Energy Resources – Non-renewables, Teachers Notes

Learning objectives:

- Understand the definition of a natural resource, energy resource and give examples
- Understand the difference between non-renewable and renewable energy resources
- Understand how fossil fuels are made, what they are used for and give examples of pros and cons for coal, oil, gas and nuclear energy.

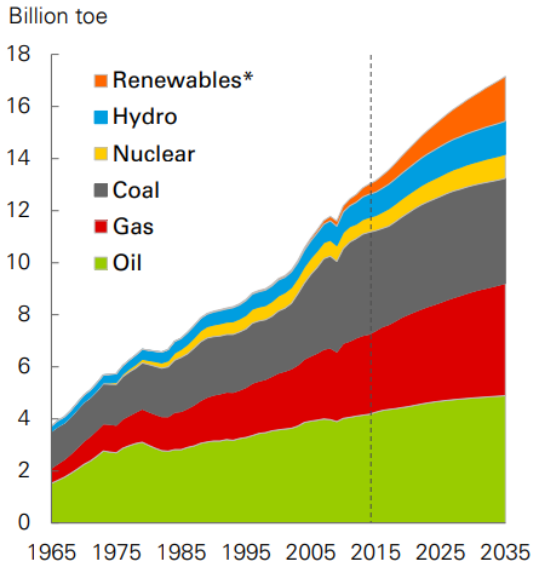
Presenter notes

Some suggested notes for each slide and information for the presenter. Questions the presenter could ask students are highlighted in bold. The Geological Society gives permission for presentations and notes to be adapted to suit the presenter's needs.

Natural resources and energy resources

Natural resources are any kind of natural substance which is required (or desired) by humans e.g. minerals and metals like iron, gold, copper, silicon are used as building materials and in technology such as computers, phones and cars, forests and rainforests are used for timber and medicines as well as being important habitats for thousands of species of animals, plants and fungi, crops like wheat, vegetables and fruits are grown for food, fossil fuels like coal, oil and gas are burnt for energy. Natural resources are not equally distributed across the Earth, as a result, countries must trade their natural resources to ensure that their needs can be met.
Natural resources used to generate energy (heat or electricity) are energy resources. Nations don' tend to be able meet their energy consumption needs from one energy resource so they must have an energy mix.

Non-renewable energy resources are finite and cannot be easily replaced; we as a planet are using them up faster than they are being made so they will inevitably run out. Non-renewable resources include crude oil, coal, gas and nuclear power – they are commonly known as fossil fuels. Renewable energy resources will not run out or can be easily replaced. Note that renewable doesn't necessarily mean no carbon dioxide emissions – burning biofuel and wood releases CO_2 (but these plants also take CO_2 when they are growing though photosynthesis), in the process of building hydroelectric dams and wind turbines non-renewable energy sources must be used (at present!).

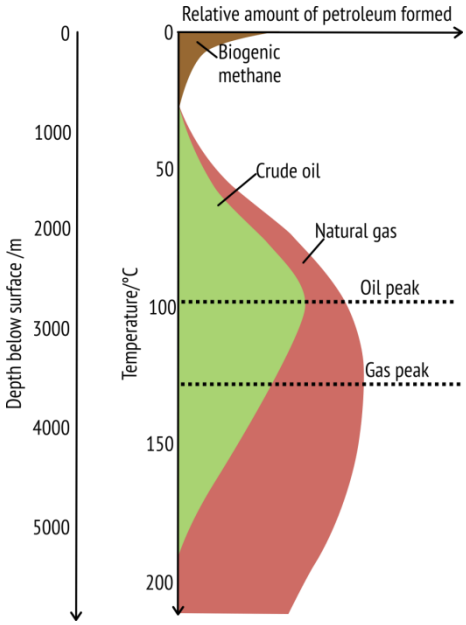


Graph of global energy consumption from BP 2017 Energy Outlook. Renewables in orange includes wind, solar, geothermal, biomass and biofuels. Dominant sources of energy at present are coal, oil and gas. In 2035 oil gas and coal are still predicted to account for more than 75% of total energy supplies, however hydroelectric power, nuclear and renewables are predicted to increase. The dip in 2009 relates to the global recession - caused primary energy consumption to fall by 1.1% (BP Statistical Review of World Energy).

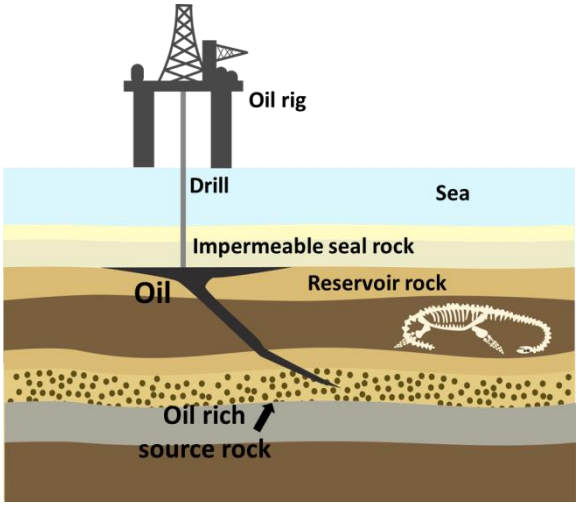
Oil and gas

Crude oil and natural gas are hydrocarbons formed from organic matter – largely phytoplankton (plant plankton) and zooplankton (animal plankton).

How do oil and gas form? Microorganisms sink to the bottom of the ocean and are gradually covered in layers of sediment creating layers of organic rich sediment. Environments with high primary production, low hydrodynamics (stagnant water), stratified water column (no mixing between layers of the water column), poor benthic (sea floor) fauna, and anoxic (low oxygen) conditions prevailing at the bottom, are the best prospects for the development organic rich source rocks as these conditions prevent the organic matter from decomposing quickly.
As the organic material is buried deeper and deeper (can be >5km burial) over thousands and millions of years the heat and pressure rises and the organic matter in the sediment is turned into petroleum (oil and gas). Temperature and burial depth determine whether oil, gas or other hydrocarbons are produced.

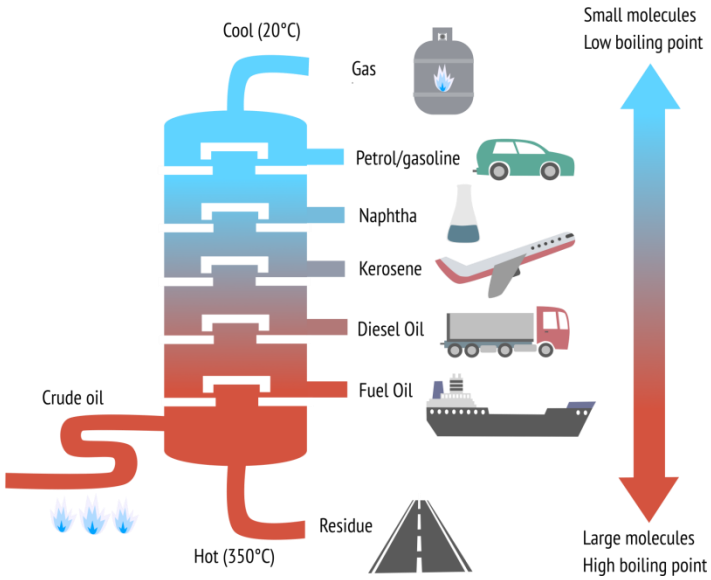


After oil and natural gas has formed, it is less dense than the surrounding rock so migrates upwards through tiny pores and fractures in the surrounding rock. Some oil and natural gas manages to get all way to the surface and escapes through vents into the atmosphere e.g. La Brae tarpits in California. Other oil and natural gas get trapped in reservoirs under impermeable layers of rock – known as seals or cap rocks. These trapped deposits are then drilled (after extensive exploration and testing) to release the oil and gas e.g. in the North Sea oil fields. Natural gas can be also extracted using hydraulic fracking. This process uses high-pressure water to split apart the rocks underground, releasing the natural gas that is trapped in rock formations.



Oil and gas can be burnt to produce electricity, to do this oil/ gas is burned in power plants to heat water and produce steam. This kinetic energy of the steam then propels the blades of a turbine (mechanical energy). The turbine is attached to a generator and when it spins it produces electricity. Oil is also used directly as fuel in cars, planes, buses and trains but it must be first be refined in an oil refinery by fractional distillation.

Fractional distillation - because they have different boiling points, the substances in crude oil can be separated using fractional distillation. Crude oil is evaporated and hydrocarbons condense at different temperatures in the fractionating column. Each fraction contains hydrocarbon molecules with a similar number of carbon atoms. Larger molecules have higher boiling points and do not ignite as easily so they condense low in the fractionation column e.g. bitumen used in roads and fuel oil for ships. The smaller molecules have lower boiling points so condense high up in the fractionation column; these hydrocarbons such as bottled gas and gasoline ignite more easily which means they make better fuels.



Natural gas is mostly made from methane and can be used for heating and cooking as well as generating electricity. Natural gas can be condensed into a liquid - liquid natural gas (LNG) which is much cleaner than any other fossil fuel and takes up less space so can be it transported and stored easily.

Pros	Cons
Oil and natural gas are relatively inexpensive to extract.	Release carbon dioxide gas into the atmosphere and contributes to global warming
Relatively reliable and dependable sources of energy	Prices can fluctuate substantially
Provide jobs and income money for the local community e.g. Aberdeen.	Oil spills are environmental disasters; oil penetrates bird feathers and mammal fur reducing insulation, buoyancy and flight ability.
Natural gas is a much cleaner fossil fuel than coal	Geopolitical issues

Coal

Most of the coal we have on Earth today was formed during Carboniferous period 360 – 299 million years ago when much of the Earth including the UK was covered in tropical swamps. As swamp plants died their remains sank to the bottom of the swampy areas, making layers and layers of squashed plant material. Upon burial the thick layers of plant material eventually turned into a brown spongey material called peat. Peat is the lowest rank of coal but it is an important fuel in places like Ireland, Scotland and Finland. Over millions of years and with changing environments layers of mud and silt build up on top of the peat bury it further. As the peat is buried deeper and deeper over millions of years, heat and pressure acting upon it turn it into coal.

The hotter the temperature, the deeper the coal is buried, and the longer the amount of time the coal is buried, the better (more efficient) coal you get – lignite, brown coal is the first type of coal (peat isn't technically coal) it has a low carbon content and a high moisture and volatiles content which means it doesn't burn very efficiently. Anthracite is the most efficient coal it has a high carbon content, very low moisture and volatiles content and burns with a short pale blue flame (complete combustion). Most of the coal we use is bituminous coal in between lignite and anthracite in terms of carbon and moisture content. Coal is still being produced today in swampy tropical regions but because it takes millions of years to form and very specific environmental conditions (needs a slowly subsiding basin to accommodate the thick layers of plant material) it is not a renewable resource.

Pros	Cons
Coal is very abundant across the Earth over 70 countries have coal reserves	Releases more CO_2 than oil and gas - is the one of the worst contributors to global warming.
Relatively cheap to extract	Releases sulphur dioxide and nitrogen dioxide into the atmosphere which contributes to acid rain.
Coal powered the UKs industrial revolution.	Coal mining is harmful to the environment and to workers; coal miners are exposed to toxic dust and face the dangers of cave-ins and explosions at work.

Nuclear power

The main nuclear fuels are uranium and plutonium these are radioactive chemical elements naturally occurring in rocks. Nuclear fuels are not burnt to release energy, they are involved in nuclear reactions where atoms are split to release large amounts of energy as heat in a chain reaction (nuclear fission). The rest of the process of generating electricity is then the same as in coal, oil and gas, the heat energy released by the nuclear reactions causes the reactor vessel to heat to about 300°C. This heat is used to boil water generating steam that spins turbines ad drives generators to produce electricity.

In the late 1990s, nuclear power plants contributed around 25% of total annual electricity generation in the UK, but this has gradually declined as old plants have been shut down. The UK currently has 7 nuclear plants with 15 operational nuclear reactors generating about 21% of total energy demand (2016 figure from Department for Business, Energy & Industrial Strategy). Half of this capacity is to be retired by 2025 so there are further sites in planning or in construction including Hinkley Point C in Somerset, currently Europe's largest building site. At present, the estimated total bill for Hinkley Point C is £20.3bn, more than twice the London Olympics.

The Scottish Government, with the backing of the Scottish Parliament, has stated that no new nuclear power stations will be constructed in Scotland.

Pros	Cons
Do not release greenhouse gases during electricity generation	Carbon dioxide emissions associated with nuclear power stations arise during construction and fuel processing,
Very efficient, a tiny amount of nuclear fuel produces a lot of energy	Radioactive waste - must be removed and disposed of from power plants it has to be sealed in containers and buried for thousands of years until it is no longer radioactive.
Reliable fuel	Nuclear accidents can occur releasing harmful radiation into the environment when e.g. the Fukushima Daachi nuclear plant melt down in 2011 as a result of the Tohoku tsunami.
	Lot of money has to be spent on safety so it is expensive.

Unconventional fossil fuels - tar sands and methane hydrates

Tar sands are sands or sometimes sandstones made from a combination of clay, sand, water and bitumen, a heavy black viscous oil. Bitumen can form in many ways but it is usually formed when lighter oil is degraded by bacteria. Bitumen is too thick and sticky to be pumped like oil and gas so tar sands have to be mined. Once extracted, the bitumen can be refined into oil. The largest deposits of tar sands are found in Alberta, Canada and thought to contain about 1.7 trillion barrels of bitumen.

Pros	Cons
We only have a finite amount of oil reserves left to use, tar sands represent a vast reserve of oil.	Oil production from tar sands uses large amounts of land (for open-pit mining), water, and energy, when compared to other oil resources.
Tar sands have provided a massive economic growth in Alberta, generating huge profits and providing thousands of jobs.	Carbon dioxide emissions are on average 15% higher when extracting bitumen from tar sands compared with standard crude oil extraction.
	Open-pit mining also produces a lot of waste (leftover sand, clays, and contaminants contained within the tar sands) that may pose a risk to nearby water supplies.
	The Athabasca Delta, where the Canadian tar sands are located, is a breeding ground for hundreds of species of birds.

Methane hydrate is a cage-like lattice of ice inside of which are trapped molecules of methane. If methane hydrate is either warmed or depressurized, it will revert back to water and natural gas. Originally they were thought to occur only in the outer regions of the Solar System, where temperatures are low and water ice is common, but significant deposits of methane hydrate have been found under the Arctic permafrost and beneath the ocean floor. They form either from biological matter or from heat processes deep within the Earth.

Pros	Cons
Methane hydrates represent an untapped reserve of fossils fuels which could provide the world with greater energy security.	CH_4 is 20 times more potent than CO_2 which means that is has a much greater warming effect on the atmosphere.
Countries including India, Japan and the US are currently developing mining techniques in order to be able to use methane hydrates as a source of energy in the future.	As methane hydrates are temperature sensitive global warming may liberate methane hydrates from the Arctic permafrost and sea floor sediments.
	Previous climate warming events in geological history – e.g. the Paleocene-Eocene Thermal Maximum ~55 million years ago have been linked with the release of methane hydrates.

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Other useful resources

Energy resources – renewable energy presentation: https://www.geolsoc.org.uk/Education-and-Careers/Resources/Activity-Sheets-And-Presentations

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