Wind Energy – A Level: Teacher notes. (2024)

This Unit of work consists of a PowerPoint presentation, and a student worksheet which includes a case study decision-making exercise, extension activities and an essay question.

The Powerpoint presentation and the decision-making exercise/case study are intended for a one-hour lesson on wind energy as part of the study of electricity generation and the energy mix in the UK.

The student worksheet and extension activities could be completed in lesson time or as a homework assignment.

The answers provided below are for guidance and are not definitive.

Wind Energy – A Level: Student activities – 2024.

1. **Formation of wind:** Using slides 2 and 3,
    a. Describe how wind is created in the earth's atmosphere. Wind is the movement of air from one place to another, caused by differences in atmospheric pressure. Winds blow from areas of high pressure towards areas of low pressure.
    b. Explain what factors affect wind strength. Wind strength is affected by the pressure gradients between the high and low pressure. The greater the difference, the stronger the wind. Wind speed is reduced by friction with rough ground, while it may be increased by being channelled around obstacles such as mountains or buildings.

2. **Electricity from Wind energy:** Using slide 4, 5 and 7, plus your notes from the video, explain how electrical energy is generated from the wind by a wind turbine. Wind turns the blades of a wind turbine. This mechanical energy is converted into electricity by a generator. The electricity is carried to a substation from where it is transferred to the grid to power homes and communities.

3. **Location of wind farms in the UK.** Using slide 6, Figure 1,
    a. Describe the pattern of average wind speeds in the UK. Greatest in North and West, lowest in South and East. Quote figures from Key.
    b. Suggest at least two reasons for the pattern shown. The windiest places in the UK are in the north-west, west and south-west, because these areas are more exposed to the prevailing south west winds. Hills and mountains are more exposed to the wind than low lying areas, because there is less

friction between the wind and the ground surface. Coastal areas are also windier, as there is less friction with the sea.

c. Explore the way wind speeds vary around the UK and Western Europe by looking at the Global Wind Atlas. Student activity – students could compare UK with areas of Western Europe such as the coast of France and Spain and inland areas e.g. Germany https://globalwindatlas.info/en

4. Development of Wind Turbines:

a. Referring to slide 8, summarise how wind turbines have developed since 1980? Wind turbines have increased in height, wind turbine diameter and power output.

b. Using slide 9, explain why is wind energy considered to be a renewable energy source when compared to fossil fuel sources of electricity such as natural gas, coal and oil? A renewable energy source does not use fuel or pollute the atmosphere and wind energy is inexhaustible. In its operation it does not emit greenhouse gases. However, in manufacturing and construction, there is a carbon footprint, for example, in manufacturing steel and cement.

5. Wind Energy in the UK. Using slide 10:

a. Explain the importance of wind energy in the UK energy mix. Wind energy is the second most important source of electricity after natural gas, a fossil fuel. It is currently becoming more important as older nuclear power stations are decommissioned.

b. Suggest reasons why is it still necessary for a country like the UK to have gas fired power stations in its energy supply mix, alongside wind energy? Wind energy varies with the weather. During periods of high pressure, winds can be light and the contribution less than on windy days. During very high wind speeds, cannot be used to avoid damage. The contribution from imports from Europe also varies. Students can explore this further using the Energy Dashboard. Energy Dashboard - real time and historical GB electricity data, carbon emissions and UK generation sites mapping

6. Where is wind energy generated in the UK? Using slide 11 and slide 6:

a. Give reasons for the location of

(i) onshore wind farms: Onshore wind farms are located more in relatively remote upland areas in Wales and Scotland with high average wind speeds. They are also located in areas which are less urbanised for example in mid Wales, Cornwall and Scotland. These areas experience

high winds, and they are less urbanised than other parts of the UK. Once generated, the electricity is distributed across the UK by the national grid.

(ii) offshore wind farms in the UK: Offshore wind farms are located in the North Sea. They are mainly in shallow water or on sandbanks, where construction is easier. There are fewer marine protected areas and areas of outstanding landscape. The East Coast is closer to centres of demand around London and the East Midlands.

b. Referring to an atlas or internet map of population distribution in the UK, suggest how the location of wind farms relates to centres of population. Many wind farm locations are some distance from centres of demand. Some wind energy can be used locally but otherwise needs to be transmitted to major population centres. Offshore locations on the East and South Coast are nearer to centres of demand, but the energy still need to be transmitted through overhead or underground cables. Students should note that many of the optimum locations for wind farms are remote from major cities.

7. **Building a wind turbine:** Using slides 12 and 15, summarise briefly the materials needed to make a wind turbine. Wind turbines are primarily constructed of steel, which can account for almost 80% by mass. Other materials include fibreglass for the turbine blads, resin and plastic, iron, copper and aluminium. Whilst the generation of electricity is renewable and carbon neutral, the construction process involving manufactured steel and plastics is not. Concrete, used for the foundations of wind turbines, has a significant carbon footprint. Composite materials used for the blades are challenging to recycle.

8. **Wind Farm end-of-life options**. The standard design lifetime of a Wind Turbine is at least 20 years according to the International Electrotechnical Commission standard. (IEC 61400-1). For many Wind Farms in the UK, the original planning permission was for only 25 years. Several wind farms will be approaching the end of their designed life in the period 2025 to 2035.
    a. Using the statistics in slide 16 and 17, explain why it is important to plan for the end-of- life options for the 11,700 wind turbines currently operational in the UK. Many wind farms and their turbines were designed to run for 25 years and will reach their planned end of life between 2025 and 2035.

b. Using slides 19 to 23, summarise the three current options for wind farms as they approach their end-of-life (Life-extension, Repowering and Decommissioning).

9. **Wind energy and the circular economy.** The circular economy model (slide 24) aims to use less raw materials, produce less waste and create fewer emissions. Using slides 25 to 30:
    a. Briefly summarise how the circular economy model could be applied to wind turbine design and construction. The circular economy aims to cut down on raw materials and residual waste by building in end-of-life scenarios where materials can be reused or recycled.
    b. Using examples, describe how the components of a wind turbine can be recycled. Components such as iron, steel, copper and some plastics can be recycled and reused in other products, providing a recycling site is within reach and has capacity.
    c. Explain the problems of fully recycling all the components and structural elements such as foundations of wind turbines. Some components cannot be currently recycled such as fibreglass, and grease. Incineration is expensive, and landfill may be locally banned. Components have to be transported to recycling points which may be expensive and will have a carbon footprint. Recycling sites may not have the ability or capacity to recycling components. Removal of foundations may disrupt local ecosystems that have developed around them, especially offshore.
    d. Produce a table to show the advantages and disadvantages of each of the three options. (Table based on the slides)

Case study and decision-making exercise: A separated student worksheet provides a case study of the Kirkby Moor Wind Farm in Cumbria, and a decision-making exercise.

Decision-making exercise Part 1: the 2015 decision

In 2015, the three options available for the Kirkby Moor Wind Farm were:

1. Life-extension
2. Repowering
3. Decommissioning

Using the available evidence from the slides your own ideas, which of the option 1, 2 and 3 would you have recommended in 2015? Provide reasons for your answer and explain why you rejected the other two options. Students should look at the various stakeholders and also the costs of decommissioning from a remote site. They should

evaluate the need for wind energy in this area and how it contributes to the national electricity grid, and also benefits local communities.

Decision-making exercise Part 2: the current situation (2024)

Permission was given to extend the life of the Kirkby Moor Wind Farm until 2027, when the when the planning permission for the current site runs out.

Look again at your decision and suggest what you would recommend as a possible course of action for when the wind farm approaches its end-of-life in 2027. Justify your answer.

Students could consider whether another extension of planning consent could be given in 2027, or a revised plan to install new larger turbines on the same site, given the need for electricity from wind energy.

Extension activities – going further.

1. **Research task:** Explore the Energy Dashboard on the internet. Energy Dashboard - real time and historical GB electricity data, carbon emissions and UK generation sites mapping
    a. Summarise how energy is being generated at present.
    b. Suggest why this varies from day to day and month to month.
    c. Explore how this has changed over the last 20 years.

    This research will vary depending on the year and month. Students could look at differences between summer and winter, and between windy days and calm days. (less wind energy produced during anticyclonic high pressure weather) Students can identify the decline of coal and oil and the rise of renewable energy over the last 20 years

2. **Research task:** Using research from the internet and other sources, explain why the decommissioning of a wind farm can cause problems. Use the following headings:
        a. Effects on the local ecosystem
        b. Effects on the local community (noise, intrusion)
        c. Difficulties concerning where and how materials can be recycled or reused.

3. **Research task: Offshore wind farms.** Research one named offshore wind farm that is approaching its end-of-life date using the internet. (UK or in Europe). For your chosen wind farm, assess the strengths and weaknesses of the following three options.
    a. Life-extension
    b. Repowering
    c. Decommissioning

Student activity – examples of offshore wind farms can be found using internet sources

4. **World pattern of use of wind energy**. Study Figures 1 and Figure 2.



Figure 1: Top 10 Countries by Wind Capacity. Source: [Top countries with the most wind power capacity in the world – MAP | UK | News | Express.co.uk]

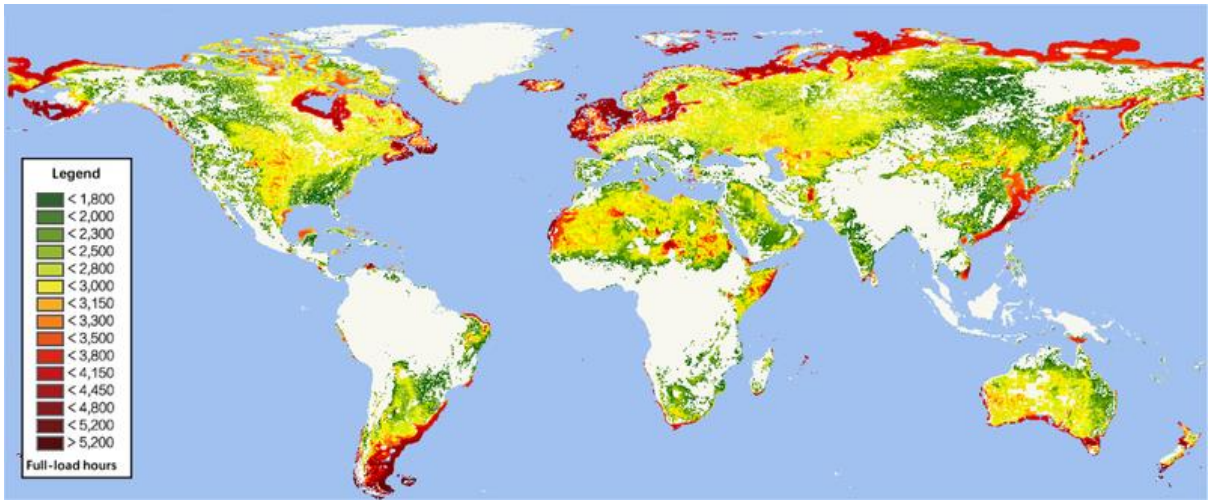


Figure 2: Distribution of global technical available areas for wind power generation and their full-load hours
Source: Distribution of global technical available areas for wind power... | Download Scientific Diagram (researchgate.net)

a. Analyse the data in Figures 1 and 2. The data shows that development of wind energy is related to the level of development of the country, the availability of wind power and levels of investment both from Government and private companies.
b. Using figures 1 and 2 and your own knowledge, suggest reasons why some areas of the world available for wind power generation have not been developed to their full potential. Students can identify the low level of wind energy development across much of the world, due to lack of money for investment in poorer countries, use of other local sources of energy, areas of low winds or with long periods of calm weather and problems with transmission of energy over long distances.

5. **Essay question.** How far do you agree that the generation of electricity from wind is a long-term sustainable energy option, as a part of a country's energy mix? Students should prepare a balanced answer which may argue that where affordable, wind energy is a long term sustainable option, but not always practical or achievable in the short term, for many different reasons. Students should use the slides to show that although wind energy is low cost and sustainable once installed, there are issues with the decommissioning of wind turbines and the recycling of materials.

Further reading and sources:

Wind Farms – Further reading

- Energy Dashboard - real time and historical GB electricity data, carbon emissions and UK generation sites mapping
- End-of-Life-decision-planning-in-offshore-wind_FINAL_AS-1.pdf (catapult.org.uk)
- https://www.eia.gov/energyexplained/wind/
- https://peak-wind.com/setting-an-end-of-life-strategy-from-day-1-key-considerations-for-a-fact-based-analysis/
- Wind power in the United Kingdom – Wikipedia
- Can wind turbine blades be recycled? | What happens to old wind turbine blades? | National Grid Group
- Beyond design life: What to do with aging wind turbines in Europe? - Rabobank
- Kirkby Moor: https://acp.planninginspectorate.gov.uk/ViewDocument.aspx?fileid=33507959
- Kirkby Moor – Ventient Energy

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