SAMPLE

Introduction: The Problems and Energy Sources

Lesson Aim

Describe the nature and scope of alternative energy.

ALTERNATIVE ENERGY

The definition of alternative energy is continually evolving. As we learn more about the earth, effects on the earth's climate, and alternatives to fossil fuels, scientists, social scientists, environmentalists, and activists may redefine meaning.

In its early days, alternative energy was usually defined as:

- Outside mainstream use.
- Environmentally sound in production.

Climate change, however, has driven interest and research into alternative energy such that its use is increasingly mainstream.

- Electric and hybrid cars are a reality, out driving on our roads.
- Wind farms are used in China, the European Union, Australia, Japan, and more.
- Solar panels are used throughout the world, and help supply cost-effective, non-fossil energy to developing countries.
- Corn-derived ethanol is used in petroleum to reduce emissions.

A key point in defining alternative energy is the word *renewable*. Renewable sources can be readily replaced or replenished, either by the earth's natural processes or by human action. Fossil fuels are a pollutant contributing to climate change, but they are also a non-renewable resource. Wind and solar power are renewable resources; corn is quick and efficient to grow, making corn-derived ethanol a renewable resource.

Energy for human activity is obtained from a variety of sources:

- Fossil Fuels (i.e. Oil, Gas, and Coal).
- Nuclear Fuels (i.e. Uranium, Plutonium).
- Renewable Fuels - Geothermal, Solar, Water, Wind Power, and Bio-fuels.

Important definitions

Alternative energy is a large, diverse, and ever-growing field. Below is a list of commonly used terms and their general definitions. It is important to remember, however, that definitions are context-dependent. The way an environmentalist defines solar energy may be different to how an atmospheric physicist defines solar energy.

Alternative Energy

Alternative energy is energy that is created in a way that does not deplete the earth’s natural resources, i.e. it is created from renewable sources in a way that is considered environmentally desirable or safe. Nuclear energy is generally not considered to be a form of alternative energy. Although nuclear energy production itself if considered to be clean energy, nuclear power uses uranium which when mined releases a lot of C02 into the atmosphere. In addition, the fuel has to be replenished periodically, requiring the mining of more uranium. As a further point, there is also the issue of dealing with the radioactive waste when the reactor is decommissioned after a life of approximately 40 years. The key here is therefore that alternative energy is derived from renewable sources, and therefore sustainable.

Renewable Energy
Energy derived from sources that are naturally or anthropogenically replenished such as solar, wind, wave/tidal, hydroelectric, biofuels and geothermal energy.

Solar Energy
Energy produced from the sun's solar radiation. It is often divided into passive (no mechanical devices) and active (e.g. photovoltaic).

Wind Energy
Energy generated through windmills/turbines.

Hydropower Energy
Energy generated by moving water, commonly from waterwheels, hydroelectric dams, tides and more.

Biofuels
Fuels generated from plant biomass, including bio-diesel and ethanol.

Geothermal Energy
Energy derived from the heat of the Earth's core.

WHY DO WE NEED ALTERNATIVE ENERGY?

Energy is a vital part of civilisation. Since time immemorial humans have used energy to supply many of their needs, from the heat generated by fire for cooking, through to the electricity used to build homes, factories, and office spaces. Without energy, humans would be unable to cook, drive, communicate online, and more.

Energy drives civilisation. Energy drives change. Energy is essential for communication, sharing, and globalisation.

The very structure of our social groups from families to corporations, is dependent on energy. This means our need for renewable, non-polluting energy is underpinned humanity's requirements for survival. And the more we grow, the more energy we need.

"*However imprecise it may be, most people still accept the steadfast formula: energy=progress=civilization."*
Williams (2006)

A Brief History of Energy Consumption

BC

1 Million - Discovery of Fire.

11,000 - Domestication of large animals.

7,000 - Development of agriculture and farming in China and the Middle East.

5,000 - First small cities – development of wheels, pottery, bronze, weapons, farming tools.

5,000 - Wind used to power boats on the Nile.

3,500 - Bronze Age.

1,500 - Iron Age.

200 - Windmills used to pump water in China and grind grain in Middle East.

AD

1100 - Windmills used extensively in Middle East, spreading to Europe.

1700 - A solar heater used to melt platinum.

1708 - Jethro Tull invents the mechanical seed sower leading to large scale cropping.

1709 - Iron smelted with coke by Abraham Darby.

1712 - First steam engine.

1769 - First (steam powered) automobile, Nicolas Cugot, France.

1779 - First steam powered cloth mills.

1800 - More households using coal for heat/cooking.

1800 - Voltaic Pile (literally a pile of simple galvanic cells) discovered by Alessandro.

1807 - Steamboat for commercial water transport, Hudson River (developed by Robert Fulton).

1821 - Faraday shows electromagnetic rotation which is the basis for the motor.

1830 - First known commercial use of geothermal energy – Hot Springs, Arkansas.

1832 - Samuel Morse creates the (wired) telegraph.

1838 - Morse develops the telegraph and Morse code.

1846 - Creation of nitroglycerine by Ascanio Sobrero; later Alfred Nobel invented the detonator to provide a controlled explosion of nitroglycerine.

1847 - Discovery of area known as The Geysers, San Francisco.

1852 - The Geysers developed into a spa resort.

1859 - First oil well in Pennsylvania.

1867 - Alfred Nobel patented dynamite, which was composed of nitroglycerine and absorbent materials.

1876 - Bell invents the telephone.

1879 - Edison invents the incandescent lamp.

1885 - First automobile with an internal combustion engine (Carl Benz).

1888 - First electricity generating wind turbine invented (Charles F Brush, Ohio).

1890 - First wind turbines in Denmark.

1892 - World's first district heating system in Boise, Idaho (water piped from geothermal springs).

1896 - Guglielmo Marconi develops the wireless telegraph (patented in 1897).

1901 - First mass produced car (Curved Dash Oldsmobile, Oldsmobile, Michigan).

1903 - The Wright brothers develop the airplane.

1904 - First geothermal power plant in the world (Larderello, Italy).

1908 - Model T Ford (produced on the first moving assembly line).

1920/25 - The Persian Gulf and Texan oil fields are opened.

1922 - First geothermal power plant in the US.

1928 - First transmission of transatlantic TV signals (John Baird).

1936 - First computer to demonstrate logical processes (The Turing, Alan Turing).

1941 - Russell Ohl developed the first silicon solar cell.

1943 - First electric programmable computer (The Colossus, Tommy Flowers).

1951 - First electricity generation by a nuclear reactor (EBR-I experimental station in Idaho).

1954 - Obninsk, Russia – first nuclear power reactor connected to the power grid.

1954 - First silicon photovoltaic cell.

1959 - First computer chip (Texas Instruments, New York).

1968 - Silicon Chip.

1976 - Apple II first home computer.

1983 - First mobile phones.

1991 - Internet.

1980's - Commercially viable wind turbines established in California.

2001 - 3G mobile broadband introduced, small scale.

2007 - iPhone introduced, beginning of smartphone revolution; Netflix streaming begins.

2009 - Mobile data use becomes mainstream, beginning of 4G.

2010 - Tablet devices become mainstream.

2019 - Beginning of 5G communications.

THE INDUSTRIAL REVOLUTION

An unprecedented period of growth beginning in the late 1700s, the industrial revolution saw an unprecedented amount of energy use and productivity. Prior to the Industrial Revolution, manufacture had been limited to the amount of product a person could produce alone, or in collaboration with others. The development of machines, machine production, and early automated processing quickly improved productivity. It also created a sudden surge in the need for energy.

It has been estimated that in the first two decades of the 20th century humans consumed more energy than they had used, up until that point. i.e. in 20 years, humans used more energy than all of human civilization over more than 2 millennia.

The Industrial Revolution initially relied on wood, coal, horses and water power to drive production. The advent of the steam engine and its deployment circa 1775 led to an increase in coal use – use which would soon grow into serious dependency. Increases in coal use quickly led to new levels of air and water pollution.

Climate Change

One of the most important environmental impacts to arise from the Industrial Revolution is climate change. Although the existence of climate change is sometimes debated, it is a very real, indisputable, thing.

Climate change is most often defined as a change in climate and weather patterns. It is most often attributed to anthropogenic effects, i.e. changes caused by humans, including the use of fossil fuels. Although scientists once referred to global warming alone, we now use the term climate change because changes are not limited to increasing temperature. Although the mechanisms are not yet entirely clear, many scientists believe extreme weather events are most likely side effects borne of a climate that is shifting.

Global Warming

Global warming is a real concern. It refers to ongoing increases in the earth's temperature. It is generally agreed that this is being caused by pollutants, CFCs, and increased levels of carbon dioxide which are causing an erosion of the earth's atmosphere. Global warming is an overall trend seen over a long period of time. It does not refer to single extreme weather events.

The Greenhouse Effect

This is the process through which global warming occurs. The erosion of the atmosphere and presence of gases such as carbon dioxide in the air results in more heat from the sun entering the atmosphere and then becoming trapped in these gases. This is known as the greenhouse effect.

With industrialisation, an ever-increasing number of greenhouse gases entered the earth's atmosphere. Greenhouse gases are radiatively active. This means they will send energy out in all directions. This includes radiating heat downwards, on to the earth's surface.

The earth always loses some heat to space. Greenhouse gases form a type of middle layer between the earth and the upper levels of the atmosphere. They absorb heat from the earth and send it back out again – some upward, some downwards. The heat sent downwards increases the earth's temperature.

The earth's atmosphere is composed of 78% nitrogen, 21% oxygen, and only about 1% of greenhouse gases (water vapour, carbon dioxide, methane and nitrous oxide). Since the Industrial Revolution atmospheric concentrations of CO_2 have risen from under 1 billion metric ton/year in the early 1800's to over 8.7 billion metric tons/year in 2019.

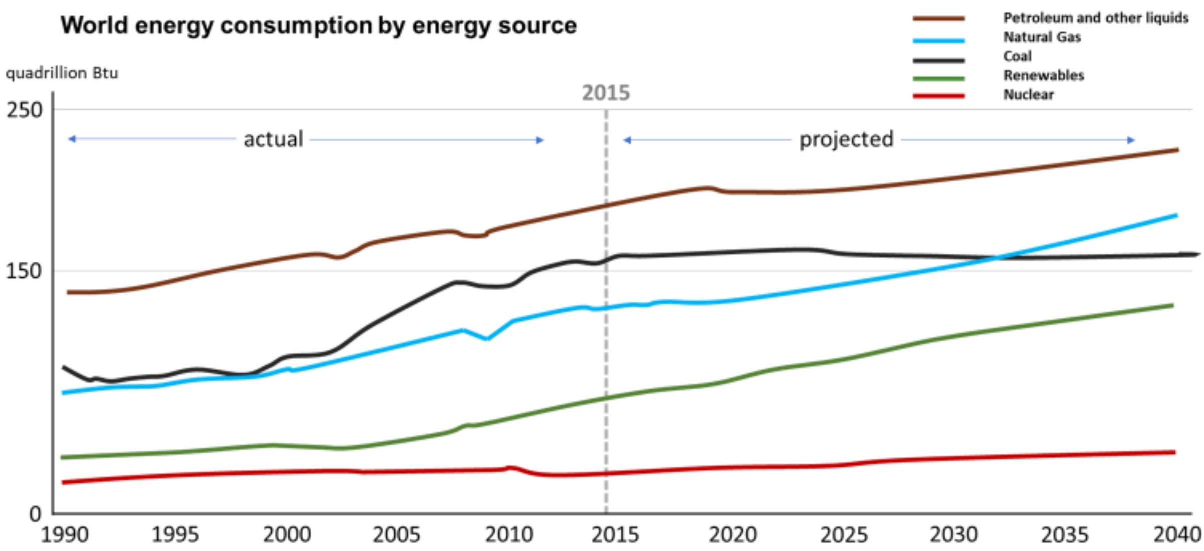
There are two main sources of anthropogenic greenhouse gasses. These are:

- Burning of fossil fuels such as coal, natural gasses and petroleum.
- Deforestation; causing CO2 to be released through both decaying vegetation and burning vegetation.

The difference between climate and weather

Although many people use these terms interchangeably, they have distinct meanings when used in the context of climate change and alternative energy. Weather is often defined as the effects we are experiencing short term, while climate is the average of weather over a long period. It might help to think of weather as a small set of data, and climate as a trend line. Scientists look at the big picture, which means they must look at trend lines.

Table: World Fuel Use by type 1980 – 2040. Note fall in consumption of coal, while renewable fuels are the fastest growing forms of energy.



Source: Adapted from the Energy Information Administration (EIA), 2017, International Energy Outlook 2017.

NUCLEAR ENERGY

Nuclear energy is a contentious topic. When well-designed and set up, it can provide safe, clean energy. If ill-maintained, or affected by natural disasters, damage to the plant can cause long-term deleterious effects to humans and the environment.

Radioactivity

The core of an atom is called the nucleus. The nucleus is made up of protons (positively charged) and neutrons (electrically neutral – no charge). Around the nucleus is a cloud of electrons (negatively charged). In a neutral atom, the number of electrons will equal the number of protons. The number of neutrons in an atom is usually calculated using weight.

The number of neutrons in an atom give it its neutron number. This tells us the atoms isotope. Isotopes occur when an atom has two or more possible forms caused by a difference in neutrons. Carbon is a good example of this. Carbon-12, the most common form of carbon, has 6 protons and 6 neutrons in its nucleus. Carbon-14 has six protons and eight neutrons in its nucleus. The number of protons in a given element remains the same; it is the number of neutrons that defines the isotope. The neutron number of an element is the number or protons plus the number of neutrons in the atom's nucleus.

Some isotopes are radioactive. This means they have an unstable nucleus and may decay. When a nucleus decays, it breaks apart and emits radiation and particles (parts of an atom). There are many types of radioactivity, but for our purposes, the three most important are:

- *Alpha:* Alpha particles are emitted from the nucleus. Alpha particles consist of two protons and two neutrons bound together into a particle. This type of particle radiation has low penetration.
- *Beta:* An electron is emitted. This is a high speed and high energy particle with medium penetration.
- *Electron Capture*: This occurs when there are too many protons in the nucleus and one of the electrons is captured by a proton to form an extra neutron in the nucleus. The atom's atomic number will decrease, but its mass will stay the same. This is because electrons have a negligible amount of weight.

Half-life

The half-life of an isotope is the amount of time it takes for one half of the nucleus in a given atom to decay. This is the common way of expressing the time for radioactive decay. Half-lives of known radionuclides vary widely, with highly radioactive substances decaying much faster than those that are weak.

Table: Half-Life Values of Some Common Isotopes.

Parent Isotope	Daughter atom (stable)	Half-life Value
Rubidium 87	Strontium 87	50 billion years (error of 30-50 million years)
Uranium 235	Lead 207	700 million years
Uranium 238	Lead 206	4.5 billion years
Potassium 40	Argon 40	1.3 billion years

Radioactive Waste Disposal

The disposal of radioactive material is arguably one of the greatest problems with this type of energy production. This is due to the extremely long half-life of the materials used. It is estimated that one reactor can produce up to 30-40 tonnes annually of waste. Although this may seem like a lot of waste, it is quite small in terms of the energy output generated, and especially so when contrasted with fossil fuel extraction and use. Nuclear waste is often isolated or diluted to reduce likelihood of harm. Some waste is buried deeply underground. Depending on waste type, there are also treatment options available to reduce or remove radionuclide content.

Energy Units

When comparing energy consumption, British Thermal Units, or Btus, are often used. Btus are a measure of heat energy. Here are some commonly used conversions.

- 1 barrel (42 gallons) of crude oil = 5,800,000 Btu
- 1 gallon of gasoline = 124,000 Btu (based on U.S. consumption, 2008)

- 1 gallon of diesel fuel = 139,000 Btu
- 1 gallon of heating oil = 139,000 Btu
- 1 barrel of residual fuel oil = 6,287,000 Btu
- 1 cubic foot of natural gas = 1,028 Btu (based on U.S. consumption, 2008)
- 1 gallon of propane = 91,000 Btu
- 1 short ton of coal = 19,988,000 Btu (based on U.S. consumption, 2008)
- 1 kilowatt hour of electricity = 3,412 Btu.

PROBLEMS AND CONTROVERSIES

All energy supplies have problems. The current trend for alternative energy sources is driven by a host of long-range ubiquitous problems associated with fossil fuels. Alternative energies, however, can cause problems of their own.

Fossil Fuels: Coal, Gas and Petroleum

Common environmental issues include:

- contribution to climate change via greenhouse gasses
- atmospheric sulphur dioxide (SO2), also known as acid rain
- smog and airborne particulates which contribute to lung diseases
- nitrous oxide (N2O) which contributes to ozone formation at low altitudes
- carbon monoxide (CO) and heavy metals.

Aside from environmental issues, fossil fuels are non-renewable. Their supply is finite.

The actual extraction of these types of fuels is as problematic and environmentally damaging as their actual consumption. Some risks associated with the production of these fuels includes: oil spills; heavy metal contamination and habitat disturbance.

Coal

Alongside the more general environmental problems associated with mining, coal is sometimes extracted via mountaintop removal. This means a company clears forest and topsoil, then uses explosives to access coal seams running through the mountain. Deleterious effects include toxic runoff, habitat destruction, and ecosystem damage caused by the resulting debris.

Natural Gas

Often considered the cleanest of fossil fuels, natural gas is a popular alternative to petroleum and some domestic supplies. The mining of natural gas, however, can cause significant environmental impacts. Fracking, a common technique, is a hydraulic fracturing process that breaks through shale to collect natural gas. This means a mixture called fracking fluid is pushed into the shale. This fluid is comprised of water and chemicals, and can contaminate groundwater and other water resources.

Hydroelectricity

Although hydroelectricity is renewable and relatively non-polluting, it does have some fairly significant environmental costs. Hydroelectricity is generally the production of electricity from the movement of water. Traditionally, this is done by damming a river to create a reservoir of water; this water is then used via controlled release to drive turbines.

Problems associated with damming and channelling water through a turbine include:

- Reservoir stratification leading to a decline in the amount of dissolved water.
- Habitat loss through dam construction.
- Changing water levels in reservoir; sedimentation of the reservoir which can also lead to nutrient loading.

- Erosion
- Dramatic changes in habitat for wildlife and fish.

Tidal Energy

This type of energy is produced through tidal wave energy generators. These are turbines set up underwater in marine areas with high tidal movement. They work in a similar fashion to wind turbines.

Problems associated with underwater turbines include:

- Environmental impact on marine life, including fish, mammals, and birds.
- Open water restrictions.
- Disruption to tidal cycles.
- Decrease in salinity.
- Reduction in currents in the area, potentially important for the ecosystem.

Wind Turbines

Wind turbines arguably have the lowest environmental impact of all the alternative energy options. The major argument against wind turbines is appearance: many landowners dislike the change in views, while others simply find them unappealing. Some countries are successfully deploying wind turbines on rooftop space, where they are less visible, and may be used to supply the energy needs of the building they are placed on.

Outside of appearance, the two major issues with wind turbines are:

- Lightning attraction (turbines acting as lightning rods).
- Flight patterns, migration, and flying wildlife (birds, bats).

Solar Photovoltaics

Solar energy is an almost clean renewable resource. It is, however, costly to produce and install. The production of photovoltaic cells may also create environmental impacts.

Unlike wind energy, solar energy is also affected by pollution and daylight hours. Energy can only be stored during the day; pollution affects the amount of solar energy reaching the cell.

Ethanol

Ethanol derived from corn and added to petroleum can reduce transport emissions. The production of this ethanol, however, has significant environmental and societal impacts.

Environmental

Significant amounts of electricity are required to produce corn derived ethanol. This amount is so great that it is not offset by the corn's carbon dioxide sequestration during growth. This problem holds true for other biofuel options, such as sugarcane.

Corn is often heavily treated with pesticides, and pesticide use on corn not used for animal or human consumption is not regulated in the same way as corn grown for food purposes.

Societal

Growing ethanol crops can create food displacement. The land used for these crops can no longer be used for food agriculture, which affects both supply and price. Alternatively, the demand for corn for ethanol generation creates a new market, which increases demand and thereby drives up the price of corn and corn-related products for the average consumer.

SET TASKS

Set Task 1

Spend some time researching textbooks, references or the internet to find out more about our history of energy production and consumption. If using the internet, please be mindful of the credibility of the sites you are looking at. Spend no more than one hour on this task.

Set Task 2

Do a thorough inspection of your home. Look at the different ways you use energy.   How do you think you could minimise energy usage in your home? Take notes. Spend no more than one hour on this task.