THE PROVISION OF ENERGY WITHOUT FEAR

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The Global Warming Policy Foundation
Note 41

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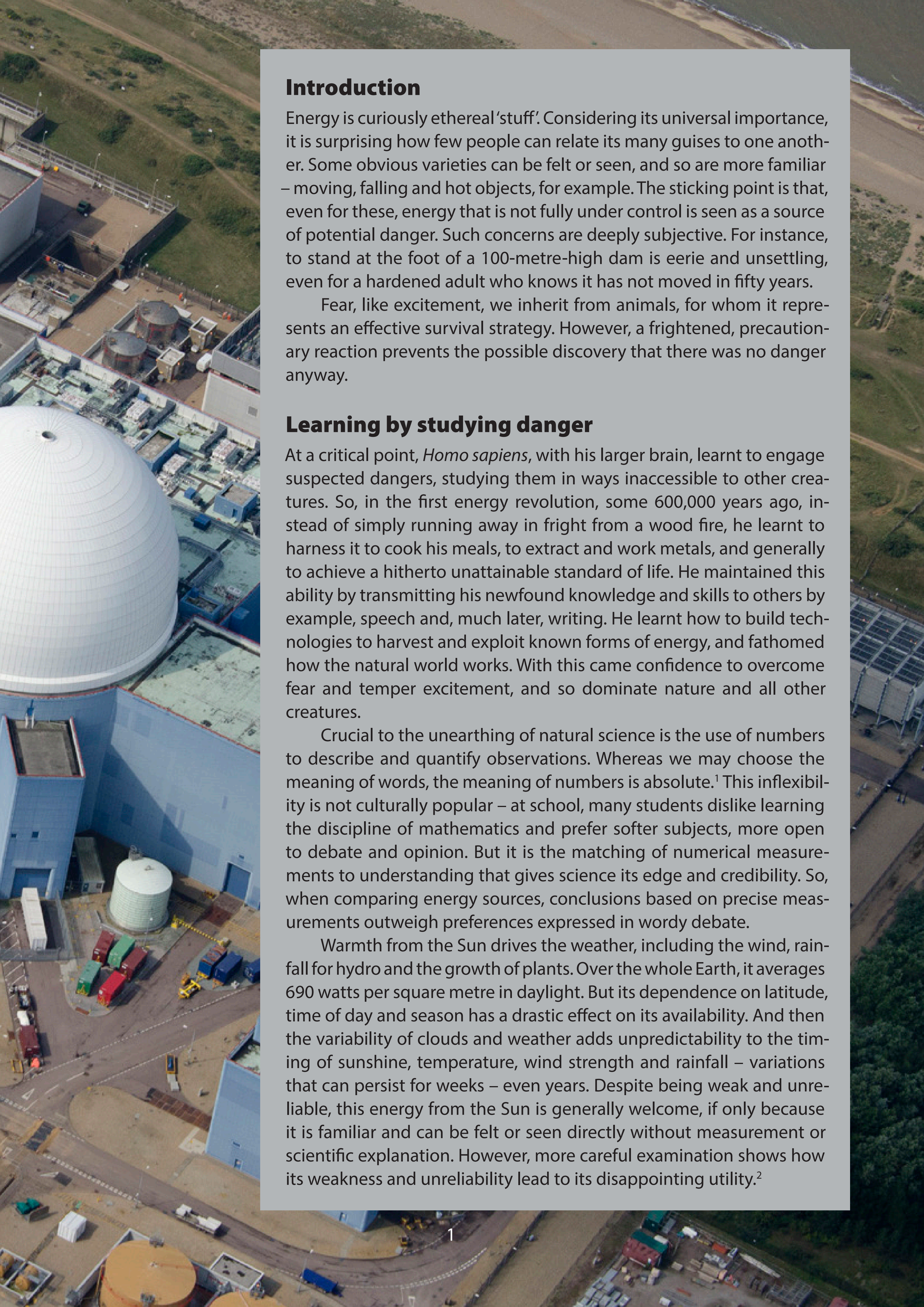
Might energy be made freely available at any time of day or night? And would human society welcome that? The human race stands at the threshold of a new revolution that offers answers to these questions. The impending revolution will be worldwide, but the greatest benefits will come to those who take the first steps. In previous centuries Britain has been a leader, but for the past seventy years it has shown a loss of confidence and a disdain for committing immediate effort towards long term objectives without an immediate electoral return. Its political and economic heft should make forward looking decisions at the expense of currently fashionable but scientifically superficial investments.



Introduction

Energy is curiously ethereal 'stuff'. Considering its universal importance, it is surprising how few people can relate its many guises to one another. Some obvious varieties can be felt or seen, and so are more familiar – moving, falling and hot objects, for example. The sticking point is that, even for these, energy that is not fully under control is seen as a source of potential danger. Such concerns are deeply subjective. For instance, to stand at the foot of a 100-metre-high dam is eerie and unsettling, even for a hardened adult who knows it has not moved in fifty years.

Fear, like excitement, we inherit from animals, for whom it represents an effective survival strategy. However, a frightened, precautionary reaction prevents the possible discovery that there was no danger anyway.

Learning by studying danger

At a critical point, *Homo sapiens*, with his larger brain, learnt to engage suspected dangers, studying them in ways inaccessible to other creatures. So, in the first energy revolution, some 600,000 years ago, instead of simply running away in fright from a wood fire, he learnt to harness it to cook his meals, to extract and work metals, and generally to achieve a hitherto unattainable standard of life. He maintained this ability by transmitting his newfound knowledge and skills to others by example, speech and, much later, writing. He learnt how to build technologies to harvest and exploit known forms of energy, and fathomed how the natural world works. With this came confidence to overcome fear and temper excitement, and so dominate nature and all other creatures.

Crucial to the unearthing of natural science is the use of numbers to describe and quantify observations. Whereas we may choose the meaning of words, the meaning of numbers is absolute.[1] This inflexibility is not culturally popular – at school, many students dislike learning the discipline of mathematics and prefer softer subjects, more open to debate and opinion. But it is the matching of numerical measurements to understanding that gives science its edge and credibility. So, when comparing energy sources, conclusions based on precise measurements outweigh preferences expressed in wordy debate.

Warmth from the Sun drives the weather, including the wind, rainfall for hydro and the growth of plants. Over the whole Earth, it averages 690 watts per square metre in daylight. But its dependence on latitude, time of day and season has a drastic effect on its availability. And then the variability of clouds and weather adds unpredictability to the timing of sunshine, temperature, wind strength and rainfall – variations that can persist for weeks – even years. Despite being weak and unreliable, this energy from the Sun is generally welcome, if only because it is familiar and can be felt or seen directly without measurement or scientific explanation. However, more careful examination shows how its weakness and unreliability lead to its disappointing utility.[2]

Two more energy sources

But there are two other forms of primary energy widely available on planet Earth today. 'Only two? What about hydrogen and batteries?', you may ask. But those are secondary, and require charging from some primary source – the latter being what we need to find. Given a reliable primary source, batteries and hydrogen can become important energy carriers.

Unlike the touchy-feely 'renewables' – wind, sun and waterpower – these two other forms of primary energy have no obvious visible mechanism or clockwork. Nevertheless, they are studied and measured to facilitate comparison with the solar-driven renewables. Do they provide more energy? Are they controllable?

Any store of energy is likely to run down or discharge if left alone – cups of coffee go cold, boulders roll downhill, batteries go flat – never the reverse. Apart from energy from the Sun, the Earth has been isolated for the past 4,500 million years. So primary sources that survive must be exceptionally secure.

The first is fossil fuels. The remains of life, starved of air and buried in the Earth during earlier geological epochs, these have been preserved on a vast scale. The energy storage mechanism we call 'chemistry', although it was only in the 1920s that chemistry's underlying 'clockwork' was understood to be the quantum motion of electrons in atoms and molecules. Since then, a whole range of chemical, electronic and biological phenomena has been studied, and their technologies developed, all arising from the kinetic energy of electrons in materials, and all with similar quantitative values for energy density, some thousand times greater than renewables. However, fossil fuels are unique among chemicals in being readily available on a large scale, and with moderate stability; in other words they are fairly safe. Only fossil fuels could have provided the primary energy-on-demand that was crucial to the engines of the Industrial Revolution, with its extraordinary benefits. Indeed, the distinction between those who have ready access to fossil fuels and those who do not has been the driver of international and social politics for two hundred years – and remains so today.

But change is at hand. The world decided in Paris in 2015 that combustion of these fuels should be curtailed for the sake of a stable environment.

Exactly what the consequence would be if their use were to continue remains unclear, but the concentration of exhaust gases in the atmosphere is certainly rising and this has been true throughout the Industrial Revolution. At the same time, the climate, unstable at the best of times, seems to be changing quite rapidly. Many believe that this relationship is causative; others deny it. Some cling to simplistic articles of faith, such as 'carbon dioxide is the molecule of life', neglecting the simple fact that, as for most agents, an excess can be as harmful as a dearth. It may be that, while emissions triggered the change, it is now progressing with its own momentum, as the ice cover melts and the polar albedo changes. I suggest that we don't know, and never will. It is equally uncertain how and when the change will stabilise. Geological history records that, while the climate has been relatively stable for the past 12,000 years, great changes have occurred before, and wiped out many forms of life. Anyway, as expressed in the Paris Agreement, few are keen to pursue this game of Russian roulette with nature.

But we do know that without fossil fuels, or another source of energy at least as potent and widely available, our civilisation would collapse. In addition, we will probably need the resilience to withstand a changing climate and turbulent weather, whatever the cause. Such provision will depend on our scientific knowledge and may involve major changes in where and how we live. For this we can be sure that education, deep and broad, will be key.

Unearthing new primary sources of energy

But what is the other primary source of energy? Here, at least, the news is both positive and assured! In fact, it is so secure that its very existence was quite unknown until the closing decade of the 19th century.

The first clue came in answer to the question 'What keeps the inside of the Earth hot?' The answer is energy from the radioactive decay of atomic nuclei. These were energised, before the Earth was formed, in supernovae – stellar explosions that are also observed today when they occur far away in the Universe. In fact, all chemical elements heavier than iron in our world today were formed in this way. However, only uranium, thorium, and the isotope potassium-40 decay sufficiently slowly that less than half has not yet done so already.

The released energy is manifest in volcanic activity, earthquakes and tsunamis. In a few places on Earth, such as Iceland, this radioactive decay heat is a viable source of primary geothermal power, but that is exceptional. Geothermal energy is only a minor manifestation of the power of the nucleus. It was only the study of radioactively decaying elements, by Henri Becquerel, Marie Curie, Ernest Rutherford and others, that revealed the full potential of nuclear fission. While in radioactive decay a nucleus suffers a small change, in fission it splits in two. While radioactive decay is spontaneous and cannot be controlled, the fission process is strictly controllable. Furthermore, the energy released in fission is a hundred times greater, as discovered by Lise Meitner, Enrico Fermi and others. Comparing the energy per kilogramme of all primary sources, fossil fuels are a thousand times more energetic than renewables, but nuclear fission is a million times more energetic than even fossil fuels – that is than chemical processes.

Where is this mechanism? All matter is composed of atoms, comprising electrons and nuclei, and the characteristic energies of electronic and nuclear states depend on the same quantum principles. Only the sizes and masses differ. The reasons for their energies and the large factor between them can be explained and understood quantitatively in simple student terms.[3] There is nothing uncertain about this. It has been established for a century.

Nuclear energy can provide a primary source to replace fossil fuels, spectacularly well and without endangering the quality of life on which the stability of society depends. If the factor of a thousand in energy density transformed society in the Industrial Revolution, the further factor of a million available with nuclear energy should offer an even greater social uplift, as Winston Churchill presciently observed as early as 1931:[4]

> The discovery and control of such sources of power would cause changes in human affairs incomparably greater than those produced by the steam-engine four generations ago.

While Churchill had the vision, it was another 25 years before it was demonstrated that nuclear fission energy could be delivered under control and to order. Indeed, so effective is the natural security of nuclear energy that society thinks of it as manmade and unnatural – a view that still dogs its public image seven decades later.

The nuclear revolution

Acceptance of a new and unfamiliar form of energy represents a hurdle to society, despite any subsequent benefits. No doubt, some 600,000 years ago when fire was first domesticated, there were many accidents and social unrest, too. There were certainly riots and loss of life at the start of the Industrial Revolution, and social upheavals such as the migration of the rural population into the cities. But the privations described by Charles Dickens should be compared to the sorry state of rural life in previous centuries and the quality of life that the Revolution delivered subsequently.

The Nuclear Revolution has provided extraordinary personal benefits in clinical medicine during the 20th century. Now, in the 21st, we ought to welcome its communal benefits in the energy sector with similar expectations. The reasons that this has not yet happened is a long story.[5] Suffice it to say that a century of scientific, medical and sociological evidence confirms that nuclear energy is the safest and most environmentally harmless energy source known. Following early experience with nuclear radiation, in 1934 the International Commission for Radiological Protection (ICRP) agreed safe limits for human exposure rates.[6] Commenting on these in 1980, Lauriston Taylor[7] stated:

> Today we know about all we need to know for adequate protection against ionizing radiation. No one has been identifiably injured by radiation while working within the first numerical standards [2m Gy/day] set by the [National Council on Radiation Protection and Measurements] and then the ICRP in 1934.[8]

His conclusion remains true today, although, in response to social and political pressures unleashed by the Arms Race, the recommended public safe limit was made 700 times more cautious in the 1950s, despite the lack of any supporting evidence. Since then, few, even in the medical field, have dared to challenge this artificial narrative of radiation protection promulgated by ICRP.[9,10]

Nuclear power plants are reputed to be expensive and take long to build. This is strange because they need little land, do not require large quantities of exotic raw materials, have long lifespans and have a minimal impact on nature. The principal requirement is a team of engineers who know what they should do, and the supply chains behind them. Organisation and team building is a big investment for the first build, as for any civil construction. Otherwise, they only require civil engineering, with quantities of steel, concrete and water, and instrumentation. However, further costs are added to an extent seldom incurred for comparable industrial construction projects. These arise from poor political confidence – the extended public inquiries and related delays, and the risk of policy change. To soothe public concern, plants are over-designed and over-manned to comply with extreme safety regulations. Liability for unjustified compensation claims gets added. Yet the evidence from seventy years of experience do not justify any of these exceptional costs and delays.

As our forebears did a million years ago, when deciding to bring fire into the home, society today should weigh the evident benefits of nuclear power against only those risks that can be substantiated. The alternative is either a rapidly carbonising world, or a relapse into a pre-industrial existence sufficient to support only a fraction of the population today. The former suggests a less habitable planet with consequential social instability; the latter would lead to global revolution.

On the other hand, accepting a world powered by nuclear energy opens a remarkably positive view of the future, with a host of technical possibilities from which to choose. A similar situation applied to road transport in about 1900. The development of large steam engines on railways during the 19th century did not encourage popular support for allowing them onto the roads. However, the advent of smaller cars with internal combustion engines in France and Germany persuaded even the British authorities to relax their overly cautious regulations. Suddenly, scores of cars were designed. Most used petrol, some were electric, others were diesel. Steam cars were produced into the 1920s. Many failed to reach adequate production levels, but within the field were Mercedes Benz, Rolls Royce and Henry Ford's Model T. If Henry Ford had been permitted to build only one car with gold plated safety, it would have been prohibitively expensive by the time it had passed through innumerable committees, each anxious to avoid any liability that might fall on them – but then that was never the way to develop and market an innovation in any field. In 1896, with safety regulations re-based on evidence, the time was right for motor transport. Now, similarly, the time is right for nuclear power with new realistic regulations.

The choice of technologies

Today there are about seventy new reactor designs, all struggling for finance and regulatory approval, and looking to capture the enthusiasm of a rising generation of engineers and the wider public. Unfortunately, the regulatory authorities are still burdened by the mindset of seventy years ago.

But what do today's young developers have to offer the world? The classic nuclear reactors of the last century remain effective and safe. However, smaller reactors, built from parts manufactured and tested in factories, have considerable advantages. They can be sited conveniently close to consumers to reduce transmission costs. Like the older reactors, most small modular reactors (SMRs) use water as coolant and moderator, pressurised to 155 bar. This brings two drawbacks. Firstly, the operating temperature and therefore efficiency are limited. Secondly, many of the engineering and physical safety measures required are related to this pressure, including the size of the safety region around the reactor, known as the Emergency Planning Zone (EPZ). This is despite there never having been a fatality from a blow-out of radioactive fuel. The regulations in this area are inept.

However, a second class of small reactors, the Generation IV Advanced Modular Reactors (AMRs), operate at ambient pressure, using a coolant and moderator that is liquid but does not boil, even in a reactor at much higher temperature – and higher efficiency. Such liquids include molten salt, liquid sodium metal and molten lead. These designs should justify a substantially reduced EPZ. When the use of AMRs for the propulsion of large ships is considered, the EPZ should then be contained within the hull – and with it the liability concerns that currently prevent port visits by nuclear shipping.[11]

Even higher temperatures are available with high-temperature gas-cooled reactors (HTGRs). These would facilitate the most efficient production of hydrogen and electricity. Like other ideas, these designs have been developed in many countries over many decades.

There are varieties of fuel cycles too and, as for the cars in 1900, many designs would work. The question should be one of organisation: which design is developed and ready to build on a viable scale for a world market? If we continue to dither, other more resolute and equally capable regimes will flood the world with their product in thirty years. And make no mistake, to replace the use of fossil fuels worldwide, thousands of reactors will be needed. Authorities should not delay choosing between the competing SMRs, AMRs and HTGRs. The development needs focus, otherwise skilled engineers will go elsewhere. What is needed is education, organisation and confidence. What is not needed is the dead hand of the unjustified radiological safety regulations that have been obstructing the roll-out of the nuclear revolution for seventy years already.

Notes

1 The flexible meaning of a word was expressed by Lewis Carroll in *Alice in Wonderland*, thus: 'When I use a word…it means just what I choose it to mean – neither more nor less.' A mathematician himself, he would never have written that about a number!

2 The failure of wind as a reliable source of electrical energy https://www.researchgate.net/publication/367177083_The_failure_of_wind_as_a_reliable_source_of_electrical_energy.

3 Nature, Energy and Society – A Scientific Study of the Options Facing Civilisation Today. https://www.mdpi.com/2673-4362/3/3/13.

4 Churchill quote at: https://www.nationalchurchillmuseum.org/fifty-years-hence.html.

5 Nuclear energy and society, radiation and life – the evidence https://www.researchgate.net/publication/311175620_Nuclear_energy_and_society_radiation_and_life_-_the_evidence_1.

6 International Recommendations (1934) ICRP https://www.icrp.org/images/1934.JPG.

7 Doyen of radiation physicists, charter member of ICRP (1928), founder and chairman of US NCRP for 48 years. https://en.wikipedia.org/wiki/Lauriston_S._Taylor.

8 The Sievert Lecture 1980. *Lauriston Taylor: Some Non-Scientific Influences Radiation Protection Standards and Practice in Radiation Protection: A Systematic Approach to Safety*. Proc. 5th Congress of the International Radiation Society. Pergamon Press. pp. 3–15. https://scholar.google.co.uk/scholar?q=health+physics+1980+39+851&hl=en&as_sdt=0&as_vis=1&oi=scholart.

9 A serious attempt by the joint French Academies of Science and Medicine in 2005 that was dismissed by ICRP. Dose-effect relationships of Ionising Radiation, Tubiana, M. and Aurengo, A. Académie des Sciences & Académie Nationale de Médecine. http://www.researchgate.net/publication/277289357_Acadmie_des_Sciences_Academy_of_Sciences-_Acadmie_nationale_de_Mdecine_National_Academy_of_Medicine.

10 For a recent discussion of the evidence and references: https://www.researchgate.net/publication/311175620_Nuclear_energy_and_society_radiation_and_life_-_the_evidence_1.

11 Nuclear shipping prospects https://www.youtube.com/watch?v=otS9cBpKl8A.

About the Global Warming Policy Foundation

People are naturally concerned about the environment, and want to see policies that protect it, while enhancing human wellbeing; policies that don't hurt, but help.

The Global Warming Policy Foundation (GWPF) is committed to the search for practical policies. Our aim is to raise standards in learning and understanding through rigorous research and analysis, to help inform a balanced debate amongst the interested public and decision-makers. We aim to create an educational platform on which common ground can be established, helping to overcome polarisation and partisanship. We aim to promote a culture of debate, respect, and a hunger for knowledge.

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