

*Leonard Brookes PhD*  
*Fellow of the British Institute of Energy*  
*15/05/1919 to 02/04/2016*



*Taken in 1976*

Dr Len Brookes, who has died aged 96, was a mathematician and economist, who before his retirement from full time employment with the United Kingdom Atomic Energy Authority in 1979 was their Chief Economist with responsibility for Economics, Forecasting and Energy Policy. He was subsequently self employed as an author of papers on energy and associated matters and as a consultant to a large number of organizations in the public and private sectors in the UK and overseas. He gave invited evidence on energy and on global warming to the Government and Parliament (the Lords) on a number of occasions – the last being in 2005 when he was 86. Before entering this field of work in 1967 at age 48, he enjoyed a successful career as a Civil Service Administrator and was a RAF staff instructor during WW2.

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Len was born in Balham, South London on 15<sup>th</sup> May 1919, the eldest of three children. He showed promise from a very early age, having won a scholarship to Emmanuel School in Clapham - a public school where he excelled, winning prizes in many subjects, including Latin and Greek and achieving a distinction when he matriculated. His headmaster was very keen to support his application for a bursary for him to study maths at University but sadly his parents wanted him to go out and earn his living so he took the entrance examination for the civil service and began work with the Ministry of Transport as a junior administrator in 1937. It was here he met his wife, Joyce, whom he later married in July 1942.

During World War II Len served as a pilot in the Royal Air Force. Having been called up in 1941 he was sent, along with 39 other new recruits that formed No1 BFTS (British Flying Training School), to Terrell in Texas where he was taught to fly. He was a natural as a pilot and on his return to the UK he was appointed as a commissioned staff instructor at the RAF Flying Instructors' Schools at initially Montrose, Scotland and later at Upavon, Wiltshire. He taught on a range of aircraft from fighters to heavy bombers. Len always looked back with

some nostalgia at having been chosen to give a public aerobatic display at Upavon on the first Battle of Britain commemoration day on 15 September 1945.

Of the original flight of 40 sent to Texas, only 6 survived the war (one of whom was “Bonzo” Broderick of “Great Escape” fame). Len’s group were the first to go to Terrell but many others followed and subsequently formed the BFTS Association. The Association continued to meet up regularly after the war and this culminated on the fiftieth anniversary with an invitation to the survivors and their wives to return to Terrell, to be made honorary Texans and to meet again those families and their descendants who had opened their homes to the young RAF pilots so many years before. Len was the last of the survivors of No1 BFTS.

Sadly Len’s younger brother, Bill, never returned from a reconnaissance flight and was presumed dead in 1943. His sister, Joyce, was famously the blonde girl in the iconic picture celebrating in the fountain at Trafalgar Square during the VE Day celebrations. Joyce sadly passed away in November last year in Vancouver, Canada, having married a Canadian serviceman and moved there after the war.



*Len prepares to celebrate his eightieth birthday by taking the controls of a Stearman PT18 like the one he learned to fly in 1941 in Texas*

After the war, Len returned to his work in the civil service and received regular promotions until in 1960 he left the Ministry of Agriculture and joined the UK Atomic Energy Authority (UKAEA) at **Winfrith** in Dorset as their Personnel Manager and the family – by then there were 4 children ranging in age from 18 to 1 - moved to Bournemouth

Although Len enjoyed his time at Winfrith, his real interest was still economics and in 1967, aged 48, he managed to persuade the Atomic Energy Authority to give him a job in their Economics & Programming Branch at **Harwell** in Oxfordshire. He embraced this new challenge with gusto, wanting to prove to them that he was worthy of their faith in him. He very quickly learnt how to write computer programs so that he could prove his economic/mathematical theories with computer modelling on the large Harwell mainframe computer. Clearly all this wasn’t keeping him busy enough:

thirty plus years after being denied the opportunity, Len was studying (in his spare time) for a degree in maths with the newly created Open University. He was subsequently amongst the first cohort to achieve his BSc with the OU and some years later went on to be awarded a Doctorate in Mathematics following the publication of the book he jointly authored with Dr Homa Motamen (then of the economics department of Imperial College) “*The Economics of Nuclear Energy*”. Ironically he later authored the Open University’s course unit on Energy.

After just a year or so at Harwell Len was submitting his work for publication and receiving recognition first nationally and then internationally. He finally retired from the UKAEA in 1979 but continued working as a consultant for many years after during which he travelled widely attending seminars and conferences all over the world most often as invited speaker. His interest in economics never waned and his last published paper was in 2007 when he was 88. His main fields of interest were:

**Analysing the role of nuclear power in electricity systems and presenting the public case for a substantial component of nuclear power in the UK electricity system** – he famously took part in a fiery TV debate with Tony Benn back in the late 1970s following publication of his paper “The Plain Man’s Case for Nuclear Energy”. Latterly he was invited to comment on the Government’s 2002 draft paper on energy and their 2007 White Paper on a new nuclear power programme. His comments exposed technical and economic inadequacies of wind power as a source of relief to pressures on the price and security of supply of gas as North Sea gas runs out and argued strongly that a revival of nuclear power was overdue as a hedge against rising prices and politically insecure sources of supply

**Development of mathematical approaches to forecasting electricity demand.** This included the development of a forecasting model of the UK electricity supply system that incorporated a trend extrapolation “S” curve. Initially published internally in 1968 and thereafter as “The forecasting model of the UK electricity system” Atom No 165 July 1970.

**However, what Len is most noted for is scepticism about the benefits, if any, of attempts to achieve energy conservation through the medium of widespread improvements in energy efficiency.** He has very many papers published in journals and at conferences between the 1970s and the present century stating that widespread individual measures to raise energy efficiency at the microeconomic level are associated with increases in energy consumption at the macroeconomic level. In 2005 at the ripe old age of 86 Len was invited to give evidence to the Lords Science and Technology Committee for their study of energy efficiency. His work in this area continues to be cited in articles published in top energy journals all over the world

**Len is also known for deep scepticism about whether any threat from climate change can be attributed to the emission of CO<sub>2</sub> from man’s use of fossil fuels.** He submitted as invited paper on the subject to the study by the UK House of Lords Committee on Economic Affairs of the economics of climate change. Len also produced a detailed study demonstrating the intrinsic unsuitability of wind energy parks as elements in national electricity systems and therefore as having any relevance to a programme of reducing carbon emissions (August 2004)

Not surprisingly, Len came up against considerable opposition to his ideas but he had tremendous self-belief as well as a terrific sense of humour which helped him “roll with the punches”. His good friend and fellow energy economist – Dr Harry Saunders of California – wrote on hearing of his death: *I first met Len a bazillion years ago at a conference in Oxford where he was a keynote dinnertime speaker. He was funny, insightful, entertaining and engaging. Our paths crossed multiple times in later years. He was the first economist in the modern era to dare to suggest that conservation might not deliver what everyone supposed. He took a whole lot of flack for his ideas, but he was right. I'm so glad he hung in there; the profession owes him a great debt and his place is assured in the history of economics.*

To offset his professional life, Len enjoyed playing the music of the 40s and 50s as well as composing and recording his own tunes (he had originally learnt to play the piano as a boy. Over the years he also enjoyed and participated in a range of sports - rowing, tennis, sailing and golf. In retirement he spent many an amusing afternoon composing Letters to the Editor of the Daily Telegraph on a whole range of subjects from nuclear energy to civil service pensions. A man of many parts.

Len leaves behind a huge and loving family – his wife Joyce (they were married for 73 years), his four children, nine grandchildren and nine great grandchildren.

See over for a more detailed list of Dr Brookes' fields of interest and details of his published works.

1. Analysing the role of nuclear power in electricity systems and presenting the public case for a substantial component of nuclear power in the UK electricity system. This has included analytical papers in learned journals; papers presented at conferences in the UK and other countries; public debates with leading members of the anti-nuclear-power movement; and book reviews of pro and anti books on nuclear power. He was joint editor and part author in partnership with Professor Homa Motamen then of the economics department of Imperial College of the collection of papers comprising the book “The Economics of Nuclear Energy” published by Chapman and Hall in 1984.

Publications in this area. See for example: “The plain man’s case for nuclear energy”; Atom 234; April 1976; “The nuclear power implications of OPEC prices”, Energy Policy June 1975; “Energy policy, the energy price fallacy and the role of nuclear energy in the UK “, Energy Policy, June 1978; “The case for building Sizewell B”, The Electrical Review, Vol. 211, No.13, 22Oct. 1982; “Evidence to the Sizewell nuclear power inquiry”; summarised in Nuclear Energy, Vol.22, No:4, 1983”. Reviews mainly in the UKAEA Journal Atom of books for and against nuclear power – e.g., “The health hazards of not going nuclear” by Petr Beckman, Atom No.244 Feb.1977; and “The nuclear challenge” by Alan Wyatt, Atom 267, January 1979 (both pro-nuclear); “Is Nuclear power necessary” by Amory Lovins – in Atom; and “The Fissile Society” by Walter Patterson, in BNFL News Dec.1977 (both anti-nuclear). Personally invited comments on the Government’s 2002 draft white paper on energy. Brookes’ comments exposed the technical and economic inadequacies of windpower as a source of relief to pressures on the price and security of supply of gas as North sea gas runs out and argued strongly that a revival of nuclear power was overdue as a hedge against rising gas prices and increasingly politically insecure sources of supply; (Paper “DTIconsrepcoms” dated 11 October 2002) Brookes’ invited comments on the Government’s White Paper on a new nuclear power programme. Brookes’ paper carried further the strategic case for a significant nuclear power programme and commented extensively on the details of the Governments paper, (GovNuc2 , 8 October 2007)

2. Techno-economic assessment of research programmes. For example, leading a study of the case for research on high temperature fuel cells and as a leading member of a study on the economic case for the UKAEA’s programme of basic nuclear research leading to a recommendation for an appropriate level of expenditure in this area.

3. Development of mathematical approaches to forecasting electricity demand. This included the development of a forecasting model of the UK electricity supply system that incorporated a trend extrapolation “S” Curve identified by utilising Brookes’ fundamental discovery of a generalisation of the linear regression formula that exploited the fact that many important complex functions have linear transforms – see below\*. The model itself incorporated the full details of the UK Electricity system and computed the key economic and planning parameters of interest to electricity planners.

\*The standard linear regression formula emerged as a special case of this generalisation. When the generalisation itself was invoked it greatly simplified the necessary curve-fitting operations for important functions (including some for which satisfactory methods had not previously been found) without transgressing the fundamental requirements for true statistical fits. The methodology employed weights linking the linear transforms of original observations to the values of the original observations themselves. This element was not new: the novelty of Brookes’ discovery lay in a formulation of a generalised version of the standard linear regression formula that had not been previously put forward and which delivered unequivocal best least squares fits to the original function. His first paper announcing this discovery was published on 18 November 1968 as PAU Internal Memorandum No: 21, a member of a series

under the auspices of the Programmes Analysis Unit (PAU) sited at Harwell. Further developments appeared as PAU Internal Memos culminating in No:43 dated 24 February 1970 announcing the availability of a sophisticated computer programme named “Alfit” capable of producing fits to a wide range of functions and incorporating fitted weights in lieu of the original empirical weights in order to produce greater accuracy.

Publications in this area. “The forecasting model of the UK electricity system” was published in Atom No. 165, dated July 1970. The generalised version of the linear regression formula was published in the PAU series mentioned above.

4. Developing expert systems programs (Artificial Intelligence) (1) for balancing the benefits of hydro-electric systems against the environmental disbenefits in developing countries and (2) for providing the government of Malta with a tool for balancing economic benefits of new capital projects against any likely environmental disbenefits. The full descriptions of these programs were reported to the Commonwealth Scientific Office under contract to whom the work was carried out.

5. Analysing the mathematical characteristics of the way commercial-energy-dependent activity penetrates national economic systems as they become more industrially developed. This involved separating the process into two components (i) a non-time dependent component for each of a lengthy series of years identified by a series of cross-section fits analysing the relationship between countries in different states of development at single points in time and (ii) a time-dependent component identified by fitting a descending curve to the annual values of one of the key parameters identified by the annual cross section fits.

Published in the Journal of Industrial Economics Vol.XX1, No.1, November 1972 under the title “More on the output elasticity of energy consumption”.

6. But what Len Brookes is most noted for is scepticism about the benefits – if any – of attempts to achieve energy conservation (in mitigation, for example, of a presumed global threat from carbon emissions from fossil fuel consumption) through the medium of widespread improvements in energy efficiency. Brookes has contended in many papers offered in journals and at conferences between the nineteen seventies and the present century that widespread individual measures to raise energy efficiency at the microeconomic level are associated with *increases* in energy consumption at the macroeconomic level. (He subsequently discovered that the great liberal economist W. Stanley Jevons had published similar claims over 100 years earlier!) He further contends – as indeed did Jevons also – that his conclusions apply equally to other economic resources. Perhaps his most original contribution to this area of understanding has been the identification of two fallacies – (i) a fallacy of composition (believing that savings at the microeconomic level can be totted up to produce the total saving at the macroeconomic level) and (ii) a “lump of energy dependent activity” fallacy (believing that the amount of energy dependent activity in the economy will remain substantially constant while important changes are being made in the composition and disposition of the underlying economic resources).

7. At about the same time as Brookes’ earliest papers on this topic were published, Professor Daniel Khazzoom of San Jose State University, published papers making the same point about mandated standards for domestic appliances. In 1992 Dr Harry Saunders, an economist practising in California demonstrated that, over a wide range of assumptions Nobel Laureate economist Robert Solow’s neo-classical growth theory is consistent with what he – Saunders – dubbed “the Khazzoom-Brookes postulate. This provided welcome support for Brookes work at 6 above but has led to some confusion about whether Saunders conclusion is essential to the claims made by Brookes and Khazzoom whose updating of what has come to be called “the Jevons paradox” does not in fact depend upon the acceptability of Saunders’ erudite work.

Publications by Brookes relevant to items 6 and 7. See for example: “A Low energy strategy for the United Kingdom” by Gerald Leach et al., an extensive review and reply by L.G. Brookes, Atom 269, dated March 1979; “The economics of energy price hikes”, a paper presented at the June 1982 Annual Conference of the International Association for Energy Economics” and summarised in “International Energy Markets” edited by Paul Tempest and published by Graham and Trotman in 1983; “Devil’s Advocate”, in Energy Manager, for September 1982; “The homeostatic model of energy/economy interactions and its relevance to the present oil price situation”, paper presented to the Oxford Energy Policy Club on 15 March 1983; “The greenhouse effect: the fallacies in the energy efficiency solution”, Energy Policy March 1990; “Energy efficiency and the greenhouse effect”, Energy and Environment, Vol.1, No.4, 1990 (This article was rather badly sub-edited but nevertheless is more comprehensive than the Energy Policy version); “The ‘fifth fuel’ and the greenhouse effect”, Energy World, Feb 1990; “Fifth fuel - the debate continues” by Paul Spare, Energy World April 1990; “Energy efficiency fallacies revisited”, a contribution to a collection hosted by Dr Lee Schipper in Energy Policy No. 28 (2000); invited evidence to the House of Lords Science and Technology Sub Committee on “Energy Efficiency”: written evidence page 179 et seq, oral evidence page 185 et seq, HL Paper 21-II.

8. More recently Brookes has demonstrated graphically that if “energy efficiency“ is defined in economic terms energy cannot be used with greater economic efficiency than in a system in which all the relevant resources used in delivering an energy service or product are jointly used unpreferentially with maximum economic efficiency. This makes the economic efficiency of energy simply part of general economic efficiency (thus providing support for an earlier contention by Professor Nathan Rosenberg of Stanford University, California). It follows that any attempt to give priority to energy-saving (or indeed the saving of any other individual resource) is likely to entail misallocation of economic resources and lead to a sub-optimal result (a higher than necessary total cost) unless by sheer chance the energy (or other privileged resource) saving approach happens to coincide with the minimum total cost approach. It further follows that such an extra cost needs to be justified as serving an environmental or other non-economic end: it cannot be justified on the frequently claimed grounds that, for example, carbon saving can be delivered at zero cost or even at a profit .

Relevant Publications “Energy efficiency fallacies revisited”, Energy Policy 28 (2000) and evidence to the House of Lords sub-committee cited above; “Energy fallacies revisited – a postscript”, Energy Policy 32 (2004).

9. In the course of his studies he claims to have identified two cultures in the personnel working in the broad energy efficiency field – one consisting principally of those who think primarily in terms of raising energy efficiency to reduce energy consumption and those who think primarily in terms of raising energy productivity, which could be expected to lead to a higher level of employment of energy relative to other available resources just as one expects improvements in labour productivity to lead by to higher levels of employment of labour. In a paper published in the Energy Journal, distinguished US economist Ronald Sutherland made a similar distinction, referring to “the conservation paradigm” and the “economics paradigm”, accusing adherents to the former of embracing a “free lunch” fallacy, believing that carbon emission targets can be achieved at low cost or even at a profit by high profile energy conservation measures. (See ““No Cost” efforts to reduce carbon emissions in the U.S: an economic perspective.’ The Energy Journal, vol.21 No.3, 2000.) Richard Gordon, Professor of Mineral Economics also dismissed the attitudes of conservationists in his paper “Energy, exhaustion, environmentalism and etatism” in the Energy Journal Vol.15 No.1, 1994, saying “Even more problematic are the claims made by energy conservation enthusiasts, (Grubb 1990 and Grubb et al 1991) who insist that global warming can be cured almost costlessly by adopting energy-saving measures claimed to be socially profitable. The argument for global warming in any case is independent of global warming and [is] implausible”.

10. When invited by the Lords' Science and Technology Committee to offer evidence to their study of energy efficiency Brookes presented a paper based on 6 and 8 above plus other arguments. This was well received by their Lordships who, in their report, suggested that the Khazzoom-Brookes Postulate provided a possible explanation for the failure of the Government's strenuous efforts to reduce Carbon Dioxide emissions by measures to raise energy efficiency. The Government responded by financing three studies, one by a team at the University of Strathclyde, another by a team from Cambridge headed by the Cambridge Centre for Climate Change Mitigation Research, and a third by the UK Energy Research Centre based on the University of Sussex. All three acknowledged that there was some loss at the macroeconomic level (they called this "rebound") of savings at the microeconomic level but maintained that this loss was substantially less than 100%. (But their estimates of rebound covered a wide range – from 11% to 40.) However they could be categorised as using approaches based on the "conservation paradigm" notwithstanding the erudition of much of what they wrote. The UKERC group offered a detailed partial rebuttal of Brookes' version of the K-B postulate in a supporting paper to their report. Regrettably this incorporated serious inaccuracies in its contentions about Brookes' beliefs, stipulations and statements and ignored important points and papers that he drew to their attention at their drafting stage. The UK Government sees its reliance and expenditure on energy efficiency in all its forms as vindicated by these studies but Brookes sees nothing in these three studies to lead him to revise his ideas in this area. At the highest levels of aggregation energy consumption continues to rise despite the long term pattern of a steady fall in energy consumption per unit of economic output which provides strong support for Brookes' conclusions without going so far as providing proof of them.

11. In addition to scepticism about the claims made for what can be achieved by raised energy efficiency, Brookes is also known for deep scepticism about whether any threat from climate change can be attributed to the emission of CO<sub>2</sub> from man's use of fossil fuels. (He submitted an invited paper on the subject to the study by the UK House of Lords Committee on Economic Affairs of the economics of climate change). He has also produced a detailed study demonstrating the intrinsic unsuitability of wind energy parks as elements in national electricity systems and therefore as having any relevance to a programme of reducing carbon emissions. (See Windpor August 2004)

Written by his daughter, Jackie Jordan (née Brookes), drawing on material on his work previously provided by Dr Brookes  
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