Energy for the People of the World
Reflections on Gaudium et spes

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1. Introduction

The Conciliar document *Gaudium et spes* is an invitation to the Church, and indeed to all men, to consider our responsibilities in the light of the rapidly changing conditions of the world that have been brought about by modern science and technology. In order to do this 'we must recognise and understand the world in which we live (202[1]).

It is undeniable that in so many ways 'technology is now transforming the face of the earth' (203), so that 'in the practical order the technology which stems from the mathematical and natural sciences takes on a mounting importance' (203). However, 'this transformation has brought serious difficulties' (202). While it is undoubtedly true that 'never has the human race enjoyed such an abundance of wealth, resources, economic power, a huge proportion of the world's citizens is still tormented by hunger and poverty' (202). This is an intolerable situation because 'the right to have a share of earthly goods sufficient for oneself and one's family belongs to everyone' (278). In spite of this, 'while an enormous mass of people still lack the absolute necessities of life, some, even in less advanced countries, live sumptuously or squander wealth' (271).

To tackle this situation 'there must be made available to all men everything necessary for leading a life truly human, such as food, clothing and shelter.' (225). This can be done 'with the help of science and technology' (231). 'Therefore, technical progress must be fostered, along with a spirit of initiative, an eagerness to create and expand enterprises, the adaptation of methods of production and the strenuous efforts of all who engage in production' (273).

It is necessary to recognise that 'God intended the earth and all that it contains for the use of every human being' (278), so that 'men are obliged to come to the relief of the poor' (278). Thus 'everyone must consider his every neighbour without exception as another self, taking into account first his life and the means necessary to living it with dignity.' (226)

The practical problem to be addressed is how to ensure that this is done. The question is urgent because today many billions of people are living below the poverty line and lack the necessities of decent living. On the material level, the key is the provision of adequate amounts of energy. There is a close relation between the energy available

[1] The references are to page numbers in 'The Documents of Vatican II' edited by Walter M. Abbott and published in 1966 by Geoffrey Chapman (London).

and our standard of living: people living in the countries using more energy are healthier and live longer and enjoy an altogether fuller and richer life.

Without energy, we would not be able to heat our homes or cook our food. Long-distance travel and communications would be drastically changed, and our factories could no longer produce the goods we need. The world demand for energy has increased rapidly due to the increase of population and the overall rise in living standards. Globally, the world population is doubling every thirty-five years and the energy use every fourteen years. Furthermore, there is a crucial difference between energy use and energy need: much energy is wasted in the richer countries, while the poorer ones lack the minimum needed for an acceptable lifestyle.

A century ago the world's energy came almost wholly from coal and age-old sources such as wood, crop residues and animal dung. These are indeed still widely used in the poorer countries. Then in the late nineteenth century oil and natural gas became an important energy source. The use of oil and gas grew steadily through the twentieth century and are now globally more important than coal.

In the last few years there have been many signs that the world is experiencing a growing shortage of energy. Already the price of gas is rising and is expected to increase by 20% by 2010 and that of oil has reached $38 per barrel. Several areas, including California, have experienced acute energy shortages. At present we are highly dependent on oil, particularly for transport. Road transport is brought to a standstill in a few days if the supply is cut off. Agriculture is also heavily dependent on oil for fertilisers and machines. Planes are completely dependent on oil.

The vital question is how long will there be enough oil, and the other fossil fuels gas and coal, to supply our needs. Some current estimates are that at the present rate of use there is enough oil to last forty years, natural gas sixty years and coal 230 years. These figures are not so alarming as they appear, because they are obtained by dividing the known reserves by the annual consumption and this does not imply that after these times the reserves will be exhausted. Indeed, continuing studies reveal the surprising fact that these figures remain almost constant from decade to decade, The explanation is that as the existing reserves are used up the price rises and this stimulates searches for new oilfields and the development of new techniques for extracting more oil from existing ones. This produces more oil, so the price falls again. This in turn increases consumption, so that more oil is used and the price rises again. The overall result of this feedback mechanism is that the oil price remains fairly steady in the range $15 to $30 per barrel. Of course this cannot go on forever, and then it will become economic to use other sources such as tar sands and oil shale. Already the cost of oil from tar sands has dropped from $28 to $11, and there are vast deposits of oil shale. So, contrary to the general belief, there is no immediate danger of an oil shortage. Similar remarks apply to gas and coal.
In addition to these economic considerations, oil prices are subject to political decisions by the OPEC countries. This was the reason for the sharp rise in oil prices in 1973.

These remarks refer to the world as a whole. The changes are more rapid in individual countries. Thus for example in Britain the oil will be exhausted in about five years, and gas in about seven years. After that, without a new energy source, we will have to rely on gas imported from Libya and Russia.

Thus while there is no reason to expect an imminent shortage of fossil fuels, there is continuing need for flexible planning and the search for new sources. They are, however, polluting the atmosphere, leading to climate change, acid rain and global warming. This situation is likely to worsen, as world energy demand is expected to rise from 9.3 btoe (billion tons of oil equivalent) in 2000 to 15.4 btoe in 2020, mainly due to increases in China, India and Latin America.

Despite many resolutions at international conferences promising to reduce emissions, the emission of carbon dioxide and other greenhouse gases due to the burning of fossil fuels is steadily increasing, and with it many indications of global increases in temperature. The resulting air pollution has been estimated by the Royal Commission on Environmental Pollution to contribute to 24,000 deaths in the UK each year and the World Health Organisation attributes about 150,000 deaths per year to global warming, and this is likely to increase. Furthermore, a global rise in sea level is predicted, which will not only have serious environmental effects but will affect communities worldwide, as many of the world's cities and much of the industry is located at less than 5 metres above sea level.. Extreme weather events have increased tenfold in the last fifty years, and the average cost of these is estimated to be around forty billion dollars per year. It is therefore imperative to reduce our reliance on fossil fuels as rapidly as possible. If we fail to do this, we may well irreversibly pollute our earth.

This situation has led to a demand for energy sources that are non-polluting, and the so-called renewables are seen by many as the answer to the problem. While many of us would be happy if this were so, detailed analyses show that they are unable to provide the energy we need, and that they are relatively dangerous and costly, as well as being injurious to the environment. This had led many people and Governments to look again at nuclear power.

At present most of our energy needs are supplied by oil, natural gas and coal, together with some biomass in the poorer countries. These sources are limited, but are likely to last for the foreseeable future. They do have, however, the crippling disadvantages that they produce carbon dioxide and a whole range of poisonous chemicals. The carbon dioxide is responsible for a gradual global warming and other climatic effects that may well prove devastating in the long run. The poisonous chemicals affect our health, and cause acid rain. It is therefore urgent to reduce our dependence on these energy sources. Other possible sources must be examined using the criteria of capacity, reliability, cost, safety and effects on the environment. Of the other sources, hydropower is useful, but for geographical reasons can never provide more than about 3% of our needs. That leaves the so-called renewables wind, solar, wave, tidal and geothermal. Some of these, specially solar, have useful applications to small scale needs, but none of them is able to provide the huge amounts of energy that are needed. Wind is the most promising, but costs twice as much as the existing major sources and is unreliable and harmful to the environment

2. Climate Change

Before considering nuclear power, it is useful to discuss the effects on the climate of the burning of the fossil fuels coal, oil and natural gas. It is being increasingly realised that present energy policies may be having a disastrous effect on the word climate. The burning of fossil fuels inevitably releases large amount of carbon dioxide into the atmosphere. There is no economic way of avoiding this because the chemical reaction that releases heat is the combination of carbon and oxygen to produce carbon dioxide. In addition, fossil fuel power stations release into the atmosphere many poisonous substances that eventually fall to earth as acid rain, killing trees and rendering rivers and lakes sterile.

The world climate is constantly changing, and we can take averages for a local region or for the whole earth. Climate is determined by many natural causes, and in addition there is evidence that it is affected by human actions. We cannot do anything about the natural causes, but if there is a causal link between human actions and climate change we may have reason to expect the present changes to continue, and furthermore we will have a strong incentive to take action to mitigate the harmful effects of climate change.

Such a causal link has been proposed. Extensive measurements have shown that the concentrations of carbon dioxide, methane and some other gases in the atmosphere are steadily increasing: The annual increase of carbon dioxide is now 0.4%, that of methane 1.2%, of nitrous oxide 0.3%, of the chlorofluorocarbons 6% and of ozone about 0.25%. In the European Union, fossil fuels are the main source: oil 50%, natural gas 20% and coal 28%. Of this, electricity generation accounts for 37%, transport 28%, industry 16%, households 14% and the service sector for 5%. These are established facts, and in addition there is a strong correlation between carbon dioxide concentrations and temperature changes. It is then suggested that these increased concentrations are responsible for global warming and that global warming is responsible for other climate changes and predicted effects such as a worldwide rise in the sea level. This conclusion is supported by recent results from the analysis of eight glacial cycles from the Antarctic ice core extending over the past 740,000 years showing that every time the carbon dioxide concentration has increased there has been a corresponding increase in the temperature.

The connection between the increase in carbon dioxide and global warming is known as the greenhouse effect. The argument is that, as in a greenhouse, the sun's rays penetrate the atmosphere and warm the earth. Some of the heat is emitted with a different wavelength that cannot escape because of the carbon dioxide; in the case of the greenhouse it is the glass that does this.

This argument is plausible, but needs careful scientific analysis before the conclusion can be established. Many scientists worldwide have been making detailed calculations using increasingly sophisticated models of the atmosphere. This is obviously a very complicated task. What, for example, do we mean by the temperature of the atmosphere? We can measure the temperature at a particular place and height, but this needs to be done over the whole surface of the earth and for heights up to several miles. The best we can do is to establish a grid of points and measure the temperatures at these points as a function of the time. Even a coarse grid contains millions of points and the calculations are very time-consuming even on a fast modern computer. The more accurate we want our calculations to be the longer they will take. In addition, the results may be very sensitive to the initial conditions; this is called the butterfly effect. The main uncertainty at present seems to be the effects of water vapour, which are greater than those of all the other gases combined. These are sensitively affected by changes in the cloud cover which in turn changes the amount of solar energy absorbed or reflected.

The results of such calculations are published periodically by the Intergovernmental Panel on Climate Change, under the Chairmanship of Sir John Houghton. With many qualifications, the conclusion of the latest work is that there is good evidence that world temperature is increasing, and it is predicted that the average temperature will rise by about four degrees Centigrade by the year 2100. In the same period the sea level will rise by about 60 cm. or by 40 cm. if the emissions are controlled. Such rises will eliminate many islands such as the Maldives in the Indian Ocean, and will inundate much of Bangladesh and some of Holland.

There are many uncertainties in these arguments, but uncertainties are not uncommon in human affairs. We have to make a decision on the basis of incomplete knowledge. It is easy to say that we must undertake more research and do nothing until we are absolutely sure what is the best thing to do. This is nearly always the worst decision of all. We must take our decision on the basis of the best knowledge that we have, even if it is to some extent uncertain. And concerning climate change, the best knowledge that we have is contained in the results of the model calculations. It is therefore important to explore any practicable means to reduce the emission of gases that are responsible.

If that was all that could be said, the prospects of satisfying world energy needs without polluting the earth and causing drastic climate change would be thin indeed. However there is another source to be considered, namely nuclear power.

3. Nuclear Power

Nuclear power stations are now operating in many countries and provide about 20% of world electricity They are very reliable and almost completely non-polluting. The countries that have built nuclear power stations have dramatically reduced their carbon dioxide emissions. Thus France is about 80% nuclear and has halved its carbon dioxide emissions; Japan (32% nuclear) has achieved a reduction of 20%, while the USA (20% nuclear) has reduced them by 6%. The emission of sulphur dioxide is also drastically reduced by replacing coal power stations by nuclear ones. The British Government has set a target of a 10% cut in carbon emissions in the period from 1990 to 2010. By 1995, a cut of about 6% had been achieved, but this was due to the increase in nuclear output by 39% from 1990 to 1994. Nevertheless, emissions rose by 1% in 2003 and in the next few years they will rise as the older nuclear power stations reach the end of their lives, and no new ones are being built. There is thus no hope that the targets will be met, and the situation is similar for the USA. On a longer term, the US Energy Administration forecasts that global carbon dioxide emissions will rise from 23.9 bnt (billion tonnes) to 37.1 bnt in 2025.

The cost of nuclear power is generally comparable to that of coal and oil. It is not easy to make precise estimates because nuclear power stations are much more costly to build than coal power stations, but are cheaper to run. The amount of fuel that has to be brought to a nuclear power station is very small, compared with the thousand tons per day needed by a coal power station. The relative cost therefore depends on the working life of the power station and in that time the value of money undergoes substantial changes. Nuclear power stations are more costly to decommission, but these costs can easily be covered by investing a small amount during each year of a reactor's life. Thus it seems that the costs of nuclear and coal power are quite similar, but this does not take into account the costs of pollution and global warming that are due to coal and other fossil fuel power stations.

Nuclear power stations compare well with other sources for safety. No energy source is perfectly safe; there are always some deaths and injuries due to accidents in the extraction of the fuel, its transport to the power station, its construction and maintenance and in the distribution of power to the user. Nuclear reactors have few adverse effects on the environment. Most important, they emit almost no greenhouse gases and so do not contribute to acid rain or global warming. In 1996, 2312 TWh of electricity was generated by nuclear power. The same amount would be produced by burning 900 million tons of coal or 600 million tons of oil. Thus the emission of 3000 million tons of carbon dioxide has been saved per year by using nuclear instead of coal power stations. When nuclear power stations are built, the emission of poisonous gases is strikingly reduced.

Nuclear reactors are continually being improved, and new types studied. Among the new fission reactors the pebble-bed reactors seem promising. Fast reactors, which burn the uranium 238 which comprises 99.3% of natural uranium, have been studied for many years and pilot plants have operated successfully. At present they are not economic compared with the present reactors, but are available to take over from thermal reactors if uranium becomes scarce. This seems unlikely to happen for many decades because the cost of the fuel is a small fraction of the total cost of running a reactor. In addition, uranium is very widespread though often in small concentrations.

Experiments have been in progress for over fifty years to use the fusion reaction to produce energy. Successive devices have come nearer to the goal of producing more energy than is used to start the reaction, but this has not yet been achieved. If and when it is, practically unlimited energy would become available because the deuterium used as fuel is a component of ordinary water. As the feasibility of fusion reactors has not yet been demonstrated, they should not be considered in the context of providing for our present needs, although they are a bright hope for the future.

4. The Opposition to Nuclear Power.

There are several reasons for the widespread opposition to nuclear power. First there is the fear of nuclear weapons. The more reactors there are around the world, the more likely that a rogue country will divert some plutonium, make a few bombs and threaten the world with destruction. This danger is already with us, and will not be reduced by abandoning nuclear power. On the contrary, the scramble for the remaining oil supplies during the coming decades is a potent cause of international tension.

Secondly, there is the fear of nuclear radiations. They are deadly and invisible to the senses. We can receive a fatal dose of radiation and feel nothing. However, nuclear radiations can easily be detected in exceedingly small amount by simple instruments, thus allowing protective measures to be taken. We are all continually exposed to nuclear radiation from the radioactive minerals in our own bodies, in the earth and from the cosmic radiation. In some areas this natural background dose is a hundred times the average value yet even then the amount received is too small to cause any danger, so the much smaller amount due to the nuclear power industry should not be a cause for concern. There is even some evidence that small radiation doses are beneficial, as they induce bodily repair processes.

There is also widespread fear that nuclear radiations from reprocessing plants such as that at Sellafield, and also from nuclear power stations, can damage the health of people living nearby. In particular, there seems to be more cases of leukaemia in such regions. Such installations do emit minuscule amounts of radiation, far less than the natural background to which we are exposed all the time. Detailed medical studies of the frequency of leukaemia around nuclear installations have shown that it cannot be attributed to nuclear radiations. An alternative explanation, due to Kinlen, is that the excesses leukaemia cases, where they occur, are due to viral effects connected with the movement of populations has been supported by the detection of similar effects in regions not associated with nuclear installations.

There is also widespread fear about the safety of nuclear reactors after several accidents and particularly the disaster of Chernobyl. This was due to an unsafe design and flagrant breaches of the operating instructions. On the fatal night the operators wanted to make an experiment on the reactor at low power and to prevent the reactor being automatically shut down they switched off the safety circuits. Inevitably disaster followed. To oppose nuclear power because of Chernobyl is like opposing modern cruise liners because of the Titanic disaster.

One of the arguments most frequently used against nuclear power stations is that they produce highly radioactive nuclear waste. This accumulates and remains dangerous for thousands of years, so by building nuclear power stations we are imposing an intolerable burden on future generations. However, the method used to deal with nuclear waste has been well understood for many years. First, it is allowed to stand in secure tanks for about forty years to allow the short-lived isotopes to decay, and then the residue is concentrated and fused into an insoluble ceramic and encased in steel cylinders. It is then buried deep in the earth in a stable geological formation where these is no chance that it will ever come into contact with people. Eventually the remaining radioactivity will decay to a level comparable with that of the surrounding rock. A recent OECD NEA Report on the disposal of long-lived radioactive wastes concluded that ‘there is a consensus among the engaged technological community that engineered geologic disposal provides a safe and ethical method for the long-term management of such wastes’. The amount of high-level radioactive waste produced by a reactor each year is quite small; it could be loaded into a minibus. For comparison, coal power stations produce millions of tons of toxic waste each year.

5. Comparison of Energy Sources

In order to provide the very large amounts of energy we need to sustain our living standards, and to raise those of people in the poorer countries, we need energy sources of high capacity. The only sources in this category are the fossil fuels and nuclear.

The fossil fuels are unacceptable because of the pollution they produce, and the likelihood that they are responsible for global warming. It is imperative to reduce our reliance on them before the earth is polluted beyond repair. The renewable sources do not at present produce amounts remotely approaching our needs, and they are also inherently and unavoidably unreliable.

A recent French report gives some alternative ways to generate the electricity produced by a 1000 MWe nuclear power station: 6000 windmills of 20m blade diameter; 30,000 square km of forest; 2.3 million tonnes of coal per year; 1.9 million tonnes of oil per year; 18 thousand million cubic meters of gas per year; or 100 square km. of solar panels. As the present nuclear capacity of the UK is 13,000 MWe, these figures have to be multiplied by 13 to provide the actual equivalents.

For large-scale power generation the costs are all-important, and numerous figures have been published. Thus a commission was appointed by the Belgian Government to examine the costs of energy generation in various ways. They took into account the costs of fuel, investment, operations and maintenance, atmospheric air pollution, noise, greenhouse gases, construction, grid connection and decommissioning and produced the estimates shown in the Table. For comparison, some figure from the Performance and Innovation Unit, the Royal Academy of Engineering and BNFL are also given. To facilitate comparison the Belgian figures have been normalised to equalise the costs of coal production. The last two columns show figures including external costs. These have been estimated as 4-7 for coal, 1-2 for gas and 0.25 for nuclear. One may add a US estimate of nuclear costs as 1.7 cents/kWh and a UK estimate of 1.67 p/kWh. Taking account the different circumstances there is reasonable agreement among these figures, except that the figure of 4.0 for nuclear for PIU seems definitely too high.

TABLE: Costs of electricity generation in p/kWh

Energy Source	Belgian Costs*	PIU +	RAE”	BNFL**	Fr^
Coal	2.34 (3.5)	3.5	2.5-3.2	7.2	4.88
Gas	1.74 (2.6)	2.0	2.3	3.8	4.24
Wind (off-shore)	2.39 (3.6)	3.0	5.5 (7.2)	6	-
Wind (on-shore)	3.26 (4.9)	2.5	3.9 (5.4)	-	-
Nuclear	1.25 (1.8)	4.0	2.3	3.5	3.3

* Figures in brackets normalised to PIU coal.
\+ Performance and Innovation Unit
“ Royal Academy of Engineering (backup costs in brackets)
**British Nuclear Fuels, including external costs
^French estimates in e/kWh, including external costs

6. Political Considerations

In view of these facts, it is remarkable that conferences are held to discuss ways to combat climate change and they discuss fiscal measures, wind, wave and solar power, but make no mention whatsoever of nuclear power. The only explanation is that Governments are aware that nuclear power is politically so unpopular that they would lose their support if they advocated the construction of new nuclear power stations. The possible reasons for this have been discussed above, but what is of more concern is that all the efforts of scientists to inform the public seem to be in vain. There is a strong reluctance to face the truth. All this hides psychological problems should be resolutely faced, and not simply ignored as if they do not exist. Reality may be avoided for some time, certainly during the period before the next election, but in the end the problems will have to be faced, and the longer this is postponed the more difficult it will be to solve them, if indeed it is not already too late.

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The full text of this lecture, with figures and tables, may be obtained from Peter E. Hodgson, Corpus Christi College, Oxford OX1 4JF UK.