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Coal

FOSSIL FUELS

Carbon Saved	**1**/100
Energy Density	**60**/100
Sustainability	**10**/100
Deployability	**95**/100
Reliability	**90**/100
Cost Efficiency	**85**/100

Coal is the largest source of energy worldwide, being more abundant than other fossil fuels, but it produces the most waste and greenhouse gases per unit of energy produced. Coal was the fuel that powered the industrial revolution.

Natural Gas

FOSSIL FUELS

Carbon Saved	**10**/100
Energy Density	**65**/100
Sustainability	**6**/100
Deployability	**95**/100
Reliability	**95**/100
Cost Efficiency	**90**/100

Natural gas comprises of a mixture of flammable gases. As with other fossil fuels, the burning of gas produces air pollutants, but produces half the amount of greenhouse gases than coal does.

Oil

FOSSIL FUELS

Carbon Saved	**3**/100
Energy Density	**70**/100
Sustainability	**8**/100
Deployability	**95**/100
Reliability	**90**/100
Cost Efficiency	**75**/100

Oil can be used to generate electricity by using a steam engine, or by means of a turbine driven by exhaust gases. Oil has many other uses, most notably the fuel used in most of our vehicles is derived from oil.

Carbon Capture Coal

FOSSIL FUELS – CARBON CAPTURE

Carbon Saved	**55**/100
Energy Density	**40**/100
Sustainability	**4**/100
Deployability	**25**/100
Reliability	**85**/100
Cost Efficiency	**70**/100

Capturing carbon released from coal fired power stations and storing it in depleted oil reservoirs can reduce their carbon emissions. This reduces CO_2 release but takes more energy which means natural resources are used less efficiently.

Carbon Capture Gas

FOSSIL FUELS – CARBON CAPTURE

Carbon Saved	**65**/100
Energy Density	**47**/100
Sustainability	**2**/100
Deployability	**25**/100
Reliability	**95**/100
Cost Efficiency	**73**/100

Capturing carbon released from gas power stations works similarly to carbon capture coal. However, as gas is cheaper and has lower carbon emissions, the cost of carbon capture gas is less and the carbon saving is more.

Photovoltaic

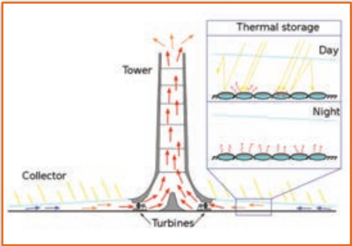
RENEWABLES – SOLAR

Carbon Saved	75/100
Energy Density	33/100
Sustainability	95/100
Deployability	80/100
Reliability	30/100
Cost Efficiency	2/100

Photovoltaic cells convert energy from the sun directly into electrical energy. This is more economical in areas with lots of sunlight but, it also requires a lot of land.

Solar Updraft Tower

RENEWABLES – SOLAR



Carbon Saved	**50**/100
Energy Density	**2**/100
Sustainability	**90**/100
Deployability	**10**/100
Reliability	**10**/100
Cost Efficiency	**1**/100

Solar updraft towers use large areas of greenhouse structures to heat air which flows up a chimney via a turbine to generate electricity. The very large areas required are not entirely lost as they can be used to grow plants too.

Molten Salt Storage (Solar)

RENEWABLES – SOLAR

Carbon Saved	60/100
Energy Density	23/100
Sustainability	97/100
Deployability	20/100
Reliability	60/100
Cost Efficiency	2/100

The molten salt storage method for concentrating solar power uses reflective mirrors to direct sunlight at molten salt to store heat energy. The stored heat energy can be used to generate electricity even when the sun is not shining.

Concentrated Solar

RENEWABLES – SOLAR

Carbon Saved	60/100
Energy Density	25/100
Sustainability	95/100
Deployability	30/100
Reliability	30/100
Cost Efficiency	10/100

The concentrated solar method uses lenses or mirrors to focus a large area of sunlight onto a small area to generate steam for powering a turbine as the light is converted to heat. This is good for large areas with lots of sunlight, but not effective when dark.

Pressurised Water Reactor

NUCLEAR FISSION

Carbon Saved	**82**/100
Energy Density	**85**/100
Sustainability	**60**/100
Deployability	**95**/100
Reliability	**95**/100
Cost Efficiency	**79**/100

PWRs are the world's most common type of nuclear reactor. Water is kept under pressure (to prevent it from boiling) and removes the heat from fuel to generate steam in the steam generators.

Boiling Water Reactor

NUCLEAR FISSION

Carbon Saved	**82**/100
Energy Density	**85**/100
Sustainability	**60**/100
Deployability	**90**/100
Reliability	**93**/100
Cost Efficiency	**79**/100

In a BWR the fuel is used to directly generate steam (unlike a PWR) which drives a turbine. This is the second most common reactor type after the PWRs, but there are none in the UK.

Advanced Gas Reactor

NUCLEAR FISSION

Carbon Saved	**75**/100
Energy Density	**78**/100
Sustainability	**55**/100
Deployability	**80**/100
Reliability	**65**/100
Cost Efficiency	**79**/100

AGRs are the second generation of UK gas cooled reactors. They operate at higher temperatures than Magnox reactors to increase efficiency. Carbon dioxide is used as a coolant.

Magnox Reactor

NUCLEAR FISSION

Carbon Saved	**80**/100
Energy Density	**74**/100
Sustainability	**50**/100
Deployability	**63**/100
Reliability	**66**/100
Cost Efficiency	**74**/100

Magnox reactors were the first commercial scale reactors in the world for producing electricity. They use carbon dioxide as a coolant, unlike most reactors deployed today which use water. The Magnox name comes from the cladding of the fuel "MAGnesium Non OXidising".

CANDU Reactor

NUCLEAR FISSION

Carbon Saved	86/100
Energy Density	75/100
Sustainability	53/100
Deployability	88/100
Reliability	90/100
Cost Efficiency	79/100

The CANada Deuterium Uranium reactor uses natural uranium fuel with heavy water as a moderator and coolant. Heavy water replaces the hydrogen in water with slightly heavier deuterium, which permits the use of un-enriched fuel.

Liquid Metal Fast Reactor

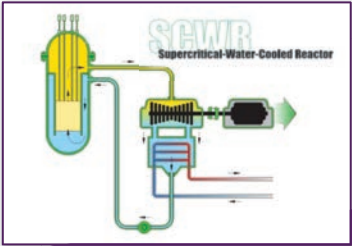
NUCLEAR FISSION

Carbon Saved	95/100
Energy Density	94/100
Sustainability	90/100
Deployability	20/100
Reliability	50/100
Cost Efficiency	59/100

LMFRs are also known as fast breeder reactors, they use a metal coolant and can be used to breed more than they use making them very sustainable. This may become more important as uranium reserves run out. They also have the potential to use long-lived radioactive waste as fuel.

Super Critical Water Reactor

NUCLEAR FISSION

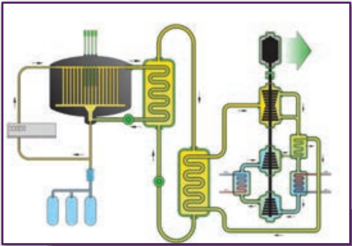


Carbon Saved	**95**/100
Energy Density	**94**/100
Sustainability	**90**/100
Deployability	**3**/100
Reliability	**50**/100
Cost Efficiency	**56**/100

SCWRs, like the liquid metal fast reactors, use resources more efficiently and are one of the next generation reactor designs being considered. However, a SCWR has never been built and has issues with corrosion.

Molten Salt Reactor

NUCLEAR FISSION



Carbon Saved	**95**/100
Energy Density	**84**/100
Sustainability	**88**/100
Deployability	**5**/100
Reliability	**95**/100
Cost Efficiency	**59**/100

An MSR reactor can use thorium instead of uranium (more abundant than uranium in the earth's crust) where the fuel makes up a liquid molten salt. This has several advantages over non-liquid fuel based reactors but is much less developed.

Pebble Bed Modular Reactor

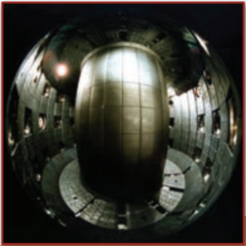
NUCLEAR FISSION

Carbon Saved	**90**/100
Energy Density	**85**/100
Sustainability	**65**/100
Deployability	**20**/100
Reliability	**95**/100
Cost Efficiency	**77**/100

In a PBMR, fuel is embedded in tennis ball sized graphite "pebbles" which are incredibly hard. This fuel form makes this reactor type inherently safe and allows the reactor to shut itself down with no human intervention.

Magnetic Confinement Fusion

NUCLEAR FUSION

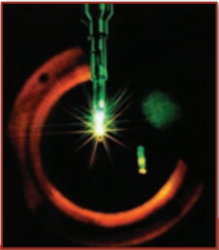


Carbon Saved	97/100
Energy Density	100/100
Sustainability	98/100
Deployability	3/100
Reliability	15/100
Cost Efficiency	5/100

Magnetic confinement fusion uses fuel with a temperature of 100 million°C, which would destroy any material it comes into contact with. To prevent this, magnetic fields are used to hold the hot fuel in place. This is the most well developed aspect of fusion power.

Inertial Confinement Fusion

NUCLEAR FUSION



Carbon Saved	97/100
Energy Density	100/100
Sustainability	98/100
Deployability	1/100
Reliability	10/100
Cost Efficiency	2/100

Inertial confinement fusion involves multiple lasers to compress pellets of fusion fuel to achieve very high temperatures in order to initiate fusion. This has many decades of research to go before it can be said to be a viable source of energy.

Onshore Wind

RENEWABLES – WIND

Carbon Saved	**90**/100
Energy Density	**10**/100
Sustainability	**92**/100
Deployability	**95**/100
Reliability	**20**/100
Cost Efficiency	**77**/100

In onshore wind farms the kinetic energy from the wind is converted to mechanical energy. Many of the largest operating onshore wind farms are located in the USA. They are generally located in hilly or mountainous areas.

Offshore Wind

RENEWABLES – WIND

Carbon Saved	**85**/100
Energy Density	**15**/100
Sustainability	**90**/100
Deployability	**90**/100
Reliability	**24**/100
Cost Efficiency	**66**/100

Offshore wind farms are more difficult to construct than their onshore counterparts, but the wind is stronger and more consistent at sea making them more reliable and able to generate around 50% more electricity than an onshore wind farm of the same size.

Deep-Offshore Wind

RENEWABLES – WIND

Carbon Saved	89/100
Energy Density	25/100
Sustainability	90/100
Deployability	7/100
Reliability	27/100
Cost Efficiency	28/100

Deep-offshore wind farms are designed as floating wind turbines. They are far from commercial deployment and only one is in use worldwide. Deep-offshore wind is very expensive compared to near-offshore wind.

High-Altitude Wind

RENEWABLES – WIND

Carbon Saved	**92**/100
Energy Density	**8**/100
Sustainability	**94**/100
Deployability	**7**/100
Reliability	**37**/100
Cost Efficiency	**30**/100

High-altitude wind is currently being developed as kites or lighter than air devices. These can reach high altitudes in places where there is always wind. None are yet at the stage where they are being used to produce energy.

Biomass

RENEWABLES – BIOMASS

Carbon Saved	**70**/100
Energy Density	**6**/100
Sustainability	**84**/100
Deployability	**91**/100
Reliability	**93**/100
Cost Efficiency	**79**/100

Biomass energy is generated from living, or previously living things (e.g. alcohol, wood and waste). Careful management of crops helps to minimise the environmental impact of this energy form.

Carbon Capture Biomass

RENEWABLES – BIOMASS

Carbon Saved	**110**/100
Energy Density	**3**/100
Sustainability	**78**/100
Deployability	**15**/100
Reliability	**90**/100
Cost Efficiency	**59**/100

Carbon capture biomass energy has the potential to remove more carbon than it generates by the growing of plants and capture of carbon after material is burnt.

GEOTHERMAL

RENEWABLES – GEOTHERMAL

Carbon Saved	**90**/100
Energy Density	**10**/100
Sustainability	**79**/100
Deployability	**60**/100
Reliability	**90**/100
Cost Efficiency	**84**/100

Geothermal heat pumps use the heat energy stored in the earth to create steam which is used to drive turbines. This requires a large underground area as the energy density is very low. Unlike most renewables, geothermal energy has the advantage of not being intermittent.

Hydroelectric

RENEWABLE – HYDRO

Carbon Saved	95/100
Energy Density	23/100
Sustainability	97/100
Deployability	95/100
Reliability	62/100
Cost Efficiency	87/100

Hydroelectricity can be generated when water held behind a dam is passed through a turbine. It is the largest renewable electricity source worldwide.

Tidal Barrage

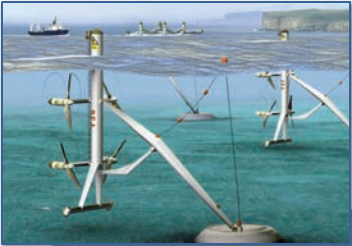
RENEWABLES – TIDAL

Carbon Saved	82/100
Energy Density	20/100
Sustainability	91/100
Deployability	51/100
Reliability	84/100
Cost Efficiency	25/100

Tidal barrages built across a river or bay can generate electricity as the tide goes in and out. The environmental effects aren't known and it is very expensive to set up, but during high tides the energy can be stored in the barrage and released when needed.

Tidal Stream

RENEWABLES – TIDAL

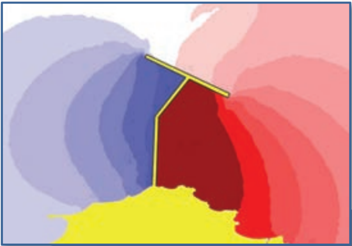


Carbon Saved	**84**/100
Energy Density	**22**/100
Sustainability	**97**/100
Deployability	**50**/100
Reliability	**71**/100
Cost Efficiency	**47**/100

Tidal stream uses underwater turbines to generate electricity from the predictable and reliable movement of water. Tidal forces arise from the gravitational force of the moon and rotation of the earth.

Tidal Dynamic

RENEWABLES – TIDAL



Carbon Saved	78/100
Energy Density	18/100
Sustainability	88/100
Deployability	14/100
Reliability	72/100
Cost Efficiency	30/100

The tidal dynamic method is under development. It is based on the fact that by building a dam off the coast, electricity can be generated from the water level differences on either side of the dam (red – high, blue – low).

WAVE

RENEWABLES – WAVE

Carbon Saved	88/100
Energy Density	16/100
Sustainability	95/100
Deployability	42/100
Reliability	27/100
Cost Efficiency	24/100

Wave energy is captured by absorbing the up and down movement of water to generate electricity.

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Attributes

Attributes are shown as percentage values on cards.

Carbon Saved

A measure of how the technology can contribute to reducing our carbon footprint. This takes into account lifecycle emissions from: material uses, construction, transport and waste, etc. A higher number reflects a bigger saving compared to other technologies.

Energy Density

A measure of how much electricity can be generated in a given volume. This takes into account: facility size, land required to mine materials and land required to dispose of waste, etc. High energy density is required for countries with high population densities like the UK.

Sustainability

A measure of how long natural resources will last to fuel and build facilities. Some fuels have limited supply whereas others are completely renewable and depend only on the material requirements to build new facilities.

ATTRIBUTES (cont.)

Attributes are shown as percentage values on cards.

Deployability

A measure of how developed and deployable a technology is. Some systems have been used on a large scale, others aren't commercially developed. Similarly, some technologies are commercially available but unlikely to be mass produced by private industry due to issues such as cost efficiency.

Reliability

A measure of how consistent energy production is. Some systems are constant, others are predictably intermittent and others are unpredictable. This also takes into account the probability of breakdowns and the need for offline maintenance.

Cost Efficiency

A measure of the average cost of a unit of electricity over the lifetime of a facility. This takes into account buildings, operating costs, decommissioning and waste disposal. The higher the number, the more cost efficient (and therefore cheaper) a system is for producing electricity.

How To Play

Shuffle the cards and deal them all out, face down. Players hold their cards in a face up stack, with only them being able to see their own. The player to the left of the dealer begins, choosing one of the attributes on the card at the top of their pile and reading out the value. Each player then reads out the value for that attribute on their top card. The person with the highest value for the chosen attribute wins and keeps all of the cards, putting them at the bottom of their pile. The winner can then choose the attribute for the next round.

Play continues until one player has all of the cards and is the winner of the game.

Ties

If a tie situation occurs, when two or more players have the same winning value, all players place their top card in the middle of the table and the turn

How To Play (cont.)

remains with the same player who chose that attribute. The next player who wins the round of cards also collects the pile of cards from the middle of the table.

Variations

Some play so that a player who has three or fewer cards left can look at them all and choose in which order to play them. This significantly lengthens the game.

Another variation for playing is to choose your own card deck (or mix of different energy sources) by laying out all the cards in the pack face up and then drawing lots to decide who is to get the first pick. This player gets to choose his first card. The person to the left of this player gets to pick the second card, and so on, with players continuing to take turns picking cards until there are none left. The game is then played as per normal.

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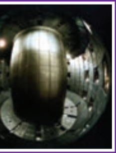  

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