

The Journal of the Christian Engineers' Association

CEA Perspective – Summer 2005

In this Issue...

Editorial <i>and</i> Reviewing the Issue	John Baden Fuller	1
Something of Myself	John Baden Fuller <i>shows how God has worked in his life</i>	2
My Involvement in a Small Start-up Company which eventually fails	Richard Riggs <i>asks where was God when the project was closed down</i>	6
Rural Telephony in Developing Countries	Steve Chandler <i>shares his experience of project which appears to fail</i>	8
A Liberal & Christian Education	Percy Hammond <i>discusses how engineering can provide a liberal education</i>	12
Nuclear Feature <i>discusses the pros and cons of nuclear energy</i>		
Risk – A Christian Perspective: Further Thoughts	David Kay	14
Christian Ethics & Nuclear Power	J. George Butler	16
Nuclear Energy, the God-given Solution to Global Warming?	John Baden Fuller	18

Editorial

John Baden Fuller

How do you experience God's guidance? For me, God usually guides by coincidences. There is the well known phrase (which I expect I have used before) *When people pray, coincidences happen*, and God seems to guide by coincidence. My guidance usually consists of a good idea subsequently reinforced by other people independently. Hence, I find inspiration for this Journal. I have already shared with you how 'Risk' came to me as an idea for the last issue. It was reinforced by other contributions from different sources all centring on the topic of *risk*. So, what is the theme for this issue of the Journal? Over the last two issues, different members of our committee have shared with us *Something of themselves*. This summer it is my turn. I had already contributed a description of my life in an earlier issue 14 years ago, so that article has been brought up to date.

Then, completely out of the blue, I received two contributions for the Journal from two independent sources both reinforcing my idea. They were both personal stories, and originally, Richard Riggs had titled his contribution, *My Story*. They both told of feeling God's guidance to work on a particular project, yet in the end the project failed and they both ask, Why? The prosperity gospel is not necessarily God's way. Is it that God is much more interested in the growth in Christian maturity in the participants than in the success of the project? Your comments will be welcomed.

With thanks to all contributors, I received sufficient material for this issue of the Journal two months before the due date and I have been able to put together an issue that ought to be published in time!

Reviewing the Issue

In this issue we start with the three contributions, mentioned above, from myself, Richard Riggs and

Steve Chandler about our personal experiences of God working in our lives. Then we have another welcome contribution from Professor Percy Hammond who takes a philosophical view of engineering education in the university. We end with three articles giving different views about the ethics of nuclear power. We are indebted to David Kay for raising this topic for discussion. He felt that my article in the last issue of the Journal was unduly biased in favour of Nuclear Energy. Hence our Nuclear Feature beginning on p. 26, with an introduction from David, an article highlighting the risks generated by the use of nuclear energy, and a contribution from myself in favour of nuclear energy. As publication date is before the spring meeting of our committee, there is no committee report in this issue of the Journal. I can assure you that any important decisions will be reported in the next issue.

Please send us your contributions

The CEA Journal ought to reflect the views of our members, and we welcome contributions from any of our members. There is always the danger that any issue will only reflect the views of the editor and committee, so please send us your contributions for the next issue before **1st October 2005**. Details of the mailing address is given on the inside front cover. If you would rather send your contribution by e-mail, please send it to David Kay at the address given there.

Acknowledgement. Scripture quotations are from The Holy Bible, English Standard Version, published by HarperCollins Publishers, © 2001 by Crossway Bibles, a division of Good News Publishers. Used by permission. All rights reserved.

Webmaster

Although no member of the committee has been able to supervise our web pages, I am pleased to report that Richard Riggs has continued to work on our web entry. However when the present revision of our entry is completed, he is unable to continue, so **If you have the time and expertise to undertake the revision of our web pages, please contact me soon.** The depth of revision would be up to you. There is no need to make a commitment to undertake an enormous operation or to become a member of the committee although new committee members will always be welcome. **Even the smallest offer of help will be welcome.**

Something of Myself

John Baden Fuller

This is an expanded and updated version of an article first published in the CEA Newsletter Autumn 1991, under the title 'Now unto Him...'

I have been a Christian for over 50 years so it may be best to say something of the way God has guided me throughout my life. A sort of mini biography. Often when we read about Abraham in the Old Testament and consider that great story of faith, we do not realise that some of his great experiences of God were at least ten years apart. So, if we wish to find out how God has been guiding us, we need to go back over our lives. Inevitably, this will be the story of my life!

I was brought up to go to church, baptised as a baby and confirmed at 16. At boarding school everyone had to attend sung matins and evensong every Sunday but it was rather routine. It was not until university that I had the conversion experience that changed my whole life. Suddenly the Bible came alive. I wanted to read the Bible because it spoke about my Saviour. The prayer book services were no longer meaningless ritual. They said what I wanted to say so much better than I ever could.

Conversion

I was converted at a Christian Union mission when I was challenged as to whether I had been 'born again'. I remember reading John 3 v.3 at school. I knew that I was not born again but I thought that I was a good Christian, because I went to church and I tried to live a good life. We were taught to criticise the Bible so I just assumed that that part of the Bible was wrong. How wrong I was! God convicted me of the sin of unbelief and I was forgiven and accepted Him into my life. Then the Bible came alive and the prayer book services were no longer meaningless ritual. I became an enthusiastic member of the CU.

Nine months later I went to participate in a student city mission. Students were attached to churches throughout the town for a week. I was a member of a team of about 12 attached to one church under the leadership of a visiting pastor. A group at that church had been praying regularly for our visit for about 18 months! Was it because of this prayer that our team were filled with the power of the Holy Spirit and much blessing came to that church congregation? I experienced a deep conviction of sin, that my lifestyle was not worthy of the name of my Saviour although I was not doing anything particularly wrong. My belief had been converted nine months earlier but now my whole life was going to be devoted to God. I had a wonderful experience of God filling my whole being and of walking on air. All the colours were brighter. As we said at the time, everything was suddenly in Technicolor. God took over my life.

A Second Blessing

I went back to college bubbling over with my new found experience and made the mistake most of us make. We expect everyone to have the same experience as we have had. I was very worried that other members of the CU didn't have the same filling of the Holy Spirit that I had experienced. I needed to learn that, just as we are all different people, so God deals with each one of us in a different way. However, I did find a group in the CU who had had an experience similar to mine and we met regularly for fellowship. In the 1950's we called our experience, 'the second blessing'.

Was I being called to ordination?

I regularly participated in CU activities which did so much to build me up as a Christian. Then there was a big question to answer. Should I offer myself for ordination? Lots of my friends were thinking about it. I was already studying for a degree in Engineering. Was I to be an engineer, or what? A clergyman friend turned me to 1 Corinthians 7 v.20. It may have been taken out of context, but it was conclusive to me. I was to continue in what I was already doing. If God wanted me ordained, he would make it unmistakable and create a conviction I could not refuse. So I continued as an engineer. God guided me in many little ways, often by coincidences, but when people pray, coincidences happen.

While at college, I took a vacation job in Rugby. I stayed in the apprentice hostel and the only other active Christian in the place was in the next bed. He introduced me to a number of evangelical youth activities in that town. I also attended an evangelical Church of England church there and met a young man in the church who was a Reader and had just been elected to the Church Assembly, the predecessor of the General Synod. He continued in membership of the General Synod for at least forty years. Many years later I remembered his enthusiasm and was elected to the General Synod.

Industry

In my eight weeks vacation, I quite liked what I saw of factory life and found the job interesting. A year later, after qualification, I was offered a job and went back to the same factory which was then known as BTH. I became a very regular attender at the factory Christian Fellowship, which was affiliated to the *Workers' Christian Fellowship* (now *Christians at Work*). While in Rugby, I felt a

call by God to preach, but not to be ordained. After a very short period of training, I was admitted as a Reader in the C of E. That is equivalent to being a lay preacher in many other churches. As a Reader, I have taken services and preached in a large number of parish churches. That was 47 years ago and I still preach regularly. After three years in Rugby, the firm moved me to a new factory in Leicester. There I gathered with some Christian friends and we met weekly for fellowship and to encourage one another.

Factory Christian Fellowship

When the Christian Fellowship group at the new factory had been meeting for about a year, I sought to make the meeting official and wrote to the factory management seeking their approval. God provided, because unknown to me an industrial missionary employed by the city churches also approached the management asking to hold an open meeting. So the open meeting coincided with the formation of our Christian Fellowship and also introduced me to some keen Christians working in another part of the factory. As we had sprung from the Rugby fellowship, we affiliated to the Workers' Christian Fellowship and the factory group still exists as an affiliated group of Christians at Work. I was the founder leader for six years until I left. I also became Leicester Regional Secretary for the organisation and co-ordinated some local activities for the factory fellowships in Leicestershire.

Leicester College of Technology

I enjoyed designing things. It is very satisfying to see them made and working, but I was restless and wanted more contact with people. So I applied for a lecturer post at Leicester college of Technology (now DeMontfort University). I was not successful which was a good thing because the post was in electrical engineering as opposed to electronics in which I had specialised. A year later, the same post was advertised again, but I had a very strong feeling not to apply.

Later I discovered that a Christian friend from the same factory had applied and got the job which he held for a long time. As I was older and more experienced, it is unlikely that he would have got the job in competition with me. However, a few months later, another post was advertised which was much more in my line and I was appointed. I enjoyed lecturing but I was only to stay with the college fifteen months. Then I went as a lecturer to Leicester University.

Leicester University

My appointment there was a coincidence. My wife had had to stay with her parents, because one of our children became ill when we were on holiday there, while I returned to Leicester. One day, waiting for the washing machine to finish, she glanced at a pile of old newspapers and saw an advertisement for a post at the University. I applied and was appointed. If my son had not been ill, my wife would have never seen the advertisement and I would have never known about the post. For me, the University was a marvellous job. I like teaching, but I also liked the technical aspect of design and research. We were encouraged to do both.

Inevitably I found some Christian friends among the staff and we met regularly for prayer and discussion. Some years ago, I went for two months to work at a government research establishment at Malvern. On my second day, while I was being shown round the library, one of the staff recognised the Scripture Union badge I was wearing and told me about the Christian group that met weekly at that establishment, so I was able to join them while I was there.

When I was a student at University, I met a Christian who was one of our lecturers. After I graduated, we kept in touch with one another. Thirty seven years ago he persuaded me to write a textbook on Microwaves in a series of which he was editor. I hesitated because there seemed to be lots of good books on the same subject already. However, eventually, on reflection, I decided to write the book

which was successful. It ran to three editions and was in print for thirty years, and has been translated into German. This started me off, and by the time I retired as a lecturer, I had written five textbooks, although none did as well as the first one!

General Synod

As I mentioned earlier, 35 years ago God led me to stand for election to the General Synod of the C of E and I was elected. To me, this was obviously God's guidance. Three different people, quite unknown to one another, had all suggested that I stand for election although I was a young man and generally unknown among the church members who were the electorate. I was one of three lay people representing the diocese of Leicester on the Synod. Because the Synod meets for three weeks midweek, it is often difficult for lay people to find the time to attend.

God arranged things for me. There were a number of Christians on the staff of our department at the University, including two other Readers and a Methodist lay preacher. They all encouraged me to stand for the General Synod and made it easy for me to attend by helping out with classes while I was away. We had to be re-elected every five years and I survived five elections and continued as a member for 25 years until it seemed right to make way for someone younger. At the same time, membership of the General Synod made me a member of a number of other committees in the Leicester Diocese. God seems to guide in so many little ways that it is only afterwards, looking back, that we can see how he led us forward. I believe that my vocation was to glorify God by doing my job as a lecturer in electronics and to encourage Christians to be Christian where they are.

IEE committees

When I graduated, I joined the IEE as my professional institution. While lecturing at the University, I started to participate in IEE activities and eventually was appointed to a number of IEE committees both locally and centrally in London. I was a member of the Microwave Professional Group committee for six years. The IEE limited membership of such a committee to six years so afterwards I sought membership of the Engineer in Society Professional Group Committee as somewhere where I could exercise a more specifically Christian influence.

I was a member of that committee for six years. I took a particular interest in the ethical aspects of engineering. Afterwards, I became their representative on the editorial board of the IEE Engineering Management Journal. The editorial I wrote on the topic of Risk was republished in the last issue of our CEA Journal.

CEA

After graduation, I seemed to be working as much as a research scientist as a design engineer so I joined the *Research Scientists' Christian Fellowship* (now *Christians in Science*). Then, when I became a University Lecturer, I joined the *University Staffs' Christian Fellowship* as well. Some years later, there was a notice about the *Engineers' Group* in the annual UCCF subscription reminder so I also joined that. I never participated in the organisation of the group but I maintained my subscription and read the literature rather as an interested spectator. Imagine my surprise when, completely out of the blue, I was invited to become chairman of the Engineers' Group (now the *Christian Engineers' Association*).

Those of you who have been members of CEA for some time know the rest of the story. How God provided the members of a committee. How we have been able to work together in harmony to organise the group. I believe that my vocation is to glorify God by doing my job well and to encourage Christian members of CEA to be Christian where they are.

My Involvement in a Small Start-up Company which eventually fails

Richard Riggs

An enjoyable 5 years with a small company has led to some questions, which others might find helpful.

God appeared to be in the project from the start

God was in it from the start (as he usually is of course, but more clearly this time). The job was there at the agency the day after I was last made redundant. It was just the sort of thing that suited me, a small company, six when I joined, growing to about 20. This included about four Christians, which is more than I have found in one workplace before. A good team, with good relationships and a minimum of bureaucracy. Professionally, I found I was drawing on an unusually wide range of experience, and others brought the right talents at the right time. It was stretching without being overwhelming.

God moves in mysterious ways

God moves in mysterious ways at work. When there were important technical decisions to make or new things to learn, the right source of advice or help always turned up just when needed. It's walking by faith (or is it working by faith?) There were times like one of the marketing visits to the Far East. The company was developing a new display technology for next generation TVs, and the demonstration display, and the electronics, both died just after returning from the visit. What a pity it is so hard for others to see God at work in such things. The trouble is, part of workplace culture is to minimise risk and feel in control, and for most people close shaves do not look like a good advert for a life of faith.

Sooner or later most good things come to an end

Sooner or later most good things come to an end. Getting a new technology into a cut-throat consumer market is uphill work, and after some frustrating ups and downs the investors decided to give up. Then things moved very quickly, as we went into administration and were put up for sale. Eight jobs went, which must have been very hard for the person who had to select the victims, but two of them went back into retirement, and the ones who needed a new job found them very quickly. Then we had a visit, which had been arranged earlier, from a Taiwanese company, and it went very well. They really wanted to buy us, but could they convince their senior management in time? It did not look hopeful, and some days of hovering on the brink followed.

Where was God when the project was closed down?

That time led to some interesting thoughts. We could debate the investors' wisdom and timing, but if they wanted to write off several million, that was their decision. The question to ask here is, why were there those signs of God at work, if he knew we were heading into a dead end? Perhaps it echoes what you find in the Psalms where God is asked why he has withdrawn his blessing after giving it in the past. Well, one answer must be to beware of the prosperity gospel. Since material success is not a sign of his blessing, it follows that his blessing is not a sign that we can expect material success. So how does God see it? Our main asset was a good team, backed by intellectual property. It's a pity about the money, and it's a bigger pity to see the team dispersed. Taking a broader view, that sort of thing happens every day - money, talents, resources, and the fruits of years

of human effort, are wasted. These actions reflect the sense of values of the people making the decisions, which are normally to do with the bottom line. If we place ourselves in their hands, our fate will be decided on the same basis.

Commercial success is not a reliable guide to God's blessing

We may share the same fate as many others, but that is not the final verdict on the value of what we have done. Commercial success is not a reliable guide. In our throwaway culture, with its unsustainable lifestyles, you can argue that the marketplace is a rotten judge of true value, and that to give it that status is idolatry. We brought nothing into this world, and we can take nothing out of it, so piling up money for its own sake is pointless. The actions that matter in this world are the ones that reflect the character of God, who wants us to be like him. Do our lives, actions, relationships, creations, etc., in some way show his character, and produce the fruit of the spirit – love, joy, peace, and so on?

Why did it fail when God seemed to be in it?

The question is not yet answered: what does it mean when God seemed to be in it but it failed? Industry is not just about making products. At its worst it just buys in people with skills, milks them dry, and spits them out. At its best it develops them, building qualities that don't show on the balance sheet but make a huge difference, like relationships, skills, experience, and confidence. A good team is an excellent nursery, and when people move on they carry these things with them. God did a similar thing when he allowed the church in Jerusalem to be scattered, causing it to be planted in new places.

God is patient with us: His balance sheets are not calculated in money

Another way I looked at our experience is that when the investors backed us to try to develop and license this technology, they had a pretty good idea of the risks. They did the due diligence checks, which we passed, and we put together a good team, although of course we still made mistakes. I doubt if anyone else would have done much better, in fact technically we were leading the pack. So I do not think we let them down. God lets us make mistakes, and he gives us fresh chances. He is patient with us, and his balance sheets are not calculated in money.

One issue we often faced was that we needed to press on with the basic research, so as to understand the technology, but that conflicted with the show biz side – keeping potential partners happy by building demonstrators that could be taken half way round the world just so they could see with their own eyes. There will nearly always be some conflict between show biz and quietly building up foundations: question for discussion – do churches suffer from it too?

There will be conflict between showbiz and building foundations: do churches suffer from it too?

So how did it turn out? There was a lot of interest in the company, and the administrators kept postponing the day of decision, so we remained on the brink for another two weeks. But in the end none of the interested parties were prepared to put in enough money to keep it going, so we were closed down. But we will remember that period. Beneath the frustration and gloom, there was still cheerfulness and good relationships. It was a contrast with other situations I have known, which I think says a lot for the way the company had been run. The younger ones will surely take that experience with them, and hopefully draw on it as they rise into more senior positions.

Some former directors of the company described here have formed a new company to continue

developing the technology with funding from the Far East. At the time of writing, they are hopeful that it will go ahead.

Dr. Richard Riggs worked as a physics lecturer in Ghana, then as an electronics engineer in medical electronics and on super conducting magnets.

Rural Telephony in Developing Countries

Dr. Steve Chandler

Sierra Leone

The launch moved slowly against the strong current between the mangroves, which lined the banks of the Jong, as my family and I started on our return journey to England from Bonthe. The town, of about 5000 inhabitants, is on an island in a delta region at the mouths of five major rivers off the coast of Sierra Leone. It is the capital of a district, and had been a major trading post exporting agricultural produce (and slaves – this was where John Newton had worked) from the 17th century. It had fine British colonial planning and architecture. However the replacement of rivers by roads for transportation, the changing sourcing policies of customers and the change of government to one representing the more northerly tribes conspired to let it become a neglected by-water. Most people now lived by fishing or subsistence agriculture. It had been our home during the installation of a village communication system, which I had designed, which provided a type of telephone service based on CB radios under a microcontroller control.

Fourah Bay College

We had first visited Bonthe about ten years previously when I lectured in the Electrical Engineering Department of Fourah Bay College. This well respected institution was founded in 1837 as a college of Durham University to provide theological training for indigenous clergy, and played a pivotal role in the evangelisation of British West Africa. It is now the principal constituent of the University of Sierra Leone.

Warwick University

Now working at Warwick University, I still felt a strong commitment to Sierra Leone. I was then keen to take the opportunity, when it arose, to contribute my views to the Maitland Commission on Telecommunication in developing countries. I felt, as did many others, that although there was much room for improvement in telecommunications provision in developing countries overall, the greatest need was in the rural areas. Serving their needs would also give the greatest economic benefit as almost all income generating activity such as agriculture and mining take place in the rural areas. It seems unjust that the economic benefits of exporting these products mostly accrue to traders and dealers, rather than the producers.

Provision of communications technology to rural dwellers would surely help them to get a fairer price for their produce. Also the increasing discrepancy in availability of modern technology in urban and rural areas must exacerbate the urban migration, which causes such immense hardship and degradation in developing countries. (This is not to say that it is the only cause of what seems to be an age-old problem. The “Prodigal Son” was all too typical of many young people of all ages seeking to escape the strictures of traditional rural societies by migration to the bright lights!)

Rural telecommunications

Despite the unarguable need for improvements in rural areas, foreign telecommunications investment in developing countries has always resulted in cherry-picking the more lucrative urban areas where foreign companies, government departments and NGOs have their headquarters. Many governments have attempted to enforce a universal service requirement. However many experts and consultants question the level of demand and point out that the revenue could never remotely cover the cost of providing a universal service, which is certainly huge using conventional telephone technology. The only provision in rural areas has been that of some telephones in larger towns and more recently the spill-over of mobile services from more densely populated areas. However my experience had given me the conviction that there was a desperate need to find a solution.

Prayer

My wife and I spent a day praying with a wise and older Christian couple as to whether I should seriously pursue a project I had embarked on earlier with student projects. A low-cost interim solution could be provided by means of 27 MHz CB radios, which were then very cheaply available. These would be powered by photovoltaic panels, and controlled by a microcontroller to provide a telephone-type service within a local area. A network based on these would be able to acquire real traffic data, which could otherwise only be guessed at, and which would be needed to justify a business case for the viability of rural telecommunications. So I continued this work with greater commitment.

God gives others the same idea

Shortly afterwards, I heard from a friend working for the Sierra Leone P&T that a friend of ours had had the same vision as I had of a CB based village telephone system in the area around Bonthe. He had earlier installed a, by then defunct, radio link to supply telephones in Bonthe town and the mining companies on the mainland not far away. Our collaboration was invaluable in getting the project implemented even though by the time of the installation he had suffered a major stroke, which left him unable to speak or actively participate in the project. Why God lets these things happen I do not understand, but at least I had been able to implement his idea for him, with much help and co-operation from too large a number of people and organisations to list here.

It had been a very challenging but enjoyable few months in Sierra Leone after several years of preparatory work. Although at many times problems, both technical and human, had seemed insurmountable, God had always answered prayers with a solution. There were many fortuitous coincidences. For example, I had just finished programming the last EPROM with a correction to the code when the town power station went off. It has still not come on again fifteen years later! Apart from that programmer, everything else worked off 12 volts and could be powered from the solar panels.

Multiple benefits!

Although I had thought that the main benefits would be in facilitating economic activity, it became apparent there were many others too. Many calls related to family matters and to seek factual reassurance about the subject matter of rumours. One Paramount Chief was particularly thankful, as he feared for his life due to a local factional feud, which went back to colonial times. The justification for his fear was borne out by his grizzly murder, several years later during the civil war, by the rival faction collaborating with the rebels. During the early years of the war the network helped to prevent the island being invaded. Though we had first hand experience, this is not the place to discuss that appalling war, which witnessed incredible evil countered by incredible courage, faith, and self-sacrifice.

The system installed in the Bonthe district had much going for it but was far short of the functionality of a proper telephone system. It had demonstrated the need for local-to-local communications, but was not able to provide communication over distances exceeding around 40 km. I was, though, able to obtain usage statistics from stations outside this 1-hop range by using the packet relaying capability of the controller. A network comprising radio stations which could provide similar digital relaying of duplex voice signals would be able to provide full telephone functionality if it were connected at some “gateway” station to the national telephone network.

BT Martlesham

The opportunity to investigate such a system arose soon after returning to Warwick with a short-term fellowship with BT at Martlesham. In the short time I was there, I made some significant theoretical discoveries, which confirmed that such “ad-hoc” networks as they are now known, were a viable solution to providing telephone services by radio to scattered rural communities. I did, in fact describe many technical aspects of what was to become Dart. In terms of research, it was the most exciting and productive few weeks of my life!

Success?

Over the next few years, things went very well. I was able to establish a small team to help realize the concept at Warwick and teamed up with S., a lecturer from Southampton University, and a committed Christian, and with P., a successful salesman in Telecommunication. We set up Rural Radio Systems Ltd (RRS) and later, J., a business angel who invested some cash and provided much valuable help joined us. I managed to get some further sabbatical leave to do research with S. at Southampton. Everything seemed to be going well, and that is where a testimony would end!

A meeting was held at which a production version would be made and a design conference was held. It was decided that rather than split the design team in two locations, it would be located at Southampton under S., who had more industrial experience, and a number for new graduates from there were recruited. Which meant I had nothing to do. I objected but was over-ruled and had to find some other research topics to work on to remain research active at Warwick. But I was delighted when the first Dart units were made and worked, even if not completely reliably.

Progress

After some small sales of Dart units, we needed to get further funding to further develop and market it. Eventually a deal was made with GPT (later Marconi) which offered a real way forward. About this time we seemed to have gained an order for 6000 units to provide a rural network in Nigeria.

GPT were keen to supply the Chinese who were very keen on the technology after GPT had demonstrated it there. However, when GPT tested the units more thoroughly than had been by RRS, they found that there were aspects of the radio hardware performance that needed improvement, and that the software was unreliable. These clearly needed to be attended to for Nigeria as well as for GPT.

Seeing the opportunity to re-engage in the project, I left the University and joined the company, setting up a small office/lab in Coventry to re-design the radio hardware. My brief was to make minimal changes to the existing design, which was based on analogue filtering and demodulation. I believed a DSP based transceiver was necessary for mass production, as the existing design required much skilled tweaking.

The Southampton team would concentrate on fixing the software. In the end the transceiver worked fine and was able to be produced without alignment, though with the expected minor changes to deal with problems that arose during production.

Problems

The software, though, never worked reliably. When GEC, by now Marconi, tests found problems, the fixes usually caused further problems. Eventually Marconi downgraded their interest in the project, I suspect partly because they felt they were going round in circles, and partly by misguided priorities of their new, and incompetent, Board. (Anyone unfortunate enough to follow the advice of all the City advisers to buy shares in them will be painfully aware of the result!) The Nigerians eventually only sent Letters of Credit for the supply of 1500 units, which were duly manufactured and sent to Nigeria. However, with a change of Government there, all contracts were subjected to scrutiny and re-assessment, and our units spent the next three years deteriorating in a warehouse in Lagos Harbour. When the cash ran out and a potential investor pulled out in the absence of the reinstatement of the rest of the Nigerian order, and despite much work by P. and I, Rural Radio Systems had to cease trading. It was eventually wound up in May this year by a components supplier from whom components for 6000 units had been ordered but from whom RRS had only been able to take delivery of 1500 units' worth.

My own business

In the mean time I had set up a small company (RRT) with P. to do contract R&D and license some technology I had patented to the cellular industry and others. When the Nigerians put in an order to RRS to install the 1500 units as RRS, though still extant, was no longer functional, the installation was subcontracted to another company P. was involved in, with technical backup provided by RRT. We recruited two excellent software engineers who managed to identify and fix a number of crucial problems with the software. They were also able to identify its underlying problems and propose plans to tackle them.

Difficulties

However the installation work was hampered by arguments about who pays for things which had disappeared during the 3 years the kit had sojourned in Lagos Harbour, network planning which ignored technical limitations, corruption, employing a number of expatriate installation engineers before they were needed, lack of Nitel co-operation and a project manager only being appointed when things had already gone astray, as well as the erratic Dart software. This programme eventually ran into the sand with a substantial sum owing to my company, which had to lay off the software engineers, and with them the future of Dart.

Failure?

RRT had to go back to contract R&D and licensing my patents to the telecommunications industry. Originally I had hoped that this might generate sufficient cash to pay for the development of a new Dart type system, which I had learnt investors would never support. The original design is now technologically archaic, and starting from scratch would be quicker and cheaper than fixing component obsolescence and inherent design weaknesses of the present design, as well as better satisfying current market expectations. However there remains a deep recession in telecommunications. Few manufacturers, even the large ones, are able to make any money at all. Indeed many of the over-hyped technology-push solutions, which caused us such problems with getting investment, have now crashed. A minute proportion of the money lost on these ventures could have enabled Dart systems to provide telecommunications to most of the rural areas of the developing world.

I can no longer afford to pay for a loss making enterprise, and will probably have to put my company in the deep freeze and get a job outside the telecommunications sector. With this, as far as I can see, goes the chance of helping the rural communities I have come to have such a commitment to, as I have no other relevant skills to offer them.

Conclusion

What can I conclude? It seems God has not answered my and my family's many prayers, and those of many other Christians. But that does not mean He has not heard them. His answer may not be what I hoped for. David Watson was not healed, and innumerable other things that would seem to be for the good of many and have been the subject of much prayer have not happened. Sometimes with hindsight we can see that our prayers were based on a limited understanding, but sometimes we are just faced with saying "let your will be done, not mine". It seems to me that He gave us a wonderful opportunity to use engineering skills for His ends rather than Mammon, but we messed it up. Thinking about how this happened and who was responsible is probably not helpful. All of us have at times thought more about our own good than the success of the project and glorifying God.

What next?

The experience has enabled me to follow Jesus and many Biblical writers in identifying more closely with those for whom life and their fellows have dealt with far more harshly than me! What is certainly not sustainable is the belief of some rich and powerful Christians that their material success is a reward from God for their good deeds/prayers/sound doctrinal position, implying that those less well off deserve it for their un-confessed sin. Will someone else be chosen to bring affordable telephones to rural Africa? I will pray for this, as there is real need, and I would do all I could to help them.

A Liberal & Christian Education

P Hammond

Engineering education

The job specification for the Vice-Chancellor of a British university is very demanding. Externally he has to represent, and to fight for, his institution and internally he must provide leadership for a wide variety of prickly colleagues. All this has to be accomplished through attendance at endless committees as well as by back-stage lobbying. As a result vice-chancellors seem to have little time for pondering the purpose of university education.

During my 25 years as head of a university engineering department I have served under five vice-chancellors: a specialist in English Literature, a geneticist, a lawyer, a historian and an engineer, all of them able men. My favourite was the historian who was cheerful, accessible and consistent. Moreover he seemed to be able to detach himself from the daily pressures and to take a wider view of university education. When I said farewell to him, he told me that one of the lessons he had learned during his tenure was that engineering could provide a truly liberal education to young people. It is a remark I continue to treasure.

Engineering can provide a truly liberal education:

Is there a connection between Christian truth and a liberal education?

The vice-chancellor's remark was clearly meant as a compliment and I took it as such. But what is a liberal education and why should it be thought desirable? Moreover, is there a connection between Christian truth and a liberal education? Can an engineering education be a positive contribution to a life that is to be spent in the Lord's service? These are tough questions and in a short article I can attempt only some hints that may lead to the answers.

What is a truly liberal education?

First, then, let us consider the features of a liberal education. All education involves the transfer of (useful) knowledge. An important constituent of such knowledge consists of information and such information has to be detailed enough to make it useful. A university therefore has to have specialist departments, which in turn consist of various specialist sections. However, knowledge is progressive and it is impossible to predict those developments which will be appropriate in the working lives of the students.

There is therefore no possible way of designing a curriculum that will be either necessary or sufficient for future usefulness. Although this is obvious, it conflicts with the desire to provide an education which will meet the specific needs of the present day. Education is costly in human and financial resources and the paymasters naturally look for quantifiable value for their money.

The universities are therefore subject to various accreditation schemes, by which it is hoped to ensure that the students have been given the best and most useful kinds of information.

Detailed knowledge by itself is insufficient

The trouble with such an approach to education is the omission of a vital ingredient. Detailed knowledge is by itself insufficient not only because it has a limited shelf life, but also because it omits the context of the knowledge and the connections between the isolated particles of information. A liberal education includes the links that are needed to make sense of the information. And the bad news is that modern universities are bad at providing such links either for their staff or for their students.

Society has a low view of the value of human beings

Various remedies have been sought for this lack of liberal education. Some universities have introduced general courses to supplement the specialist subjects, but such offerings have found little favour with students. Moreover the teachers regard such courses as a chore that will do nothing to advance their careers. In any case these general courses do not readily connect with the specialist ones. What is needed is a balanced diet rather than a dose of vitamin pills after the daily portion of burgers and chips.

Present universities operate in this society and reflect a low view of the value of human beings

The real obstacle to the provision of a liberal education cannot be removed by changes to the syllabus. The problem lies far deeper. The present universities operate in a society that has a low view of the value of human beings. It regards them as no more than embodied digital storage devices like computers. This view is reflected in the universities. They, too, have forgotten that men and women were created by God in his image and that the Son of God took on himself our human nature to make it possible for us to have fellowship with God.

We must not confine Christian values to specifically Christian activities

What can be done to remedy this sorry state of affairs? Although the individual witness of Christians in the universities is important, it is insufficient. Throughout my career I have enjoyed the fellowship of Christian colleagues and our weekly lunch-time prayer meetings have been a great source of encouragement. But my conviction is that we must not confine Christian values to specifically Christian activities. That involves their introduction into the academic subjects.

Engineering espouses personal human values

Of course the notion of values is abhorrent to those wedded to politically correct views. However, the good news for engineers is that engineering is always about value in terms of 'fitness for purpose', where the notion of fitness is unavoidably linked to human needs. In my experience the faculties of engineering and medicine are the chief and only bastions of personal human value in the modern university, because they regard human beings as having intrinsic value. That does not mean that engineering and medicine are necessarily Christian, but these subjects make it possible and indeed inevitable to speak of values in the educational context. It counteracts the prevailing doctrine of atheism in the university.

Value judgments generated by personal links with practising engineers

The introduction of value judgments in engineering education can be helped by contact with the real world of engineering outside the university. Such contacts can best be brought about by personal links between practising engineers and university staff in R & D work. Students can be given small tasks of various kinds. These will give the opportunity for the development of creativity, which is an important part of a liberal education and which is often sadly lacking from university courses. The exercise of creativity is an essential part of the image of God in human persons.

I doubt whether my favourite vice-chancellor was aware of the reasons that make engineering particularly suitable for a liberal education, although I suspect he was aware of my motivation as a Christian.

I thank God for letting me be a part of such a worthwhile enterprise as engineering education

Professor Percy Hammond is a Fellow of the Royal Academy of Engineering. He was head of the Electrical Engineering Department at Southampton University until his retirement. He is a Reader (local preacher) in the Church of England.

Nuclear Feature

Editorial note: David Kay feels that my article in the last issue of our Journal was unduly biased in favour of Nuclear Energy. Consequently, he has kindly discovered the following article by George Butler which portrays some of the risks generated by the use of nuclear energy. He has also written an introductory article. I believe that this gives an undue bias against Nuclear Energy so I have written what I believe to be a balancing argument in a following article.

Risk – A Christian Perspective: Further Thoughts

David Kay

Living with risk – nuclear power

The article *Do we ever take risks?* by John Baden Fuller in the previous issue of this journal considered the advantages of nuclear power, but did not deal with the disadvantages.

We are therefore publishing an abridged version of an article that addresses the problems of nuclear power. This article, *Christian Ethics and Nuclear Power*, dates from 1979, but the general scope of the arguments is still valid today.

Both articles were written by Christians, but the *Risks* article was first published in a secular journal, and consequently does not address the subject from a declared Christian perspective. The *Ethics* article was published in a Christian journal, but only a minor part of the article deals explicitly with the Christian perspective, and even here the treatment is quite general. It is apparent that the authors take respectively contrasting positions. Neither author attempts to quantify the safety of nuclear power. As far as nuclear power is concerned in the widest sense as a future source of energy, there are no conclusions, only opinions! Even if a conclusion could be arrived at, something would happen tomorrow to alter the equation at least in a small way. On April 26, 1986, the Chernobyl accident altered the equation substantially, as far as people's perception of nuclear power was concerned.

A further contribution to the debate occurred in the Royal Institution Christmas Lectures 2004 (on Antarctica), when a reference was made to the future effects of global warming – widespread flooding, with many millions affected. This outcome could be compared with the 45 deaths caused by the Chernobyl accident. However, there were also many other long-term casualties.

Assessing risk probabilities for major events

Some events have already occurred that would have had remote probabilities prior to the event. In the nuclear industry both the Three Mile Island and Chernobyl accidents are probably in this category. Nearer home an example can be cited from the railway industry, where the issues can be easily identified. An accident occurred at Southall in 1997 when a high-speed passenger train hit a freight train crossing the main line. One could ask whether it was really a coincidence that so many things went wrong at the same time:

- 1 The AWS was not working.
- 2 The train was not reversed at the starting point despite the above problem.
- 3 A freight train was routed across the path of the passenger train.
- 4 The driver was not paying attention to his duties, as he was packing his bags.

These examples indicate the weakness of the risk assessment process.

Major global events

Nuclear waste decomposes anyway eventually, so it could be argued that it is CO₂ waste rather than nuclear waste that is the greater threat from activities caused by people in the long term.

The world was reminded by the tsunami on December 26, 2004, of the potential for catastrophic events. A similar event could occur if a volcano on the island of La Palma split apart, thereby causing a tsunami that reached America. It is necessary to think on a wide scale when considering the topic of risk, and consider the big issues.

Finally, two of the conclusions in the article *Risk – A Christian perspective* in the previous issue of the journal are restated:

1. Everyone must decide for himself what risks to take, and to what extent personal risk assessment is appropriate.
2. The techniques of risk analysis are difficult to undertake, but are valid, and reflect truth. Proper execution of the methods can be seen as a potential source of pleasure to the one who performs the calculations, and a means of bringing glory to God.

Christian Ethics & Nuclear Power

J. George Butler

Christian ethics has as its frame of reference Jesus' idea of God. God is creator of heaven and earth, a loving God concerned about human beings – the children of God who are of infinite worth in his sight. We must reverence all of his creation: humanity as well as the earth. The psalmist sang: "The earth is the Lord's and the fullness thereof." Nearly 500 years ago Martin Luther questioned the distinction between the sacred and the secular: all life is sacred. And long before Luther, the creeds of Christendom spoke of God as "maker of all things visible and invisible."

From this perspective, Christian ethics has a great deal to say about nuclear power -- its potential to destroy life and to poison the earth. Christians often use the word "stewardship," but most often in a narrow sense, in connection with the practice of tithing one's worldly goods. True Christian stewardship embraces the larger meaning found in the ancient creeds: all of life, "the world and they that dwell therein."

"Christianity," wrote Anglican Archbishop William Temple (*Nature, Man and God*, 1935), "is the most avowedly materialist of all the great religions": it is concerned with daily bread as well as things spiritual, for the two are inextricably interrelated. Because of this materialism, Christian ethics must examine nuclear power in broad perspective. From the standpoint of stewardship of life as well as stewardship of the earth.

The Rasmussen Report

Let us consider nuclear power first in its relation to life. What dangers does it pose? Nuclear advocates assure us that the risk of catastrophic accident is negligible. For example, the public-relations department of the Illinois Power Company puts out an attractive brochure which quotes from a government report, the Rasmussen Reactor Safety Study: "Assuming 100 operating reactors ... the chance of a nuclear accident involving 1,000 fatalities [is] in the same class as that of a meteor striking a U.S. population centre, causing the same number of deaths."

But the Rasmussen report is not the scientific document it purports to be. Henry Kendall of the Massachusetts Institute of Technology, founder of the Union of Concerned Scientists, took advantage of the Freedom of Information Act to pry from a reluctant Nuclear Regulatory Commission (NRC) some material heretofore suppressed. His objective review of the Rasmussen document says simply that Americans have been deceived by it.

Prodded by the work of the Union of Concerned Scientists and by Congressman Morris K. Udall (D., Ariz.), chairman of the House subcommittee on energy and the environment, the NRC finally issued a report on January 19, 1979, repudiating major portions of the Rasmussen document. As the January 20 *New York Times* reported: "The decision [by the NRC] to reject totally the Rasmussen Study's summary was based on a finding that the summary 'is a poor description of the contents of the report.'"

Though nuclear advocates contend that reactors are safe, the American insurance industry apparently does not agree. There is not one homeowners' insurance policy written in America which does not have a nuclear-exclusion clause. Further, no private group of insurance companies would consider writing nuclear-insurance coverage for the civilian nuclear power industry. Congress was forced to pass the Price-Anderson Act, guaranteeing \$560 million of government insurance, before the civilian nuclear power program could begin operations.

Unforeseen risks

Though evidence continues to surface that there have been many more accidents than the nuclear industry likes to admit, let us assume that the chance of catastrophic accident is indeed negligible. Then one still must ask: What threat does low-level radiation from these reactors pose? Two factors must be borne in mind: the civilian nuclear-power industry is relatively young, with its large (600-800 megawatt) reactors having been in service for but a few years. Cancers from low-level radiation do not develop overnight, but take at least 20 to 25 years to appear. Only recently has the nation become alert to the dangers from the uranium tailings used a score of years ago in the foundations of houses. Now owners of such homes find them uninhabitable because of the cancer risks from the low-level radiation emitted by this discarded rock from uranium mines.

There is mounting evidence to suggest that permissible safe limits of radiation exposure should be cut by a factor of ten. Such a reduction would have a devastating effect on the industry, which up to now has assumed that it was operating with safe, low-level radiation emissions.

Radioactive waste disposal

If low-level radiation poses a greater threat than was thought possible 25 years ago, what of the danger to life and to the earth from high-level radioactive waste? It is generally agreed that high-level waste poses risks. Industry spokespersons say, however, that it can be safely dealt with. Other scientists, including Linus Pauling, predict genetic damage to millions yet unborn. Even a 1 per cent addition to the natural background radiation of the earth, says Dr. Pauling, means thousands of additional defective children born, and thousands more cases of cancer.

Last April the Government Operations Committee of the U.S. House of Representatives issued a report titled "The Costs of Nuclear Power." The document is significant because it represents the first instance that any unit of the federal government has acknowledged that there are grave unsolved questions regarding nuclear power. (The government has heavily subsidized the civilian nuclear-power industry since creating the Atomic Energy Commission in 1948.) The committee contends that nuclear power is not cheap. The problem of nuclear waste has not been solved, despite more than 5,000 "studies" by government agencies. High-level waste is dangerous to life for a quarter of a million years. Should the earth survive even a fraction of that time, how will coming generations know where such waste is stored? What right do we have to mortgage the future of the earth in this manner? The committee asks:

If the technology exists and the problem of waste disposal has been solved, why has DOE not yet chosen a permanent federal repository for these wastes? And why has the technology for that disposal not yet been identified? The demonstration of that technology could terminate the controversy which threatens the survival of the nuclear industry.

An expensive option

If nuclear power poses a threat to life as well as to planet earth itself, why do we continue to travel down the nuclear road? Prudent economics would indicate, as indeed the Government Operations Committee concludes, that other options are cheaper. And in fact the civilian power industry is beginning to turn its back on nuclear power for economic reasons.

The most thoroughgoing and trenchant economic analysis of nuclear power available is to be found in Saunders Miller's book *The Economics of Nuclear and Coal Power* (Praeger, 1976). An investment banker, Miller is also an economist whose field is economic risk analysis. After examining nuclear power solely from the perspective of profit and loss, he concludes that "from an economic standpoint alone, to rely upon nuclear fission as the primary source of our stationary energy supplies will constitute economic lunacy on a scale unparalleled in recorded history, and may lead to the economic

Waterloo of the United States.”

One need not be a Marxist to understand that ethical questions are often determined by economic considerations. Slavery was abolished in America, not only because of the aroused Christian conscience against it, but primarily because it was becoming unprofitable. Nuclear-fission power, with its tremendous capital costs and its poor reliability record, has reached its present nadir primarily because it has been weighed in the economic balance and found wanting.

This is an abridged version of an article which appeared in the *Christian Century* April 18, 1979, p. 438, and is reprinted by permission. The full text, prepared for *Religion Online* by Ted & Winnie Brock, may be viewed on the website www.religion-online.org/showarticle.asp?title=1225. Copyright 1979 *Christian Century*. Subscriptions: \$49/yr. from P.O. Box 378, Mt. Morris, IL 61054. 1-800-208-4097.

Mr. Butler, a retired United Methodist minister, is a trustee of the Vermont Electric Cooperative, Inc., and chairman of its alternative energy committee.

Nuclear Energy, the God-given Solution to Global Warming?

John Baden Fuller

Global warming and excessive CO₂ production is a matter of great concern. Is it possible that nuclear power, which is a negligible producer of CO₂, is God's answer to the possibility of global warming? In 1992, in the *CEA Newsletter*, I floated the idea that we will not run out of essential raw materials because change-of-use will occur before any shortages become critical (A.J. Baden Fuller, Talking Point, *CEA Newsletter*, Spring 1992, p.17.) The obvious evidence which brought it to my attention was the shrinkage in size of electronic circuits and computers using silicon instead of copper and, in communications, the replacement of copper wire with thin strands of silica optical fibre. In the 1950s copper was in short supply and was stockpiled by the USA government whereas Silicon is one of the most abundant elements on the earth's surface.

Are our natural resources really likely to run out?

Subsequently, I was able to find other examples of the same effect and the idea was published by the IEE (A.J. Baden Fuller, Are our natural resources really likely to run out? *Eng. Management Jour.* Vol.7. pp.131-133. 1997) and presented as a substantial paper at an IEEE/IEE conference (A.J. Baden Fuller, Raw materials - why should they ever run out? 1997 Int. Symp. on Technology and Society, *Technology and Society at a Time of Sweeping Change*, Proc. pp.181-184.) I believe that my point was well made; certainly, nobody that I know of has refuted it. Consequently, is nuclear energy one of the solutions to giving the disadvantaged people of the world adequate electrical power without increasing emissions of CO₂?

Why not use nuclear?

When I became chairman of CEA, because I felt that, as Christians, we needed to consider the possible advantages of nuclear power, I promoted a number of contributions to our *Newsletter* on the subject.

1. After Chernobyl, Peter Hodgson, p.24, *CEA Newsletter*, Autumn 1987.

2. Letter in reply, K.S.Hawkins, p.5, *CEA Newsletter*, Summer 1988.
3. Green Energy (reprint from IEE News), p.17, *CEA Newsletter*, Autumn 1989.
4. Energy feature, p.3, *CEA Newsletter*, Autumn 1992.
5. The ethics of nuclear energy, Peter Wilson, p.5, *CEA Newsletter*, Autumn 1992.
6. Green energy, Alan Foster, p.14, *CEA Newsletter*, Spring 1993.

Item 4 was a contribution from the wife of someone who worked at Sellafield nuclear plant and item 5 from Peter who was a development chemist there.

Fossil fuels?

In the UK we use about six tonnes of coal (energy equivalent) per head per year. The world demand for energy is likely to double by the year 2050. The question is, where will it come from? One contribution will come from more efficient use in industry and the home. Only limited gains in energy efficiency are possible in fossil fuel power stations, because great improvements have already been achieved. At the moment, fossil fuels provide about 90% of the world energy requirements. There is still a great quantity of coal available worldwide, even though Europe including the UK is busy closing coal mines. However, coal is not an environmentally clean fuel. It leads to the generation of acid rain, and contributes gasses to the greenhouse effect, CO₂, water, ozone, methane and chlorocarbons. At the moment, fossil fuels account for about half of the world emission of CO₂. In Britain, with supplies available from the north sea, we have moved to oil and gas to power our fossil fuel power stations. Gas has provided a small but useful reduction in our CO₂ output. But north sea supplies of gas are likely to run out and we shall soon be relying on places such as the Middle East, Algeria and Russia to supply our needs.

Alternatives?

Growing global concerns about the availability and price of fossil fuels and the dangers of climate change have resulted in a revival of interest in alternatives. If we do nothing, the problems appear to be insurmountable. There is likely to be a sea level rise of 20 cm in the next century accompanied by an increase of violent storms and hurricanes.

Renewables?

Renewables can provide much electric power but, at the moment, they are considerably more expensive than fossil fuels. A number of systems are being assessed at the moment. They tend to be intermittent and unpredictable, so they are not the complete answer to our power requirements. It is necessary to have supporting systems for peak time demand and base load supplies. Fossil fuel generators can supply peak time demand and nuclear power could provide the base load supply.

Hydroelectric

Hydroelectric power is being used in many parts of the world and in the developed countries most available sites are already in use. Tidal barrage sites are still available but any barrages will affect the wildlife in any estuary. The operation of new sites is not without its difficulties. Hydroelectric could provide a small proportion of our total estimated need.

Wave power

Wave power is another possibility but much research is still needed. The availability of useful wave power appears to be at isolated sites away from centres of population. It would also be an intermittent supply depending on the state of the sea.

Wind power

Wind power is excellent for isolated sites, but there are problems for the general provision of our power needs. The energy density of any wind farm is low. It would need between three and four thousand wind generators to replace the power output of an average power station. Also, the output of wind generators is intermittent depending on the wind strength. Some of the best sites are in areas of natural beauty so that there is likely to be local opposition to their use.

Solar

Solar photovoltaic panels set in the roof of buildings are the most common local renewable electricity source. The only need is an unshaded, south-facing roof. Initial costs are high but there are no moving parts so maintenance is minimal and a well designed properly installed system has an expected life of over 25 years. Maybe in the future, all new buildings will have solar panels in their roofs. But any solar panel system needs to be supported by battery storage or an external electricity supply because we make the most use of electricity during the hours of darkness, when the output from solar panels is zero.

Nuclear

Nuclear is the other alternative which does not generate CO₂. It is dangerous, so do we really need it? There are significant issues to be overcome, including the economics of new build, waste management, decommissioning and the safety of nuclear installations. However, it is already widely used for electricity generation. One sixth of all the electricity used in the world today is generated in nuclear power stations. There are no emissions contributing to acid rain or global warming.

Nuclear power stations are expensive to build but the running costs are low. A disadvantage is the need to provide nuclear radiation and explosion shields. The containment of the radioactive cores is difficult to breach. A redundant airliner was propelled at 500 mph into a concrete wall similar to the containment building. The wall suffered superficial damage whereas the plane was destroyed entirely. Similarly, a train was crashed at 100 mph into a vehicle carrying a nuclear waste containment flask. The flask survived and was still safely sealed against leakage of the contents. No one died at Three Mile Island in the USA and research has shown that there were no adverse effects outside the plant. Safety systems worked.

One advantage is that fuel volumes are low. One tonne of nuclear fuel is equivalent to 20,000 tonnes of coal. Energy is wasted in transporting fuel to coal-fired power stations whereas the CO₂ generated in transporting nuclear fuel is negligible. Vast quantities of uranium ore are widely available throughout the world and are not confined to just a few sites. Waste management is a problem. It is expensive but the volumes are very low. The high-level waste produced in the UK from the civil and military programmes, before vitrification, would fill only four double-decker buses. Less than 0.1% of the total radiation absorbed by the population is due to nuclear power stations. The latest research suggests that long-lived radionuclides could be separated from the residual waste and transmuted into materials that decay more quickly. (*IEE Review*, October 2004, p.14) It is reasonable for us to expect that solutions will be found. Nuclear power stations are compact with a large and generally reliable output but emit none of the CO₂ largely held responsible for the threat of climate change.

Dr. Robert Hawley, former chief executive of Nuclear Electric and an IEE past president, believes that the only way to secure the UK's power supplies for the future is to build new nuclear power stations soon. It is the only long-term means of meeting future energy supplies without adding to the problem of climate change, (*IEE Review*, March 2005, p.18.)