGE

9-13 years

TIME

Five lessons of approximately 60 minutes. Each lesson includes core and optional activities.

LEARNING OBJECTIVES AND CURRICULUM ALIGNMENT

This unit is designed to support the development of both knowledge and skills. Specific learning objectives are:

- to develop students' knowledge of renewable energy, specifically solar electricity
- to raise awareness of the Sustainable Development Goals, in particular Goal 7
- to give students the opportunity to use the core skills of creativity and imagination; citizenship; critical thinking and problem solving.

We recommend teachers identify opportunities within the school's curriculum where this knowledge and these skills can be taught, whether this is through English, citizenship, geography, maths, science or other subjects.

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DRAFT LEARNING OBJECTIVES

Overall, the aim of the project is to help students demonstrate enhanced knowledge, skills and understanding, and for them to know how to contribute responsibly to society, both locally and globally. We encourage you to add subject-related objectives and, if necessary, revise the following draft objectives to meet the needs of your students and your school's curriculum.

Creativity and imagination: to visualize alternative solutions.

Citizenship: to understand the possibilities for providing affordable, clean energy for all.

Critical thinking and problem solving: to evaluate evidence for and against different positions.

Geography: to consider what is possible and what is the best solution within a particular geographical context.

Maths: to practice handling data and understand the different ways of recording and presenting data.

COLLABORATING WITH COLLEAGUES AND ADAPTING THE MATERIALS

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Summary

Here are the suggested steps for planning the unit and collaborating with other teachers in your school and/or internationally:

1. What do we want students to learn?
2. What would be the best way to learn this?
3. How would we know what they have learned?
4. What resources do we need?
5. What did students learn during the unit?
6. What other reflections do we have about the unit?

Please use the teacher planning template on page 5 to reflect further on these questions.

Finding a partner school

If you do not have a partner school but would like to find one and set up an online collaboration space to work together, further information can be found at: https://schoolsonline.britishcouncil.org/partner-school

LEARNING MATERIALS THAT HAVE BEEN CREATED FOR THIS UNIT:

Lesson 1: What do we already know about electricity: how can it improve our wellbeing, where does it come from and what does it cost?

Lesson 2: What is 'energy poverty' and how can it be tackled? What are the problems with conventional sources of energy?

Lesson 3: How can we make electricity from sunlight? How does this address the problems around conventional sources of energy?

Lesson 4: How can this technology be accessible to people suffering from energy poverty?

Lesson 5: Identify issues around affordable, clean energy in the school or community on which students could plan to take action and consider how renewable sources of energy (such as solar, wind or biogas) could help Africa achieve universal access to energy by 2030.

TEACHER'S PLANNING TEMPLATE

This can be used individually, in collaboration with colleagues in your school or with teachers from another school teaching the same unit, either in your country or in another country.

Question	Notes	Your thoughts
1. What do we want students to learn?	Think about the most important learning objectives for this unit. Read through the materials that have already been created and consider what is most important for your students to learn. Reflect on the objectives suggested around creativity and imagination, citizenship, critical thinking and problem solving. Revise them if necessary. Consider the standards of your National Curriculum and reflect: which standards can be met through this learning unit? Be realistic about the time that you have available for this unit and what can be achieved in this time.	
2. What would be the best way for them to learn this?	Given the learning objectives you have decided on, think about the learning activities that would be most effective for your students. What is the best way for them to learn about the current state of affordable, clean energy in your community, country and internationally? How can they learn about the facts (data) and personal experiences (stories) that illuminate different aspects of the current situation? How can they learn about the various causes of energy shortage and climate change? How can the activities of people living far away from you contribute to climate change that directly affects you/your life? What should society do more broadly to mitigate these effects? How could this be used as an opportunity to practise creativity and imagination, citizenship, and critical thinking and problem solving? For example, to visualize alternative solutions, think about the provision of sustainable energy, and about evaluating evidence. How to learn about the potential solutions to tackle energy shortage and climate change, especially those that have been very successful in many countries. How to design a project that addresses energy shortage and sustainability in your community.	

Question	Notes	Your thoughts
3. How will we know what they have learned?	Given the learning objectives you have decided on, think about assessment. How will you find out what your students already know about this topic before beginning the unit? Consider what sort of evidence you would need to see that students have learned the knowledge, skills or attributes you would like them to learn.	
4. What resources do we need?	Given the learning activities you are planning, think about the resources you will need. People – who would you like to engage in the unit so that students can learn more about the causes of energy shortage or scarcity, climate change, and potential solutions? Written materials, music, art – what additional materials would be beneficial to your students in this unit? Places – where would it be useful for your students to learn during this unit?	
5. What did students learn during the unit?	During and after the unit, think about what students are learning by using formative assessment and checking for understanding as students work through the activities. To what extent did students meet the learning objectives of this unit? What other, surprising things did students learn? What were students confused about?	
6. What other reflections do we have about the unit?	During and after the unit, think about what went well with this unit and what could have been done differently. Which learning experiences were particularly valuable? Were the learning activities appropriate? What worked well? What would you do differently next time? How can you use formative assessment (or Assessment for Learning: AfL) to help your students' learning or understanding to progress from this point?	

LESSON 1

Affordable, reliable, sustainable and modern energy: electricity, its benefits, costs, and sources

STUDENTS WILL:
- consider how electricity can improve human wellbeing
- find out how much electricity costs in their country
- find out how electricity is generated in their country.

NOTES ON CORE SKILLS
This lesson relates to the core skill of critical thinking and problem solving as it involves evaluating reasons and evidence from different sources. There is also an opportunity to use some creative thinking and imagination in an extension activity, and for using digital literacy skills through online research.

Step 1

1. In pairs or small groups, ask students to answer the question 'What do you already know about electricity?' Then ask them 'What do you want to find out?' Record their responses using an enlarged version of the KWL Chart (**Appendix 1**). Keep the partially completed KWL Chart available for Lesson 3.

2. As a stimulus to prompt ideas, you may wish to display some photographs. Possible examples to download can be found in the 'Sources of further information' section at the end of this resource. You may also wish to broaden the discussion with prompt words from Sustainable Development Goal 7: Affordable, reliable, sustainable and modern energy for all.

3. Share with students the expected learning outcomes (re-word them if necessary) and discuss what they might mean:

- **Creativity and imagination:** to visualize alternative solutions.
- **Citizenship:** to understand the possibilities for providing affordable, clean energy for all.
- **Critical thinking and problem solving**: to evaluate evidence for and against different positions.

Step 2

1. Ask students to come up with a list of basic human needs. This can be done as a whole class or as a small group, with students making suggestions on separate pieces of paper. Their suggestions can be accompanied by simple drawings.

2. There might be some discussion about what constitutes a basic survival need (like clean water) and what constitutes a right (like education). Allow students to extend the definition to include rights, but not luxuries. A list of rights can be found on page 14 of the Gender Equality template project.

3. The needs, written on the pieces of paper, are then sorted by students into two groups: those needs which can be more easily met with the help of electricity and those for which electricity would make no difference.

4. Invite students to back up each of their suggestions for sorting the needs. Allow other students to challenge or question the reasons until there is general consensus about the grouping of the needs.

Step 3

1. It is likely that students will have many needs which can be more easily met with the help of electricity. Ask students to each choose one of these needs and to think of a way of measuring how much electricity might be used to meet it.

2. Distribute printouts of the table below for students to complete to help them work out how much electricity (measured in Watts) is likely to be used by different appliances to meet the different needs in a year. Students could work out an estimate based on their own personal needs (taking into account the electricity needs of their household, divided by the number of people). If they do not use electricity, then they could use the table to estimate the cost for someone who does.

3. Find out, or ask a student to find out, the cost of a kilowatt-hour (kWh) in the country in which they live – links to figures for the prices in different countries can be found in the 'Sources of further information' section at the end of this resource.

4. Ask students to estimate the total number of kilowatt-hours they or someone else might use per day to meet their basic needs (not luxuries) from the agreed class list and how much this would cost.

5. Students should also list the particular benefits of the electrical appliance. In some cases a non-electrical appliance, such as a fuel efficient stove, might be a better use of money.

Human need	Household appliance	a) Power needed (Watts)	b) Hours used per day (hours)	c) Energy used per day, kWh (a x b)	d) Cost per kWh	e) Cost per day (c x d)	f) Cost per year (e x 365)	Benefits
To see in the evening to cook etc	Light (comp. fluor) **E**	28 watts **X**	6 hours **A**	0.17 **M**	15p **P**	2.6p **L**	£9.49 **E**	No air pollution in household
Clean water	Well pump	500						
Fresh food	Fridge	200	8 (fridges cycle on and off, even if on all day)	1.6				
Contact	Mobile phone	2						
Healthy temperature	Electric fan							
	TOTAL:							

Step 4

1. Support students to find out how the electricity in their country is generated. A good online source is the electricity section of the IEA Energy Atlas. Students can also get a more detailed picture of the electricity produced by fuel in specific countries by using the graph generator on the IEA Statistics website (under the 'Topic' drop-down menu choose 'Electricity and Heat').

2. Students' results should be displayed in the form of a pie chart (i.e. x % Fossil fuels, y % Renewables, z % Nuclear). This could be followed by a discussion and some follow-up research about the possible reasons for these forms of electricity generation for the country.

3. As an extension activity, groups of students can be invited to find out more about the different types of electricity generation and present their findings to the class, for example, by using posters, drama, or by making models. Links to further information and activity ideas, including the 'Energy Debate Activity' from Carbon Partners, can be found in the 'Sources of further information' section at the end of this resource.

Potential collaboration with partner school

The results and outcomes of these activities can be shared between partner schools to bring in additional perspectives, for example, about needs, rights and luxuries. It would be interesting to compare information in the two countries around the uses, costs and sources of electricity and the possible reasons for any discrepancies.

A boy stands under an electricity pylon in rural Tanzania. Over 35 million of Tanzania's 41 million people don't have access to the electricity grid - even many who live close to pylons like this one. © Russell Watkins/DFID

LESSON 2

Energy poverty and climate change

STUDENTS WILL:

- consider the meaning of the term 'energy poverty'[1] and explore its prevalence across the world
- consider how many forms of energy cause pollution, either directly in the home or more widely, to affect the local or global environment
- find out about the levels of carbon dioxide emission from different sources of electricity generation.

NOTES ON CORE SKILLS

This lesson relates to the core skill of citizenship – students will consider the social justice and sustainability issues around energy poverty and the burning of fossil fuels to generate electricity. There are also opportunities to embed critical thinking and problem solving, as information from different sources is handled and used to work out problems. There is also the opportunity to apply digital literacy skills through online research..

Step 1

1. Ask students to try to come up with a definition of energy poverty using 'think, pair, square': think of an idea (by themselves – one minute), discuss and refine it with a partner (in a pair – one minute) and then again with the partner and another pair of students (a square – one minute). Definitions can then be shared with the class. Elements can be picked up that relate to the following definition:

   Energy Poverty is not having access to enough non-polluting energy to meet day to day living requirements. The International Energy Agency (IEA) definition of energy access involves consumption of 250 kilowatt-hours (kWh) of electricity per year for a rural household and 500 kilowatt-hours (kWh) per year for an urban household.

2. Students could compare these figures with their own calculations from Lesson 1 and to the world average consumption of 3,064 kWh of electricity per person per year (source: UN Data).

3. Display information and world maps showing energy consumption in the world and ask students what patterns they notice. This could include satellite images of the world at night time showing the amount of light emitted by different areas of the world and this World Mapper.com map of the world where the size of different countries are changed according to the amount of access to electricity they have. A more detailed energy atlas of electricity consumption is provided by the IEA and figures for different countries can be looked up on the UN Data site.

1 If preferred, the term lack of 'energy access' can be used as an alternative to 'energy poverty'. This term may be preferred if there is a perceived need to avoid reinforcing negative stereotypes about countries in Sub-Saharan Africa.

Step 2

1. In pairs, ask students to list some of the problems that people without access to electricity in their homes might have. These can then be shared with the rest of the class. Problems might include pollution of the air in the house, the risk of fire from candles or kerosene lamps, and the harder work involved to meet the needs that students identified in Lesson 1.

2. Ask students what wider environmental problems the production of electricity might cause. This will depend on how the electricity is generated (refer back to Lesson 1, Step 4). If some students are unaware of the contribution of carbon dioxide from burning fossil fuels to climate change, this will need to be explained – the Climate4Classrooms education pack provides activities to help students understand climate change and can be downloaded from Schools Online.

Potential collaboration with partner school
Students can investigate and compare electricity consumption levels and the related carbon dioxide emissions produced per person in the two countries.

Step 3

1. Explain to students how different forms of electricity generation result in different amounts of carbon dioxide being produced for each kilowatt-hour (kWh) of electricity used.

2. Start by showing students the graph in **Appendix 2**, which indicates how much carbon dioxide is produced by generating electricity from coal, oil, natural gas and renewable sources. Then show them the 'carbon intensity of electricity' world map also in **Appendix 2** – this indicates (in brown) which countries use mainly fossil fuels and produce a lot of carbon dioxide for each kWh of electricity used and which use mostly renewable energy and, as a result, produce less (in green).

3. Ask students to work out roughly how much carbon dioxide would be produced by the electricity they calculated would meet their needs (Lesson 1, Step 3) using column c) of the table and the map in **Appendix 2**. To allow for more accurate calculations, more detailed information on the carbon intensity of individual countries can be found from page 19 onwards in this report from Ecometrica.

	c) Energy used per day, kWh (from Lesson 1)	g) Energy used per year (c) x 365 days) kWh	h) Energy intensity (kg of CO_2 for every kWh of electricity)	i) CO_2 produced (kg per year) (column 2 x 3)
Example	2.77	1011	0.55 (UK figure from Ecometrica)	556
YOUR TOTAL:				

LESSON 3

Producing clean electricity from the sun

STUDENTS WILL:

- find out about clean and renewable electricity generation through solar power
- consider whether or not solar power is a real alternative source of energy for electricity generation by finding out how it is captured, how much it costs and what its impact is on the environment.

NOTES ON CORE SKILLS
This lesson relates to the core skill of critical thinking and problem solving and the citizenship concept of sustainability

Step 1

1. Working in pairs or small groups, ask students to list examples of clean or renewable energy (this may build on their research from Lesson 1). It may be useful to distinguish between sources of energy which produce smoke – such as burning wood or biomass – and are therefore not considered clean if burnt locally, but still regarded as renewable because they produce the same amount of carbon dioxide that the plants took in while growing. On the other hand, nuclear power is often regarded as clean, as it does not produce carbon dioxide (although it has other pollution risks), but not as renewable because uranium is a finite resource.

2. Explain that the next few lessons will investigate solar energy as a renewable, clean source of electricity. You may wish to add any additional student contributions to the KWL Chart as per appendix and previous comment started in Lesson 1.

Step 2

1. Explain that students will be investigating whether solar power is a real alternative source of energy for electricity generation by finding out how it is captured, how much it costs and what its impact on the environment is.

2. Depending on how much students know about how solar energy and electricity work, you may wish to start the lesson off with a video or other activity. The Richard Comp video on 'How do solar panels work?' provides a five-minute overview of solar power, how it works and its benefits and limitations. Some explanatory text from the Ashden Awards can also be found in **Appendix 3.**

3. Students may be interested to know that Albert Einstein was the first person to explain the photoelectric effect, which is how photovoltaic cells work (photons of light causing the release of electrons in certain materials). Photovoltaic (PV) cells were also developed for use on early space missions as one of the only viable options for powering satellites and space stations. Most PV cells are made from crystals of the element silicon, which is extracted by heating sand (silicon dioxide) to 2,200°C with carbon. A long cylindrical crystal of silicon is then formed by inserting a rod into molten silicon (at 1,500°C) and then slowly pulling it out and rotating it (students may have had past experience of growing crystals in science). When the crystal has cooled, it is finely sliced into 'wafers' and the edges cut off to make the dark squares with round corners seen in PV panels.

4. Each PV cell has two differently charged wafers of silicon, one lying above the other. The top one is negative and is made by adding phosphorus (an electron donor) to a batch of the molten silicon. The bottom one is positive, and is made by adding the element boron (an electron accepter) to another batch of molten silicon. When the sun shines on a PV cell, electrons are released from the lower positive wafer and travel to the negative (electron accepting) wafer on top. If there is a wire between the two wafers, electricity will then flow down it as the electrons try to get back from the now electron rich top wafer to the now electron poor lower wafer (see the diagram on the Explain that stuff website). This electrical current can provide one to two watts of power, which is enough to power one LED light. Many cells are joined together to form a module and many modules to form a panel.

5. If you have a solar lamp or solar panel attached to a light, fan or other device, students can then investigate the effects of bright sunlight, shade or darkness on them – a list of suggested websites for student research can be found in the 'Sources of further information' section at the end of this resource.

Step 3

1. Ask students to work out the size of solar panel that would be needed to produce enough electricity to meet the needs they identified in Lesson 1. This will depend on the average number of hours of sunshine per day in their country, which can be checked on the world sunshine map **Appendix 4.**

2. Now ask students to work out what this system might cost to set up, taking into account the need for the panels (e.g. £60 [UK 2016 prices] x 23), a charge controller (about £10), a battery if the electricity is to be stored (about £45), an inverter if running mains voltage appliances or wanting to feed electricity back into the grid (about £200) and roof installation costs (about £800). Local prices should be checked where possible. For example, in East Africa 8Wp home solar lighting and phone charging kits can be obtained for around £165 from manufacturers like M-Kopa Solar.

3. To offset this cost, ask students to refer back to the cost of electricity per year that they worked out in Lesson 1 (column f). In the example below (2.77 kWh per day), the total cost per year would be 2.77 x 365 x 15p = £152.

4. Finally, students should work out how long it would take for the solar panels to pay for themselves (beyond which time they would provide almost free electricity, allowing for any repairs or replacements). In the UK example above, the panels would take around 16 years to pay for themselves, or less if the price of mains electricity rises. In the UK and some other countries, the payback time has been reduced to around ten years on large systems because of government support through payment for the electricity generated. Solar panels are thought to have a lifetime of at least 25 years.

Step 4

1. Ask students to find out the amount of carbon dioxide they would save each year by having solar panels, based on the amount of electricity they worked out in Lesson 1 (see Lesson 2, column i). Because the manufacture of solar panels requires energy and produces carbon dioxide itself (SiO2 + C ----> Si + CO2), this needs to be taken into account when working out the actual environmental benefits of solar panels.

2. In order to be sustainable, the amount of energy required to produce and transport solar panels must be less than the energy that they generate. This is known as the 'life cycle assessment'. The calculation has to consider various factors, such as the type of PV cell, the country it is made in, and the energy or carbon intensity of its electricity (see **Appendix 2**) and transportation. Many studies agree that the 'Energy Pay Back Time' (how long it will take for a PV to generate as much electricity as it takes to produce it) is about two years. Explain to students that although solar panels may take about ten years or more to pay for themselves financially, they only take about two years to pay for themselves environmentally.

Potential collaboration with partner school
Students in each partner school can compare hours of sunlight and the prices of solar panels, as well as installation costs for domestic solar power in each country. Students can also work out and compare financial payback times.

	c) Energy used per day, expressed as Watt hours (KWh x 1000)	j) Number of 30 watt-peak (Wp) panels: (46cm x 54cm = 0.25m²) c) / 30Wp x k)	k) Average hours sunlight per day	l) Energy produced per day, kWh. 30w x j) x k)	m) Area of solar panels needed, m². (0.25m² x j)
Example	2770	23	4 (UK)	2.76	5.75
YOUR TOTAL:					

LESSON 4

Solar electricity for people without mains electricity

STUDENTS WILL:

- become acquainted with examples of small-scale solar electricity providing lighting, phone charging and water pumping in rural areas of Sub-Saharan Africa
- consider the costs and benefits of such initiatives.

NOTES ON CORE SKILLS

This lesson relates to the citizenship concepts of social justice and sustainability. There are also opportunities for critical thinking and problem solving as evidence is evaluated.

Step 1

1. Use this short quiz presentation 'Africa or Not?' from the Royal Geographical Society, which seeks to help dispel common misconceptions and stereotypes of the whole of Africa being rural and poor (unless students are fully aware of this).

2. Ask students to look back at their lists of possible problems that people living in 'energy poverty' might face (Lesson 2, Step 2) and introduce the case study in **Appendix 5.**

3. Invite students in pairs or small groups to answer these questions:

- Out of the problems that you identified in Lesson 2, Step 2, which do you think Isele has solved with her home solar system?
- Isele says that the system will pay for itself in eight to 12 months if she asks people to pay a small amount to charge their mobile phones. If she charges an average of five phones a day, how much would she need to charge people per phone charged to pay off the cost in ten months? (eight pence)
- Isele did not take into account the saving she is making by not having to buy kerosene for lighting any more. How long would her system take to pay for itself, based on avoiding the need to buy kerosene? (12 months)
- If the source of income and the saving are added together, how long would it take for the system to pay for itself? (five and a half months) If the reduced health costs she mentions are also taken into account, the payback time for the system could be even shorter.

Ivanpah Solar Power Plant, Mojave desert
Photo © Gregg Tavares. Cropped image used under the Creative Commons Licence

Step 2

1. Some examples of solar home systems can be found on the websites of manufacturers M-Kopa and Bboxx, who are being funded through the UK Department for International Development's Energy Africa Campaign.

2. The cost of Isele's system from Solar Aid (£120) is too much money for many people and it is hard for a lot of people to get credit. Invite students in small groups to design and then present their ideas for a solar powered device that could help meet the needs of people who are unable to afford a full solar home system.

Step 3

Show students **Appendix 6**, which shows low cost solar devices in use in rural Kenya, Tanzania and the Gambia. The design and specifications of the devices can be found by visiting the manufacturers' websites, D-Light and Sun King. Videos about small solar devices for rural communities can also be found on the Ashden Awards website.

Step 4

Distribution of solar technology to people in remote communities with very little finance is a major issue. **Appendix 7** shows the costs to set up libraries for solar lamps in local schools and the initial impact. Invite students in pairs or small groups to answer these questions:

- How much money was spent on shipping the lamps from Kenya to the Gambia? *(£380)*
- As well as being loaned out through local schools, the lamps are also sold at cost price in a local 'Solar Shop' *(set up cost £1,645 with a stock of 230 lamps).* If a family that bought a solar lamp no longer has to spend £1 a week on candles, how long would it take for the lamp to pay for itself? *(five weeks based on purchase cost of lamp alone, or about seven weeks based on set up costs for the shop)*
- What other benefits do you think a family would have from renting or buying the lamps? *(improved health and education)*

Mobisol stall holders. Mobisol is a solar energy company receiving support to grow their business from UK aid. In return, they help provide solar electricity to some of Tanzania's poorest people. © Russell Watkins/DFID. © Russell Watkins/DFID

Coral reefs – one of the earth's habitats which is most at risk from climate change. Some experts have warned they could be extinct by 2050 Photo © US Fish and Wildlife Service/Jerry Reid . Cropped image used the Creative Commons Licence

Step 5
Solar panels are also used to meet needs in remote communities other than lighting and charging mobile phone. **Appendix 8** gives a couple of examples. Invite students in pairs or small groups to read these examples, look back at the basic needs they identified in Lesson 1, Step 2, and answer the following questions:

- Which of the basic needs that you identified are being addressed by solar power in the two examples in the Appendix? What might the longer term benefits for the community be?
- Both these projects, and the solar lamp projects in **Appendices 6 and 7**, were made possible with funds raised by overseas projects: Project Gambia, Alton Maasai and Gambia Intouch. The two Gambian projects are run by teachers or former teachers in Stourbridge, UK – Project Gambia is run by Ridgewood High School, and Gambia Intouch by the former head teacher of Hagley Primary School. Alton Maasai and Intoafrica is co-run by a member the local Maasai community who now lives in the UK.
- Try to come up with some ideas about how local people, with the support of their local or national governments, might be able to gain access to solar energy in areas where there is no support from charitable projects. One initiative which is trying to stimulate private sector investment in off-grid solar energy in African countries is the UK government's Energy Africa Campaign, which was launched in 2015. By focusing on 14 countries across Africa, the initiative seeks to take on the inefficient markets, policy barriers and under-investment which mean that Africans can pay as much as 66 times more for their electricity than someone in the UK – it does this by working with a range of partners, including M-Kopa and Bboxx.

Potential collaboration with partner school
Students in each partner school could compare their designs for solar devices and evaluate the different solar lamps and devices on sale in their respective countries.

LESSON 5
Mini projects

STUDENTS WILL:
- consider possible actions they could take to promote clean, affordable energy in their schools, homes and communities.

NOTES ON CORE SKILLS
This lesson relates to the important idea of citizenship as a 'practice', demonstrated through examples of citizens taking action to improve people's lives and to protect the environment. It also relates to creativity and imagination and other core skills.

Step 1
1. Recap with students the idea of basic needs and rights (covered in Lesson 1, Step 2) that could be met through clean affordable energy, such as solar electricity.

2. Invite students to build on the learning from this resource and to choose from a range of ideas for mini projects, or to come up with their own. Ideas could include:
- finding out the electricity needs of their school and calculating the costs and benefits (financially and to the environment) of installing solar panels. A schools electricity carbon calculator can be used for this purpose
- finding out the electricity needs of their own households and calculating the costs and benefits (financially and to the environment) of installing solar panels using the tables in Lessons 1 to 3 and internet research
- finding out the cost of charging mobile phones (e.g. at home, festivals and other outdoor events) and/ or the costs of batteries used in torches, calculators, cameras or other portable electric devices, and calculating the costs and benefits (financially and to the environment) of using solar energy or devices instead

If the school has an existing charitable relationship with a school in another country, consider exploring the Carbon Partners model as a way of reframing the relationship from one of charity, to one of justice.

Explore futuristic ideas about the possibilities for solar power. For example find out about the Solar Impulse aircraft that has now flown around the world, or new giant concentrated solar energy farms such as Crescent Dunes in Nevada, USA. These might be sources of inspiration for creative writing and art and design projects.

Step 2
Present ideas or project plans to the rest of the class using posters, visual aids and persuasive speeches. Invite constructive critical questioning from other students to help develop the ideas.

Step 3
Consider the possibility of selecting and supporting certain project ideas.

Potential collaboration with partner school
The project ideas could be shared between partner schools and even lead to joint initiatives.

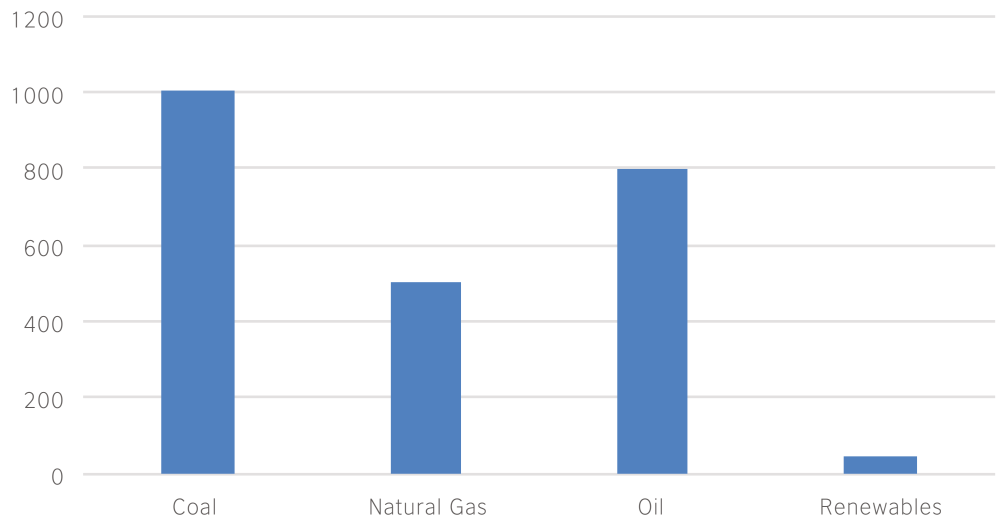
APPENDIX 1
KWL Chart

What do we already **KNOW** about this topic?	What do we **WONDER** about this topic? What questions do we have?	What have we **LEARNED** about this topic?

APPENDIX 2

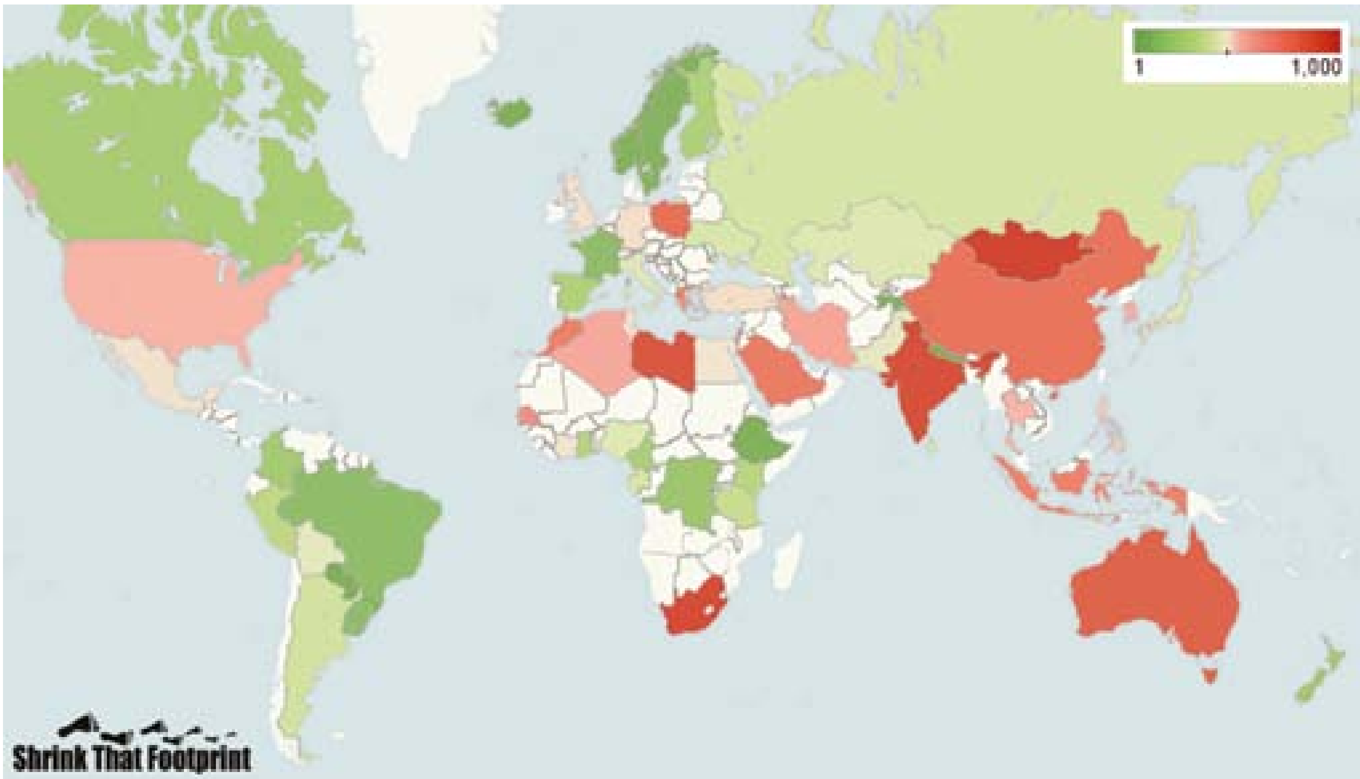
Energy and carbon intensity

ENERGY INTENSITY (CO2/KWH)



Source: IPCC
Available at: https://www.ipcc.ch/pdf/special-reports/srren/SRREN_FD_SPM_final.pdf

CARBON INTENSITY OF ELECTRICITY (G CO2/KWH)



Note: 2010 figures for direct combustion emission only (IEA 2010)
Source: Shrink that footprint
Available at: http://shrinkthatfootprint.com/electricity-emissions-around-the-world

APPENDIX 3

How solar home systems and solar lamps work

Solar home systems and lamps use photovoltaic (solar-electric or PV) cells and rechargeable batteries to provide electrical power away from the mains grid. Lamps provide a single light, sometimes phone charging, and are portable. Solar home systems are fixed in a home and can supply several lights, phone charging and other small appliances.

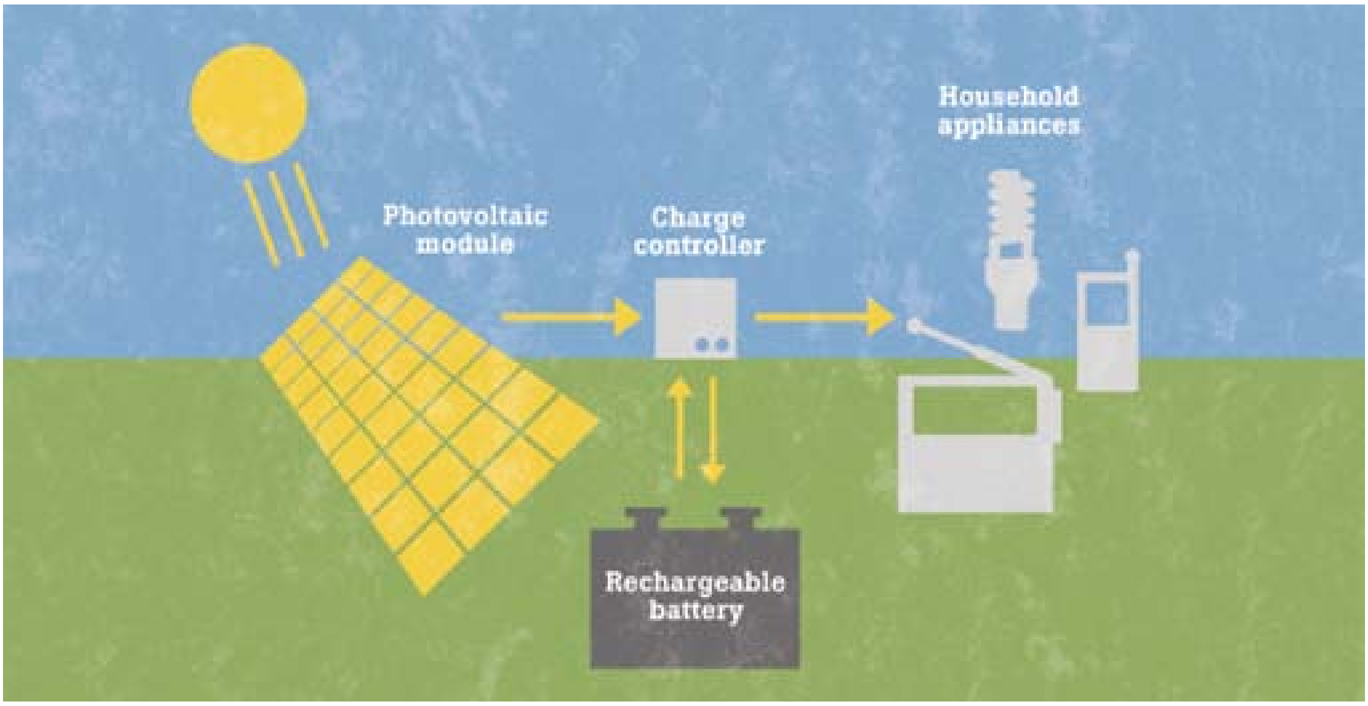
PV cells are made from semiconductor materials, such as silicon, and generate DC electricity from sunlight. A number of cells can be connected together and sealed in a weatherproof casing to form a PV module.

PV cells and modules are specified by their 'watt-peak' (Wp) rating, which is the power generated under standard conditions, equivalent to bright sun in the tropics (they still work at lower light levels though). Solar home systems use between about five and 100 Wp of PV, solar lanterns between about 0.5 and two Wp.

The rechargeable batteries store electricity, so that it is available at night and on cloudy days, as well as when the sun is bright, and they also provide a stable voltage for the appliances that use the electricity. Larger solar home systems normally use lead-acid batteries designed specifically for solar use – standard car batteries don't last long with the deep levels of discharge needed in a solar system. Nickel-cadmium and nickel-metal-hydride batteries have been used in lanterns and smaller systems because they are easier to make portable and in small sizes. But lithium-ion batteries are rapidly becoming the most popular because, with good electronic controllers, they last longer.

An electronic charge-controller protects the battery from being overcharged (when it is very sunny) or over-discharged (when people try to get too much electricity from the system). Other features can also be built into the controller, like different brightness setting for lamps. Appliances that are powered directly must operate at the dc voltage of the battery but, an inverter (dc to ac converter) can be included in a larger system so that standard mains-voltage equipment can be used.

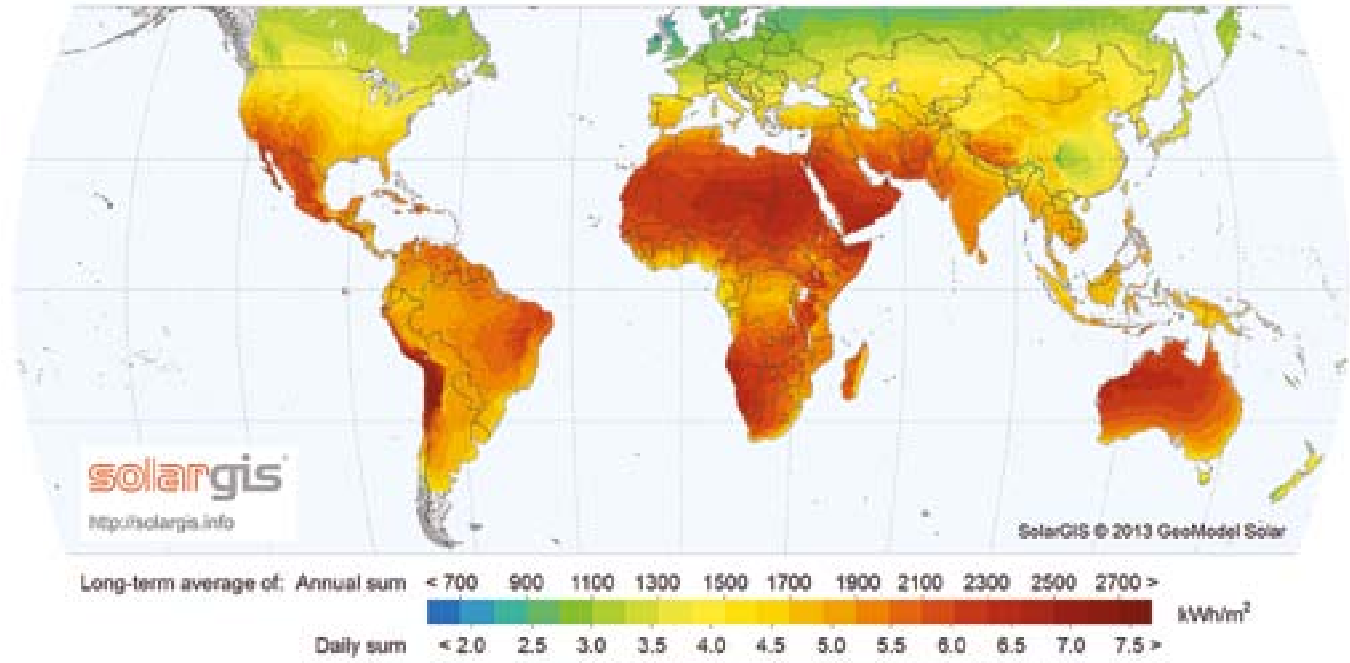
Source: Dr Anne Wheldon, Ashden Awards, www.ashden.org



Source: Ashden
Available at: to www.ashden.org

APPENDIX 4

Hours of sunshine across the world map



Source: Solargis
Available at: http://solargis.com/products/maps-and-gis-data/free/download/world

APPENDIX 5
A solar home system in rural Kenya

My Name is Isele Tankile, I live in Ololulunga near the famous Maasai Mara game reserve in Kenya. I am a subsistence farmer. I grow crops on my farm and keep livestock and poultry. We have no electricity in my village so many people, including myself, use kerosene lamps. This has a lot of problems:

1. it is expensive – it costs a total of £10 per month;
2. it creates a lot of smoke in the home, which affects children doing revision and myself doing beadwork.

The electricity company came round to the villages trying to sell the idea as a new development. They said the village would look like the city which people thought would be a good idea. They said that to install it people had to give their title deeds to guarantee the installation, so if you couldn't pay the amount needed the land could go.

I decided to purchase a solar panel. Although it was expensive, costing me about £120, I saw massive benefits. I had power in all the rooms in my house and started helping my family and neighbours to charge their phones. This encouraged a lot of people within the community to start buying solar devices for their homes.

I would definitely recommend it to others. It is way cheaper than normal electricity. You can charge phones, have power at home, and cut health costs as there are no eye problems caused by smoke.

It saves money. If you decide to charge a small fee to charge mobile phones, then it can take about eight to12 months to pay off.

Isele Tankile © Intoafrica

APPENDIX 6
Solar devices in use in the Gambia, Kenya and Tanzania

Alton Maasai, Kenya © Intoafrica

Rural village in Tanzania © Intoafrica, Kenya

Jan Jan Bureh, the Gambia © Gambia Intouch

Elizabeth Mukwimba, an M-Power Off Grid Electric customer in Tanzania
© Russel Watkins/DFID

APPENDIX 7
Project proposal

Proposal for generating interest and providing affordable access to individual solar lights in the Central River Region of the Gambia

Phase 1: November 2015

Aims:
- to generate interest in high-quality solar lamps
- to provide study lamps for rental to students.

Actions:
To set up 'Solar Libraries' in four 'off grid' schools in the Central River Region close to Jan Jan Bureh. Each school is to have 25 x S2 'd-light' study lamps (at £4.30 each) and 4 x S20 (at £5 each) and single S300 lamps (at £16 each) for teacher use in the following schools:

1. Jan Jan Bureh Methodist Lower Basic
2. Banni Lower Basic Primary School
3. San Kuleh Kunda Lower Basic Primary School
4. Boraba Lower Basic Primary School.

Budget:

Initial purchase of lights for evaluation	Costs (covered by sponsor)
120 solar lights (including shipping from Kenya)	£954
Travel and transportation costs	£270
Coordinator expenses	£269.98
Total	**£1493.98**

Phase 2: December 2015 to February 2016

Aims:
- to evaluate the effectiveness of 'Solar Libraries' in improving students' quality of home study
- to evaluate the level of confidence and interest in solar lamps as replacements to existing methods
- to evaluate the quality of lamps used.

Budget:

<table>
<tr><th colspan="2">Action/item</th><th colspan="2">Cost</th></tr>
<tr><td colspan="2">Appoint head teacher to monitor until February/March</td><td colspan="2">£100</td></tr>
<tr><td colspan="4">First three weeks of 'Solar Library' evaluation. Numbers rented (November/December 2015)</td></tr>
<tr><td>School</td><td>Week 1</td><td>Week 2</td><td>Week 3</td></tr>
<tr><td>Banni Lower Basic</td><td>25</td><td>25</td><td>25</td></tr>
<tr><td>Boraba Lower Basic</td><td>25</td><td>25</td><td>25</td></tr>
<tr><td>San Kuleh Kunda Lower Basic</td><td>25</td><td>25</td><td>25</td></tr>
<tr><td>Methodist Lower Basic</td><td>5</td><td>6</td><td>6</td></tr>
</table>

Outcomes:
- all lamps in the three rural 'off grid' schools were fully used and all were rented each week
- the one school in 'on grid' community rented fewer lamps but the headteacher feels interest is growing as power is inconsistent and electricity not always affordable
- all schools are pleased with the lamps and three rural schools would like more.

Source: Gambia Intouch

APPENDIX 8
Using solar panels to meet needs in remote communities

Sintet, the Gambia
Sintet is a rural farming village located in Western Gambia on the Senegalese border, 140km from the Gambia's capital city, Banjul. The community lived in basic conditions with no electricity or running water and in the dry season, which runs from November to late May, they had no access to water for farming.

Following the tragic death of Mustapha, an eight-year-old boy who fell down one of the wells, and two years of drought in the 'rainy' season, the need for a pump was greater than ever. With the support of Project Gambia, funds were raised for a solar panel and water pump and the villagers installed four large water tanks. The tanks feed six taps on the farm and this provides 20,000 litres of water a day, which means that crops can be grown all year round to feed the whole community. Trenches were then dug by hand and over 1500m of pipe work installed. 16 taps were also installed in the village, which now provide clean drinking water for the whole community.

Mustapha's mother and grandmother © Project Gambia

The solar panel that powers Sintet's water pump © Project Gambia

Alton Maasai, Kenya
Alton Maasai Primary School is located in the remote Maasai community of Oldanyati in the Narok South District of Kenya. The community's population of approximately 3,000 people live in dispersed traditional 'Bomer' houses. The school's current access to water and power is through the solar panels on the roofs of the classrooms.

In the past, during the wet season, students collected standing ground water as and where they found it. During the dry season, the only water source was an eight kilometre walk to a river. Both of these sources are shared with livestock and wild animals, including lions and elephants.

The school now has access to toilets and hand washing facilities through a water harvesting system with the pump that uses solar energy.

Alton Maasai Primary School © Intoafrica

Sources of further information

Background and context

Big IdEAs: Mary Robinson:
www.youtube.com/watch?v=LTIfm_jqqUs

Lesson 1

Step 1: possible photograph stimuli from Solar Aid:
www.solar-aid.org/assets/ssresources/sunny-schools/5-photocards.pdf

Step 2: a list of rights can be found on page 14 of the Connecting Classrooms Gender Equality Template Project:
https://schoolsonline.britishcouncil.org/classroom-resources/list/gender-equality

Step 3: information on the power consumption of other appliances from Daft Logic:
www.daftlogic.com/information-appliance-power-consumption.htm

Statista, global electricity prices:
www.statista.com/statistics/263492/electricity-prices-in-selected-countries/

Energy Use Calculator, global electricity prices (including taxes):
http://energyusecalculator.com/global_electricity_prices.htm

Step 4: Energy Atlas, electricity generation by country:
http://energyatlas.iea.org/?subject=-1118783123#

International Energy Agency, electricity generation by fuel and by country:
http://www.iea.org/statistics/statisticssearch/

Lesson 2

Step 1: The Earth at night time:
http://eoimages.gsfc.nasa.gov/images/imagerecords/55000/55167/earth_lights.gif

World Mapper maps:
www.worldmapper.org/posters/worldmapper_map346_ver5.pdf

UN Data on energy consumption:
http://data.un.org/Data.aspx?d=WDI&f=Indicator_Code%3AEG.USE.ELEC.KH.PC

Energy Atlas, electricity generation by country:
http://energyatlas.iea.org/?subject=-1118783123#

Step 2: Connecting Classrooms, Climate4Classrooms Education Pack:
https://schoolsonline.britishcouncil.org/sites/so/files/files/Climate4Classrooms%20-%20Education%20Pack.pdf

Step 3: Carbon intensity of electricity around the world:
http://shrinkthatfootprint.com/electricity-emissions-around-the-world

Carbon emissions of electricity generation by country:
https://ecometrica.com/assets/Electricity-specific-emission-factors-for-grid-electricity.pdf

Sources of further information

Lesson 3

Richard Comp's Ted-Ed video on how solar panels work:
https://www.youtube.com/watch?v=xKxrkht7CpY

Energy Saving Trust:
www.energysavingtrust.org.uk/scotland/tools-calculators/solar-energy-calculator

Ofgem, UK Feed-In Tariff:
www.ofgem.gov.uk/publications-and-updates/feed-tariff-fit-generation-export-payment-rate-table-01-july-30-september-2016

Universitat de Barcelona, Life Cycle Assessment of solar panels:
http://diposit.ub.edu/dspace/bitstream/2445/57523/1/TFM_MERSE_AlejandroCalderon.pdf

Explain That Stuff, how a solar photovoltaic cell works:
http://www.explainthatstuff.com/solarcells.html

Lesson 4

Royal Geographical Society, Africa or Not quiz:
www.rgs.org/OurWork/Schools/Teaching+resources/Key+Stage+3+resources/Africa+A+continent+of+contrasts/Dealing+with+common+misconceptions+of+Africa.htm

Ashden Awards on solar power:
www.ashden.org/films?technology=25&region=All&tag=All&year=All

Lesson 5

Carbon Partners, Schools Electricity Carbon Calculator:
www.carbonpartners.org.uk/resources

Carbon Partners model:
www.carbonpartners.org.uk/

The Guardian, 'How sun, salt and glass could help solve our energy needs':
www.theguardian.com/environment/2016/jul/31/crescent-dunes-concentrated-solar-power

Solar Impulse:
www.solarimpulse.com/

Solar Active:
http://solar-active.com

The authors would like to thank Kevin Bailey, David Garlovsky, Beverley Hodt, Rimas Tankile Morris, Isele Tankile and Guadalupe Velazquez Velazquez for their contributions to this resource.