Energy fit for Life and the Environment
An accessible scientific comparison of possible sources renewable, fossil fuel and nuclear

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Summary. *Life needs energy that is powerful, reliable and has minimal impact on the environment. Which of all possible sources match these requirements? The differences are stark and nuclear energy stands out. However so far its general adoption has been hampered by an institutionalised culture of apprehension for which there is no justification.*

To most creatures energy means food and warmth. Squirrels may hedge against changing conditions by simply hoarding nuts, but early humans expanded their interest in energy as they learnt to use fire, power mills and sail ships. This won them supremacy on the planet, though their population was still small and standard of living poor. Later, vastly increased supplies came with the use of coal and steam. But it was the new reliability that transformed civilisation and eclipsed the resources offered by wood, water and wind. However today the use of fossil fuel, the foundation of the Industrial Revolution, is seen to cause unacceptable damage to the environment. What energy sources are available to support civilisation while caring for nature?

	Pre-industrial (Renewables)	**Industrial Revolution Chemical/carbon**	**Nuclear fission (also fusion)**
Fuel	Water, wind, solar, vegetation	Coal, oil, gas, food	Uranium, thorium (Hydrogen)
Typical energy density per kg	0.0003 kWh	7 kWh	20 million kWh
Lifetime supply in tonnes per person	Eg 10 million t water over 100 m high dam	500 t coal, emitting 1,800 t CO2	1/1000 t uranium or thorium
Points in favour	Familiar and accepted	24/7 availability, Standard of living	24/7 availability, No harm to life or the environment
Points against	Intermittent, Damage to the environment	CO2 emissions, Poor safety	Popularly feared, unfamiliar, poorly covered by education

Fuel is useful energy

Locating useful energy is a question for science. Technology and invention are essential but can only harvest energy where and when it exists. A hundred and fifty years ago it was understood that energy is everywhere around us, but that to be useful it needs to be concentrated. So the search for energy becomes a search for its concentrations, or “fuel” as we call it. Then come the questions: how big is the fuel's energy density and how did it come to be concentrated.

Boulders on a slope roll downhill only, unless pushed. In fact the direction of all change is downhill, that is towards reducing concentrations of energy. There are other examples: hot water tends to cool and ice tends to melt. Heating water and rolling uphill increase the concentration, but need a superior energy source to make them happen. Continuing with this picture, only the boulders some way up the hill are useful primary sources of energy. But how did they get to be there? Physical science offers just three types of primary fuel, each with its distinct range of energy and means of creation. These are compared in the columns of the Table.

The first is the sporadic source available from wood, wind and water, all powered by recent sunshine falling on Earth. The energy density is about 0.0003 kWh per kg, for instance, of water held behind a 100 metre high dam or wind blowing at 20 mph. This density is very low but was enough for mankind to build great cities, sail round the world and refine metals. Yet seasonal variations and the vagaries of weather meant that these supplies failed altogether, frequently and unpredictably, as they still do today. The energy density of any large moving object, like a water wave, an arrow or a bullet, lies in a similar range. However, simple quantum physics describes how much higher energy densities may be found if the objects are microscopic, like the electrons and nuclei within atoms.[1] Columns 3 and 4 of the Table refer to these.

Chemical energy and the creation of fossil fuels

Electronic energy densities are the business of chemistry, lasers, batteries and electronics, all of which lie in a similar range. For example, food is chemical with a density near 1 kWh per kg – directly related to the energy content printed on the food packet. But most of these chemical "boulders" are found at the bottom of the hill, as it were. Chemical energy fuel is not generally available on a large scale. For example, there are no natural stores of free hydrogen on Earth or pre-charged lithium batteries. If there were, they would be a good primary energy source.

Fossil fuels are the exception. They occur in nature, fully "charged" and on a large scale. Over hundreds of millions of years the energy of the Sun accumulated deposits of carbon by photosynthesis, effectively converting atmospheric and oceanic carbon dioxide into its separate atoms, carbon and oxygen. The energy density of this on-demand fuel, 10,000 times that of wind and water, drove the Industrial Revolution – for those who had the benefit of it. For 200 years whoever had access to fossil fuels ruled the world and enthusiasts in society, politics and finance eagerly followed who they were.

But no longer. The release of carbon dioxide into the atmosphere is a global threat. Though the environmental consequences remain unclear, the likelihood of an existential catastrophe makes burning fossil fuel no longer acceptable.

The effectiveness of 100% renewables

An obvious contribution can be made by improving building insulation and the efficient use of energy. However far more radical changes are also needed. The popular environmentalist reaction is to revert to the renewables. The same familiar wind, water and sunshine that served before the Industrial Revolution except that now they may be collected with modern technology. However the method of collection does not alter their low density and unreliability, and to harvest the energy required huge plants are necessary. Their size, often presented as impressive, in reality indicates just how weak is the energy they collect. Hydroelectric projects flooding hundreds of miles of river valleys and displacing millions of people. Many square miles of land and sea festooned with very large turbines. Hillsides and meadows completely hidden from view beneath arrays of solar panels. Forests felled and cleared to make space for planting biofuels. If Wordsworth were to return today he would not understand how such developments could be seen as environmental or *green*. And nor should we.

Crucially renewables only provide their advertised energy about 30% of the time, frequently much less and over long periods. Short fluctuations of a minute or two may be bridged by batteries, but most of the 70% back-up comes from fossil fuels. Germany has been attempting a transition to 100% renewables, the Energiewende experiment.[2] To prevent the high cost falling on industry

1 For a simple discussion read pages 159-161 of *Radiation is for Life* ISBN: 978-0956275646

2 https://www.cleanenergywire.org/news/climate-goal-failure-warrants-high-energiewende-priority-gov-advisors

domestic utility charges have risen sharply. The continued use of coal and gas means that carbon emissions have not come down and the experiment has failed.

Nevertheless and with the best of intentions, environmental movements around the world still place their faith in a future with 100% renewables.[3] Vested interests in fossil fuels, seeing the opportunity to provide energy when renewables cannot, are ready to support the deployment of renewables.[4] But the extra plant is either idle or continuing to emit carbon. These emissions and the defacement of large areas of land belie the image of carbon-free environmental energy. This deception is becoming increasingly evident to the public who also have to meet higher utility costs. But there is a viable alternative.

The creation of nuclear fuel

The final column in the Table refers to nuclear energy which has an exceptionally high energy density. What is the source in nature of the huge energy able to “charge up” nuclear, or roll it uphill, so making it widely available as fuel?

Before the solar system was formed 4.5 billion years ago violent nuclear change created all the elements around us today (except hydrogen). Similar extreme activity is seen today in the explosive merging of neutron stars and black holes.[5] The exceptional driving energy is provided by gravitation collapse. Although the vast majority of the unstable nuclei created decay quickly, there are just four varieties that decay so slow that many atoms are still found on Earth today: potassium-40, uranium-238, uranium-235 and thorium-232. All except potassium-40 can be used to produce enormous energy, a million times more than fossil fuel. With a density of 20 *million* kWh per kilogram, a single kilogram of fuel offers enough energy for a person for their entire life. Furthermore, there is sufficient fuel available on Earth to provide energy for mankind for more than a century.

A nuclear power station can be compact and resilient with a negligible impact on the environment. It needs little fuel and produces even less waste. This can be recycled and the residue buried, simply and safely. A power plant can run for 60 to 80 years with brief annual breaks for servicing. There are older designs that have worked well for decades and newer designs in development. Small modern modular plants (SMR) are designed for factory production and short construction times of 4-5 years. Many of these are lined up awaiting approval to invest in a first prototype.

Hurdles of superstition, missing education and vested interests

But there is a catch: the population generally, and those in authority too, are frightened by the label *nuclear*.[6] Fear of a nuclear holocaust was a psychological weapon used during the Cold War with extraordinarily powerful effect. Indeed collateral damage from that remains our problem today. At the time radiation safety regulations, wildly more cautious than justifiable by scientific evidence, were enacted to appease general concerns. In this they failed, instead ruling that fear of radiation was a matter for deliberation by the UN.[7] Still in force today, these regulations could be safely relaxed by a factor near a thousand. This is confirmed by all scientific evidence available today, including the accidents at Chernobyl and Fukushima. The radiation casualty figure at Chernobyl was 43, but at Fukushima none at all.[8] In each case fear and ignorance inflicted severe social, economic and environmental damage, both locally and worldwide, that far exceeded any effect

3 Including many voices who speak in the name of the US Green New Deal.

4 https://www.theguardian.com/environment/2015/jan/22/fossil-fuel-firms-accused-renewable-lobby-takeover-push-gas

5 https://arxiv.org/abs/1710.02142

6 As more fully discussed in the book *Radiation and Reason: the Impact of Science on a Culture of Fear* ISBN 978-0956275615

7 Sunbathing and the effects of ultraviolet radiation are far more dangerous in practice, but are better handled personally with advice from a pharmacy not the United Nations.

8 The references to the evidence are discussed in the books *Radiation and Reason* and *Nuclear is for Life* respectively.

from the radiation itself.

Because nuclear energy is so powerful many people find it hard to accept that it is not extremely dangerous. But there is a reason for this. Life on Earth evolved exceptional natural protection at an early stage. It had to, otherwise it would never have survived radiation levels substantially higher than today. Mutations of DNA are extremely common, and biological cells are adept at detecting and repairing them. Those that survive with mutations are eliminated by the immune system. For these reasons, low levels of radioactivity are harmless. Further reassurance comes from 120 years of clinical experience with doses of radiation used routinely to diagnose and cure cancer. Many people are living evidence of these health benefits of radiation.

A major social error has been that the science of nuclear energy and its benefits are little taught in schools, so that few people, teachers included, have any real familiarity with them. Those with jobs or investment in fossil fuels or Renewables are not motivated to learn more about nuclear energy. Many commentators oppose nuclear because power plants are too expensive and take too long to build – but both statements are consequences of the regulations and so unnecessary. The protracted planning and public consultation, the over-design of plants, unproductive working practices – all rest on the presumption that nuclear is safety critical. Many people have jobs that depend on this caution, and their salaries and self-interest only add to the supposed barrier of cost and opinion that deters the adoption of nuclear. In historical record shows that nuclear is by far the safest power source, and it could be cheap and quick to deploy too.

Where the future dangers for society lie

With a changing climate the most likely real dangers are extremes of weather, loss of energy supply and ensuing social instability, not the nuclear disasters imagined in fiction. Entertainment by horror involving radiation sells well, if the public is persuaded that it is true. However a stable society needs to be educated and anchored in the world of science. Safety in the real world, including its jobs and costs, should be clearly distinguished from the world of entertainment. More generally, all those who understand and care about the environment should work to expose wherever the task of mitigating climate change is obstructed by bogus safety costs.

A crash investment programme in nuclear power is needed worldwide, supported by genuine public education. Our grandchildren will not forgive us if we fail to use our knowledge and act accordingly. We should not wait, but follow the example set by Churchill who would write on important war-time minutes "*Action this day*".

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