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Energy Trumps

Gas

Gas (methane) is mostly used for heating buildings, producing electricity, and in industry. Small amounts are used for other uses, such as cooking. Gas provides about one third of UK total energy supply, but most is now imported.

Climate change CO_2e per kWh	400 grams / 240 grams	400 is for electricity from gas and 240 for heating and hot water. Escapes of unburnt gas add methane to the atmosphere.
Impact on nature	Moderate	Gas is mostly transported by pipeline with little local impact except installation. Burning gas and gas leakages contribute to climate change.
Risks	Moderate	Possible explosion of a storage depot, through accident and attack. Gas leaks can cause explosions in buildings.
Visual impact	Tiny	Mostly transported by buried pipelines.
Cost now	Very low	Gas cheap now, but price increasing. Could be rapid increases.
Cost 20 years	Moderate/Low	As gas stocks decrease and world energy demand increases, price likely to increase. Carbon taxes would increase cost but less than other fossil fuels.
The UK resource	Poor	Most of the UK "conventional" natural gas reserves have been used and sold. Imports now needed .
Reliability/ flexibility	Excellent	While stocks last, gas is a flexible and reliable, 'instant-on' and 'instant off' fuel for many uses.

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Energy Trumps

Coal

About one fifth of Britain's energy comes from coal, mostly used for generating electricity in large power stations. Most of it is imported, even though large UK coal reserves.

Climate change CO_2e per kWh	1100 grams	This figure is for coal-fired electricity production and would be lower for heat from coal.
Impact on nature	Very high	Coal mining has severe local effects. Gases from coal combustion cause acid rain and add a lot of green house gases to atmosphere.
Risks	Very high	Miners risk ill health and accidents. Emissions into the air cause respiratory illnesses. Mines can collapse.
Visual impact	Moderate	Spoil heaps, subsidence and open cast mining impact on the landscape. Many deliveries needed to fuel a power station.
Cost now	Very Low	Electricity from coal is cheap now and heating is even cheaper.
Cost 20 years	Moderate	Costs are likely to increase over the next 20 years in response to environmental regulations and carbon taxes.
The UK resource	Moderate	Large UK coal reserves. About 10-20 years supply is economic to extract, the rest may be too expensive
Reliability/ flexibility	Very Good	Coal can supply reliable heat and electricity. Quite bulky to transport and not suitable for all uses. Possible to convert to liquid fuel for transport.

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Energy Trumps

Oil

About a third of Britain's energy comes from fossil fuel oil, mostly imported. Some oil is used for heating and electricity production but mostly used as liquid fuels for transport.

Climate change CO_2e per kWh	**1200 grams** / **900 grams**	900 is for electricity from oil and would be lower per kWh of fuel used for heating. 1200 is for transport.
Impact on nature	**High**	The largest impacts are in the sea, from oil rigs, drilling materials, tanker spills. Also spills on land. Burning oil adds greenhouse gases to atmosphere.
Risks	**High**	Oil workers face risks including oil platform fires. Refineries / stores vulnerable to accident or attack. Countries may go to war to secure supplies. Oil pollution can affect health.
Visual impact	**Low**	Local impacts from refineries, road tanker movements and gas flaring. Big surface pipelines in some countries.
Cost now	**Moderate**	Fairly cheap now but costs likely to keep rising as world transport demands increase and supply peaks. Securing oil supplies could add to costs.
Cost 20 years	**High**	Oil likely to get more expensive as supply reduces from easier to extract sources. Carbon taxes and environmental regulations could also increase cost.
The UK resource	**Very Poor**	The UK has sold and burned most of its oil resources and will increasingly depend on imports.
Reliability/ flexibility	**Excellent**	While stocks available oil can reliably and flexibly provide heat, electricity and mostly transport.

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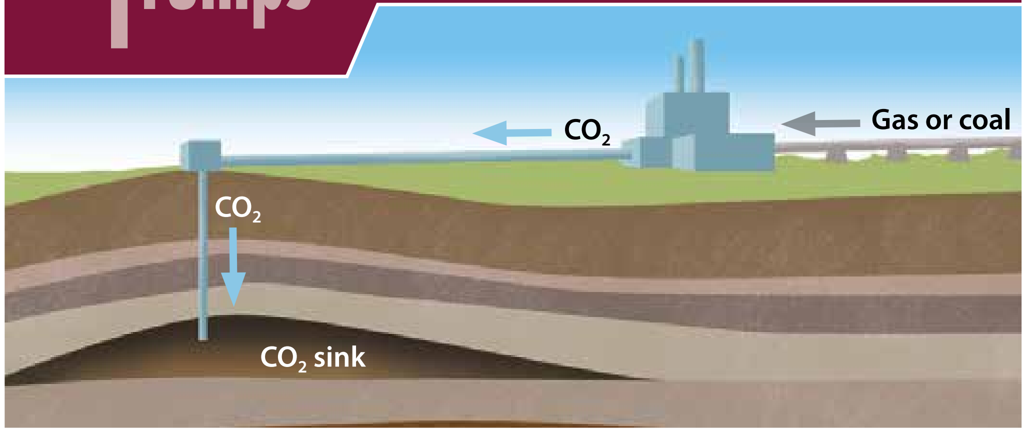
Energy Trumps

Carbon Capture and storage (CCS)



Not an energy source but a way to capture and store carbon dioxide from various fuels, so less enters the atmosphere. Most likely to be used with coal (and possibly gas or biomass). Even with CCS,10-20% of carbon dioxide still emitted, so emissions still high for coal. Not yet operating with a large power station. Needs pipelines in place to where it can be stored.

Climate change CO_2e per kWh	**200 grams**	200g emissions to the atmosphere after CCS for coal. Emissions could be negative if CCS used with biomass from a replanted source.
Impact on nature	**Low**	Most CCS takes place inside factories, pipelines and underground such as old gas or oil fields.
Risks	**Moderate**	Risk of increased climate change if the CO_2 stores leak but unlikely to occur quickly. CCS with coal reduces CO_2 emissions but may increase others.
Visual impact	**Very Low**	Only local impact, extra pipelines and pumping station.
Cost now	**Moderate**	Adds 50-70% onto the cost of electricity generated without CCS.
Cost 20 years	**Moderate/Low**	Costs likely to lower as technology develops. Would be more cost effective if carbon taxes applied to fuels.
The UK resource	**Good**	The UK has a good range of places to store carbon dioxide, in old gas/oil fields and saline aquifers. CCS only likely to be practical with power stations and some industry
Reliability/ flexibility	**Good**	New technology expected to reliably capture carbon dioxide but storage on large scale needs proving. CCS can be applied to a range of fuels but not all situations, for example transport.

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Energy Trumps

Nuclear Energy

image © Anglesey Môn Information Website

Nuclear power stations generate about 18% of Britain's electricity. Most stations are due to close by 2023 but there are plans to build more. Nuclear power currently relies on supplies of Uranium.

Climate change CO_2e per kWh	20 grams	Very little CO_2 is emitted in operation, but some is emitted during construction, mining, fuel processing decommissioning and waste storage.
Impact on nature	Low	Uranium mining is often opencast. Power stations use a lot of water. There is debate about the harm to nature from radioactive releases.
Risks	Very high/ Terrible	Accidents are rare but can be disastrous. Possible radiation risk from accidents, attack, sabotage, obtaining nuclear material and nuclear waste. Risk of radiation over very long time.
Visual impact	Low	Low visual Impact for kWh electricity produced. Power stations have few fuel deliveries. Uranium mines usually opencast.
Cost now	Low	Nuclear generation costs are disputed. Costs may not cover full decommissioning of the power station, waste storage over very long time period and the impact of major accidents.
Cost 20 years	Moderate	Likely to be increasing competition for declining stocks of uranium. Processing of lower quality stocks increases cost.
The UK resource	Very poor	No UK uranium mining resources. Small amounts in weapons and spent fuel.
Reliability/ flexibility	Very Good	While fuel stocks available can provide reliable electricity output but not very flexible.

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Energy Trumps

Passive Solar Building

Buildings can be designed to maximise warming from sunlight, with features like more glass on the south side (for this part of the world), dense materials to store solar heat gain and features to stop overheating in summer.

Climate change CO_2e per kWh	10 grams (for heat)	The only CO_2 emissions arise in making and installing extra materials.
Impact on nature	Tiny	No effect on natural systems except materials used.
Risks	Tiny	Badly designed passive solar buildings can overheat in summer.
Visual impact	Very low/Tiny	Need to be positioned to receive maximum sunshine with features to provide shading in summer.
Cost now	Low/Very low	A building with these features needn't cost much more and will save heating fuel costs.
Cost 20 years	Very low	Likely to become cheaper if more buildings built like this as design, building materials and building skills more widely understood.
The UK resource	Moderate	Won't run out but short daylight in winter and cloudy days limit benefits.
Reliability/ flexibility	Moderate	Can provide a contribution to heating quite reliably especially in spring/autumn. Not flexible and needs back-up heating.

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Energy Trumps

Solar Water Heating

In a solar water heating (SWH) system sunlight warms the water in solar panels. Over a year in the UK SWH can provide around 40-60% of a households' hot water, which reduces the use of other hot water sources like gas. Solar panels are usually part of or added onto a roof, but can be anywhere that faces towards the sun.

Climate change CO_2e per kWh	20 grams (for heat)	The only CO_2 emissions arise in making and installing the equipment. The warmth from the sun is carbon free.
Impact on nature	Tiny	No impact on natural systems except small amount of materials used.
Risks	Tiny	Only small local risks such as installing the panels on a roof.
Visual impact	Very low	Some people and planners may not like the look of SWH added onto older buildings. Panels can be integrated into a roof.
Cost now	Moderate	Equipment and installing costs are still quite high compared to money saved. Grants may be available in UK.
Cost 20 years	Low	SWH systems will probably be installed in new homes in the future, so costs should fall.
The UK resource	Moderate	Solar won't run out but cloudy days limit benefits; there's more solar gain in summer than winter. UK receives less solar gain than countries nearer the equator.
Reliability/ flexibility	Moderate	SWH panels work reliably but depend on sunlight, seasons and the weather. SWH works well to reduce the use of another hot water source. System not flexible when only SWH.

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Energy Trumps

Solar Photovoltaics

The technology for producing electricity directly from sunlight is called Photovoltaics (PV). PV panels are getting cheaper, subsidies in UK reducing. PVs mostly on buildings. Large areas of land for PVs called PV farms. PVs also used on appliances.

Climate change CO_2e per kWh	45 grams (for electricity)	The only CO_2 emissions arise in making, installing, maintaining and disposing of the equipment.
Impact on nature	Very low	Some impact from materials used in manufacture. Recycling of materials is improving. No impacts in use.
Risks	Tiny	Some installation risks if installing at height and while connecting panels. Toxic chemicals used in manufacture must be carefully dealt with.
Visual impact	Very low	PVs can be designed to blend in well but some poorly sited. Large area "PV farms" may have more impact.
Cost now	Moderate/High	Panel costs have reduced. Subsidies can further reduce ownership costs
Cost 20 years	Low	Costs are declining with increased sales and technology improving.
The UK resource	Moderate	Solar won't run out but cloudy days limit benefits. UK light levels poor, especially in winter.
Reliability/ flexibility	Moderate	PV electricity output depends on daylight, seasons and the weather; some reliability and predictability. Not flexible, variation in output needs balancing by other sources.

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Energy Trumps

Concentrating Solar Power

(with heat storage) (CSP)

In climates sunnier than Britain, it is economic to use reflectors to concentrate sunlight, producing high temperatures, steam and electricity. Stored heat (usually as molten salts), can be used to generate electricity at any time. This electricity could be imported to Britain by "supergrid" links not yet built.

Climate change CO_2e per kWh	26 grams (for electricity)	The only CO_2 emissions arise in making and installing the equipment.
Impact on nature	Low	No pollution caused, but can occupy large areas of ground and might affect some arid habitats.
Risks	Low	No major risks, but some possible occupational hazards with high temperatures and high structures.
Visual impact	High	The solar collection structures are large and highly visible from far away.
Cost now	Moderate/ High	Installation costs high for production and storage as CSP is still at early stage of development.
Cost 20 years	Very low	Development likely to bring costs down, although a "supergrid" needs building to import the electricity into the UK.
The UK resource	Very poor	The UK climate is unsuitable. CSP electricity would be imported to UK via long-distance 'supergrid' links.
Reliability/ flexibility	Very good	The ability to store solar energy as heat for several days means electricity could be produced mostly as needed, if the CSP is in a suitable sunny region.

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Energy Trumps

Liquid Biofuels

(first generation)

Crops such as wheat, sugar beet and oilseed rape (in UK) and sunflowers, soya bean and sugar cane can be turned into liquid biofuels such as biodiesel and bioethanol, for transport fuels. Food shortages could occur if much cropland is used to grow biofuel crops, rather than food.

Climate change CO_2e per kWh	560 grams (for transport) 350 grams (for electricity)	Carbon dioxide photosynthesised by the crop is added back to the atmosphere when it's burnt as a fuel. Artificial fertilizers and energy to process the crops also add greenhouse gases.
Impact on nature	High	Annual biofuel crops need a lot of land, fertiliser and probably pesticides.
Risks	High	Land used for biofuels competes directly with cropland for food, forcing world food prices up. Risk of soil nutrient depletion.
Visual impact	Low	Large areas of land are required, crops can be highly visible, but no more so than other crops.
Cost now	Moderate	Biofuels are probably more expensive than fossil fuels. Fuel companies are required to include a small percentage of biofuel in all transport fuels sold.
Cost 20 years	Moderate	Fuel crops still compete with food growing and other land uses, so cost unlikely to decrease.
The UK resource	Low	Land suitable for annual crops is limited, mostly used for food. Some land used for grazing could grow these crops. This would reduce meat and dairy production.
Reliability/ flexibility	Excellent	If produced, these storable, liquid bio-fuels are instantly available for many different uses.

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Energy Trumps

Solid Biomass

Biomass, usually from forestry thinnings, willow plantations and high-yielding tall grasses such as miscanthus, can be grown for heating and electricity. They take a lot of space to grow, but can be stored and used as required.

Climate change CO_2e per kWh	40 grams (electricity) 15 grams (heating)	Carbon dioxide photosynthesised by the biomass is added back to the atmosphere when it's burnt as a fuel Some energy used to harvest and process.
Impact on nature	Moderate/Good	Very large areas needed to supply much heat or electricity. Big local impact, but not usually for the worse as provides habitat, depends what replacing.
Risks	Very Low	Some local risks when planting and felling especially on slopes. Soil needs care. Diverting land from food crops could be a problem.
Visual impact	Moderate/High	Increased plantings of these crops would change the look of the countryside. Lot of lorries needed to transport crops.
Cost now	Low	Cost varies depending on site, size of area, ease of harvesting and processing
Cost 20 years	Low	Costs might increase in future with competition between land uses or reduce with improved processing.
The UK resource	Moderate	Biomass crops may keep being regrown, but the rate of growth and land availability in the UK are limited.
Reliability/ flexibility	Excellent	Stores of biomass fuels are able to supply reliable steady heat and electricity as required.

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Energy Trumps

Biogas/Bio-methane

image © EnviTec International

Biogas is a mix of methane and carbon dioxide from processing food wastes, animal manure, and other plant materials in "anaerobic digestors" (AD). Biogas is mostly used to produce electricity. Removing carbon dioxide produces "biomethane" that can be used in the gas grid. Leftovers after AD can be used as fertiliser and soil conditioner..

Climate change CO_2e per kWh	11 grams 5 grams	AD produces biogas from grown wastes. This is a nearly carbon neutral process, but some methane escapes. Emissions usually lower for heat production than electricity. 11g for electricity, 5g for heat.
Impact on nature	Tiny	"Cleans up" wastes that could cause pollution problems. None of the processes are toxic or take much space.
Risks	Low	Only a small risk of fire or explosion from gas at current rates of production.
Visual impact	Low	Local impact of industrial-scale equipment. Some truck and tanker movements.
Cost now	Moderate	AD processing usually done on a medium scale. The set up cost of equipment is quite high. Currently subsidised.
Cost 20 years	Low	Costs likely to be lower with research, investment and once the set-up costs are covered.
The UK resource	Moderate	Limited by waste inputs although special grass crops might also be used.
Reliability/ flexibility	Excellent	Reliable and flexible as long as biomass inputs available. Biogas/ methane can be stored for electricity generation or heat when needed.

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Energy Trumps

Landfill Gas

Nwy Tirlenwi Bryn Pica Aberbare

Many landfill sites produce a mixture of methane and carbon dioxide gas from rotting wastes. Modern landfill sites collect this gas to generate electricity, reducing greenhouse gas emissions. Wastes that rot are likely to be used in other ways in future.

Climate change CO_2e per kWh	16 grams 7 grams	Modern landfill sites collect most of the methane produced from rotting wastes. 16g for electricity, 7g for heat.
Impact on nature	Very low/Tiny	The collection and electrical generating facilities are compact. Greenhouse gas emissions are reduced.
Risks	Very low/Tiny	Rare risk of local explosion. Worse risks if landfill gas not collected and used.
Visual impact	Low	The equipment is situated on landfill sites and has little extra impact.
Cost now	Very low	The gas is readily available and easy to collect if the right structures are installed. Produces cheap electricity.
Cost 20 years	Moderate	Less gas produced if fewer biological wastes are added to landfill sites.
The UK resource	Poor	The amount of waste going into landfill is limited and declining.
Reliability/ flexibility	Excellent	Stored gas can be reliably and flexibly used as long as it is produced.

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Energy Trumps

Energy from Burning Waste

Cornwall Energy Recovery Centre (CERC)

Although recycling is encouraged there is much mixed waste still produced. Quite a lot of this is incinerated (burnt), generating energy for heating and electricity.

Climate change CO_2e per kWh	415 grams 166 grams	415g is for electricity from mixed waste that is 60% biomass (wood, paper, food and garden waste etc.), and 40% non-biomass (plastics etc.). 166g is for heat.
Impact on nature	Low/Very low	Incinerators fairly compact, potentially polluting emissions mostly dealt with when well run. Impact depends on how else waste would be dealt with.
Risks	Low	Could discourage recycling and waste resources if rubbish unsorted and burnt to keep incinerators fired up. Some health risks from chimney gases.
Visual impact	Low	Incinerators are compact relative to their output. They need a large number of waste deliveries.
Cost now	Very low	'Waste to energy' incinerators are paid to deal with waste as well as generate heat and electricity.
Cost 20 years	Low/Very low	Waste treatment centres might be paid to generate liquid fuels and materials for "carbon sequestration" instead.
The UK resource	Poor	The total resource is small, and likely to get smaller with more recycling and other treatment systems.
Reliability/ flexibility	Very good	An incinerator can reliably and flexibly produce heat and electricity as long as waste is available. Best if mixed waste not stored for days.

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Energy Trumps

Combined Heat and Power (CHP)

The new CHP plant at Birmingham Heartlands Hospital

Gas, coal and some other power stations produce about two and half units of heat for every unit of electricity. This heat is mostly wasted up "cooling towers" but could be used for industrial processes or for heating buildings through a "district heating system". Balancing production of heat and electricity over the year, with what is needed, could be difficult.

Climate change CO_2e per kWh	300 grams	Using natural gas this technology reduces fuel use and emissions by around 25%. Greater carbon savings possible if biomass used as fuel. This figure would be higher for coal.
Impact on nature	Very low	The technology is compact, with no toxic by-products. Some materials needed for extra infrastructure. Climate change impact improved.
Risks	Low	Balancing production of heat and electricity over the year could be difficult.
Visual impact	Very low	Similar visual impact as power station. Temporary local impact if pipes installed for delivering heat.
Cost now	Low	With low fossil fuel costs, may pay to waste the heat in making electricity rather than finding a use.
Cost 20 years	Low	Fuel costs likely to be higher, making CHP a preferred option and planned from the beginning.
The UK resource	Moderate	Finding a use for the heat is limited by where it's produced. Heat from electricity production could decrease if production methods change.
Reliability/ flexibility	Moderate	CHP works best where there is steady demand for both electricity and heat but sometimes it is difficult to balance these. Heat storage can help.

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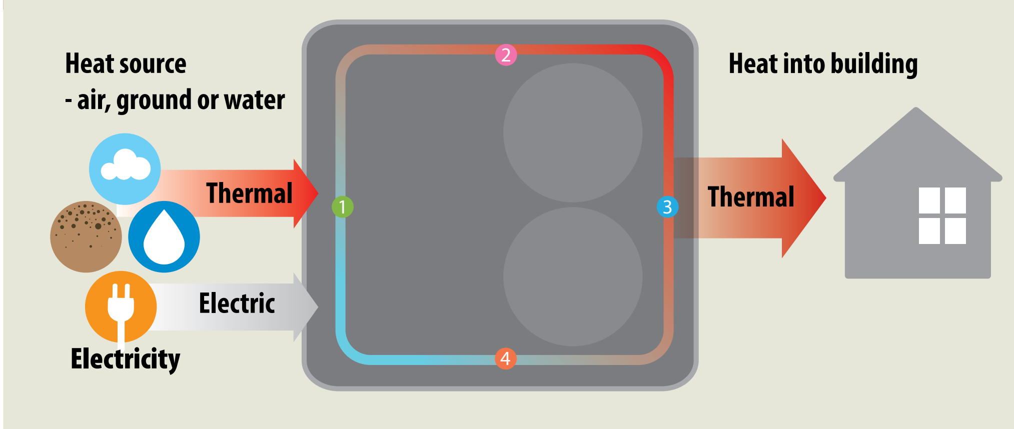
Energy Trumps

Heat Pumps



Most heat pumps use electricity to collect heat from the ground or air to provide space-heating and/or hot water. In the right circumstances the amount of heat-energy they collect is greater than the energy they need to run.

Climate change CO_2e per kWh	200 grams per unit of heat	Mains electricity, used to run heat pumps, is still mostly from sources producing a lot of greenhouse gases. Heat pumps can have much lower emissions if fossil fuels not used to provide the electricity.
Impact on nature	Low	Some local disturbance to the ground when heat-collection pipes are installed. Impact also depends on source of electricity used.
Risks	Very low	Very small risk of ground freezing if many ground source heat pumps installed close together. Badly designed systems can use too much energy.
Visual impact	Moderate/Low	Air-source heat pumps require large collector units outside a building. Ground source are buried.
Cost now	Moderate	The costs of installing a heat-pump system can be quite high. The savings come later.
Cost 20 years	Low	Heat pumps using low-carbon sources of electricity could be cheaper than other forms of heating especially if there is a carbon tax.
The UK resource	Very good	With insulated buildings and low carbon electricity, heat pumps could be the main source of heating in buildings.
Reliability/ flexibility	Moderate	Good most of the time but air source heat pumps are less effective in exceptionally cold weather.

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Energy Trumps

Geothermal

image © Southampton Geothermal Heating Company

In some parts of the world very hot water comes to the surface of the earth. This can be used for heating and generating electricity. Drilling down to hot rocks and pumping water through them also extracts heat. This is only possible in a few areas of the UK.

Climate change CO_2e per kWh	**40 grams** **16 grams**	Heat used is generated by processes inside the earth. Some emissions in making and installing the equipment and the processes. 14g for elecrticity, 16 f
Impact on nature	**Very low**	The heat mostly escapes anyway. Building a power station has a small local impact.
Risks	Low	Might risk triggering a small local earthquake in some cases. Some financial and planning risk estimating how long heat can be extracted.
Visual impact	**Very low**	A power station has a local visual impact and there are often large clouds of steam.
Cost now	**Very low/ Extremely high**	Where the resource exists, it can usually be accessed at a very low cost for heat. Electricity much higher.
Cost 20 years	**Very low/High**	Costs may reduce a little with improved technology.
The UK resource	**Poor**	Britain is not geologically active. Some UK areas have modest supplies. The potential for electricity production is debated. Heat would be used locally.
Reliability/ flexibility	Good	Once Geothermal is installed it can produce heat or electricity very reliably for decades. Output can be flexible but increases costs, best kept steady.

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Energy Trumps

Large-scale Hydropower

image © Caniluna Pty Ltd

In Britain large scale hydro power has been produced since the 1920s and most reservoirs were built over 50 years ago in steep valleys which submerged little vegetation. Reservoirs in some (especially warmer) parts of world produce lots of methane due to vegetation rotting in the reservoir.

Climate change CO_2e per kWh	**7 grams (for electricity)**	Methane emissions (depend on local circumstances and how long established) low for UK. Some emissions from materials used.
Impact on nature	Low	Big dams can have impacts on life in the river both before and after the dam. Once established reservoirs and surroundings can provide good habitat for wildlife.
Risks	Low	Dams can fail causing catastrophic flooding. Populations have been relocated to build dams.
Visual impact	Low	A large dam is highly visible but not usually from far away. Some pipes may be seen.
Cost now	**Very low/Tiny**	In a suitable place cheap power generated over a long time period.
Cost 20 years	**Very low/Tiny**	Likely to stay the same or cheaper relative to other energy sources.
The UK resource	**Poor**	Britain does not have many mountainous regions. Some steady resources, particularly in Scotland, most good sites already used. Climate change could alter rainfall and river flow.
Reliability/ flexibility	Good	Mostly reliable, usually more in winter. Supply could be affected by long drought. Flexible as water can be stored in reservoirs till needed. Inclusion of pumped storage (pumping water back up into dam) increases flexibility.

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Energy Trumps

Wave Power

The energy in waves comes originally from the wind. Wave power is still a fairly new technology, many designs have been developed to capture wave energy. The UK has good potential areas for wave power.

Climate change CO_2e per kWh	10 grams (for electricity)	Emissions only arise from making and installing the equipment.
Impact on nature	Very low	Close to shore wave installations might have effects on coastal habitat. Most wave power would be off-shore.
Risks	Very low	Risks while installing and maintaining devices at sea. Small risk of collision for shipping
Visual impact	Very low	Close to-shore installations might be large and obtrusive. Most would be off-shore.
Cost now	Moderate/ Extremely high	Wave power is expected to be expensive at first. It needs to be very robust to withstand extreme storms.
Cost 20 years	Moderate	Costs will fall as more are installed and with improved technology.
The UK resource	Good	Could provide about 7% of UK electricity and it won't run out.
Reliability/ flexibility	Moderate	Wave power depends on wind conditions but the hour to hour variability is less. Not flexible.

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Energy Trumps

Offshore Wind Farms

Wind farms in the sea benefit from stronger winds and are not easily seen from land if far enough offshore. Most offshore turbines are fixed to the seabed at depths up to 80m. In deeper waters floating turbines are possible.

Climate change CO_2e per kWh	11 grams (for electricity)	CO_2 emissions only arise in making, installing and maintaining the equipment.
Impact on nature	Very low	Sea-bed disturbance during installation (less if floating designs used). Vibrations may affect some marine mammals. Foundations can create habitat for sea creatures. Careful siting minimises bird disturbance.
Risks	Low	The main risks are to workers making and installing turbines in a harsh environment.
Visual impact	Very low	Most offshore wind farms are barely visible from the coast.
Cost now	Moderate	Costs high now as technology still developing in a challenging environment.
Cost 20 years	Low	Costs likely to come down as technology develops.
The UK resource	Excellent	Usually windy somewhere in the UK, windiest place in Europe. The wind is even stronger over UK waters.
Reliability/ flexibility	Moderate	Offshore winds can be reliably predicted over a few days, usually windy somewhere round UK. Variations in supply can be balanced by other electricity sources.

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Energy Trumps

Onshore Wind Farms

Britain is the windiest country in Europe. Onshore wind farms generated 3.5% of Britain's electricity in 2012 and more are being built.

Climate change CO_2e per kWh	**11 grams (for electricity)**	CO_2 emissions only arise in manufacturing and installing the equipment.
Impact on nature	**Very low**	Most disturbance during installation, particularly making foundations and if access tracks are needed. When well sited little impact in operation. Birds and bats occasionally fly into them.
Risks	**Very low**	Possible risks to installers and maintenance teams.
Visual impact	**Very high**	Can be highly visible as likely to be in an exposed possibly high place for best wind speeds, but may be remote.
Cost now	Low	Wind-power is fairly cheap now, and getting cheaper.
Cost 20 years	Low	Likely to be cheaper than now. If wind supplies a high % of UK electricity could be small extra costs to balance variability of supply.
The UK resource	**Excellent**	It is usually windy somewhere in the UK, one of the windiest places in Europe. Windfarm land can also be used for farming as little land is used.
Reliability/ flexibility	**Poor**	Wind power varies but can be predicted days ahead. Usually more in winter, which matches energy demand. Variations in supply can be balanced by other electricity sources.

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Energy Trumps

Tidal Barrage

La Rance tidal barrage in France

Dam-like structures are built across estuaries. Water flows through turbines in the dam as the tide comes in and out twice a day, generating electricity. Britain has the best tidal resources in Europe.

Climate change CO_2e per kWh	**9 grams (for electricity)**	A lot of materials needed to build a barrage but no emissions when generating electricity.
Impact on nature	**High**	Could be large impact on the estuary habitat due to changes in water flow.
Risks	Low	Construction workers may face some risks. Flood risks could be increased and decreased.
Visual impact	Low	A barrage is a huge clearly visible structure capable of generating a lot of power. Impact per unit of output is low.
Cost now	Moderate/High	Barrages are expensive to build but cheap to run.
Cost 20 years	Moderate	Cost may not reduce much but will be much lower than fossil fuel costs if there are carbon taxes.
The UK resource	Good	Britain has best tidal resources in Europe.
Reliability/ flexibility	Good	Tides have a reliable pattern. This can be part of a mixed-source electricity supply. Not usually flexible but multi-basin schemes could be more flexible.

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Energy Trumps

Tidal Lagoon

Artist's impression: wall of the Swansea tidal lagoon, planned for 2017

Tidal lagoons are enclosures built in places with a big tidal range, such as some estuaries or offshore. They fill up on a rising tide, empty on an outflowing tide and turn turbines in the lagoon walls.

Climate change CO_2e per kWh	**11 grams (for electricity)**	Large amount of materials needed to create a lagoon but very few emissions in operation.
Impact on nature	**Very low/Low**	Lagoons can be sited so the main flow of water in an estuary is not interrupted.
Risks	**Very low**	Construction workers may face some risks.
Visual impact	Low	Tidal lagoons look like low islands or large swimming pools.
Cost now	Moderate/High	Lagoons are expensive to build.
Cost 20 years	Moderate/ Very low	Cost may not reduce much but will be lower than some energy sources if there are carbon taxes.
The UK resource	Good	UK has the best tidal resources in Europe. Lagoons could produce around 5% of UK electricity.
Reliability/ flexibility	Good	Electricity produced reliably and predictably, with known variation over day and year. Water could be stored pumped into or between lagoons for extra flexibility.

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Energy Trumps

Tidal Stream

Tidal stream turbines are anchored underwater, driven by strong tidal flows in suitable places to produce electricity. UK has several excellent potential sites.

Climate change CO_2e per kWh	**8 grams (for electricity)**	Energy-intensive materials needed for the installations, but few emissions in operation.
Impact on nature	**Very low**	Some local disturbance when installed. Only small disturbance in use as little marine life in fast flowing waters.
Risks	**Very low**	Some installation and maintenance risks.
Visual impact	**Tiny**	Installations are underwater and need markers to indicate position.
Cost now	Low/High	Still at an experimental stage, likely to be expensive to build and cheap to run.
Cost 20 years	Low	Cost likely to come down as more built and technology improves.
The UK resource	Very Good	Tides will always flow and Britain has the best resources in Europe. Could produce a third to a half of current UK electricity.
Reliability/ flexibility	Moderate	Electricity production reliable and predictable but variable and not flexible. Can be integrated into a mixed-source electricity grid.

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Energy Trumps

Energy Efficiency

This is not an energy source, but ways of using energy better to get a similar result such as, insulating a house to stay warm, changing to energy efficient appliances and lighting. It is one of the quickest, cheapest and easiest ways to reduce carbon emissions.

Climate change CO_2e per kWh	**minus 100 grams**	Reduced emissions due to changing what done and how it's done. Some emissions with new equipment but these lead to savings.
Impact on nature	**Tiny or better**	Some impact from materials for equipment. Reduced contribution to climate change.
Risks	**Very low**	Very few risks unless money from energy saved spent in ways that produce higher emissions.
Visual impact	**Very low**	Some solutions have a visual impact others don't.
Cost now	**Very Low/ Tiny or better**	Could be some costs at first but money is likely to be saved with lower energy bills.
Cost 20 years	**Tiny or better**	Likely to save even more in the future, as carbon energy costs likely to increase.
The UK resource	**Very good**	The UK is quite energy wasteful. A range of solutions could save about 60% of the energy used at the moment and meet the same needs.
Reliability/ flexibility	**Excellent**	Energy efficient designs are likely to be at least as reliable and flexible as other designs and can improve systems overall.

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Energy Trumps

Low-carbon Life-styles

Living a low carbon lifestyle means making choices that produce lower greenhouse gas emissions (GHG). Some choices are quick and simple, but some take more effort and may not suit everyone.

Climate change CO_2e per kWh	**minus 200 grams**	Examples: reduced (or not) flying and driving, keeping the heating down, low-meat/dairy diet, buying less.
Impact on nature	**None or better**	Likely to be a positive impact
Risks	**Tiny or better**	Few risks. Choices may not suit everyone which could lead to more divisions in society.
Visual impact	**Very low**	Things may be kept longer and repaired rather than replaced. Fewer planes, cars and cows likely for example.
Cost now	**Tiny or better**	Very likely to save money.
Cost 20 years	**Tiny or better**	Still likely to save money.
The UK resource	**Very good**	Lot of potential to reduce carbon emissions if people prepared to make changes
Reliability/ flexibility	Good	Low carbon choices will reliably reduce GHG emissions. Less flexible than present choices as fewer choices available.

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Energy Trumps

Liquid Biofuels (second generation)

Perennial crops grow over many years. Coppiced willow, poplar and giant grasses like Miscanthus need few inputs and can be grown in places unsuitable for food crops. These can be turned into liquid biofuels for planes and lorries.

Climate change CO_2e per kWh	120 grams (for transport) 75g (for electricity)	Some emissions from transporting and processing crop. Carbon dioxide photosynthesised by the crop is added back to atmosphere when bio-fuel used.
Impact on nature	Moderate/Good	Changing land use to perennial crops will have temporary impacts, but provide plenty of food and habitat for wildlife. Large areas needed
Risks	Very low	Some small occupational risks during planting, harvesting and processing. Soil needs care. If land diverted from food could be a problem.
Visual impact	Moderate/High	Tall crops covering large areas that used to be grassland would have a big visual impact, especially at first.
Cost now	High	Although the technologies already exist to convert these crops, they are only done on a small scale and remain expensive.
Cost 20 years	Moderate	Improvements may be made in processing as well as increased yields from the crops planted.
The UK resource	Moderate	Land in the UK is limited but large grassland areas could be converted for this especially if less meat and dairy produced.
Reliability/ flexibility	Excellent	These fuels can be stored and used whenever required in a wide variety of applications.

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Energy Trumps

Micro Hydropower

Small-scale (micro) hydropower systems could provide small but useful quantities of renewable energy in many parts of Britain. Mostly the stream or river is not completely dammed for small scale hydro, so less likely to produce methane from rotting vegetation.

Climate change CO_2e per kWh	7 grams (for electricity)	Emissions from making and installing equipment. Methane emissions if waterway dammed and vegetation submerged and rots.
Impact on nature	Low	River flow is reduced a little between the intake pipe and turbine outflow. A grill over hydro pipes stops wildlife entering.
Risks	Tiny	Tiny risks in installation and maintenance.
Visual impact	Very low	Hydro pipes and turbine housing may have local visual impact but may be overgrown.
Cost now	Very low	In suitable sites can be a very cheap source of electricity.
Cost 20 years	Very low	Good, but in some areas climate change might reduce river flows in the long term.
The UK resource	Good	Many good sites especially in hilly areas. Could add about 1% to UK electricity.
Reliability/ flexibility	Moderate	Output affected by rainfall, seasons and site chosen. If water available, electricity produced reliably. Can be flexible if reservoirs used. Climate change might affect river flows.

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Energy Trumps

Hydrogen

Hydrogen is mostly produced from fossil fuels at the moment. It can also be created by electrolysing water. This would be a way of storing excess renewable electricity. Hydrogen can be stored and used for heat or in a fuel cell for electricity or transport. Hydrogen (in combination with carbon from biomass) could also be used to make synthetic liquid and gas bio-fuels.

Climate change CO_2e per kWh	**700 grams** **Very high at present as the hydrogen is mainly made from natural gas.**	Could be much lower in the future, if the hydrogen is produced from water by electrolysis, using renewably-generated electricity.
Impact on nature	High to Very low	Impact depends on how hydrogen produced. Electrolysis of water produces only hydrogen and oxygen. Water is produced when hydrogen is burned or used in fuel cells. Climate change impact high when produced from fossil fuels.
Risks	Low	Hydrogen can be safely stored, but is potentially explosive mixed with air/oxygen.
Visual impact	Low	Electrolysis production facilities are compact, although will require power lines to electricity grid.
Cost now	**High**	Hydrogen by electrolysis is not yet widely used.
Cost 20 years	Moderate	Equipment costs should reduce as more installations. Excess electricity to make hydrogen will be cheap.
The UK resource	**Very Good**	The UK could produce lots of renewable electricity. At times of excess supply this could be used to make hydrogen.
Reliability/ flexibility	**Very Good**	Hydrogen can be stored and used reliably and flexibly as required. Compression is required to reduce tank size especially for vehicles. Special tanks reduce risk of leakage.

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Energy Trumps

Shale Gas

Fracking, or hydraulic fracturing, is a technique to extract fossil fuel gas and oil from shale rocks. Fracking involves drilling down into the earth and injecting a high-pressure water, sand and chemicals mixture to fracture the shale rock and release the gas or oil inside.

Climate change CO_2e per kWh	**500 grams** 265 grams	500g for electricity from shale gas, 265g for heating hot water. Emissions higher if gas leaks occur during well construction. Higher for Shale oil.
Impact on nature	Moderate	Greenhouse gas emissions contribute to climate change. Much of the water used during fracking process, will need storage and waste treatment.
Risks	Moderate	Small earthquakes possible. UK legislation reduces risk that water contaminated in the process, would impact on water supply. Risk that legislation not complied with.
Visual impact	Moderate	Fracking operations are most visible at installation. Thousands of well sites needed to extract significant amounts. Increased traffic moving waste water.
Cost now	Moderate	Fracking has reduced cost of gas in U.S but UK regulations are stricter making it cost more to drill.
Cost 20 years	Moderate	Developing techniques and supply chain could reduce costs in UK but higher carbon taxes would increase the cost.
The UK resource	Moderate	Stocks exist but how much extractable once all legislation complied with and at what cost is uncertain.
Reliability/ flexibility	**Excellent**	Once produced, shale gas is a reliable and flexible fuel.