A history of the UK renewable energy programme, 1974-88: some social, political, and economic aspects.

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Abstract

Following the global oil crisis of October 1973 the UK government funded and administered a range of R&D programmes in renewable energy. Despite the discoveries of large deposits of oil and gas in the North Sea during the late 1960s and continuing faith in nuclear energy the government was keen to explore the potential of renewable energy as what it described as an 'insurance technology'. This thesis examines the creation and evolution of the UK renewable energy programme from 1974 until its demise prior to the privatisation of the UK's nationalised energy industries in the late 1980s. The thesis shows the important role that social movements - in this case, the new environmentalism - played in the promotion of renewable energy in the UK. This will suggest that the programme can be seen in some senses as a tokenistic gesture by the government acting within the uncertain political, social, and economic landscape of the 1970s. This thesis shows that government decisions on renewable energy were continually driven by socio-political factors which overwhelmed the unreliable economic case for renewables at that time. This is achieved by a close historical account of the two key elements of the wider programme: the Wave Energy Programme and the Wind Energy Programme. Using a mix of the existing literature, historical archive and interviews this thesis builds a historical account of renewable energy R&D in the UK between 1974 and 1988.

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Declaration

I declare that, except where explicit reference is made to the contribution of others, that this thesis is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution

Signature…………………………………………………...

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Abbreviations

Archives

SA - Salter Archive

TNA – The National Archives, Kew

Organisations

ACORD – Advisory Council on Research and Development (for Fuel and Power)

AERE – Atomic Energy Research Establishment (Harwell)

BEA – British Electricity Authority

BRAD – Biotechnical Research and Development

BWEA - British Wind Energy Association

CAT – The Centre for Alternative Technology

CEB – Central Electricity Board

CEGB – Central Electricity Generating Board

CPRS – Central Policy Review Staff

DoEn – Department of Energy

DTI – Department of Trade and Industry

EDA - Electrical Development Association

ERA - Electrical Research Association Ltd

ETSU - Energy Technology Support Unit

ITDG - Intermediate Technology Development Group

MEMTRB – Mechanical Engineering and Machine Tools Requirements Board

NCB - National Coal Board

NEL – National Engineering Laboratory

OETB – Offshore Energy Technology Board

RMC - Ready Mixed Concrete Ltd.

SCST - Select Committee on Science and Technology

SEA - Sea Energy Associates

SERA - Socialist Environment and Resources Association

UKAEA – United Kingdom Atomic Energy Authority

WEG - Wind Energy Group

WEP - Wave Energy Programme

WESC – Wave Energy Steering Committee

WIG - Wind Energy Programme

WISC - Wind Energy Steering Committee

Technical

AC – Alternating Current

DC – Direct Current

HAWT - Horizontal Axis Wind Turbine

kW - Kilowatt (1,000 watts)

Mtoe - Million tons of oil equivalent

MW - Megawatt (1,000,000 watts)

PV – Photovoltaic

OWC - Oscillating Water Column

VAWT - Vertical Axis Wind Turbine

Others

BFS – A Blueprint for Survival

LTG – Limits to Growth

Introduction

> In sum, it is difficult to change the direction of large electric power systems - and perhaps that of large sociotechnical systems in general - but such systems are not autonomous. Those who seek to control and direct them must acknowledge the fact that systems are evolving cultural artifacts rather than isolated technologies. As cultural artifacts, they reflect the past as well as the present. Attempting to reform technology without systematically taking into account the shaping context and the intricacies of internal dynamics may well be futile. If only the technical components of a system are changed, they may snap back into their earlier shape like charged particles in a strong electromagnetic field. The field also must be attended to: **values may need to be changed, institutions reformed, or legislation recast**.[1]

In recent times renewable energy development is increasingly advanced by politicians and commentators as a key ingredient in addressing the future of both domestic and global economies.[2] The terms 'green economy' and 'green jobs' have become commonplace and in the public mind these are closely associated with renewable energy sources. Speaking in June 2010, US President Barack Obama said,

> Each of us has a part to play in a new future that will benefit all of us. As we recover from this recession, the transition to clean energy has the potential to grow our economy and create millions of jobs - but only if we accelerate that transition. Only if we seize the moment…[3]

However, renewable energy represents a dilemma for modern society.[4] On one hand, as well as the much-touted aid to economic recovery, it also offers solutions to many of the challenges that face present and future civilisations by providing energy that is both infinite and benign. On the other, it presents massive technological and social challenges that are only now becoming fully understood. The dilemma arises because, on the surface,

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[1] Hughes, T. P., *Networks of Power: Electrification in Western Society, 1880-1930* (London: The Johns Hopkins University Press, 1983) p.465

[2] LoBianco, T., 'Obama's budget focuses on renewable energy', *The Washington Pos*t, 27 February 2009, http://www.washingtontimes.com/news/2009/feb/27/obamas-budget-focuses-on-renewable-energy/ [accessed 11 July 2010]; Vinod, T., and Chomitz, K. 'From crisis to opportunity', *The Guardian,* 16 February 2009. This is a comment piece by senior officials of the World Bank; Adam, D., 'Nicholas Stern: Spend billions on green investments now to reverse economic downturn and halt climate change.' *The Guardian,* 11 February 2009.

[3] The White House website, http://www.whitehouse.gov/issues/energy-and-environment [accessed 9 July 2010]

[4] For an excellent discussion of this dilemma from a current US perspective, Sovacool, B. K., *The Dirty Energy Dilemma: What's Blocking Clean Power in the United States* (London: Praeger, 2008)

the way forward in energy terms appears to be straightforward. Steadily depleting reserves of oil and gas, and to a lesser extent coal, should gradually and incrementally be replaced with wind farms and other now familiar renewable options in order that our growing energy needs remain fulfilled in the future. This path to the energy future was officially considered by the government in Britain for the first time in the 1970s following the first oil price shock. In more recent years the gradual acceptance of the facts of climate change have placed an even greater emphasis on the need to find an alternative to fossil fuels. However, the process of displacement and replacement anticipated by some has been characterised by a painfully slow rate of progress towards these goals. Advocates of renewable energy became increasingly frustrated as the UK lurched back and forward from nuclear energy to renewables programmes and back again. This pattern, in general terms, has been echoed around the developed world. In the UK in 2007, nearly thirty-five years after the need to develop renewable energy had been officially recognised by the creation of a dedicated R&D programme, renewable sources accounted for just over 3% of total final energy consumption and less than 5% of total electricity generated.[5] What can explain this lack of progress toward such apparently obvious goals?

In recent decades there have been numerous attempts to account for the slow and uncertain adoption of renewable energy sources, both in the UK and worldwide. Typically these have fallen within one of two disciplines - science (broadly defined) and political science.[6] Not surprisingly these studies have tended to suggest explanations that coincide with their field of study. This is not to suggest that the conclusions reached within either discipline are necessarily flawed, but rather that they understandably give less attention to perhaps equally compelling factors derived from within alternative narratives. We have many technical studies dating back to the beautifully illustrated 1894 study by Wolff[7] that focus on the technological challenges that confronted the inventors and innovators in renewable sources of energy. These offer some insights into the alleged 'reverse salients' of science and engineering that slowed the development of renewable energy sources but

[5] BERR (Department for Business, Enterprise and Regulatory Reform), *Energy in Brief July 2008,* National Statistics Publication. These figures for renewables include hydropower.
[6] For a clear example of this see, Grubb, M. J., 'The Cinderella options: A study of modernized renewable energy technologies: Part 1 - A technical assessment', *Energy Policy*, 18:6, July-August 1990, pp. 525-542; Grubb, M. J., 'The Cinderella options: A study of modernized renewable energy technologies: Part 2 - Political and policy analysis', *Energy Policy*, 18:8, October 1990, pp. 711-725. Here the author deals with technical issues and policy issues in separate articles.
[7] Wolff, A. R., *The Windmill as a Prime Mover* (New York: John Wiley & Sons, 1894)

show less interest in the impact of the ‘decision-makers’.[8] We also have a number of generally more recent studies that examine renewables within the broadly political context of energy ‘policy’.[9] At this time no book-length treatment of the development of renewables within this perspective exists for the UK other than Ross’s 1981 study which concentrates exclusively on wave power. However Ross (a journalist) was an energetic campaigner for wave energy and his output - which included a number of similar articles [10] - has been criticised, with some justification, for presenting a rather partial account.[11] A number of these studies have utilised policy-network theories to emphasise the importance of power and influence in advancing or retarding renewables and many conclude that the overwhelming power of the established energy industries (particularly nuclear) and lack of government will was responsible for slowing the adoption of renewables during the 1970s and 1980s.[12] Similarly, in these accounts, very little attention is directed towards the technical challenges of renewables such as grid connection. What is clearly missing from the literature is an explicitly historical account of the development of renewable energy in the UK which includes some consideration of both of these elements combined with a broader social and political context which this thesis will seek to provide.

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[8] Some examples include, Loferski, J. J., ‘The First Forty Years: a Brief History of the Modern Photovoltaic Age’, Progress in Photovoltaics: Research and Applications, 1:1, pp. 67-78; Smith, C., ‘Revisiting Solar Power’s Past’, Technology Review, 98:5 (July 1995) pp. 38-48; Shaw, R., Wave Energy: A Design Challenge (Chichester: Ellis Horwood, 1982); Simeons, C., Hydro-Power: The Use of Water as an Alternative Source of Energy (Oxford: Pergamon Press, 1980); Barrows, H. K., Water Power Engineering, 3rd ed. (London: McGraw-Hill, 1943); Golding, E. W., The generation of electricity by wind power (London: Spon, 1955); McGuigan, D., Small Scale Wind Power (Dorchester: Prism Press, 1978); Musgrove, P. (ed.), Wind Energy Conversion 1984: Proceedings of the Sixth BWEA Wind Energy Conference, University of Reading, 28-30 March 1984 (Cambridge: CUP, 1984): Musgrove, P., Wind Power (Cambridge: Cambridge University Press, 2010)

[9] Just some of the examples include, Watt, R. N., ‘Towards a synthesised network approach: an analysis of UK nuclear and renewable (wave) energy programmes 1939-85’, (University of Birmingham, 1998, PhD thesis); McInnes, D., ‘Policy Networks within the Department of Energy and Energy Policy’, Essex Papers in Politics and Government, No. 82, University of Essex ; Ayling, G., Renewable Energy and Sustainable Energy Policy in the UK, (University of Birmingham, 1994, MPhil thesis); Connor, P. M., ‘UK renewable energy policy: a review’, Renewable and Sustainable Energy Reviews, 7 (2003) pp. 65-82.; Brown, A., ‘The UK Renewable Energy Programme’, Renewable Energy, 3: 2/3, (1993) pp. 279-288; Elliott, D., ‘Renewable Energy R&D in the UK: A Strategic Overview’, Technology Analysis & Strategic Management, 1:2 (1989) pp. 223-237; Elliott, D., Renewables: Past, Present and Future: The UK Renewable Energy Programme, NATTA (Milton Keynes, 1997); Elliot, D., ‘UK Energy Policy’ in P. Cunningham (ed.) Science and Technology in the UK, 2nd ed. (Cartermill, 1998); Ross, D., Energy from the Waves (Oxford: Pergamon Press, 1981)

[10] Ross, D., ‘The Parting of the Waves’ The Guardian, 16 February 1990; ‘On the Crest of a Wave’, New Scientist, 19 May 1990; Ross, D., ‘Scuppering the Waves’, Network for Alternative Technology and Technology Assessment, Energy and Environmental Research Unit, Faculty of Technology, The Open University (Milton Keynes: May 2001)

[11] Watt, ‘Towards’, p.57

[12] In particular see, Watt, ‘Towards’: McInnes, ‘Policy networks’.

> The basic features of the course of demand for energy are fairly simple and so is the chronology of the emergence of competing sources of supply. Much more complexity appears when one seeks the determinants of the relative strength of the various components of the market, especially those which stimulated demand in one direction rather than another and those which bore upon the relation between cost and price.[13]

The central hypothesis proposed by this research is that decisions taken by the UK government on the development of renewable energy are driven primarily by socio-political factors; this is illustrated by the quotation above from Ashworth. Consistently, from the oil crisis of 1973 until the present day, the UK government has reacted to social movement pressure (both domestic and global) in formulating policy on alternative forms of energy. In recent years this response has been created and encouraged by the growing realisation of the impact of climate change, but in earlier decades the social and political pressures were more varied. In the period, which this thesis examines, the issues of energy security, problems with the nuclear programme, the development of renewable energy sources in other countries (most notably the United States), and the emergence of the 'new environmentalism' compelled the government to respond. The suggestion of this thesis is that the UK renewable energy programme was this response.

This thesis, therefore, is a work of historical enquiry which seeks to place much of the existing non-historical literature on renewable energy during the period within a more reliable and robust empirical narrative. It will seek to question the 'tepid pursuit' of renewable energy programmes through a chronological historical narrative set within the social, political and economic context of the period, and show how socio-political concerns dominate.[14] As noted above there are very few purely historical accounts of renewable energy.[15] Indeed we may perhaps have the feeling that renewable energy has not yet accumulated any history. Clearly this notion is undermined by the general sense that renewables have not fulfilled their potential in the UK and elsewhere: this suggests that a history for renewables in the UK should in fact exist.[16] The extant accounts of renewable energy development in the UK tend to be partisan in nature (see above) and a focused

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[13] Ashworth, W., The History of the British Coal Industry: Volume 5: 1946-1982: The Nationalized Industry (Oxford: Clarendon Press, 1986)
[14] Bobrow, D. B., and Kudrle, R. T., 'Energy R&D: In Tepid Pursuit of Collective Goods', International Organisation, 33:2 (Spring 1979) pp. 149-75
[15] Certainly insofar as we understand 'renewable energy' today. There does exist a great many studies of windmill and watermills, many of which emphasise the symbiotic relationship between society and technology.
[16] Although this is largely seen in terms of the 'failure' of renewables as an energy source, it is also increasingly understood as 'failure' in exploiting renewables as an economic opportunity.

scholarly history remains to be written. This thesis intends to begin the process of building that work of historical scholarship in this important area. The advantage of the historical approach is that a very wide range of documentary evidence has accumulated and this can now be utilised along with valuable interview material from many of the key individuals involved in renewable energy in the UK from the 1970s onwards. The aim is that this will create an account of renewable energy development in the UK during the period 1974-88 which will then provide a basis for future historical enquiry and scholarship. Moreover, it is hoped that this work can help to inform future energy policy by providing a reliable historical record of previous attempts at renewable energy development.

Ultimately the main feature of the programme in 1970s – wave energy – was closed down in controversial circumstances. The government at the time opted to justify the closure on economic grounds. This thesis will contend that the closure had little to do with the unreliable and inaccurate costings for wave power generation. Instead, once again, social and political imperatives demanded that the UK be seen to be not just developing but demonstrating renewable energy. This is the face of a burgeoning wind energy programme in the United States. This caused a Conservative government, pledged to cutting R&D expenditure, into the political shift to wind energy.

Renewable Energy

Renewable energy appears to many to be a relatively modern concept. Wind 'farms' and tidal barrages are often presented as new and uncertain technologies, 'alternatives' vying for adoption next to the more 'traditional' fossil fuels of coal, oil and gas and the now familiar 'modern technology' of nuclear energy. However, renewable sources of energy have an ancient history.[17] They represent the first example of humanity using non-human and non-animal effort as a source of power for human endeavour. Beginning with water power, in the form of the water wheel, it was recognised that the ceaseless flow of rivers and streams could supplement and replace the human and the ox in the milling process. As Lynn White Jr. has pointed out, this took place in conjunction with technological innovation in engineering that made this new transmission of power possible.[18] Eventually the potential of the wind as a power source was also recognised (probably from sail) and early windmills began to appear based on the same principles as the water wheel. The

[17] Sørensen, B., 'A history of renewable energy technology', *Energy Policy* (January/February 1992) pp. 8-12

[18] White Jr., L, *Medieval Technology and Social Change* (Oxford: Oxford University Press, 1962)

development of wind and water power took place over centuries. It always depended heavily on innovation and improvement in engineering which achieved incremental increases in the efficiency of energy capture. Indeed, such was the efficiency of the watermill that by the nineteenth century at the height of the age of steam power water power remained a key source of energy for many industries, particularly in the United States. Beginning at the end of the eighteenth century in Britain, the pace of industrialisation had forced the development of the steam engine and coal also began to be used as a fuel input to generate motive power.[19] The technological focus was concentrated on improving the steam engine which had many clear advantages over site-specific water power and gradually the widespread industrial application of the watermill all but disappeared.[20]

This thesis will seek to explain the historical lack of progress in harnessing renewable energy sources in the UK by examining Britain's renewables programmes between 1974 and 1988. It will propose the oil price shock of October 1973 as the pivotal event in the modern technological development of renewable energy in the UK. This caused economic and political turmoil on a global scale which had an important impact on conventional - fossil-fuel based - thinking about energy policy in Britain. Certainly, this was certainly not the first energy shock that was felt in the UK in the post-war era. The first global postwar energy crisis occurred as a result of the Suez crisis of 1956, and a contrast can be drawn between the reaction to this first energy crisis and the later shock of 1973.[21] In the 1950s concern over 'energy security' was a new and disturbing concept to Britain and it resulted in a massive up-scaling of the civil nuclear power programme. This was at a time when the capital costs of nuclear power stations were more than three times

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[19] P. Mathias, *The First Industrial Nation: An Economic History of Britain, 1700-1914,* 2nd ed. (London: Routledge, 1983) pp. 121-25.

[20] Musson argues that steam power grew gradually in nineteenth century Britain. A. E. Musson, 'Industrial Motive Power in the United Kingdom, 1800-70', *The Economic History Review,* New Series, 29:3 (Aug., 1976) pp. 415-439. A perhaps wider range of sources deals with this transition in the United States. Among these are: L. C. Hunter, *A History of Industrial Power in the United States, 1780-1930, Volume One: Waterpower in the Century of the Steam Engine* (Charlottesville, University Press of Virginia, 1979); J. Atack, F. Bateman, and T. Weiss, 'The Regional Diffusion and Adoption of the Steam Engine in American Manufacturing' *The Journal of Economic History,* 40, 2 (June 1980) pp. 281-3; D. E. Nye, *Consuming Power: A Social History of American Energies* (London: The MIT Press, 1999); P. Temin, 'Steam and Waterpower in the Early Nineteenth Century', *The Journal of Economic History,* 26:2, (June 1966) pp. 187-205. Each of these accounts point out that this was a much slower process of change from water and wood to steam power in what soon became the world's largest consumer of energy, the United States. Atack *et al* estimate that even by as late as 1870 waterwheels outnumbered steam engines in the US by 5 to 4.

[21] For a brief account of the Suez crisis see, Stokes, R. G., 'Oil as a Primary Source of Energy', in Fink, C., Hadler, F., and Schramm, T. (eds.) *1956 - European and Global Perspectives* (Leipzig: Leipziger Universitatsverlag, 2006) p.250-252; Chick, M., *Electricity and Energy Policy in Britain, France and the United States since 1945* (Cheltenham: Edward Elgar, 2007) pp. 22-23

that of traditional coal-fired stations.[22] Therefore, massive capital investment in a largely untried technology was seen as the solution to Britain's energy needs. The uncertain nature of this technology and the massive economic cost did not deter the government in a period characterised by an unshakable faith in 'big science'.[23] In the 1970s continuing faith in the promise of nuclear technology was a key reason that a similar leap of technological faith for renewable energy was absent.[24] One purpose of this thesis is to uncover some of the explanations for this.

This thesis will argue that in this period the UK was perhaps the first developed nation to fully uncover the dilemma that has impeded the global progress of renewable energy: renewable energy sources cannot simply *replace* fossil fuels. There are a number of reasons for this. Firstly, and most fundamentally, renewables do not represent the *store* of energy that fossil fuels offer (see Appendix II). Renewable energy provides an intermittent and site-specific energy source that relies by definition on the vagaries of nature. The development of fossil fuels as an energy source since the end of the eighteenth century occurred largely *because* they offered a solution to this ancient problem. Therefore, in a sense the acceptance and adoption of renewable energy represents a symbolic reversal of progress and a failure of human endeavour. This helps to explain the continuing commitment to civil nuclear power despite the many problems that this technology had experienced since the 1950s. However, despite the overwhelming reality of this fundamental difference in storage capacity this thesis will focus on another explanation for the lack of development in renewable energy: dominant systems of power.

Dominant systems of power

Central to the development of electrical mains power in the latter part of the nineteenth century was the introduction of electrical power systems: electricity networks and grids. The history of this process has been charted in meticulous detail by a range of eminent

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[22] Hannah, L., *Engineers, Managers and Politicians; The First Fifteen Years of Nationalised Electricity Supply in Britain* (Basingstoke: Macmillan, 1982) pp. 178-9;

[23] Freeman, C. and Soete, L., *The Economics of Industrial Innovation*, 3rd ed. (Cambridge, Mass.: The MIT Press, 1997) pp. 373-395.

[24] In particular the possibility of nuclear fusion was held many to offer the solution to all future energy needs. This was a view that was readily accepted also (at least initially) by the growing environmental movement. See, Bunyard, P., 'The Energy Crisis', *The Ecologist,* 3:5 (May 1973) ' In theory there is unlimited energy in the world. All man has to do is to build breeder reactors and to achieve thermo-nuclear fusion on a commercial scale.' This also highlights the debate that exists over whether nuclear energy should perhaps be considered a 'renewable' source of energy also. Critics of this approach point to the declining global reserves of uranium - the fuel required for nuclear fission.

scholars.[25] For the UK, Hannah's meticulously researched two volumes provide a compelling account of the scale of the engineering and institutional challenge in the UK. Conceived by Thomas Edison, amongst others, these grids grew rapidly from the 1880s based mainly on the properties of fossil fuels as an energy source and the steam turbine as prime mover.[26] Coal had been used extensively as a source of primary energy since the development of the Watt steam engine in the late eighteenth century and remains the dominant fuel in the production of electricity today.[27] Oil was discovered in the USA in the mid-nineteenth century, but was considered initially as a luminant rather than a fuel until the development of the internal combustion engine. As time passed the actual fuel utilised in the generation of electricity shifted to include oil, natural gas and nuclear, but each shared the same essential characteristic of fungibility: a flexible, in most cases transportable, *store* of energy that could be utilised in the sites where it was needed most (and people were willing to pay for it). By the 1970s in the UK the electricity grid was mature, extensive and central to modern developed society. The oil price shock of October 1973 then combined, and as Beckerman pointed out, was to some extent confused with the growing awareness of the impending exhaustion of fossil fuels.[28] This was highlighted most famously in 1972 by the stark warnings of The Club of Rome's study *The Limits to Growth* and the official recognition of the United Nations Conference on the Human Environment (UNCHE) held that same summer in Stockholm.[29] Both of these hugely influential events followed the publication success in Britain of *A Blueprint for Survival* from *The Ecologist* magazine.[30]

In the 1970s (and still today) many thought that renewable energy sources could be 'plugged in' to these complex and demanding systems. This was mistaken and represents

[25] Examples include, Hughes, *Networks;* Hannah, L., 'A Pioneer of Public Enterprise: The Central Electricity Board and the National Grid, 1927-1940', in Supple, B. (ed.) *Essays in British Business History* (Oxford: Clarendon Press, 1977); Hannah, L., *Electricity before Nationalisation: A Study of the Development of the Electricity Supply Industry in Britain to 1948* (Basingstoke: Macmillan, 1979); Hannah, *Engineers*; Chick, *Electricity*; Hausman, W. J., Hertner, P., and Wilkins, M., *Global Electrification: Multinational Enterprise and International Finance in the History of Light and Power, 1878-2007* (Cambridge, Cambridge University Press, 2008); Gooday, G., *Domesticating Electricity: Technology, Uncertainty and Gender, 1880-1914* (London: Pickering & Chatto, 2008)

[26] Many early systems were based on hydropower in those areas most geographically suited. Indeed, so prevalent was this that in some areas such as in the province of Ontario, Canada, electricity is known to this day as 'hydro'.

[27] In the UK in 2006, coal-fired power stations accounted for 37.5% of electricity production. The equivalent figure for coal in the US in 2008 was 48.2%. BERR, Energy 2008; Sovacool, Dirty, fig. 1, p.3

[28] Beckerman, W., In Defence of Economic Growth (London: Jonathan Cape, 1974) pp.249-50

[29] Meadows, D. et al., The Limits to Growth (London: Pan Books, 1974).

[30] Goldsmith, E., A Blueprint for Survival (Harmondsworth: Penguin, 1972) For a discussion of the growth of environmental awareness in the period see, Wilson, J. C., 'Energy and the New Environmentalism: the view from The Ecologist, 1970-75', (University of Glasgow, 2007, MSc thesis)

one explanation for the lack of success in renewable energy programmes in the UK during the period, and perhaps to this day. This thesis will suggest that the successful adoption of renewable energy sources required a much more fundamental shift in thinking about energy: one that both the developers and the policymakers either failed to fully understand at the time, or shied away from. It required, among other things, a paradigm shift away from centralised energy supply. This would demand both a fundamental reorganisation of the National Grid and a massive investment in more localised energy systems on a scale similar to that which had taken place in the 1950s to extend and standardise the national grid.[31] This was not something that could ever be achieved by developing renewables as an 'insurance' technology, as it was described by the government through the 1970s.[32] It also required a shift away from the pervasive notion that a single dominant source of fuel should provide the bulk of Britain's electricity-generating energy needs. The result was that the public investment in renewable energy was misguided and inadequate. It is no surprise therefore that some commentators judge that the adoption of renewable energy technology 'failed' in this period and beyond.[33] However, this thesis will propose the counter argument that it was the dominant system that 'failed' the successful adoption of renewable energy.

This thesis will focus on the more recognisable aspects of renewable energy; wave and wind energy.[34] These two energy sources represented the most ancient forms of renewable energy and dominated the 1974-88 UK renewables programme. The study will conclude in 1988 as this coincides with a major shift in UK energy policy. At that point the free-market, liberalisation drive of the Conservative Government under Margaret Thatcher resulted in the privatisation of British Gas in 1986 and the electricity industry followed soon after.[35] In 1988 the government produced a key statement on renewable energy, *Renewable Energy in the UK: The Way Forward*.[36] This paper proposed a new incentive-based scheme to promote renewables which has shaped the policy response of successive

[31] Hannah, *Engineers,* pp. 70-1
[32] TNA, EG 16/1, Department of Energy, 'Energy Prospects: A Background to Research and Development', Advisory Council on Research and Development for Fuel and Power, undated (1975), p.8. The report goes on to say, 'There has, however, so far been insufficient inducement to warrant taking out such a potentially very costly insurance policy.'
[33] Grubb, 'Cinderella: Part 2', p.711
[34] See Appendix for a technical explanation of renewable sources of energy
[35] Elliott, D., 'Renewables and the privatisation of the UK ESI: A case study', *Energy Policy,* 20:3 (March 1992) pp. 257-268
[36] Department of Energy, *Renewable Energy in the UK: The Way Forward,* Energy Paper 55 (London: HMSO, 1988)

UK governments to the present day and signalled a move away from Government-sponsored RD&D (research, development and demonstration) programmes.[37]

The most common application for renewable energy in modern times is in the production of electricity and consequently this thesis will concentrate entirely on that particular aspect of energy history. It is also the case that electricity provides one of the most visible manifestations of growing energy consumption in the twentieth century and is a clear example of our overwhelming demand for energy. Attention will be given to the evolution of electricity networks since the late nineteenth century in order that the challenges to renewable energy can be more fully understood. Electricity has helped to shape the world that we occupy, and the systems that have grown since their introduction in the 1880s are now seen as essential. Both domestically and in industry there is a fundamental reliance on electricity to provide instant and reliable energy at the flick of a switch.[38] The pervasiveness of this understanding is crucial in beginning to understand the apprehension that arises when fundamental change is suggested. The dominance of the electricity grid network in the UK acted as a barrier to any serious attempt to integrate renewable energy sources into the National Grid during the 1970s and 1980s. However, this thesis will show that the emergence of 'energy morality' in the 1970s, through the emergence of the new environmental movement in the UK, helped to create a different context in which that struggle took place. I will return to this theme.

Themes

A central theme of this thesis is the impact and extent of government involvement and intervention in energy matters in the UK, with the emphasis on renewable energy. In Britain the central importance of the rapidly developing grid network was quickly recognised by the UK government in the first half of the twentieth century and after the Second World War the electricity industry was nationalised; followed soon after by the coal and gas industry. Additionally, as a relic of Churchill's decision in 1914 the UK government owned a majority stake (51%) in the major international oil company, British Petroleum.[39] Furthermore the 1950s saw the development of Britain's civil nuclear

[37] Brown, 'UK Renewable Energy Programme'.
[38] Patterson, W., *Transforming Electricity* (London: Earthscan, 1999); Patterson, W., *Keeping The Lights On: Towards Sustainable Electricity* (London: Earthscan, 2007)
[39] '[BP] was widely perceived as the instrument of the government on the understandable assumption that what the state owned, it surely controlled.' see, Bamberg, J. H., *British Petroleum and Global Oil, 1950-1975*: *The Challenge of Nationalisation* (Cambridge: Cambridge University Press, 2000) p.39

programme paid for and controlled (for obvious strategic and defence reasons) by the government.[40] Therefore by the mid-1950s virtually all of Britain's energy production and consumption was coordinated - in theory at least - by the government. This means that any consideration of UK energy in the postwar age must necessarily pay attention to the role of government and the impact of nationalisation. The work of Kelf-Cohen, Millward & Singleton, and Tivey on Britain's nationalised industries, and Hannah, Chick, and Hausman *et al* on the electricity industry, all provide useful and reliable accounts of this aspect of the history.[41]

Hannah and others have shown that the extent of nationalisation was not unique to Britain in the postwar period. However, the dominance of government control in energy through nationalisation is central to historical development of renewable energy in Britain. The control of all of Britain's energy providers by the government had a profound impact on the evolution of renewable energy. At one level, this manifested itself in multiple layers of bureaucracy that many of the innovators found stifling.[42] More crucially though it also meant that the path and pace of innovation in renewable energy was set by the government mainly by means of the budget that was allocated to the programme. This thesis will concentrate on the example of Britain's wave and wind power programmes in the 1970s and 1980s to examine the attitude of the government towards renewable energy in the period. There will be a particular focus on wave energy as this was the first large-scale renewable energy programme undertaken by the UK government.[43] Between 1975 and 1982, when the programme was effectively closed down (amid controversy) the majority of the UK budget for renewable energy R&D was devoted to wave power programmes. Previous scholarly studies of wave power have been produced, most notably by Watt and McInnes, as well as the aforementioned contribution of Ross.[44] However, in the case of Watt and McInnes, these contributions seek to use the example of wave power to explore the existence of policy networks within government in the period from a wider political

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[40] Williams, R., *The Nuclear Power Decisions: British Policies, 1953-78* (London: Croom Helm, 1980) provides the best account of this relationship

[41] Kelf-Cohen, R., *British nationalisation, 1945-1973* (London: Macmillan, 1973); Millward, R. and Singleton, J., *The political economy of nationalisation in Britain 1920-1950* (Cambridge: CUP, 1995); Tivey, L. (ed.) *The nationalized industries since 1960: A book of readings,* Royal Institute of Public Administration (London: George Allen & Unwin, 1973); Hannah, *Engineers*; Hannah, 'Pioneer'; Hannah, 'Electricity'; Hausman et al, *Global Electrification*

[42] Salter, S., 'Looking Back' in Cruz, J (ed.), *Ocean Wave Energy: Current Status and Future Prospects* (Springer: Heidelberg, 2008)

[43] In addition, due to the thirty-year rule on access to public documents, the archives for the wave energy programme are currently more extensive and therefore allow a greater depth of historical archival analysis.

[44] Watt, 'Towards a Synthesised Approach'; McInnes, 'Policy Networks'; Ross, *Waves*

science perspective. Whereas Ross, as previously mentioned, uses his study as a largely unsubtle device to advocate wave power take-up in Britain. This thesis will instead place the story of the wave power programme within the broader unfolding of renewable energy development during the two decades.

Crucial to understanding government involvement in energy is a discussion of the economic assessment of energy technologies in the period. Although the facts of carbon emissions and climate change were not widely known at the time (certainly during the 1970s) there were other environmental pressures growing at the time which insisted that the energy debate be widened beyond the purely economic. Despite these demands, both government and the dominant energy industries remained impassive, and were fixated on their own economic assessment of renewable energy technologies on a strict cost per kWh (kilowatt hour) basis. This cost was calculated on the basis of capital costs (annuitized over the lifetime of the plant), fuel costs, and the operation and maintenance costs. This approach caused a number of challenges for renewables as this thesis will show. Firstly, although renewable 'fuel' is effectively free, the capital costs of establishing renewable generation can be high. This makes renewable energy particularly sensitive to the cost accounting methods used in assessing potential energy developments. Both the discount rate used and the investment period selected are crucial to the decision to invest (or not) in alternative energy projects. Furthermore, this initial barrier to renewable energy development severely hampered any possibility of cost reductions through the well-recognised processes of scale economies, 'learning by doing', and 'learning by using' that was so instrumental in the development of the incumbent energy technologies. Chapter 7 will discuss these issues in some more depth.

This leads to a second theme that will be explored - the evolution of energy technology; and more specifically, renewable energy technology. Despite its apparent novelty renewable energy technology has a significantly longer history than the more 'traditional' fossil fuel or nuclear technologies alluded to above. Many have explored this history of renewable energy technology and more recently Vaclav Smil has extended his authoritative energy histories to include the evolution of wind, water and solar power.[45] This thesis will focus on the accelerated evolution of the technology after 1973. In

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[45] Smil, V., *Energy in World History* (New York: Westview, 1994); Smil, V., *Energies: An Illustrated Guide to the Biosphere and Civilization* (London: The MIT Press, 1999); see footnote 5 above

particular, it will use a case study of Stephen Salter at the University of Edinburgh, and the invention of 'Salter's Duck' to explore some of the technological challenges that faced the renewables community in the period.[46] This study of renewable energy technology will be delineated within the broader understanding of technological development and its interaction with society advocated by Social Construction of Technology (SCOT) School. As Callon stated '... the development of scientific knowledge and technical systems cannot be understood unless the simultaneous reconstruction of the social contexts of which they form part is also studied.' [47] Already mentioned is the seminal contribution of Hughes on electrical power systems which demonstrates in meticulous detail how modern power systems grew out a combination of technical, economic, political and social factors. Hughes presented an account of technological development that challenged the determinist view that saw technology as driving historical change. Much of this crude determinism emerged from postwar neo-classical economic theory where 'technology' became the key variable in economic growth and influential studies such as Mokyr's *The Lever of Riches* and Landes' *The Unbound Prometheus* appeared to confirm the relentless influence of technological advances on economic growth.[48] Historians of technology and society such as Bijker and Pinch came to challenge this straightforward account as they presented technological innovation in terms of its negotiated evolution within society.[49] Of particular interest to this thesis is the work of Langdon Winner who has made a significant contribution within this field to the specific study of energy choices.[50] He argued that, 'Choices about supposedly neutral technologies – if "choices" they ever merit being called – are actually choices about the kind of society in which we shall live'.[51]

Closely related to the above is another theme that will be explored; the phenomenon of what I will term 'energy morality'. This describes a view of energy policy that extended beyond technical considerations and extended into a broader critique of

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[46] I am particularly grateful in this regard to Prof. Salter for allowing me unrestricted access to his personal archive.

[47] Callon, M., 'The Sociology of an Actor-Network: The Case of the Electric Vehicle' in Callon, M., Law, J. and Rip, A. (eds.) *Mapping the Dynamics of Science and Technology: Sociology of Science in the Real World* (London: Macmillan, 1986) p.20

[48] Landes, D., *The Unbound Prometheus: Technological change and industrial development in Western Europe from 1750 to the Present* (Cambridge: Cambridge University Press, 1969); Mokyr, J., *The Lever of Riches: Technological Creativity and Economic Progress* (Oxford: Oxford University Press, 1990)

[49] Bijker, W. E., Hughes, T. P., and Pinch, T. J. (eds.), *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (London: The MIT Press, 1987)

[50] Winner, L., *The Whale and the Reactor: A Search for Limits in an Age of Technology* (London: University of Chicago Press, 1986); Winner, L., 'The Political Philosophy of Alternative Technology: Historical Roots and Present Prospects', in *Technology in Society,* 1:1 (1979) pp. 75-86

[51] Winner, "Alternative Technology', p.85

western capitalism. I will argue that this represents an example of Winner's argument, alluded to above, that 'artifacts have politics'.[52] This broader consideration of the implications of energy choices emerged in the 1960s, but found its first full expression in the 1970s. In Britain energy morality was most closely identified with the rise of the new environmentalism, which had grown from a mixed bag of influences ranging from Victorian amenity societies to the US counter culture movement. During the early part of the 1970s the new environmental movement was concerned with a range of issues from pollution to nuclear disarmament. Closely related to both of these issues, the question of energy came to occupy a central role in environmental action and debate. What began as 'Ban the Bomb!' marches in the 1950s widened to include active opposition to civil nuclear power. The founding of Friends of the Earth UK (FoE UK) in 1972 and the output of the influential magazine *The Ecologist* ignited the energy debate in the UK and in the view of Williams forced what had been a private discourse into the public arena.[53]

The final theme that this thesis will explore is the attempted commercialisation of renewable energy technology. Chapter 5 will feature a case study of Sea Energy Associates Ltd (SEA), the short-lived commercial collaboration between Stephen Salter and Ready Mixed Concrete Ltd (RMC). A strong feature of the current dominant perceptions of renewable energy in Britain is that industry has 'missed' opportunities to take a lead in the global development of this technology. These are familiar criticisms to the ears of the economic historian and arguably have their roots in the alleged lag that the UK experienced from the time of the Second Industrial Revolution. Furthermore, as Edgerton pointed out, it is a common view among nations that they themselves 'are good at inventing, but bad at developing and using technology'.[54] It is not the intention of this thesis to examine the veracity of the claims, or the extensive literature on Britain's relative economic decline in the post war era. Rather, this research will primarily outline the relationship between business and renewable energy technology between 1973 and 1988. At present there is no standalone account of the evolution of this important relationship for the UK for this formative period. Vietor and Sovacool both pay some attention to commercial developments in the US, where government policy encouraged private capital from the outset. John Berger provides a useful analysis of the 'business' of renewable

[52] Winner, *The Whale and the Reactor*.
[53] Williams, *Decisions.*
[54] Edgerton, D., 'From Innovation to Use: ten eclectic theses on the historiography of technology', *History and Technology*, 16:2 (1999) p.132 *fn*,32

energy in the US which this thesis will use to tease out some essential contrasts in the UK.[55]

It is not the intention of this thesis to develop its argument within a single dominant theoretical perspective. Rather, it will employ a number of theoretical devices as appropriate. These will be utilised primarily as organisational tools rather than any attempt to prove their inherent explanatory power. Watt has previously explored both wave energy and nuclear programmes through a ‘synthesised network approach’ within a broadly political discourse.[56] His thesis adopted a meso-level analysis of the wave energy community in the 1970s to reach conclusions about the effectiveness of energy policy communities during that time. McInnes undertook a similar exercise, employing the policy network theories of Marsh and Rhodes to explore the structure of the UK Department of Energy.[57] This thesis will draw on some of the conclusions of this previous valuable research and will use network theories insofar as they help to explain the relationships within the broader energy community. Of particular interest to this thesis will be an examination of the particular interest groups that contributed directly or indirectly to energy policy.

The examination of these themes will be based on a wide reading of the existing literature, a close examination of primary source material, and a selection of interviews with some of the key individuals involved in energy during the period. The primary source material is drawn mainly from government records held at the National Archive at Kew. This has involved a great number of Freedom of Information requests to access relevant material that nestles within the thirty-year rule. In addition to this a significant amount of primary source material was very generously made available to the author by Professor Stephen Salter who has built a detailed (and extensive) personal archive of his involvement in renewable energy since 1973. Whilst undoubtedly the historian of more recent events faces many challenges as these events are still to a large extent unresolved, it also provides tremendous opportunities. In methodological terms, this thesis is able to develop the interplay between documents and individual interviews. This allows the often neutral tone

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[55] Berger, J. J., *Charging Ahead: The Business of Renewable Energy and What It Means for America* (London: University of California Press, 1997)
[56] Watt, ‘Synthesised Network Approach’
[57] McInnes, ‘Policy Networks’

of official records to be enhanced by personal recollection and interrogated by historical enquiry.

Organisation of thesis

The material will be presented in two main parts and these will follow a chronological narrative based on the wide range of source materials. The parts reflect a chronological order that coincides with moments of change in the development of renewable energy in the UK. Part one will encompass a fairly broad historical sweep of the period leading up to the 1970s, concluding at the end of the Golden Age and the changed social and economic context of Britain in the 1970s. The first part will include two chapters. Chapter 1 will summarise the development of renewable energy and electricity until the 1974. The aim of this is to demonstrate continuity in many of the issues that confront renewable energy innovation and development. Chapter 1 will also address the evolution of mains electricity and will focus heavily on the development of electricity grids in the UK. This chapter will consider the nationalisation of the UK's energy industries after the war, and will examine the significance of Britain's civil nuclear programme from the 1950s, drawing particular attention to the impact that the Suez crisis had on UK energy policy. According to the central theme of this thesis this discussion will be primarily focussed on the theme of government involvement in energy policy and technology.

Chapter 2 will examine the growth and spread of the new environmental consciousness in the early part of the 1970s in the context of the period and will show the significance of this for energy policy in Britain. This chapter will develop and discuss the theme of energy morality in the period. This describes a sense in which debates over energy, for so long confined to government and the nationalised energy industries, spread out to encompass the general public. This was encouraged by the re-emergence of the debates over reactor choice and the industrial unrest in the coal industry, but this chapter emphasises the key role that the new environmentalism occupied in forcing energy into the mainstream. A key conclusion of this thesis is that the 1974-88 UK renewables programme was in many senses a tokenistic gesture, responding to the new social movement pressure. Therefore, the examination and explanation of the role of a new energy consciousness propagated by the 1970s environmental movement helps in understanding just why such a gesture was deemed necessary.

The second part of the thesis will concentrate on the period 1974-88, and will include four chapters. Chapter 3 sets the context for the creation of the UK renewables programme. It includes a discussion of the role that Lord Rothschild's Central Policy Review Staff (CPRS) played in encouraging the development of renewable energy in the UK. This chapter will describe the development of the infrastructure of the UK renewable energy programme, which emerged immediately following the 1973 oil crisis. This will establish the important institutional background to renewables development in the UK. Chapter 4 then focuses on an analysis of the major UK renewables initiative during the 1970s, as recommended by Lord Rothschild, the Wave Energy Programme (WEP). This chapter highlights the tremendous enthusiasm that existed for wave energy during the early part of the programme. Between 1974 and 1978, renewable energy in the form of wave power was regarded as a serious aspect of Britain's energy future. However, this chapter will also show how this initial fervor was rapidly deflated by the economic and technical challenges unveiled during the first Wave Energy Conference at Heathrow in November 1978. Thereafter, as this thesis shows, amidst dwindling government support (accelerated by the election of the Thatcher Government in 1979) renewable energy faced a much more troublesome passage.

The central figure in wave energy development was Stephen Salter of the University of Edinburgh, and therefore Chapter 5 is a case study of his involvement in the UK renewable energy programme. This chapter brings together several of the themes of this research. It will discuss the impact of the new environmentalism on forming Salter's motivation to develop a source of 'clean energy', the role of the renewable energy institutions in managing the device teams, and finally, the attempted commercialisation of renewable energy through partnership with industrial partners. Chapter 6 will explore the shift in renewables policy in the UK at the end of the 1970s. This centred on the abrupt and controversial closure of the Wave Energy Programme and a move to develop wind energy. This chapter will consider the influence of developments in the US, where a new package of financial incentives encouraged the Californian wind rush of the early 1980s. This stimulated an explosion in wind energy projects that, during the period, culminated in the massive 3MW wind turbine in Orkney at a cost of £17M. Chapter 7 will revisit and summarise some of the key economic aspects of renewable energy development during the period. This will help to emphasis the more minor role allocated to wider economic considerations in the period before the science of climate change was widely known. This channeled any economic assessment of renewable energy sources into a rather narrow calculation of the capital costs of the technology.

Chapter 1
Energy and Electricity in the UK before 1974

This chapter will help to set the background for the UK energy scene in the 1970s, which will be dealt with in Chapter 2, through a brief examination of the development of electrical networks. The main aim of this chapter is to explain how electrical systems grew from uncertain beginnings in the 1880s to dominate national energy distribution and consumption by the mid-twentieth century through the National Grid. As well dealing with the evolution of the grid this chapter will also briefly outline the growth and change in the patterns of energy consumption in the UK in the post-war period.

The story of early enterprise in electrical lighting systems has some interesting parallels with the attempts to develop renewable energy later in the twentieth century that forms the focus of this thesis. The early innovators in electric lighting in Britain were faced with a network (in their case, gas lighting) which was well-developed and widely used particularly in urban settings, and a gas industry that, in the UK, was efficiently managed.[1] Lighting faced a number of serious hurdles in developing into a competitive alternative not least of which was the fact that gas lighting remained roughly one third cheaper than electric lighting in Britain until the outbreak of the First World War.[2] The electrical power industry of the late nineteenth century was therefore confronted by many technical, legal, financial, and social barriers which I suggest were in some ways similar to the impediments that renewable energy development was to encounter in the 1970s and beyond.

In nineteenth-century Britain the demand for all those things that we would now call 'energy', both in domestic and commercial terms, was being almost entirely met by coal. In the home, cooking and heating were both achieved by burning coal[3] whilst artificial light was traditionally provided either by whale oil lamps or tallow candles until the introduction of gas lighting (also derived from coal) in the early part of the century.[4]

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[1] Byatt, I. C. R., *The British Electrical Industry 1875-1914: The economic returns to a new technology* (Oxford: Clarendon Press, 1979) p.3

[2] Byatt, *British Electrical*; Wilson, J. F., *Ferranti and the British electrical industry, 1864-1930* (Manchester, Manchester University Press, 1988) p.7

[3] Oil was not discovered until 1867.

[4] Rendered animal fat

The spread of gas lighting in the first half of the century was partly encouraged by the changing work patterns of industrialisation as the demands of the new factories changed the definition of the working day and stretched it into the hours of darkness. Factory owners faced large bills for candles and whale oil in the period before gas lighting was introduced - not to mention the frequent and expensive fires that damaged property, delayed work, and often ended in human tragedy.[5] Therefore the commercial demand (market pull) for a cheap and safe alternative prompted innovation and development in gas technologies. This eventually led to almost every town in Britain having a domestic gas supply by the middle of the century as economies of scale then successfully encouraged the shift from dedicated gas-lighting systems in factories, commercial premises and large homes to a wider public supply.[6] Generally a new gas mains network would initially be built to supply a town with street lighting and then this could easily be extended to include new domestic consumers as the supply costs fell.[7] This model of distribution was an important development in public utility systems and electrical power networks adopted it later in the century. However, the 'lusty infant' of electricity would first have to dislodge mains gas-lighting from its dominance in UK illumination.[8]

Within this early period in the development of electricity there are two aspects that are particularly relevant to this thesis. The first concerns the involvement of the government in the provision of electricity in Britain.[9] From the earliest days of electrical developments, legislation has helped to shape the rate and direction of progress in the industry. This started in the late 1870s and continued the pattern of state involvement in energy matters that had begun with the gas industry. Initially this was a practical and technical interest in the breaking of roads and the safety of the public from swaying overhead cables, but it soon was to develop into an ideological interest in electricity as a public good. Coming as it did at the end of the nineteenth century, electricity was added to the list of public utilities that municipal socialism would seek to control to 'protect' the

[5] Falkus, M. E., 'The Early Development of the British Gas Industry, 1790 -1815', *The Economic History Review*, New Series, 35:2 (May 1982) p.219. Falkus quotes the example of the Manchester firm of McConnel & Kennedy which 'burned an average 1,500 candles each night for 25 weeks in the year and consumed more than 1,500 lbs. of tallow.' The annual cost of this in 1806 was about £750.

[6] Ibid. p.217. 'During the first half of the nineteenth century gas supplies were brought to all major towns and even to must small centres numbering no more than three thousand or so inhabitants.'

[7] Falkus, M. E., 'The British Gas Industry before 1850', *The Economic History Review*, New Series, 20:3 (Dec 1967) pp. 494 - 506

[8] Hughes, T. P., 'British Electrical Industry Lag: 1882-1888' *Technology and Culture,* 3:1, (Winter 1962), pp. 27-44. Hughes quotes this description of electricity from the Paris Exhibition of 1881.

[9] Hausman et al, *Global*, pp. 23-24

public from exploitation and monopoly power.[10] Related to state involvement in electricity, another aspect of the early period of development that is crucial to this thesis is the evolution of central station electricity. As the potential scale of electrical networks grew after the invention of the incandescent bulb the potential (which Edison had anticipated) for large central generating systems offering a public supply also increased. Despite slow and unsteady progress central station electricity became the natural choice for electrical networks in the UK due to the economies of scale and the largely urbanised population.[11]

Central Generating Systems

Prior to the invention of the incandescent bulb, arc lighting systems had mainly been sold - and regarded - as independent, dedicated (self-contained) systems; similar to the early gas-lighting systems. Each installation would have its own generator and formed a complete system within itself.[12] Much of the reason for the adoption of this approach is explained by the limited and site-specific applications of arc lighting, the technical limits on lamps, and the economic limits to demand imposed by cost. However with the invention of the incandescent bulb many of the limits to electrical systems were transformed. Now that electrical lighting could actually be used in an interior setting, the possibility of selling the light to a large number of ordinary domestic consumers opened up. Even more crucially it now became a technical possibility - and economically desirable - to run huge numbers of lamps from a single generator. Just as the gas industry had shown, central generating systems offered an opportunity to drive down the costs of generating electricity by achieving the economies of scale necessary.[13]

The key figure in the development of central station electricity in the UK was Thomas Edison. Although popular legend tells of the 'heroic' inventor Edison obsessed with creating a light bulb (his team of scientists and engineers had indeed been focused on developing a reliable incandescent light bulb) the overarching goal for Edison was the potential that an electrical network offered.[14] From his earlier experience of developing the telegraph and his interest in the telephone and an awareness of the way in which gas networks had grown, Edison was convinced that the future for electricity lay in developing

[10] Ibid. p.67

[11] A further crucial factor was the technical imperative; load factor. As electrical networks developed it became essential that central generating plant was used efficiently. One example of how this could be achieved was by combining domestic demand (mostly evenings) with industrial demand (mostly daytime).

[12] Hausman et al, *Global*, p.10

[13] Falkus, 'Early Development', pp. 229-31

[14] Hausman et al, *Global*, pp. 11-12

a similar system. Hughes has shown clearly that rather than setting out to confront the purely scientific and technical barriers that this entailed Edison also had a keen awareness of the economic aspects of the challenge; he described Edison's general approach as 'econotechnical'.[15] Edison was among the first to recognise that electrical light would have to be sold in significant volume in order to compete with the well-established gas networks if it were ever to be any more than a 'luxury' light.

By the end of the First World War electrical networks had become well established in the UK, particularly in urban settings. However, these systems had developed in a haphazard way offering consumers a bewildering variety of supply-led options to the consumer; AC and DC systems operating at a range of voltages and frequencies. As Hughes noted wryly,

> Londoners who could access electricity, toasted bread in the morning with one kind [of electricity], lit their offices with another, visited associates in nearby office buildings using still another variety, and walked home along streets that were illuminated by yet another kind.[16]

Though according to Hannah,

> The fragmented nature of the British supply industry had not proved an unbearable handicap in the early stages of development, but by the end of the first decade of the twentieth century there could be no doubt that a new strategy was required and that the existing structure of the industry was not conducive to the development of large central stations and bulk supply. [17]

During the war the importance of electricity to the economy and society was made plain, and its many flaws exposed. Political attention was turned towards the industry once more as numerous 'Reconstruction' Committees began to consider the future of the electricity industry.[18] Although the scale of the problem was exaggerated in London, a similar problem operated throughout the country. There was little regional interconnection as municipal electrical enterprises often resisted expanding their networks through integration with contiguous enterprises, and as such the national picture was fragmented.

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[15] Hughes, *Systems*, p.29
[16] Hughes, *Systems*, p.227
[17] Hannah, *Electricity,* p.51
[18] Wilson, *Ferranti,* p.124; Self and Watson, *Electricity* . Around the same time in 1916 the two committees were set up, one under Lord Haldane and the other under Charles Parsons to consider manufacturing. The Williamson Committee arose as a recommendation of the Parsons Committee.

This had resulted in the UK falling behind its competitors, mainly Germany and the US, in terms of development and scale in electricity. This was not just a matter of national pride however as by the second decade of the twentieth century three of the UK's biggest electrical firms were subsidiaries of German or US firms.[19] The habit of having one eye fixed on the other side of the Atlantic was something that also had an impact later, in the 1980s, when Britain shifted its renewables programme to wind energy to follow the American lead (see chapter 6).

The Weir Committee and the National Grid

In October 1924 a Conservative government was returned to power in Britain under Prime Minister, Stanley Baldwin. By this time it was clear that electricity supply was really in desperate need of reorganisation and the short-lived Labour government (elected in January 1924) had begun to address some of these problems through a committee for Coal and Power set up under ex-Prime Minister, Lloyd George.[20] Hughes advanced the view that the barrier to change in the UK since the earliest days of electrical supply had been 'primarily political' and it was clear that by this time 'politics' was beginning to take some notice of the challenges.[21] By 1924 the damaging economic consequences of the war, increasing trade union activity, and a first Labour administration under Ramsay MacDonald had arguably weakened much of the more entrenched political impediments to change. The new Conservative government rather surprisingly found itself supporting state involvement in electricity as the only possible solution to the problems, and Baldwin immediately made this a key priority for the new administration.[22]

The report of the Weir Committee was signed on 14 May 1925 only five months after its establishment and its recommendations were bold. Undoubtedly the speed at which the committee reached its conclusions was helped in large part by the accumulated output of the various committees on electricity set up by the government since the First World War and the five years of experience gathered by the Electricity Commissioners, a creation of one of these earlier committees. From the start the Weir Committee regarded Britain as 'an ideal electrical area' and accordingly its report was focussed on the

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[19] Hannah, *Electricity,* p.37

[20] Self & Watson, *Electricity,* pp. 51-54; Hannah, *Electricity,* pp. 88-89. The Lloyd George committee engaged the services of Merz and McLellan to investigate the costs of standardisation using Clydebank as an example.

[21] Hughes, *Networks*, p.351

[22] Hannah, *Pioneer,* p.209

challenges of national interconnection.[23] The Weir Committee quickly reached conclusions that were largely similar to those of the Williamson Committee some years earlier, although they went much further in proposing *national* (rather than regional) interconnection that formed the core of their recommendations. The committee envisaged a future where there would be,

> ...generation in large stations, favourably situated as regards fuel, water and load with units of comparatively large capacity; the minimum legitimate amount of stand-by plant; and the highest obtainable load factor, to secure which stations should be inter-connected with one another. [24]

The Weir Committee also recommended the establishment of area boards, but it proposed that these would be organised under a central body, the Central Electricity Board (CEB). Weir foresaw that the entire country should form one large integrated network of generation and distribution - facilitated by an interconnected 'gridiron' - operating on a single standardised frequency and voltage.[25]

It is some indication of the awareness of the poor state of electricity in the UK and the perceived impact that this was having on international competitiveness that this time around the proposals of a government electricity committee were accepted largely unaltered by the government.[26] Despite some initial hesitancy from the government in publishing the Weir Report due to the radical nature of its proposals (and the likely reaction of vested interests), the Electricity Supply Act (1926) created the CEB and set plans for a national grid in action.[27] According to Hannah, the Weir Committee had,

> ...indulged in sensationalism and exaggeration - perhaps necessarily - in order to emphasise the seriousness of the problem and to encourage the adoption of their recommendations.[28]

Weir had promised Baldwin that the proposals would require 'courage and possibly a considerable financial investment', and accordingly the committee had estimated (based

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[23] Hannah, *Electricity,* p.91
[24] Hughes, *Networks*, p.353
[25] Ibid. Merz coined the term 'Grid' because the proposed pattern of transmission lines reminded him of a gridiron.
[26] Hannah, *Electricity,* p.96. Furthermore, it is also some indication of the influence of Lord Weir.
[27] Ibid. pp. 94-96. As noted above the report was delivered to the Government in May 1925. It was not published until March 1926.
[28] Ibid. p.93

on the commissioned reports) that their proposals, including the cost of new power stations and distribution systems, would cost £250m over fifteen years to implement but that this would result in annual consumer savings of £44m by 1940 through lowered prices.[29] These 'fragile' savings estimates convinced the government that action was required. The creation of the CEB signalled a significant new direction in state enterprise in the UK which would foreshadow much of the subsequent nationalisation of key industries. However, this thesis is particularly interested in the establishment of the national grid. The government had accepted the economies of scale that a national grid could offer and the structure of the UK's electricity networks was to be radically re-ordered through a massive engineering project to create an interconnected national electrical network.

The National Grid: *'...power, in the service of the people…'* [30]

The National Grid was begun in Central Scotland in December 1927. Through that year the newly formed CEB was assisted by the Electricity Commission in formulating plans for how the challenges of grid construction would be met. It was decided that the industrial areas such as South Wales, Central Scotland, and the Midlands should be tackled first. Given the preponderance of Scots in the CEB and Electricity Commission it was perhaps no surprise that Scotland was chosen first: many of the senior engineers had previous experience of the existing electrical networks in this area.[31] The physical scale of the challenge was huge; the construction of a network of transmission lines snaking around the nation; the standardisation of frequency, voltage, and current; and the drastic rationalization of the existing generating capacity.[32] Leaving aside the construction of new power stations, the 3,000 miles of planned transmission lines would require 150,000 tons of steel and 12,000 tons of aluminum. 28,000 pylons were erected and the system required 200,000 porcelain insulators. After some research into systems abroad the CEB decided to standardise the frequency of the grid at 50Hz and this required that more than twenty per cent of the installed capacity be converted.[33] The erection of the 'ugly' pylons stirred up some opposition from those who felt that they 'disfigured' the landscape [34] - and the CEB had to deal with 22,000 affected landowners on the issue of wayleaves. Chapter 6 shows

[29] Ibid. pp. 90-92
[30] Minister of Transport, Herbert Morrison, quoted in Hannah, *Electricity,* p.118
[31] Hannah makes mention of the disproportionate number of Scots involved in both the Electricity Commission and the CEB - not to mention Lord Weir. Hannah, *Electricity,* p.78, 103.
[32] Self & Watson, *Electricity,* p.60
[33] Hughes, *Networks,* p.358; Hannah, *Electricity,* pp. 116-118
[34] Some examples include, 'Pylons in Kent: new threat to Pilgrims' Way', *The Times,* p,11, 17 January 1930; 'Pylons And The New Forest: The Alternative Routes' (Picture Gallery) *The Times,* p.14, 5 November 1932

how this environmental opposition created a painful memory for the electricity industry that would resurface during the late 1970s when the CEGB was considering the development of wind turbines in the UK.

Fortunately for the CEB it had two great advantages. The first of these was that despite the physical challenge that the grid presented it never represented a technological challenge. Hughes in particular is clear in stressing that the CEB was able to use existing technology in constructing the grid. 'Britain's engineers concentrated on a host of relatively routine problems that were complicated more by their number, a tight schedule, and economic dimensions than by technical challenge.'[35] The second advantage enjoyed by the CEB was that the construction of the grid coincided with the Depression in the UK. This gave the construction project access to large volumes of skilled labour and materials and avoided the costly delays that might otherwise have afflicted the programme.[36] Less quantifiable but equally important was the associated benefit that this gave the CEB and the grid in being seen in positive terms as a job creator at a time of economic hardship.[37] The CEB was quick to claim that the construction of the grid created 120,000 jobs, either directly or indirectly.[38] This access to existing technology and labour helped to ensure that the national grid was completed on schedule. The last pylon was erected at Fordingbridge in the New Forest on 5 September 1933.[39] By the end of 1935 general trading was underway in most of the UK and by this time there were 2880 miles of primary transmission lines in operation.[40] The grid had been completed within schedule and within budget. The Weir Committee estimated that it would cost between £24-29m to construct the grid - and the final cost was an impressively accurate £29m.[41]

[35] Hughes, *Networks,* p.357
[36] Hannah, *Pioneer,* p.215
[37] Perhaps, an early echo of the 'green jobs' claims, emphasised in the introduction to this thesis.
[38] Hannah, *Electricity,* p.119
[39] 'National Grid Complete: A British Engineering Achievement: Electricity for all purposes', *The Times,* p.34, 5 December 1933
[40] The North East area remained outside of the national grid at this point due to problems with frequency standardisation. Self & Watson, *Electricity,* p.60
[41] Hannah, *Pioneer,* p.216

Energy and Electricity during the golden age

Economic historians, ever drawn to themes of continuity and change, have viewed the three decades beginning after the end of the Second World War as Les Trentes Glorieuses.[42] The unprecedented period of sustained economic growth, which occurred after the Second World War, led to a 'golden age' of higher living standards, and the inevitable corollary of increased consumption, for most of the citizens of the developed nations. [43] Britain also enjoyed a period of sustained growth during this time, but at growth rates somewhat more modest than its competitors.

As demonstrated by the work of Darmstadter, economic growth and energy consumption enjoy a close relationship, and one important result of the increasing wealth of individuals during this period was the increasing consumption of energy, both by industry and households.[44] Between 1950 and 1970 the total world consumption of energy increased by 151 per cent, from 2059 to 5170 million metric tonnes oil equivalent (mmtoe).[45] Within this global aggregate figure many of the industrialised nations, particularly those that had suffered infrastructure damage during the war, accounted for even greater rises in demand. As Clark put it 'a handful of nations consumed the bulk of the world's energy'.[46] Japan, which accounted for only 2 per cent of world consumption in 1950, was by 1970 consuming 6 per cent of a much increased total, as its per capita primary energy consumption rocketed over the twenty years (Table 1.1). France and Germany also witnessed massive increases in energy consumption as they rebuilt their damaged economies following the war. Despite the less spectacular incremental increases in the US in this period, the energy consumed was on a scale with no equal anywhere else in the world, at more than double the per capita consumption of Britain and Germany. Somewhat less dramatic was the rise in consumption in Britain during this period.

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[42] Chick, *Electricity,* p.1. This phrase is attributed to Jean Fourastié.

[43] N. F. R. Crafts, 'The golden age of economic growth in Western Europe, 1950-1973' in *Economic History Review,* XLVIII, 3 (1995) pp. 429-447; N. Crafts and G. Toniolo (eds.), *Economic Growth in Europe since 1945,* (Cambridge: Cambridge University Press, 1996) pp. 4-7

[44] Darmstadter, J. et al, *Energy in the World Economy: a statistical review of trends in output, trade, and consumption since 1925* (London: The Johns Hopkins Press, 1971); Darmstadter, J. et al, *How Industrial Societies Use Energy: A Comparative Analysis* (London: The Johns Hopkins University Press, 1977); see also Clark, *World Energy*, p.101

[45] Clark, *World Energy,* p.188, Table 6.1

[46] Ibid, p.102

Table 1.1

Per Capita Consumption of energy, selected years (mmtce)

	1950	1960	1970
UK	4.4	4.9	5.4
Germany	2.5	3.7	6.0
France	1.9	2.6	5.0
Japan	0.6	1.2	4.0
USA	7.9	8.6	12.5
World	1.0	1.4	1.9

Source: Clark, *World Energy,* p.188, Table 6.1

Some of the explanation for what Clark termed a 'negligible' rise in Britain's energy consumption during this period can be attributed to economic factors, and this forms part of a wider debate on relative economic decline in the post war period which falls outside the constraints of this research. However – leaving the US aside – it can be seen that the UK was the leading *per capita* consumer in the developed world in 1950 and was overtaken only by Germany by 1970. Therefore it could be argued that earlier growth had limited the potential for UK consumers (both domestic and industrial) to increase their energy consumption. Despite this possibility, the period was witness to huge growth in the demand, availability and consumption of electricity in Britain (Table 1.2). The boost that this gave to the newly nationalised industries of coal and electricity was seen only in the most positive of terms. Similarly, though perhaps more of a concern for the ongoing British preoccupation with the balance of payments, the steady growth in car ownership in the period led to increasing imports of foreign oil to the UK.

Table 1.2

UK electricity, 1950-74 (GWh)

Year	Production	Consumption (total)	Consumption (per capita kWh)	Installed capacity per 1,000/pop. (kWh)
1950	66	66	1309	376
1955	94	94	1834	531
1960	137	137	2601	697
1965	196	197	3604	906
1970	249	250	4473	1200
1974	273	273	4873	1418

Source: Chick, *Electricity,* Appendix A1, Table A1.1, p.147

Despite the rather modest increases in *total* primary energy demand compared with the other industrialised nations, Britain did reflect the shifting pattern of global energy consumption after 1950. By 1945 oil accounted for 23 per cent of world primary energy consumption; by 1970 the figure was 45 per cent. Coal which had provided 66 per cent of primary energy in 1945, had by 1970 slipped to providing only 33 per cent of world primary energy requirements.[47] Of course, primary energy needs were not provided by coal and oil alone in the golden age. But despite the massive attention and capital invested in nuclear energy in the period, it did not play a significant role in world energy by 1970; accounting for less than 1 per cent. Indeed, the only 'renewable' of any significance in the period, hydroelectricity, was providing more than twice this amount of primary energy in 1970. Much more significant was the increase in the consumption of natural gas in the period. Gas remained almost unnoticed amongst what Yergin showed as the swashbuckling allure of the international oil industry and the technological attraction of nuclear power.[48] However, from a share of only 10 per cent of world requirements in 1945, natural gas doubled to provide 20 per cent in 1970.

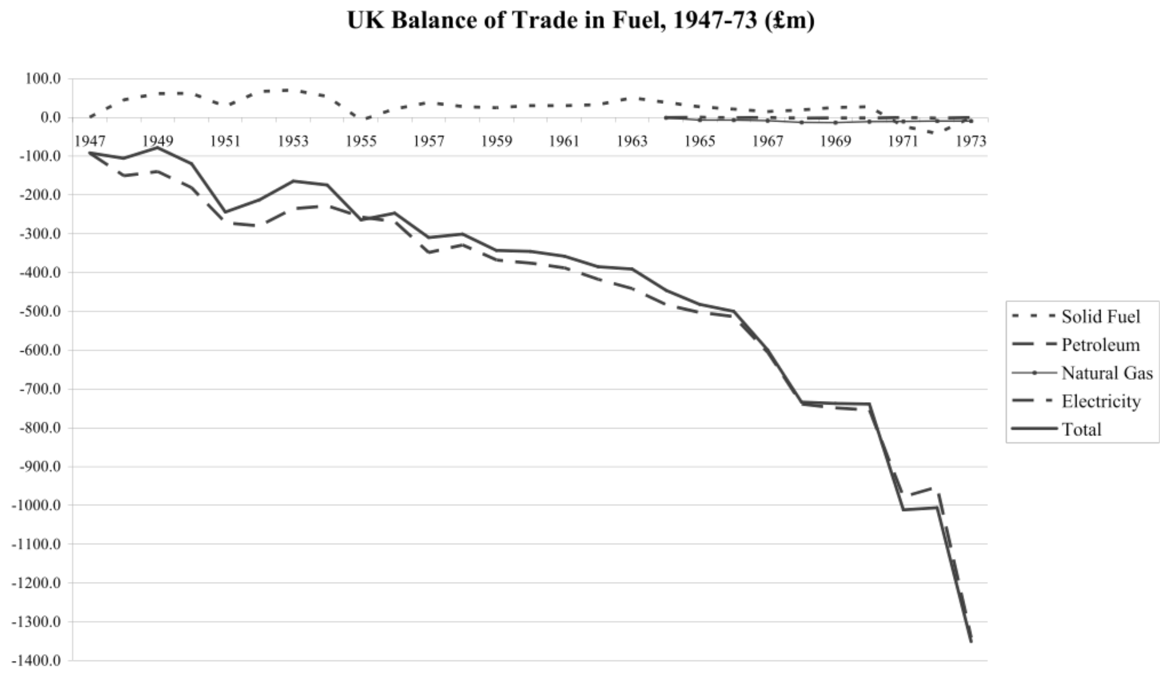
[47] Clark, *World Energy,* p.100, Table 4.1

[48] Yergin, D., *The Prize: The Epic Quest for Oil, Money & Power* (London: Free Press, 1991)

UK Balance of Trade in Fuel, 1947-88

In 1936 (in terms of the balance of trade) the UK became a net importer of fuel. Up until this point the nation had through virtue of its huge coal reserves and well-developed export networks made a profit on fuel. The one exception to this had been during the General Strike of 1926 when it was necessary to import £66.6m of fuel to replace the disrupted supply. From the mid-thirties the gradual decline in coal exports combined with increasing imports of petroleum meant that a net national outlay for fuel would become a feature of the overall economic position of the UK. Furthermore, this deficit steadily increased through time. Chart 1.1 shows the balance of trade in fuel from 1947 until the oil crisis of 1973.[49]

Chart 1.1



Sources: Ministry of Power, *Statistical Digest 1965* (London: HMSO, 1966); Ministry of Power, *Digest of Energy Statistics, 1968 and 1969,* (London: HMSO, 1969); Department of Energy, *Digest of United Kingdom Energy Statistics 1974* (London: HMSO, 1975)

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49 The values of imports are quoted 'c.i.f.' (cost, insurance and freight) and exports are 'f.o.b.' (free on board). 'c.i.f.' - 'this value is the price which the goods would fetch at that time, on sale in the open market between buyer and seller independent of each other, with delivery to the buyer at port of importation, the seller bearing freight, insurance, commission and all other costs, etc., incidental to the sale and delivery of the goods with the exception of any duty or tax chargeable in the United Kingdom.' 'f.o.b.' – 'which is the cost of the goods to the purchaser abroad, including packing, inland and coastal transport in the United Kingdom, dock dues, loading charges and all other costs, charges and expenses accruing up to the point where the goods are deposited on board the exporting vessel or at the land boundary of Northern Ireland.' Quoted from, Department of Energy, *Digest of United Kingdom Energy Statistics 1989* (London: HMSO, 1989)

Chart 1.1 shows an inexorable decline in the balance of trade in fuel in the UK during the golden age. This net cost of fuel increased steadily during the 1950s and gathered pace through the early 1960s; eventually showing dramatic shifts in the second half of the 1960s and early 1970s. The growing cost of fuel to the country reflects the concomitant shift from coal to oil that was taking place after the war. From its position of dominance, supplying over 90 per cent of fuel needs in the UK in 1947, coal was quickly being replaced by oil as the dominant fuel. Much of this growth was explained by the growth in transport from the 1950s onwards.

Electricity in the postwar era: changing inputs

The final section of the chapter will look at one aspect of the evolution of electricity in the UK from the time of nationalisation in 1948 until the early 1970s. Therefore, it is not intended as a detailed analysis of the industry within the context of nationalisation as Hannah and Chick have already admirably served this task.[50] Rather the focus will be on the growth of consumption in the period and the changing pattern of inputs within the electricity generating industry. The CEGB was the coal industry's largest customer through the postwar period, and it was the only customer for nuclear power. This meant that the decisions that the CEGB took with regard to fuel were crucial in shaping the development of energy sources within the UK. This is of particular interest to this thesis as later chapters will show that the interest and enthusiasm of the CEGB had a direct impact on the success of renewable energy sources - particularly wind energy - during the 1970s and 1980s.

The British Electrical Authority (BEA) was created in April 1948 under its first chairman Lord Citrine. During the 1950s the choice of fuel became a political issue, and Hannah notes that throughout this time, despite the supply difficulties, the BEA believed that coal would continue to be the 'fuel of choice' for electricity generation.[51] However, coal shortages prompted the Government and the BEA to consider alternative fuels, such as oil and nuclear as the NCB officially informed the BEA that they would be unable to meet the rising demand for coal by the 1960s.[52] During this period the BEA had also investigated the potential of wind power, with proposals to build an experimental turbine

[50] Hannah, *Engineers*; Chick, *Electricity*.
[51] Hannah, *Engineers,* p. 168
[52] Ashworth, *Coal,* pp. 38-39

in Wales.[53] These plans were ultimately shelved amid local opposition on environmental grounds. At this point the BEA only operated one oil-fired power station at Bankside in London and nuclear energy was yet to make any contribution to electricity generation. However the warning from the NCB over future coal supplies encouraged the BEA to reach an agreement with ESSO on oil supplies to the new oil-fired plant at Marchwood at an annual loss (relative to coal) of £1.6m on the expectation that oil prices would continue to decline.[54]

The BEA was also attracted to the potential of nuclear energy. It had 'the technical appeal of the new' and the BEA which sought a central role in its development was disappointed by the creation of the UKAEA in 1953. Clearly, the electricity industry would be the sole commercial customer for nuclear energy but sensitivity over the weapons aspect of nuclear technology caused the government to separate its operation from the BEA. Ultimately this decision would cause repeated tension over almost four decades between the UKAEA, the government, and the electricity industry over the scale of the various nuclear programmes and the perennially thorny question of reactor choice (see chapter 2). In the 1970s this would have consequences for the development of renewable energy as the CEGB operated largely outside of the official government programme. In 1957, following a report by the Herbert Commission, the UK electricity supply industry was restructured as the supply constraints began to ease. At this point the new authority - the Central Electricity Generating Board (CEGB) - controlled a vast industry with net assets of £1000m employing 53,000 people; this included 262 power stations and the 6000 miles of the National Grid. The electricity Boards were selling more than half a million appliances annually, as the dominance of electricity for lighting was extended to space heating also. Massive investment in distribution and connection continued as the Grid was upgraded through the 1950s.[55]

The reorganisation of the electricity industry coincided with the first major postwar energy crisis in the UK - the Suez crisis - and this period provides a useful insight into British attitudes to the future of inputs for electricity generation during the period. [56] The events surrounding the nationalisation of the Suez Canal and the subsequent disruption to

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[53] TNA, FG 5/330, CEGB, England, G., 'Power in the Wind', A talk to the British Wind Energy Association at their annual conference at Cranfield, Bedfordshire, 9 April 1981
[54] Hannah, *Engineers,* p. 170
[55] Hannah, *Engineers,* pp. 102 -103
[56] Chick, *Electricity*, p.21.

world oil supplies prompted what Chick and others have suggested was an over-reaction by the UK government in a massive expansion of the proposed nuclear programme.[57] This has to be seen in the context of a planned shift within the UK energy mix from coal to oil. The minutes of a meeting of the Cabinet in February 1957 summarised the situation as it appeared at the time.

> *The Minister of Power* said that, if we were to keep pace with a demand for electricity which was increasing at a rate of 7 per cent per annum, the total electricity output capacity installed by 1970 would need to be of the order of 51,000 MW. There was no prospect that supplies of coal would match an acceleration of demand at this rate, and since it would clearly be unwise, from every point of view, to rely too heavily on oil-burning plant, a considerable expansion of the existing nuclear power programme was indicated.[58]

Chick points to the 'large psychological impact on the geopolitical mindset of politicians' that this (and the later Tapline crisis in 1967) had. Accordingly, in 1957 the new Prime Minister Harold Macmillan ordered a trebling of the nuclear programme from 1,500 - 2000MW to 6000MW. National energy security dominated the fuel choices of the UK government, and by implication the CEGB, as nuclear energy moved to represent the key long-term fuel choice for the UK as the Government sought to 'liberate' themselves from oil 'to the fullest possible extent'.[59] In this way the pattern of fuel choice was set for electricity generation in the UK for decades to come. Despite the CEGB's attempts to introduce a gradual switch-over to oil-burning power stations (or dual-fire, coal and oil plants) the government imposed protectionist fuel tariffs that would force it to continue to build coal-fired power plant and to burn coal. The government recognised the coal industry's reliance on the CEGB, and as Ashworth put it 'There was thus erected a very special market relationship between the coal industry and the electricity supply industry'. [60]In addition, the dramatic up-scaling of the nuclear programme in 1957 (much against the wishes of the CEGB) would also constrain the Board's future fuel choices.

Although coal, and to some extent oil, would continue to account for the vast majority of electricity generation through to the 1970s and beyond, nuclear power came to dominate energy thinking in the UK to a disproportionate degree. In 1964 coal accounted

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[57] Ibid. p.23; Williams, *Decisions*

[58] TNA, CAB 128/31, C.C.(57), 14th Conclusions, Conclusions of a Meeting of the Cabinet held at Downing Street, S.W. 1, on Thursday, 28th February, 1957, at 10.30 a.m., p.4

[59] Chick, *Electricity*, p.23

[60] Ashworth, *Coal*, p.43

for 88% of electricity generation, and oil was 11%. The new chairman of the CEGB after 1957 was Lord Hinton who had come to the Board from the UKAEA. This was the beginning of a close relationship between the two organisations, and during the period on which this thesis focuses, Walter Marshall moved from the UKAEA to assume control of the CEGB. Again, this was a somewhat unrepresentative arrangement and a similar pattern of related appointments did not take place with the NCB. Vast amounts of government money were invested by the UKAEA and the CEGB into nuclear R&D, and slowly in the latter part of the 1960s it began to make some contribution to electricity generation, though this remained a small percentage of overall energy consumption.

This section has shown how unshakeable faith in the nuclear future shaped the development of electricity generation in the UK from the 1950s. This grew from a delight in the new technology in the immediate postwar years to an issue of national energy security from the time of Suez. Awareness that coal could not meet the rising demand of electricity consumption coupled with unwillingness to depend on foreign oil supplies compelled the government and the CEGB to rely on coal-burning and focus on a nuclear energy future. In this period renewable energy made little progress in the UK other than the isolated attempt by the CEGB to experiment with wind energy on the Lleyn Peninsula in Wales during the 1950s.[61] As usual, the only exception to this was the continued and growing contribution of hydroelectricity. It would not be until after the first oil crisis of 1973 that national governments across the developed world would turn some of their attention to the ‘alternative’ energy sources.

Conclusions

This chapter has sought to set the scene for the main focus of this thesis - the development of renewable energy technology in the UK after 1973. In this regard it has been necessary to examine two key issues that influenced the period 1974-88. The first issue that this chapter examined is the development of electricity in the UK, from the late nineteenth century and through the twentieth century. This has served to emphasise the gradual development of a national electricity distribution system based on large, centrally-located, fossil-fuelled power stations, which, by the 1970s, would prove to be a massive barrier to the introduction of renewable sources of energy. This also emphasised the disproportionate

[61] TNA, FG 5/330, CEGB, England, G., ‘Power in the Wind’, A talk to the British Wind Energy Association at their annual conference at Cranfield, Bedfordshire, 9 April 1981

attention given to the nuclear industry during this period – and the distorting effect that this had on the mindset of politicians. The second issue discussed was the increase in energy consumption during the post-war golden age and the attendant shift in the patterns of that consumption. In primary energy, the move away from coal and towards oil was reflected throughout the developed world, as was the attempts to develop nuclear energy.

Chapter 2
Energy and Environmentalism into the 1970s

In Chapter 1 the development of electricity and the growth in energy consumption in the UK is marked by a sense of continuity. Coinciding with the post-war 'golden age' of economic growth and prosperity energy supply grew to meet increasing demand for electricity along a largely uninterrupted path of development within the National Grid. But by the beginning of the 1970s this pattern was beginning to unravel. In the UK, exogenous shocks - most significantly for this thesis the 1973 oil crisis combined with a long list of internal socio-economic factors to create a new set of imperatives for energy in the UK. For energy these internal factors included political upheaval, repeated industrial unrest in the coal industry, the discovery of North Sea oil and gas, decisions over the choice of reactor for the new nuclear programme, and the emergence of the 'new environmentalism'.[1] This chapter will set the context for the remainder of this thesis through a brief examination and evaluation of how these individual factors combined to create the conditions for the creation of the UK renewable energy programme after 1974, with a particular focus on the crucial impact of the new environmentalism.

Although subsequent chapters will show that renewable energy was subsequently judged within a dominant and rigid energy paradigm in the UK, this thesis argues that increasing social pressure from the new environmentalism in the UK was an important factor in explaining the creation of a UK renewable energy programme. Moreover it is also clear that much of the motivation for many of the developers within, and outwith, the programme was founded on environmental concern. Recent work by Sine and Lee has explored the effect of social/environmental movements on the creation of new industries (mainly in renewable energy).[2] They produce compelling evidence that wind energy development in the United States was legitimised and advanced through environmentally-

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[1] Brookes, S. K., et al, 'The Growth of the Environment as a Political Issue in Britain', *British Journal of Political Science,* Vol. 6, No. 2, (Apr., 1976) p. 253. The authors describe the growth in environmental interest and the expanding range of issues included within this area in the UK as the 'new environmentalism'. I will adopt this term both as a useful phrase for identifying those groups and individuals that arose during this period and as a way of signifying the unique nature of the movement in the period.

[2] Sine, W. D. and Lee, B. H., 'Tilting at Windmills? The Environmental Movement and the Emergence of the U.S. Wind Energy Sector', Administrative Science Quarterly, 54, 2009. pp. 123-55

focused social pressure groups acting as 'disrupters of institutionalised arrangements'.[3] I suggest that a similar process took place in the UK, particularly for wave and wind power. The broad coalition of interest groups that formed the new environmental movement in the UK was the only social grouping that demonstrated any interest in energy matters during the period and through newly-formed organised campaigning groups such as Friends of the Earth UK (FoE UK), Greenpeace and the Socialist Environment and Resources Association (SERA) it exerted telling social pressure on government.[4]

This period was prior to any widespread awareness of the effects of carbon emissions and climate change, and as will be seen this concern was focused on an opposition to nuclear power, industrial pollution, and the depletion of fossil fuels. This chapter will use a brief case study of the coverage given to energy by the most influential environmental publication of the period, *The Ecologist* magazine, and will also consider the related emergence of the Alternative Technology movement in the UK. This will give a flavour of environmentalists' views on energy in the UK and will show how these views had an influence on the development of renewable energy after 1974.

UK energy in the seventies

At the end of October 1973, the Golden Age, which had limped on through a declining world economy finally collapsed.[5] In 1971 the end of the post-war Bretton Woods agreement of fixed exchange rates had seemed to confirm that the world was entering a new and less certain era.[6] It has now become the customary historical periodisation to end the Golden Age in 1973 as the first oil crisis of the 1970s hit.[7] This had had the effect of creating an intuitive causative link between much of the turmoil of the 1970s to the decision by the Organisation of Petroleum Exporting Countries (OPEC) to raise the price of crude oil. Whilst there were undoubtedly other factors to blame for the general economic decline (particularly since many of the problems pre-date the oil crisis) it is right

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[3] Sine and Lee, 'Tilting', p.124

[4] Rootes, C., 'Environmental Movements: From the local to the global' *Environmental Politics*, 8:1 (1999) p.1. The author states that, 'Of all the new social movements which emerged from the student movements of the late 1960s, it is the environmental movements which have had the most enduring influence on politics…'

[5] Armstrong, P., Glyn, A., and Harrison, J., *Capitalism since 1945* (Oxford: Basil Blackwell, 1991) p.221

[6] Cairncross, A., *Economic Ideas and Government Policy* (London: Routledge, 1996) p. 142

[7] Agreement on the definition of this period as a period of exceptionally high growth in the West is universal. Some diverse examples include; Crafts, 'The golden age'; Crafts and Toniolo, 'Postwar growth', p. 3; Howlett, P., 'The 'Golden Age', 1955-1973' in P. Johnson (ed.) *20th Century Britain: Economic, Social and Cultural Change* (Harlow: Longman, 1994); Hobsbawm, E., *Age of Extremes: The Short Twentieth Century, 1914-1991* (London: Abacus, 1994)

to conclude that the oil crisis heightened awareness of energy issues in general.[8] However, 'energy' as an issue had already begun to creep up the political agenda in Britain and elsewhere. Although I will show that the growth in new environmentalism accounts for much of this heightened awareness, it was also in some part due to the upward spiral of wages and prices and the government's controversial and complex *Industrial Relations Act* which provoked confrontation with the unions.[9] Strike action by miners in 1972, targeting power stations, resulted in power cuts that both emphasised to consumers an overwhelming reliance on energy and highlighted its vulnerability.

By 1970 oil had overtaken coal as the main source of fuel in the UK accounting for nearly 48 per cent of primary energy consumption against just over 44 per cent for coal. Natural gas had risen from 0.7 million tons of oil equivalent (Mtoe) in 1965 to 10.2 Mtoe in 1970 and now made up nearly 5 percent of energy consumption.[10] This was due mainly to the discovery of oil in the North Sea in the 1960s.[11] Nuclear power had also grown, to nearly 3 per cent of primary energy consumption, as the reactors of the UK's second nuclear programme went critical. In twenty years, from a time when British coal supplied over 90 per cent of fuel needs, Britain had become overwhelmingly dependent on imports for its energy needs. By 1970 imports constituted 107.4 per cent of primary energy consumption in the UK.[12] In the era of cheap energy this was seen as little problem, but as the economic climate began to worsen in the early 1970s this sanguine outlook changed. Energy consumption in Britain, which had grown by over 10 per cent since 1965, began to stagnate as Table 2.1 illustrates. Between 1970 and 1971 coal consumption dropped by nearly 11 Mtoe, a gap that was filled mostly by natural gas from the North Sea.

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[8] Cairncross, *Ideas,* p.143. Cairncross wrote that that the years 1970-3 'provided much of the tinder for the later blaze'. See also Armstrong *et al, Capitalism*, p.223, 226.
[9] Wrigley, C., *British Trade Unions Since 1933* (Cambridge: Cambridge University Press, 2002) p.70
[10] BP, *Statistical Review of World Energy 2007,* http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2007/STAGING/local_assets/downloads/spreadsheets/statistical_review_full_report_workbook_2007.xls [accessed 20 June 2007]
[11] Oil from the North Sea would not begin to flow until 1975.
[12] Chick, *Electricity,* p.4. This contrasts with the US where imports totalled just 13.15 per cent. In further contrast, imports of primary energy in France totalled 295.7 per cent in 1970.

Table 2.1

UK Primary Energy Consumption, 1965-1975 (Mtoe)

	1965	1970	1971	1972	1973	1974	1975
Oil	74.2	103.6	104.3	110.5	113.2	105.3	92.0
Coal	117.4	96.0	85.1	74.5	80.7	71.1	71.5
Natural Gas	0.7	10.2	16.4	23.3	25.2	30.1	31.6
Nuclear	3.4	5.9	6.2	6.6	6.3	7.6	8.2
Hydro	1.1	1.3	1.0	1.0	1.0	1.1	1.1
Total consumption	**196.8**	**216.9**	**213.0**	**216.0**	**226.5**	**215.1**	**203.1**

Source: BP, *Statistical Review of World Energy 2007,* http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2007/STAGING/local_assets/downloads/spreadsheets/statistical_review_full_report_workbook_2007.xls [accessed 20 June 2007]

A detailed analysis of the economic turmoil in the 1970s lie outwith the scope of this thesis but some sense of the scale and impact of high inflation and high unemployment is essential. Table 2.2 summarises two of the key economic indicators, inflation and unemployment, which when considered together offer evidence of the precarious position of the UK economy in the first part of the 1970s. It is clear that even before the inflation increases caused by the rise in oil prices after 1973 that the Golden Age was rapidly grinding to a halt.

Table 2.2

UK inflation and unemployment, 1970-1975 (annual rate)

	1970	1971	1972	1973	1974	1975
Inflation rate	7.2	9.3	8.5	7.0	15.0	27.2
Unemployment rate*	17.6	15.9	20.4	26.9	21.6	13.7

* Long term – defined as in excess of 12 months
Sources: Schulze, M., and Woodward, N., 'The emergence of rapid inflation' in Coopey, R., and Woodward, N., (eds.) *Britain in the 1970s: The Troubled Economy* (New York: St. Martin's Press, 1996); Woodward, N., 'The retreat from full employment' in Coopey, R., and Woodward, N., (eds.) *Britain in the 1970s: The Troubled Economy* (New York: St. Martin's Press, 1996)

The oil price shock

On October 16 1973, ten days after the outbreak of the fourth Arab-Israeli war, the members of OPEC met in Kuwait. The Yom Kippur War was to have the most far-reaching consequences of any of the previous conflicts coinciding as it did with the increasing shift in power away from the oil companies and towards the oil-producing Arab States.[13] OPEC was keen to flex its muscles and punish the West (though mainly the United States) for the support it was giving Israel in the conflict. At the meeting Iran pushed for an immediate hike in the price of crude oil and the other members agreed. The increase agreed was 70 percent on the posted price, taking the cost per barrel from $2.90 in mid-1973 to $5.12.[14] The next day the members of OAPEC (Organisation of Arab Petroleum Exporting Countries) decided to increase the impact of the price increase by simultaneously reducing production by 5 percent a month, and applying an embargo on selected countries that were seen to be offering significant support to Israel. In theory these measures were to apply until Israel returned behind its pre-1967 borders. In December OPEC met again and once again prompted by Iran the price was raised to $11.65. This then constituted a four-fold increase in the price of crude oil over a matter of months.[15] Just as James Akins and others had predicted earlier, it seemed that this time the 'Wolf' had most definitely arrived.[16]

By early November 1973 the government had drawn up contingency plans for petrol rationing following an 18 per cent drop in the amount of Arab oil reaching the world's market.[17] They also urged motorists to comply with a voluntary 50 mph speed restriction. Petrol rationing was not introduced officially though many retailers imposed their own systems in order to conserve stocks.[18] In January the government announced the creation of a new Department of Energy (DoEn) under Lord Carrington.[19] The concerns over oil prices were overtaken in February 1974 by political events in the UK, as Heath once again facing down the mineworkers asked the country with palpable exasperation, 'Who Governs Britain?'[20] The resulting defeat for the Tories provided the answer. The new Labour Energy Minister, Eric Varley, announced in March 1974 that the energy restrictions that had been placed on industry were to be lifted.[21] Despite large increases in the cost of energy to the final consumer in 1974 (see Chart 2.1) the interruption to supplies

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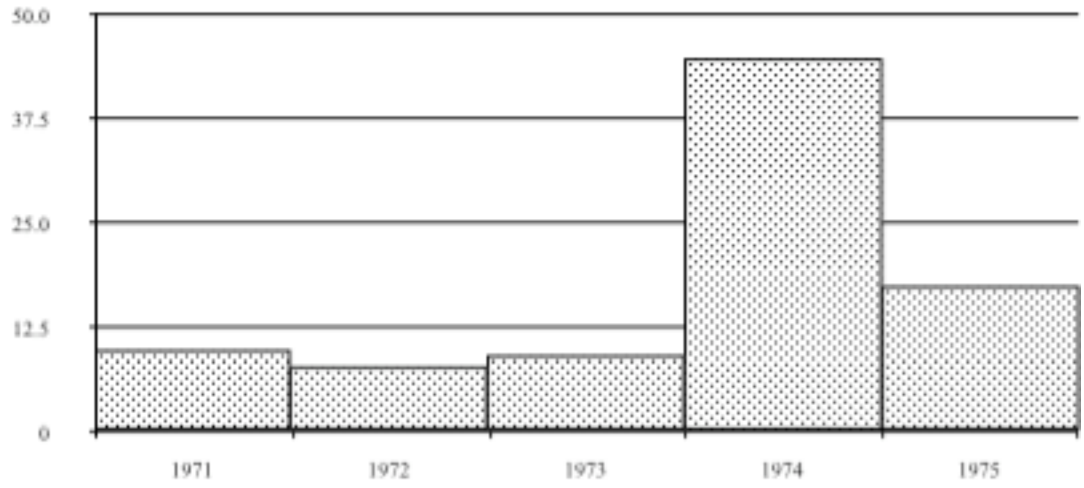
[13] Yergin, D., *The Prize: The Epic Quest for Oil, Money & Power* (London: Free Press, 1991) pp. 563-587
[14] Yergin, *The Prize,* p.625; de Montbrial, T., *Energy: the countdown,* A Report for The Club of Rome (Oxford, Pergamon Press, 1979)
[15] Yergin, *The Prize,* p.625
[16] Akins, J., 'The Oil Crisis: This Time the Wolf is Here' *Foreign Affairs* 51 (April 1973) pp. 467-490
[17] *The Times,* 'Deepening world oil crisis compels action in America and Europe', 3 November 1973, p.1
[18] Waymark, P., 'Big fuel savings under 50 mph plan', *The Times,* 20 November 1973. p.1
[19] *New Scientist,* Editorial 'Tasks for Lord Carrington' 61 (17 January 1974)
[20] Fraser,, W. H., *A History of British Trade Unionism, 1700-1998* (Basingstoke: Macmillan, 1999) p. 229
[21] *The Times,* 'Curbs on power and heavy fuel oils to go but minister urges continuing economy', 22 March 1974. p. 19

proved to be a temporary phenomenon. Varley, who was closely associated with coal mining, (he was sponsored by the National Union of Mineworkers)[22] was now faced with the 'impossible nuclear decision'.[23]

Chart 2.1

Per capita expenditure on energy by final consumers, 1970-75 (annual percentage increase)



Source: abstracted from, DTI/DoEn, Digest of Energy Statistics, 1971-76

Nuclear energy: the CEGB reactor decision

The day before OPEC met in Kuwait, the *Guardian* carried a story on its front page by its energy correspondent, Peter Rodgers. Rodgers wrote that the CEGB was planning to abandon the British Advanced Gas-Cooled Reactor (AGR) and import the controversial American Light Water Reactor (LWR) for its future programme of reactor development.[24] This 'calculated leak'[25] was a complete reversal of its earlier position, which had rejected the American reactor on economic and safety grounds; although Arthur Hawkins, chairman of the CEGB, had earlier expressed disappointment in the AGR in terms of cost and construction difficulty. [26] The appearance of the story caused an immediate reaction.[27] During the 1960s the nuclear industry and the government had carried on a lengthy debate barely reported by the press and largely ignored by the public about the choice of reactor

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22 *New Scientist,* 'The new Energy Minister' 61 (14 March 1974) p.705
23 Stephenson, H., 'The impossible nuclear decision', *The Times,* 6 May 1974, p.19
24 *The Guardian,* 15 October 1973.
25 *New Scientist,* Editorial, 'Which reactor?' 60 (6 December 1973
26 Williams, *Decisions,* p.201, 207
27 *The Economist,* 'Buying American' 27 October 1973. p.96

for Britain's second nuclear programme. The debate had split broadly between those that favoured the British designed AGRs and those that wanted to import the newer US designed LWR. The arguments ebbed and flowed over several years in the 1960s before the government arrived at a decision to support the British designed reactor. This design of reactor and the extent of the programme to build them was then more or less set for the coming years. Earlier, in August 1972, Hawkins had appeared before a government committee and summarised the Board's future requirements.

> If we take 3 ½ per cent annum growth – which, as I remind you, is a little higher than the average over the last three to four years – we should only require 19,500 megawatts of additional plant, of which 15,500 have already been committed. Therefore we would only require 4,000 megawatts more plant. That would mean in this period for commissioning until after 1980 only three new station starts, of which one would probably be nuclear - and probably the fast breeder. [28]

A range of concerns about the LWR had surfaced during the 1960s that remained unresolved in the 1970s, not least of which was safety. Therefore the British nuclear programme had avoided consideration of the US designed LWR built by Westinghouse in favour of British designed reactors. It was a shock, therefore, when Rodgers uncovered news of this complete change of heart at the CEGB and this was exacerbated by the OPEC announcement that followed within days. Therefore an issue that may have otherwise drifted down into the 'private' political realm from whence it had emerged became 'topical and controversial' and was thrust onto the front pages.[29] The oil crisis had transformed energy into a hot political topic and the decision by the CEGB was its first unwilling target.

The Select Committee on Science and Technology (SCST), since its creation by the 'white heat' Labour government in December 1966, had conducted several enquiries into the nuclear industry by 1973.[30] Having only just produced a lengthy report in June 1973 titled *Nuclear Power Policy* it was now concerned by reports of the change of heart by the CEGB over the choice of reactor, and by December 1973 it had set up an official enquiry. When Arthur Hawkins appeared in front of the committee he added to their concerns by announcing that contrary to his earlier forecast of perhaps only one new nuclear plant

[28] Patterson, W., *Going Critical,* (London: Paladin Books, 1985) p.28
[29] Kerr, M., 'The cloudy issue of reactor choice' *New Scientist,* 61 (7 February 1974) p.314
[30] Williams, *Decisions,* p.31

being required up to 1980, he now estimated that nine nuclear power plants would be required in the period 1974-79 and a further nine in the period 1980-83. He based this on a growth in electricity demand of 4¾ per cent per annum up to 1980 and 5¼ per cent thereafter; a drastic revision of his forecast in August 1972 of a 3½ per cent increase.[31] Hawkins insisted that this was not a knee-jerk reaction to the oil crisis and instead explained that it was simply the right time to act in light of a projected deterioration in coal and oil supplies. Indeed he was adamant that the plans had been devised before the oil price rise as he claimed the subtle distinction that this was not a 'panic' measure, but a 'crash' programme.[32]

The problems with the AGR reactor were well known by this time. Britain's second nuclear programme was launched in 1964 (and increased in 1965 by the Wilson government) to build four new nuclear plants with a capacity of 8,000MW (see table 2.3). By 1966 building had started on the first reactor, yet at the end of 1973 none of these plants had been completed.[33] Indeed the first plant begun in 1966 at Hinkley Point would not be operational until 1976. Costs, already increasing due to construction difficulties, had been further exacerbated by high inflation in the 1970s. Therefore the decision of the CEGB to abandon the AGR was not wholly surprising. What was shocking to many was that it favoured the import of American technology as an alternative. *The Economist* saw a clear connection between the CEGB's decision and the oil crisis and called the 'crash' programme 'just plain silly'. They argued that there was no need for such a programme given the imminent flow of oil from the North Sea.[34] After lengthy enquiries into the choice of reactor and the extent of the new programme the government finally made an announcement in July 1974. Eric Varley stated that there was to be a programme of no more than 4,000MW of capacity over four years and the chosen reactor was to be the British SGHWR.

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[31] Ibid. p.33
[32] Patterson, *Critical,* p.33
[33] *The Economist,* 'Why they forgot about nuclear power' 12 January 1974, p.74
[34] *The Economist,* 'Buying American' 27 October 1973. p.96

Table 2.3

Nuclear Programmes: Britain 1953-78

Programme	Year	Capacity (GW)	Proposed completion date
I	1955	1.5 - 2	10 years
Ia	1957	5-6	1965
Ib	1957	5-6	1966
Ic	1960	5	1968
II	1964	5	1975
IIa	1965	8	1975
III	1974	4	1978
IIIa	1978		1980s
Iv	1979	15	1982-91

Source: Williams, *Decisions*

Coal

The crises in oil and nuclear were set amidst continued turmoil in the coal industry in the period at the end of 1973. The numbers of miners employed by the National Coal Board (NCB) had fallen from around 700,000 in 1957 to about 300,000 in 1970 and through the 1960s miners had looked on with bewilderment as their wages declined relative to other industrial workers.[35] This disquiet combined with rapid price inflation in the early 1970s resulted in a national strike in January 1972 that threatened to cripple supplies to Britain's power stations. The Conservative government caved in after a very short time and awarded the miners record pay rises. However by late in 1973 rising inflation and insecurity were once again urging the miners towards industrial action. The oil crisis helped to exacerbate a further crisis as it created a strong bargaining position for mineworkers during the period. By early February 1974 the NUM had called a national strike and the government was forced to call a state of emergency and quickly introduced a three-day week.

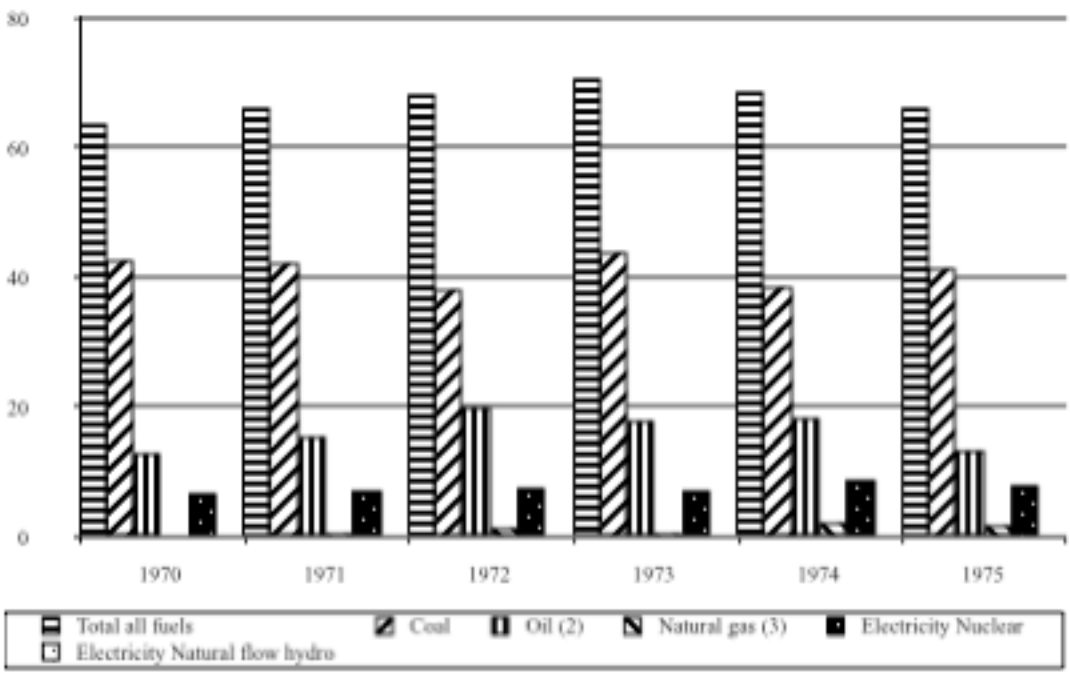
In this period coal remained the major source of power for Britain's electricity generation (see Chart 2.2) but came to be largely overlooked in the ensuing debate which focused on oil and nuclear. From 1970 oil had begun to replace coal in electricity generation, whilst nuclear remained largely static due to problems in getting its new reactors operational. Despite this fact the ensuing energy debate did not include a great

[35] D. Lyddon and R. Darlington, *Glorious Summer. Class Struggle in Britain in 1972* (London, 2001) p. 31

deal of discussion about coal as a viable fuel for the future. Long before fossil fuels were to become identified as the primary cause of global warming, the economic costs of coal burning were forcing it down the UK energy mix.

Chart 2.2

Fuel input for electricity generation, 1970-75 (Mtoe)



Source: Department for Business, Enterprise and Regulatory Reform,
http://stats.berr.gov.uk/energystats/dukes5_1_1.xls

The 'new environmentalism'

A brief survey of the history of the development of renewable energy technology prior to 1973, as recounted in Chapter 1, appears a rather inevitable tale of technological progress, such as Winner described as being 'governed by a powerful, stultifying orthodoxy'.[36] Feenberg encapsulates the challenge for the historian in this in this comment,

> …once the black box is closed, its social origins are quickly forgotten. Looking back from that later standpoint, the artefact appears purely technical, even inevitable.[37]

It has now been well established that social processes are hugely important in the 'promotion, selection, and development' of new technologies.[38] Many scholars, among them Thomas P. Hughes, Nathan Rosenberg, Langdon Winner, and David Nye, have written extensively on the social aspects of technological development – and a number of these have also given specific consideration to the development of energy technologies. In Chapter 1, this social background to innovation and development in renewable technology was not explored. This failure is partly a result of the constraints of space and focus, and partly it is caused by the lack of an accurate record. Ultimately we are forced to speculate as to the reason why the wealthy American electrical entrepreneur Charles F. Brush spent so much time and money developing a wind turbine for his backyard in Cleveland, Ohio, at a time when coal (and wood) was cheap and plentiful (see Appendix I). The inventions of Brush, and many others, appear to spring spontaneously from their drawing boards, live a brief life, and then fade into obscurity. For the period beginning after the first oil price shock in 1973 we have the opportunity to present a very much more nuanced picture of technological development in renewable energy which in this research takes account of the social pressure exerted by the new environmentalism.

The search for the origins of environmental thought can extend far back into history.[39] The environmentalists of the 1960s and 70s included many strands that combined to present an often incongruous 'front' in what the more radical groups saw as

[36] Winner, 'Alternative Technology', p. 75
[37] Feenberg, A., *Questioning Technology* (London: Routledge, 1999) p.11
[38] A. Smith, 'The Alternative Technology Movement: An Analysis of its Framing and Negotiation of Technological Development', *Human Ecology Review,* 12:2, (2005) p. 108; Sine and Lee, 'Tilting'
[39] Smout, T. C., *Nature Contested: Environmental History in Scotland and Northern England since 1600* (Edinburgh: Edinburgh University Press, 2000)

'the battle for the planet'. This section will explore the direct antecedents of the new British environmentalism of the early 1970s.

The Sixties – Planet Earth

In the 1960s the environmental debate became global for the first time. Sheail presents the view that the twentieth century is conventionally divided up by its two world wars but also perhaps by,

> ...a third staging point at the end of the Cold War, in 1989. But an environmental perspective, and a good deal of hindsight, might also bring to the fore the years leading up to 1970. As well as pictures of the oil-stricken Cornish beaches and wildlife, television and the press gave particular prominence to the thalidomide scandal….It was a time of marked disenchantment with science and technology, as developed through 'big business' and government. [40]

There was a range of factors that were all framed in, and accelerated by, the more radical mood of the decade. Criticism and rejection of the nuclear programme, which was begun in the 1950s both in Britain and the United States, became an important element of the growing 'counter culture'.[41] And all over the world people were also struck by the first images of the earth beamed back from the Apollo missions, which made the planet seem small and somewhat vulnerable.[42] In the US, landmark environmental publications punctuated social events like the Vietnam protests and the civil rights marches and environmental catastrophes like the *Torrey Canyon* in 1967, lending a more radical tone to the American movement.[43] The appearance of Rachel Carson's *Silent Spring* in 1962 is generally accepted as a key moment in the development of the new environmentalist movement that was to follow. [44] 'More than any other single document, it established the term and the idea "environment" in common usage'. [45]

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[40] Sheail, J., *An Environmental History of Twentieth-Century Britain* (Basingstoke: Palgrave, 2002) p.222

[41] Herring, H., *From Energy Dreams to Nuclear Nightmares: Lessons from the anti-nuclear power movement of the 1970s* (Charlbury: Jon Carpenter, 2005)

[42] Sheail, *Environmental History,* p. 257. 'That single image encompassed all animate life. Life itself appeared so fragile and finite'.

[43] Sheail, *Environmental History,* pp. 221-2. The author quotes the official report on the *Torrey Canyon* tragedy, which called it 'as unprecedented as it was sudden'.

[44] R. Carson, *Silent Spring* (London: Penguin, 2000) There is wide agreement about the seminal nature of *Silent Spring* among scholars. Some examples include; R. Garner, *Environmental,* p. 3; Lamb, *Promising;* pp. 23-25

[45] Lamb, *Promising,* p.23

One explanation for the enthusiastic reception that *Silent Spring* received may be found in a vague sense of unease that some environmental groups were beginning to voice over economic 'progress' – a feeling that also ran through the formation of the earliest preservation groups in the nineteenth century. In *Silent Spring* Carson's concern was the use of pesticides and the potential harm that these caused to humans and animals. Carson was herself a scientist and the thrust of her study was not 'anti-science' but rather a critique of the uncontrolled use of new technology and the collusion of the state, in the form of public officials, in covering up the potential harms of that technology. It was this theme that arguably caught the imagination of the public rather than a specific concern over DDT. In particular, this strong political theme contributed in igniting the radical imagination of young people in 1960s America and beyond and contributed to the growth of the new environmentalism.[46]

The post-war cultural influence of the United States was cast widely and extended into a reshaping the thrust of British environmentalism after 1970. The strength of anti-capitalistic rhetoric grew and became a feature of many influential environmental publications. As multinational business spread throughout the 1960s, particularly from the United States, and concern over the 'Third World' developed, there appeared to be a growing sense of discomfort with global inequality. More than twenty years after the end of the war the industrialised nations had recovered and made historic progress in raising the living standards of their populations. However, similar to the concerns over the 'population bomb',[47] the *rate* of this unprecedented economic growth began to worry many and Malthusian concerns were raised about how long this growth could be sustained. Disquiet over economic growth combined with concern over the environment was found in the work of several influential British economists writing in the period.[48] One of the earliest was from Barbara Ward, a former *Economist* contributor, who wrote *Spaceship Earth* in 1966. The book set out a very early version of the case for sustainable development.[49] Significantly, as an indication of the general mood of the period, the 'spaceship' analogy came from a speech that Adlai Stevenson had given to the UN in 1965 inspired by images of the earth as seen from space.

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[46] Roszak, T., *The Making of a Counter Culture: Reflections on the Technocratic Society and its Youthful Opposition,* (London: University of California Press, 1995)
[47] Ehrlich, P. R., *The Population Bomb* (Cutchogue, N.Y.: Buccaneer Books, 1971.)
[48] One clear example is Mishan, E. J., *The Costs of Economic Growth* (Harmondsworth: Penguin, 1969)
[49] Ward, B., *Spaceship Earth* (New York: Columbia University Press, 1966)

> We travel together, passengers on a little space-ship, dependent on its vulnerable supplies of air and soil; all committed for our safety on its security and peace, preserved from annihilation only by the care, the work, and I say the love, we give our fragile craft.[50]

Ward, who along with Rene Dubos was later to make a significant contribution to the landmark 1972 United Nations Conference on the Human Environment (UNCHE), was certainly not the first to view the planet as an interdependent system, but within the established British tradition of amenity and conservation, her prominence and influence allowed her to widen the traditional environmental debate in the UK to include wider, global issues.[51] Her analysis also formed an early example of some of the emerging differences between the US version of the debate and the British version. The central argument of *Spaceship Earth* was presented in careful, non-sensational language, which was echoed in much of the later British contributions. Her view of whole-world systems (made more famous later by James Lovelock and his Gaia hypothesis) became widespread as support for environmental issues gathered pace through the late 1960s.

The incongruence of industrial development and nature remained a central theme of environmentalism and created a clear, if indirect, link between the two. In the twentieth century, as the spread of industrial development slowed, the most tangible effect of industry remained in its polluting impacts. Air and water pollution began to concern environmental groups, and prompted the earliest environmental legislation. Arguably, this also had the effect of establishing a strong connection between energy and the environment, as the burning of fossils fuels, the production of town gas, and the expansion in transport grew into the issues of the later twentieth century. Concern about air and water pollution had been a feature of many urban philanthropic ventures since the nineteenth century but the direct relationship between energy and environmentalism was first seen in the 1950s when the National Smoke Abatement Society (NSAS) campaigned successfully for environmental legislation. The NSAS was formed in 1929 with aims made admirably clear by its name and had a diverse membership which included individuals, local authorities, and in an early example of energy tokenism, the National Coal Board (NCB).[52] Following the 'great London fog' of 1952, said to have been responsible for 4,000 deaths,

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[50] Quoted in J. Maddox, *The Doomsday Syndrome* (London: Macmillan, 1972) p.20
[51] Ward, B. and Dubos, R., *Only One Earth* (London: André Deutsch, 1972)
[52] Sanderson, J. B., 'The National Smoke Abatement Society and the Clean Air Act (1956)' in Kimber, R., and Richardson, J. J. (eds.), *Campaigning for the environment* (London: Routledge and Kegan Paul, 1974) pp. 27-43

the government set up an inquiry that resulted eventually in the Clean Air Act of 1956.[53] Although the target of this legislation was not the coal industry per se, the legislation created 'smokeless zones' and created further problems for coal in its battle with 'cleaner' oil as both domestic and industrial consumers were forced through legislation to re-evaluate their fuel choices.

The depletion of natural resources also developed into a central issue of 1960s environmentalism, which would find later expression in the landmark environmental publications of the early 1970s.[54] The argument was closely related to the Malthusian perspective on population and food, and posited that a growing population, which in the developed West was also growing richer and consuming more, would eventually run out of the earth's natural resources. Nobody could disagree over the finite nature of natural resources, and this made this 'common sense' element of the environmental position particularly compelling to the wider public. Concern over the depletion of fuel sources had a long history in Britain dating back to Jevons', *The Coal Question,* in 1856*,* which speculated over the 'probable exhaustion of our coal-mines'.[55] One hundred years later the American geologist, M. King Hubbert, would posit the same dilemma for oil.[56] The questions over the depletion of non-renewable resources were given greater prominence by the nuclear lobby that were keen to use the threat of a disappearing resource to 'sell' the benefits of new and bountiful energy supply. Supporters of nuclear power encouraged the growth in concern over the pollution emitted from oil and coal-fired power stations in a further effort to highlight the 'clean' efficiency of the 'alternative energy' of nuclear generation.[57]

By the end of the 1960s energy, though not yet a central theme of environmentalism had risen in prominence within the debate. It had entered through a variety of channels including warnings over air pollution, resource depletion, nuclear power, and energy security. However, environmentalists had little to offer in terms of

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[53] McCormick, *Environmental,* p. 9. The author refers to the Clean Air Act in 1956 as 'the world's first comprehensive air pollution control'.
[54] Among the most notable of these were; Meadows et al, *Limits*; Schumacher, E. F., *Small is Beautiful* (London: Harper Torchbooks, 1973) ; Goldsmith, *Blueprint*; Ehrlich, P. R., and Ehrlich, A. H., *Population, Resources, Environment* (San Francisco: W.H. Freeman, 1970)
[55] Jevons, W. S., *The coal question: an enquiry concerning the progress of the Nation, and the probable exhaustion of our coal-mines'* (London: Macmillan & Co, 1865)
[56] He predicted that oil production would peak by the early 1970s. M. K. Hubbert, 'Nuclear Energy and the Fossil Fuels' (1956) http://www.hubbertpeak.com/hubbert/1956/1956.pdf [accessed 12 August 2007]
57 Rocks, L., and Runyon, R. P., *The Energy Crisis* (New York: Crown Publishers, 1972)

alternatives at this time. The nuclear question, which by this time was nearly twenty years old, produced contradictory and largely unscientific responses from environmental groups. However, as 1970 introduced the new environmentalism to Britain the question of energy was to become more central to environmental identity.

Into the Seventies – Limits to Growth?

Table 2.4

Membership of environmental groups

UK Groups	**1970**	**1971**	**1975**	**1980**
Greenpeace	-	-	-	10000
Friends of the Earth	-	1000	5,000[a]	12000
World Wildlife Fund	-	12000	-	51000
Ramblers Assoc.	-	22000	-	36000
National Trust	226000	278000	500000	950000
RSPB	38,000[b]	98000		321000
RSNC		64000		140000
CPRE		21000		27000
US Groups				
Sierra Club	113000	-	147000	182000
Environmental Defense Fund	11000	-	37000	46000
Environmental Action	3500	-	-	21000

a-1976; b- 1967 CPRE – Campaign to Protect Rural England; RSNC – Royal Society for Nature Conservation: RSPB – Royal Society for the Protection of Birds

Sources: Bosso, C. J., 'Rethinking the Concept of Membership in Nature Advocacy Organizations', *Policy Studies Journal,* Vol. 31 (2003) p.400, table 2; Connelly & Smith, *Politics,* p.69, table 3.1; Garner, *Environmental,* p.23, table 7.1; Robinson, *Greening,* p.45, table 1; Lowe & Goyder, *Environmental Groups,* p.133, table 7.2; McCormick, *British Politics,* p.33.

The period 1970-1973 was a good time to be an environmentalist in Britain. Events on both sides of the Atlantic such as *Earth Day 1970* in the United States[58] and *The Countryside in 1970* series (1963-70) in Britain signified the increasing interest in environmental problems. Growing political recognition of environmental issues was also evident with the establishment in Britain of the Department of the Environment (DoE) in

[58] Earth Day Network, 'History of Earth Day', http://www.earthday.net/resources/history.aspx [accessed 12 June 2007]; Sills, D. L., 'The Environmental Movement and Its Critics', *Human Ecology,* Vol. 3, No. 1, 1975, p.5. The author describes this event as a 'massive outpouring of rhetoric and symbolic activity'.

1970, four years before the Department of Energy (DoEn) would be created.[59] This period also saw the formation of influential environmental campaigning groups such as Friends of the Earth in the UK (FoE UK) and a little later, Greenpeace.[60] According to a range of views the new environmental movement reached an initial peak in 1972,[61] culminating in the United Nations Conference on the Human Environment (UNCHE), which took place in Stockholm during the summer of 1972.[62] Though Table 2.4 shows that membership continued to grow through the 1970s. The Stockholm Conference gave international recognition to environmental problems and lent further credibility to the views of the new environmental movement. Furthermore it allowed the many grassroots activists who attended the conference, direct access to influential political figures.[63]

Coinciding with the Stockholm Conference was the appearance of the groundbreaking environmental text *The Limits to Growth* (LTG), which has been called 'the foundation-stone of Green political thinking'.[64] Sponsored by The Club of Rome and produced by a team of scientists at MIT, LTG is perhaps the most famous of all environmental texts, despite competing with many other such publications in the period.[65] It has attracted many critical responses since its publication in 1972 and its impact has been exhaustively charted.[66] Based on complex (for the time) computer models, its 'eco-doom' conclusions called for immediate action and set the tone for Stockholm and after.

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[59] The Conservative Government established the Department of the Environment in Britain in 1970. This was the first such department among any of the industrialised nations.
[60] Lamb, *Promising* ; Bohlen, J., *Making Waves: The Origins and Future of Greenpeace* (London: Black Rose Books, 2001); Wilson, D., (ed.) *The Environmental Crisis: A Handbook for all Friends of the Earth* (London: Heinemann, 1984); Weyler, R., Greenpeace: *How A Group of Ecologists, Journalists and Visionaries Changed the World* (London: Rodale Press, 2004)
[61] Sills, 'Movement'; M. Allaby, interview with author, 24 July 2007; J. Elkington, interview with author, 3 August 2007.
[62] Ward and Dubos, *Only One Earth.* This volume provides a report of the proceedings.
[63] Interview, M. Allaby, 24 July 2007
[64] Dobson, A., (ed.), *The Green Reader* (London: Andre Deutsch, 1991) p.13
[65] Sills, 'Movement', p.1. The author states that 'some 300 books on the environment, on ecology, and on pollution were published in the United States in 1972 alone'.
[66] Meadows et al, *Limits;* D. Meadows et al, *The Limits to Growth: The 30-Year Update* (London: Earthscan, 2005). Some of the responses include, Beckerman, W., *In Defence of Economic Growth* (London: Jonathan Cape, 1974); University of Sussex. Science Policy Research Unit, *Thinking about the Future: A Critique of The Limits to Growth,* H. S. D. Cole, et al (eds.), (London: Chatto & Windus, 1973); Sandbach, F., 'The Rise and Fall of the Limits to Growth debate' *Social Studies of Science,* Vol. 8, No. 4, (Nov., 1978) pp. 495-520; Galtung, J., ''The Limits to Growth' and Class Politics' *Journal of Peace Research,* Vol. 10, No. 1/2. (1973) pp. 101-114; Kaysen, C., 'The Computer that printed out W*O*L*F*' *Foreign Affairs,* 50:4 (1972: July); Golub, R., and Townsend, J., 'Malthus, Multinationals and the Club of Rome', *Social Studies of Science,* Vol. 7, No. 2, Theme Issue: Citation Studies of Scientific Specialities. (May, 1977), pp. 201-222; Schoijet, M., '*Limits to Growth* and the rise of Catastrophism', *Environmental History,* Vol.4, Part. 4 (1999) pp. 515-30

In Britain, the new environmental movement was served by the appearance of several important magazines, as well as growing support from existing, well-respected publications such as *New Scientist.* The first of these, *Resurgence,* appeared in 1966 and was the creation of John Papworth who had been involved with CND and other pacifist groups since the 1950s. It was (and remains) an eclectic mix of pacifism, anarchy, and poetry, which soon began to reflect the growth of new environmentalism in Britain. By the late 1960s articles by influential figures such as Fritz Schumacher were appearing, as the magazine began to consider in more depth the issues around nuclear power. The growing awareness of environmental issues is reflected in the appearance by 1970 of two magazines explicitly devoted to environmental issues –*Your Environment,* which appeared first in December 1969, and *The Ecologist* in July 1970. A small group that included the poet Ted Hughes started *Your Environment*. Although it was an exceedingly modest operation the magazine included contributions from key figures in the environmental movement, including the nuclear physicist Walt Patterson (later of FoE UK), who was heavily involved with the magazine from 1970.[67] *The Ecologist,* although beaten to publication by *Your Environment* by a few months, arguably made a more telling and lasting contribution to new environmentalism in the Britain in the early part of the decade, shaping much of the ensuing debate.

The Ecologist: 'tub-thumping for the environment' [68]

The coverage that *The Ecologist* devoted to energy-related matters fell into three broad categories; a) nuclear safety and waste, b) resource depletion, and c) alternative technology. The nuclear safety debate had widened in the 1960s, influenced by the publication of a range of titles in the United States, which reflected the growing polarisation of the debate.[69] The position of new environmentalism – and *The Ecologist* - was clear in its firm opposition to civil nuclear *fission* power on the familiar grounds of safety, but also increasingly on the issue of waste disposal also. Concern about these issues grew and the announcements such as the plans to build nuclear power stations at Fessenheim in the Alsace region caused some reaction in Britain.[70] However, the number of articles declined as the arguments lined up against nuclear energy arguably became

[67] Interview, W. Patterson, 2 August 2007.
[68] Interview, J. Elkington, 3 August 2007.
[69] Interview, W. Patterson, 2 August 2007. Walt Patterson mentions two books in particular that heightened awareness of nuclear safety issues. Novick, S., *The Careless Atom* (Boston: Houghton Mifflin Company, 1969) and Curtis, R., and Hogan, E., *Perils of the Peaceful Atom: The Myth of Safe Nuclear Power Plants* (New York: Doubleday & Company, 1969)
[70] Bunyard, P., 'Fessenheim – Easter Monday' *The Ecologist* 1:12 (June 1971)

repetitive and, perhaps, ineffective. Britain's nuclear programme had stuttered to a halt due to delays in completing AGR reactors and therefore it provided little ammunition to environmentalists. The main difficulty for *The Ecologist* in its opposition to nuclear energy in the period was its simultaneous acceptance of the realistic potential of nuclear *fusion*. As later editorials made clear, the magazine 'concedes the possibility of unlimited energy'.[71] Indeed Peter Bunyard wrote,

> In theory there is unlimited energy in the world. All man has to do is to build breeder reactors and to achieve thermo-nuclear fusion on a commercial scale.[72]

This view created a clear dilemma for the magazine and may explain partly why it chose to largely avoid the topic of nuclear energy in its editorials. This concession also had an impact on the magazine's coverage of depletion issues, particularly the specific concern about the depletion of fossil fuels, which was largely absent from the pages of the magazine in favour of a focus on the more general depletion of 'natural resources'. The March 1972 editorial provides a clear example of this, in which Robert Allen defended BFS from the stern attack by John Maddox, editor of the respected journal *Nature.*[73] After challenging Maddox's criticisms of the BFS view on population, Allen ponders the question of whether there are 'enough raw materials for 10 billion people, all consuming as much as we do today?' He immediately clarifies that 'he is not thinking of energy resources' before moving on to a discussion of metals.[74]

However, by 1973 increasing mentions of energy appeared in the editorial content of *The Ecologist.* This can be explained to some extent by presentational changes in the magazine as the single author editorial was (temporarily) abandoned and the wider interests of the editorial team were reflected more.[75] However, this increase in coverage is matched by a similar increase in the coverage of energy-related topics in the feature article section of the magazine. In this particular year, in the pre-oil crisis period, we see the magazine's first editorial devoted entirely to energy policy[76], two editorials with a

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[71] Allen, R., 'The sedulous ostrich', *The Ecologist,* 2:3 (March 1972)
[72] Bunyard, P., 'The Energy Crisis', *The Ecologist,* 3:5 (May 1973)
[73] Maddox, J., 'The Case against Hysteria', *Nature;* Maddox also contributed an article to *The Times* on the same subject, which also published a modified version of R. Allen's March 1972 editorial from *The Ecologist.*
[74] Allen, 'Ostrich'.
[75] Interview, M. Allaby, 24 July 2007.
[76] Bunyard, 'Crisis'.

significant contribution on energy policy[77], and two further editorials that contain several references to energy.[78] Peter Bunyard was the main contributor of this energy-related editorial material, as he was with the feature articles on energy in the period, and it was his editorial contribution in the March 1973 issue that raised the issue of energy policy for the first time in the magazine.

The short piece, entitled 'It's never too late to be a coalman', is a response to the government announcement of additional support for coal mining in February 1973.[79] Bunyard used the announcement to compare the merits of Britain's traditional fuel source with other sources, in particular oil and nuclear power. He suggested, perhaps rather presciently, that coal 'will be the only source of primary energy on which Britain will be able to rely with any degree of certainty by the turn of the century'. Bunyard justified his argument by pointing to the 'limited' resources of oil and natural gas in the North Sea and by describing the nuclear industry 'in chaos'. He went further in his criticism of British energy policy in the North Sea by suggesting that 'total costs of exploration, production and running costs over the next 10 years…are likely to run to a minimum of £2,500 million. The 25,000 new jobs anticipated by the North East of Scotland Development Association will need an investment of £10,000 each.'[80] This is an interesting departure for *The Ecologist* on two fronts. Firstly, it was the first appearance of a debate about a specific energy-related government policy, and secondly it was beginning to discuss the economics of energy.

The first editorial devoted entirely to energy policy appeared in the May issue of 1973 (3:5), written by Peter Bunyard titled 'The Energy Crisis'. Set against a background of 'crippling strikes taking place within a year of each other in the power stations, the coalmines and in the gas industry', which, he argued, give some idea of the impact of energy shortages in 'our industrial society', he offers a critique of the absence of energy planning in Britain. Although once again conceding the 'unlimited energy' available through nuclear power, this editorial offered a much more specific argument directed against the safety issues of nuclear reactors - in particular the American LWR. Bunyard

[77] Bunyard, P., ' It's never too late to be a coalman', *The Ecologist,* 3:3 (March 1973); Goldsmith, E., 'Growing market for military seizures', *The Ecologist,* 3:8 (August 1973)
[78] Goldsmith, E., 'What is the need?' *The Ecologist,* 3:1 (January 1973); Bunyard, P., 'Hunterston: the rape of Scotland?' *The Ecologist,* 3:10 (October 1973)
[79] Bunyard, P., ' It's never too late to be a coalman', *The Ecologist,* 3:3 (March 1973
[80] Bunyard, 'Coalman'.

was more positive about the safety of the 'gas-cooled, graphite moderated reactors used in Britain' but he emphasized the indecision of the British nuclear programme which he felt would fail to provide 'a viable alternative' in the face of rising prices among other fuels. In many ways this editorial predicted the conditions that prevailed following the oil crisis that was to arise five months later. It imagined a scenario of rising primary energy prices, and inadequate nuclear capacity set against the ever increasing demands of society and foresaw an 'economic depression'. Interestingly, Bunyard concluded the editorial with the suggestion that 'now is the time to seek alternatives which lead to reductions in energy use and yet which will not necessarily lead to any diminution in the so-called standard of living'.

The Ecologist included coverage of alternative technology, mainly focused on renewable energy technology, from its launch. In a series of regular columns under the titles 'Ecotechnics', 'Down to Earth', or 'Demo-Technology', articles would describe a range of initiatives in alternative technology. These ranged in content from the basic and practical to the highly technical and would often in accordance with the magazine's aims include a polemical element. The columns dealt with a range of issues, but were strongly focussed on energy-related technology. They advocated the development of wind turbines, solar power, and energy efficiency through small-scale developments that aligned with the growing Alternative Technology movement in Britain.[81] These articles serve to demonstrate the lack of technical progress in renewable energy in the post-war era. The more technical articles in *The Ecologist* on the development of active solar technology do not show much change since Frank Schuman's ambitious 1913 scheme in Egypt, and the features on wind turbines concentrate on the siting and installation of the existing decades-old designs. However, these regular columns in the magazine do appear to have provided a valuable tool for the dissemination of the existing technical information in the early 1970s, and encouraged a continued interest in renewable energy among the environmental movement.

In December 1973, the first issue of *The Ecologist* to appear after the oil crisis devoted its editorial to the situation under the heading 'The energy steeplechase'. With an

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[81] Some examples include, Hills, L. D.,'Down to Earth – The Wind is Free', *The Ecologist* 2:5 (May 1972); Hills, L. D., 'Down to Earth – Power without Glory', *The Ecologist* 2:8 (August 1972); McKillop, A., 'Demo-Technology – Heat pump heating' *The Ecologist* 3:6 (June 1973); McKillop, A., 'Demo-Technology – Living off the sun' *The Ecologist* 3:7 (July 1973)

accompanying cartoon by Richard Willson, Peter Bunyard set out the initial reaction of the magazine.[82] It focused on the issue of security of supply and rising demand, but curiously made no mention of the rise in oil prices that was a main feature of the crisis. As might be expected the magazine saw the crisis as a general vindication of its position on the industrialised nations' reliance on oil, and the thrust of the editorial centred on supply issues. However, following on from the comments of Goldsmith in the August 1973 issue concerning security of supply, the article offered an essentially cultural explanation for the crisis.[83] Bunyard made repeated reference to the Middle East as 'a part of the world which has never known peace since the dawn of civilisation' and as 'one of the world's politically hottest and least stable spots'. In the editorial he bemoaned the 'sheer idiocy' of basing the growth of industrialised economies on a resource that is found mainly in that part of the world. Bunyard also saw a clear link between the crisis and the nuclear programme and suggests that 'technocrats are hoping that nuclear power will step smartly in' to fill the energy gap. The short editorial concluded by suggesting 'that there is only one answer and that is to embark immediately on policies to reduce demand for energy' and closed with the warning that we are 'enslaving ourselves' to those that 'control the energy circuits'. Once again *The Ecologist* returns to its advocacy of reducing the consumption of energy, the 'virtues of restraint'[84], with no real suggestion of how that could be achieved.

In the same issue (3:12) Bunyard contributed a lengthy feature article, which appears to have been written prior to the oil crisis, titled 'ENERGY- CRISIS or crunch?' This article was a report on a jointly sponsored conference in London by the *Financial Times* and BOAC on 'World Energy Supplies'. The article explored the growing possibility of an energy crisis, facilitated both through the 'unity' among the oil producing countries and the increasing dependence on oil of 'western economies'. This situation is contrasted with the earlier crises of Suez in 1956 and the embargo of 1967, which Bunyard suggested failed amid a 'buyer's market' for oil. The article discussed the contributions of some of the key individuals involved in energy strategy at that time, including representatives from the U.S. Government, the banks, the oil companies, and OPEC. In particular the contribution of Dr Nadim Pachachi, a previous secretary general of OPEC was telling. Aside from a predictable call for the Arab producers to pursue 'a co-ordinated, unified policy to freeze…crude oil production at present levels until such times as Israel

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[82] Bunyard, P., 'The energy steeplechase', *The Ecologist* 3:12 (December 1973)
[83] Goldsmith, E., 'Growing market'.
[84] Bunyard, P., 'ENERGY- CRISIS or crunch?' *The Ecologist* 3:12 (December 1973)

withdraws fully from all the Arab territories occupied during the 1967 war', he also criticised the West for its unrealistic 'obsession with cheap energy prices'. This, he suggested, had forestalled the search for alternative energy sources, when 'a price of seven to eight dollars per barrel' would allow 'non-conventional oil' to compete successfully. Bunyard used the article to develop the magazine's criticism of the lack of a clear energy strategy '…governments and the major energy industries have on the whole miscalculated the investment and resources they should have been putting into energy production over the past decade'.[85]

By January 1974 the magazine with more time to consider the implications of the oil crisis produced a lengthier and more considered editorial devoted entirely to energy. In addition to a criticism of the Government, *The Ecologist* also acknowledged the significance of the decision by CEGB on reactor choice. Written by Goldsmith and Bunyard this editorial moved the oil crisis in to a context more familiar to readers of the magazine. Bunyard's contribution, following on from his previous article, criticised the 'sorry Government' handling of the economy amid soaring prices and problems with supply.[86] Bunyard pointed out that an oil crisis at some stage was widely predicted and yet the government 'dithers and vacillates when confronted with reality'. The editorial suggested that this weakness from the government creates a void into which 'private enterprise- however selfish and ruthless' can step. The site of platform building for the North Sea oil industry 'despite strong local opposition' and the requests of the CEGB to use the American LWR were used by Bunyard as examples of the government being led by big business. Bunyard also criticised government-backed programmes such as Concorde and the Channel Tunnel as further examples of its 'laughable' and 'mindless plans for growth'. The editorial concluded by dismissing the 'fiction' that thermonuclear fusion could 'solve man's energy problems'. This is a complete reversal of the magazine's repeated concession in earlier issues that 'endless energy' was possible and suggests that the magazine was beginning to shift from its previous position of a qualified acceptance of nuclear power.[87] The energy debate was clearly beginning to deepen among environmentalists.

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[85] Bunyard, P., 'ENERGY- CRISIS or crunch?' *The Ecologist* 3:12 (December 1973)
[86] Bunyard, P., 'Taking the Government by the Nose' *The Ecologist* 4:1 (January 1974)
[87] Peter Bunyard wrote 'In theory there is unlimited energy in the world. All man has to do is to build breeder reactors and to achieve thermo-nuclear fusion on a commercial scale.' Bunyard, P., 'The Energy Crisis', *The Ecologist,* 3:5 (May 1973)

Accompanying the editorial of Bunyard is a short piece from Goldsmith on energy and GNP.[88] This piece is constructed around the research of Joel Darmstadter into the correlation between GNP and energy consumption, mentioned in chapter 1.[89] Darmstadter was interested in the changing relationship between GNP growth and the growth in energy consumption in the United States. This had shifted from a positive relationship where GNP growth outpaced the growth in energy consumption between 1920 and 1965 to a negative relationship from 1965, when it appeared that efficiency savings, mainly in electricity generation, had ceased. Darmstadter speculated that the shift in the relationship was also caused by the high-energy consumption of the American consumer. Using these conclusions, Goldsmith suggested that limited conservation of energy resources would have a disastrous impact on society and the economy, by limiting the potential for GNP growth. He suggested that 'the greatest priority today' should be an attempt to maximise economic growth and minimise energy consumption. At first sight this seems an anomalous conclusion for Goldsmith to reach given his repeated criticism of industrial society. However, it is clear that Goldsmith believed that energy use *will* increase and will bring about the collapse in industrial economies that he so craved.

In 1974 there were only two further editorials that discussed energy to a significant extent. The first of these was in the March/April issue (4:3). 'The Caviar Chimera' was written by Goldsmith and covers the familiar ground of a general critique of industrial society with a few pot shots along the way at some of *The Ecologist*'s traditional enemies such as the scientist Barry Commoner and the Labour politician, Anthony Crosland. In this article Goldsmith discussed the way in which the oil crisis caused a backlash against environmentalism in the US and led to 'a veritable avalanche of anti-environmental measures'.[90] After devoting two consecutive editorials almost exclusively to energy and the oil crisis *The Ecologist* largely abandoned the topic thereafter. The number of feature articles declined and lost the focus that had been gained during 1973.[91] The reason for this is unclear but it would be reasonable to speculate on two factors that may have caused the change. Firstly, there was the recognition that energy policy, particularly nuclear, was mired in an esoteric technical debate that had little appeal to the readers of a popular magazine; the torch for this debate had clearly passed to FoE UK. Secondly, the political

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[88] Goldsmith, J., 'Energy and GNP' *The Ecologist* 4:1 (January 1974)
[89] Darmstadter et al, *Energy*.
[90] Goldsmith, E., 'The Caviar Chimera' *The Ecologist* 4:3 (March/April 1974)
[91] There were only 7 feature articles on energy-related topics in 1974; none of these featured nuclear energy.

turmoil of 1974 appeared too attractive a topic for the magazine, and political campaigning for the two General Elections in 1974 on behalf of the People's Party seemed to dominate the direction of the magazine as its output reduced to ten issues a year. The peak of its influence in this early period that followed the publication of *Blueprint For Survival* in 1972 appeared to have passed and the magazine appeared to struggle to discover a clear identity. The November 1974 issue (4:10) was a produced jointly with *Resurgence* and explored 'new value systems' based on 'religions which have not become materialist'. Arguably, this might have seemed rather irrelevant to many of the traditional readers of the magazine, the majority of who listed *New Scientist* as their other regular magazine purchase.

Technology: Soft, Appropriate, Intermediate, or Alternative?

A key aspect of the social movements of the 1960s was their shared anti-industrialism, and growing distrust of government. This mood served to unite such disparate groups as the civil rights movement, the counter culture, the anti-Vietnam protesters, CND, and the broader new wave of environmentalists. Among the specific targets of this critique were science and technology, seen as particularly potent symbols of authoritative control in the post-war period.[92] As previously mentioned, this is one explanation for the outstanding influence of *Silent Spring.* One such reaction of particular interest to the study of renewable energy from the 1970s was the Alternative Technology (AT) movement. Smith noted that the AT movement provides a rare example of a technologically focused social grouping, which was defined by pro-activity rather than pure critique (such as the anti-nuclear movement).[93] Many of the factors that combined to produce the new environmental movement were also present in the AT movement, and the AT movement was subsumed under the environmentalist banner. Adrian Smith wrote that, 'the AT movement emerged on a wave of environmental concern over the impacts of industrial society, and a radical, counter-cultural critique of its technocratic tendencies'.[94] AT advocates were motivated by this essential critique of capitalism, but in contrast to many of their fellow travellers on the counter culture trail, they offered alternatives, both product and lifestyle, as well as critique.

[92] Eyerman and Jamison, *Social Movements*, p.75
[93] Smith, 'Movement', p. 106
[94] Smith, 'Movement', p.107

The AT movement had emerged in the 1970s as a specific socio-technological response to the widespread anti-industrialism that had begun in the 1960s. Langdon Winner saw the movement's rejection of technological 'progress' as just the latest manifestation of a periodical social phenomenon that in the past had produced a range of reactions including key historical figures like Robert Owen, Peter Kropotkin, William Morris, and Gandhi, and social movements like the co-operative movement.[95] This is a process that can perhaps also be discerned in the formation of the nineteenth century amenity groups in Britain as described above. For Winner, the counter culture of the 1960s was simply the latest wave of social disillusionment. Emerging from these swirling influences a new critique of technology emerged which followed a tradition established in the 1930s by Lewis Mumford.[96] Both Herbert Marcuse's *One-Dimensional Man* and Jacques Ellul's 'outrageously pessimistic'[97] *The Technological Society* appeared in the mid-sixties, and both contained a bitter critique of the technocratic state.[98] In the same period Barry Commoner published *Science and Survival,* which focussed specifically on a critique of the scientific establishment.[99] Emerging from this background, the AT movement embraced the belief that technology should be 'liberated' from the manipulation of the 'technocracy' and handed back to society. Furthermore, and perhaps more importantly it should be 'non-violent towards people and natural resources'.[100]

Perversely, the impetus for much of the early AT movement was created and developed through traditional commercial methods and channels. In 1968 Stewart Brand produced the first of many subsequent and highly successful editions of his *Whole Earth Catalog*, which presented readers with the opportunity to purchase from an array of small-scale 'back to nature' technologies.[101] In many senses the *Catalog* offered a comfortable, consumerist vision of a different world, at a safe distance from the increasing violence of public demonstrations in the late 1960s. According to Winner, amid the apparent political and social disintegration of the globe its readers could imagine themselves as 'hippie environmentalist spacemen in the tradition of Buckminster Fuller'.[102] The *Catalog*

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[95] Winner, L., 'Building the Better Mousetrap', in *The Whale and the Reactor: A Search for Limits in an Age of Technology* (London: University of Chicago Press, 1986) p.63
[96] Mumford, L., *Technics and Civilization* (London: Routledge, 1934)
[97] Roszak, *Counter Culture,* p.6
[98] Marcuse, H., *One-dimensional Man* (London: Routledge, 1964); Ellul, J., *The Technological Society* (London: Cape, 1965).
[99] Commoner, B., *Science and Survival* (London: Victor Gollancz, 1966)
[100] George McRobie quoted in, Smith, 'Movement', p.111.
[101] Brand, S. (ed.), *The Whole Earth Catalog* (Menlo Park, Calif.: Nowels, 1968)
[102] Winner, *Whale,* p.65

included articles about specific pieces of technology, accompanied by details of suppliers. *The Ecologist* also adopted this highly successful model in Britain early in the 1970s when it set up a company called Low Impact Technology Ltd. It was run by Peter Bunyard and Andrew McKillop and sold a range of goods similar to the *Whole Earth Catalog,* such as 'Cinva Rams' for making building blocks from compressed earth, solar panels, and 200w *Winco* 'Wind Generators'.[103] The magazine used its regular alternative technology columns to develop the market for its products amongst its readership. The company also undertook some experimental work of its own, but it is uncertain whether this research ever produced any finished products, let alone any commercial success.[104]

Conclusions

This chapter has set out some of the context within which the UK renewable energy programme was created during the early part of the 1970s. The survey of the role *The Ecologist* magazine and the emergence of the AT community in the UK shows that awareness of energy issues and activity in renewable energy development was growing after 1970 and this change predates the oil crisis. Driven initially by fears of industrial pollution and then by concerns over the finite nature of fossil fuels, the new environmental movement in Britain came to influence the public debate over energy. By actively promoting and demonstrating the potential of renewable energy sources and ambitiously pointing to an alternative approach to the organisation of society the new environmental movement created a new section of public opinion that the Government addressed through its renewable energy programmes after 1974. Although the example of other countries (most notably the United States) in establishing similar programmes was also an important motivation here, it is arguable that these other programmes were also created by an awareness of growing support for the development of alternative energy sources as the work of Lee and Sine shows.[105]

An important conclusion of this thesis is that this initiative was largely conceived as a token gesture, designed to demonstrate that the government was actively addressing the new post-oil crisis energy situation. I have suggested that the emergence of a new environmental movement in the UK from 1970 had an important impact in creating the

[103] *The Ecologist* 4:10 (October 1974) p.378
[104] Interview, M. Allaby, 24 July 2007.
[105] Sine and Lee, 'Tilting'.

conditions for the government's renewable energy programme, and in explaining the perceived need for such a 'token'. The growth in awareness and recognition of environmental issues, demonstrated by the creation of the Department of Environment in 1970 and UK government's active participation in the UNCHE at Stockholm in 1972 compelled the government to consider the 'alternative' forms of energy after 1974. This led directly to the creation of the Energy Technology Support Unit (ETSU) at Harwell early in 1974, and the launch of the UK renewable energy programme to which this thesis will now turn.

Chapter 3
'Energy 1974, and after'[1]

This chapter will develop the theme of a post-war energy *techno-institutional complex* in the UK by focussing on the institutions involved in the UK renewables programme after 1974. In the few months after the oil crisis the institutional structure of UK energy policy underwent significant changes. Before 1974 the formulation of energy policy was coordinated by the DTI. The Minister responsible for energy matters was aided by a Chief Scientist and an advisory body, ACORD (Advisory Council on Research and Development for Fuel and Power). In practice however, as has been argued, the nationalised energy industries and the UKAEA were largely left to formulate their own individual policy without reference to any centrally devised plan. In the post-war energy markets, where energy prices were low and stocks appeared plentiful this was, to some degree, understandable.

After October 1973 this complacency was shaken by the oil crisis which signalled an urgent need to formulate a coherent energy policy for the UK. In addition to the challenges of the oil price shock, the continuing discoveries of North Sea oil and gas reserves in UK waters, the ongoing industrial relations problems in the coal industry, and the perennial debates on reactor choice focussed unprecedented political attention on energy policy from 1974. A new Department for Energy was established in January 1974 by the beleaguered Heath Government as a knee-jerk reaction to the oil crisis, despite the strong resistance of the Secretary of State at the DTI, Peter Walker.[2] Britain had a Ministry of Fuel and Power until the late 1960s when it was swallowed up briefly by the Ministry of Technology (Mintech), and then eventually by the new 'super' ministry, the Department of Trade and Industry (DTI), in 1970. Now, as a result of the worldwide escalation in the price of oil, a dedicated Department of Energy had re-emerged; surgically removed from the DTI.[3]

[1] TNA, PREM 16/253, 'Energy 1974, and after', Central Policy Review Staff report, March 1974.
[2] TNA, PREM 15/2103, correspondence, Walker to Heath, 12 November 1973.
[3] Department for Business, Enterprise & Regulatory Reform (BERR), 'The Department of Energy 1974-1992', http://www.berr.gov.uk/about/about-berr/history/outlines/The%20Department%20of%20Energy%201974%20-%201992/page24456.html [accessed 18 June 2008] In 1957, fuel was dropped and it became the Ministry of Power with added responsibilities in relation to iron and steel.

The chapter will chart the emergence of the broader renewable energy R&D programme after 1974 within this changed structure of UK energy policy-making, before moving on in subsequent chapters to consider the wave and wind energy programmes in more detail. In particular it will focus on three of the key institutions/organisations involved in creating and eventually sustaining that programme; these were the Central Policy Review Staff (CPRS), ACORD, and the Energy Technology Support Unit (ETSU). Both the CPRS and ACORD predate the oil crisis, but both played a crucial role at different stages of the renewables programme. In contrast, the establishment of ETSU in April 1974 was a direct result of the energy crisis and occupied the central role in managing the renewable energy programme throughout the period.

In addition, this chapter will also emphasise the importance of selected key actors within UK energy policy who occupied important roles within the above named organisations. Although a myriad of energy-related committees and advisory groups appeared after 1974 the central thrust of renewable energy policy was influenced, at least initially, by a relatively few high-level individuals. This chapter will emphasise the influence of two powerful individuals who arguably held sway over UK energy policy in the mid-1970s; Lord Rothschild, head of the CPRS, and the Chief Scientist at the DoEn, Walter Marshall.

Lord Rothschild's Think Tank

As part of the package of changes introduced by the incoming Heath Government in 1970 in the White Paper, *Reorganisation of Central Government (1970),* a Central Policy Review Staff (CPRS) - more widely known as the 'Think Tank' - had been established under Lord Victor Rothschild.[4] The CPRS was the first unit of its kind, based at the heart of Government, and set up to advise on a wide range of national policy issues. Heath saw it as an antidote to the often factional and uncoordinated thinking that existed at the heart of government, and enjoyed privileged (though occasionally problematic) access to the Prime Minister and the various Ministerial departments. Heath had used a similar advisory group whilst in opposition in the 1960s and was convinced of its value to government.

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[4] Blackstone. T., and Plowden, W., *Inside the Think Tank: Advising the Cabinet 1971-1983* (London: Mandarin, 1988) p.1; Hennessy, P., *Whitehall* (London: Secker & Warburg, 1989) p.223

Lord Rothschild was appointed to head the CPRS after retirement, aged 60, from his former post as Research Coordinator of the *Royal Dutch Shell Group*, where he gained a close familiarity with the energy business.[5] He also brought the force of his personality to the role. Rothschild, although undoubtedly a member of the elite classes, was in many ways an unconventional figure at the centre of government. He had no experience as a civil servant (although he had been Chairman of the Agricultural Research Council from 1948-58) and was largely unused to the ways of Whitehall. Undeniably also his personal wealth 'removed him from the servitude of security in presenting his opinions', and in its earliest incarnation the CPRS, and its views, were clearly seen as Rothschild 'writ large'.[6]

In early December Heath held an informal reception at No. 10 with the Cabinet and Rothschild to introduce Rothschild and the work of the CPRS; he explained to the assembled that its main function would be 'to help Ministers to make better decisions about the allocation of resources.'[7] And by late February Rothschild had provided Heath with a 'Proposed Work Programme' for the CPRS.[8] He had spent two months visiting the various government departments and talking with the Secretaries of State and senior civil servants, to get a sense of what they regarded as their most important and immediate challenges. His enquiries produced a list that was broken down into five headings; 'General', 'Long-term, relating to social and economic policy', 'Research and development - medium term', 'Specific studies', and 'CPRS - "watching briefs"'. The list included fifteen specific items ranging on a spectrum from 'Concorde' to 'Some interdepartmental implications of social policy' that reflected the free-ranging brief given to the CPRS. Until this point the establishment of the CPRS and its role in government was theoretical, and Ministers had in principle accepted the usefulness of such a body at the heart of government. They had perhaps even enjoyed the chance to discuss with Lord Rothschild the particular challenges that each of them felt that they faced. However, this was the first opportunity for the Cabinet to see exactly what work the CPRS proposed to undertake. Sir Burke Trend commented to Heath that 'this may be a rather painful process; and a few tears may be shed in the course of it' as the government departments got used to having the CPRS so closely involved in policy-making.[9]

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5 Hennessy, *Whitehall,* p.223
6 *Nature*, 'Last of the great independents?', vol. 250, 2 August 1974, p.367
7 TNA, PREM 15/406, Record of a Discussion, 2 December 1970
8 TNA, PREM 15/406, 'The Work of the Central Policy Review Staff (CPRS), undated
9 TNA, PREM 15/406, Trend to Prime Minister, Ref. A09216 Prime Minister, Work of the CPRS, (MCA(71)1), 2 March 1971

In the report Rothschild described 'Watching briefs' as those 'subjects which, while continuing to be dealt with primarily by the Departments concerned, would engage the attention of the CPRS, who would hold a "watching brief" in relation to these activities and would take an active part in the interdepartmental discussion of them'.[10] Included in this list of five items was 'United Kingdom Energy Policy'. The CPRS noted that the DTI was about to launch 'a major review of energy policy' and suggested that the CPRS would 'be in touch with this and will be discussing the scope of the study with the DTI'.[11] By September 1971, in a report on Government strategy, the CPRS was forming an initial view of UK energy policy. In a trenchant paragraph it observed,

> Energy policy. We have spread our bets too widely in the development of nuclear energy and wasted money. Looking ahead, the dominance of the Middle East in proven oil reserves looks capable of imposing a stranglehold over traditional sources of Western European energy supply. This may be eased for the United Kingdom by exploitation of the Continental Shelf in the short-term and in the longer term by nuclear energy. *There are high stakes attaching to getting our national energy policy right in this changing position.* [12]

This short paragraph provides a useful and telling snapshot of UK energy policy at the outset of the 1970s. It also demonstrates that the CPRS had a remarkably good grasp of the state of UK energy issues at the time. Two years prior to October 1973 the CPRS had in a sense predicted the oil crisis. It also made the observation that North Sea oil and gas would be a short-term solution that would only delay the requirement for a coordinated policy on energy. At this stage, though, and despite its problems, nuclear power was still seen as the only long-term solution.

An Energy Policy for Britain

In late May 1973 the first full-length CPRS report on energy policy, *An Energy Policy for Britain*, bound in the trademark red covers of the CPRS, was presented to the Government.[13] The report had been prepared with the help of the economist Michael Posner, who had worked at the Ministry of Power during the 1960s.[14] For the report the CPRS adapted a framework of 'energy scenarios' from work Rothschild had done at Shell,

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[10] TNA, PREM 15/406, Trend to Prime Minister.
[11] TNA, PREM 15/406, Annex B, Trend to Prime Minister, Ref. A09216 Prime Minister, Work of the CPRS, (MCA(71)1), 2 March 1971
[12] TNA PREM 15/407, Cabinet, Government Strategy: Sectoral notes, CP (71), September 1971. My italics
[13] TNA, POWE 63/1034, *An Energy Policy for Britain*, Report by the Central Policy review Staff
[14] TNA, POWE 63/1034, letter, Wade-Gery to various, 1 May 1973

which presented three possible futures based on oil prices projected to 1985.[15] The report then went on to construct a 'Regret Matrix', which advanced a range of current (1973) energy decisions that would be 'least regretted' in 1985. The main recommendations of the report centred on the improvement of the coal industry through 'exploratory drilling', a close look at licensing and depletion policy in the North Sea, and the continued development of the nuclear power programme.[16]

The DTI had produced its own energy report at around the same time which took a more traditional approach and contained some areas of difference. These tended to be focussed on statistical assumptions and projections though, and the DTI indicated that it was 'in full accord' with the CPRS 'on a wide range of fundamental energy issues'.[17] Despite this, the central contention of the CPRS report – that the price of imported oil would rise substantially over the following 10 years – was largely dismissed, and one DTI official found the CPRS case 'unconvincing'.[18] Overall, the report was met with the most fatal of political reactions from the Government; faint scepticism mixed with general disinterest. Ultimately however, the timing of the report, just months before the oil crisis, came eventually to increase the stature and credibility of Rothschild in energy matters. Although Rothschild's team appeared remarkably prescient in predicting the oil crisis they had in fact only reflected other long-standing and well-publicised concerns over global oil supply, particularly in the United States, referred to in chapter 2.[19] Notwithstanding this, the report sealed the reputation of the Think Tank for expertise on energy policy in the UK, and it came to occupy an influential position on energy at a crucial time. Indeed, Blackstone and Plowden argued that the CPRS came to fill a void in energy policy expertise and as a consequence it 'dominated' the new DoEn at least until the appointment of Tony Benn as Secretary of State for Energy in 1976, who had less respect for such a unit (and for Rothschild personally).[20]

[15] The EASY scenario assumed a price of $3.75 per barrel (pb), for SCARCE the assumption was $6 pb, whilst the CRISIS situation assumed a price of $9 pb. The average oil price in 1972 had been $1.92.
[16] TNA, POWE 63/1034, *Energy Policy,* pp. 1-5
[17] TNA, POWE 63/1035, 'Energy Policy: Points of difference between the 1973 Review of Energy Prospects and the CPRS report "An Energy Policy for Britain"', 30 May 1973
[18] POWE 63/1034, Note, 10 May 1973
[19] Akins, 'Wolf', pp. 467-490. This article by Akins was the most notable example.
[20] Blackstone & Plowden, *Think Tank,* p. 78; Benn, T., *Against the Tide: Diaries 1973-76* (London: Arrow Books, 1990) p.141. After a meeting with Rothschild in April 1974, Benn described Rothschild as 'rather creepy-crawly'. Interestingly, Benn also disliked the other key figure in UK energy policy, Walter Marshall, and soon after taking office had him resign from his post as Chief Scientist (see below).

Therefore, following the oil crisis the Government naturally asked Rothschild's CPRS for what had become known as 'a view' on the new energy situation. In January 1974 it produced a long report titled *Energy Conservation* quickly followed in March by another, *Energy 1974, And After*, both of which suggested that a combination of coal, conservation and nuclear energy (which became known as CoCoNuke) should form the core of any future UK energy policy.[21] The first report made recommendations in three areas; 'Transport', 'Electricity Generation', and 'Energy in the Home and in Industry'. For transport the CPRS had six recommendations, and for the section on energy in the home and industry there were eight. The section on electricity generation contained a single, though bold, recommendation; '*The first stage of a full technical and economic appraisal of harnessing wave power for electricity generation should be put in hand at once.*'[22] This immediately led the new DoEN to commission such a report from the government's own National Engineering Laboratory (NEL) at East Kilbride, and by February 1975 it had produced a positive report on the prospects for wave energy (see chapter 4).[23]

Tired out by the strain of his role at the heart of British politics during a tumultuous 1974, Lord Rothschild stepped down as head of the CPRS late that year, and was replaced by Sir Kenneth Berrill. During his four years at the helm of the Think Tank he had presented 'views' to the Cabinet on a wide range of key issues. Most of these were never published and remained as confidential advice to the Government. It is apparent though that his opinions on energy were influential in guiding the new Department of Energy in 1974. Equally clear was his role, described below, in setting up the new Energy Technology Support Unit that would manage the Government's R&D funding in the 'alternative sources of energy'. Furthermore, his enthusiasm and powerful advocacy for wave power (inspired, as will be seen below, by Gordon Goodwin at the DTI) was instrumental in launching the wave energy programme that dominated the renewables programme until 1982. To a great extent, much of the shape and direction of UK Government-funded renewable energy R&D programme was due entirely to the early intervention of Lord Rothschild.

[21] TNA, PREM 16/253, 'Energy Conservation', Central Policy Review Staff:, January 1974; 'Energy 1974, and after', March 1974
[22] TNA, PREM 16/253, 'Energy Conservation', p. 5
[23] TNA, EG 16/13, Department of Energy, Advisory Council on Research and Development for Fuel and Power, ET 4/10/012, FPRD (75) 26, Wave Energy, Note by ENT Division.

The Advisory Council on Research and Development in Fuel and Power (ACORD)

Prior to 1974 energy technology had been dealt with by the Energy Technology division (ENT) at the DTI. In this case 'energy technology' was mainly related to the three nationalised energy industries - coal, gas, and electricity; nuclear power was outside the remit of the DTI, and therefore, the ENT division. It was a relatively small section within the DTI and particularly during the period of low oil prices during the 1960s its role was not central to wider government policy.[24] The ENT division operated in close association with ACORD, which had been established in 1960 as a successor to the Ministry of Fuel and Power Scientific Advisory Council.[25] Despite its creation ten years prior to the CPRS, arguably it was not until after the oil crisis that the Council began to enjoy some real influence on UK energy policy; particularly, as will be seen, in renewable energy.

ACORD's first Chairman, following his retirement as Chairman of ICI, was Lord Fleck - succeeded in 1965 by the metallurgist, Sir Charles Sykes.[26] The members of the Council (who were unpaid) were appointed by the Secretary of State and were drawn from a range of energy-related fields. This would always include the three nationalised energy industries (coal, gas, and electricity) and the other major nationalised industries such as the British Steel Corporation (BSC). The Council also had representatives from national research bodies such as the Science Research Council (SRC) and the UK Atomic Energy Authority (UKAEA) and often a member to represent the universities. In addition, the Secretary of State could (and often did) appoint independent experts to the Council. The original terms of reference for ACORD, which followed closely those of its predecessor, were as follows,

1. To advise the Minister of Power on Research and Development in relation to his statutory duty of securing the effective and co-ordinated development of coal, petroleum, and other sources of fuel and power in Great Britain, and of promoting economy and efficiency in the supply, distribution, use and consumption of fuel and power, whether produced in Great Britain or not:

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[24] TNA, AB 88/217, 'Notes for the Record', R. L. R. Nicholson, 12 February 1974. The Chief Scientist at the DoEN, E.C . Williams, suggests that the UK had 'withdrawn' from the 'energy R&D field' in the early 1960s.

[25] TNA, EG 16/1, 'Note by its Secretariat on the Advisory Council on Research and Development for Fuel and Power', Advisory Council on Energy Conservation, DoEn, January 1975

[26] C. M. Wright, 'Fleck, Alexander, Baron Fleck (1889–1968)', rev. Frank Greenaway, *Oxford Dictionary of National Biography*, Oxford University Press, 2004; online edn, May 2006 [http://www.oxforddnb.com/view/article/33161, accessed 11 Nov 2009] Lord Fleck had some experience in advising the government on energy-related matters. He had been chairman of the Coal Board Organization Committee (1953-55) and had chaired the prime minister's committee on the Windscale accident (1957-58). He was also yet another Scot involved in the formulation UK energy policy at the highest levels.

2. To advise the Minister of new scientific and technical knowledge or applications of knowledge throughout the world, which in the opinion of the Council should be taken into account in the performance of his statutory duties:
3. To keep the whole field of fuel and power under continuous review with the object of identifying problems needing research and development and advising the Minister of these problems with a view to discussion with the industries.[27]

Despite this rather wide-ranging remit, until 1974 the primary function of ACORD had been to scrutinise the annual R&D programmes of the three nationalised energy industries and report formally on these to the Secretary of State. This role was carried out mainly through regular quarterly meetings and occasional site visits. ACORD was seen by some as a ‘paper tiger’ and for merely serving as a ‘rubber-stamp’ for the activities of the nationalised industries, and the industries commented that their proposed R&D programmes generally passed through ACORD with ease.[28] Walter Marshall later considered this task ‘as an inescapable but tedious chore to be got out the way with the minimum time and effort.’[29] This criticism was not helped by the fact that far and away the largest R&D spending among the nationalised industries, by the UKAEA lay outside the remit of the Council. Sir Harry Melville[30], who succeeded Sir Charles Sykes as chairman of ACORD in October 1970, recognised and understood this criticism, and during his period as chairman he made a concerted effort to revise the organisation and remit of ACORD.[31]

In 1973 Melville sent a short paper offering some suggestions for change to the Department, requesting a meeting with the Minister. In his proposals he expressed some frustration at the limits placed on ACORD. He stated that the core of ACORD’s duties, the ‘detailed examination of the R&D programmes of the nationalised industries...is not really necessary’. Instead he suggested that ACORD should comment on the ‘*strategy* for R&D

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[27] TNA, EG 16/54 ‘Ministry of Power: Advisory Council on research and Development: Terms of Reference’
[28] Kenward, M., ‘Energy File: ACORD’, *New Scientist,* 12 June 1975, p.628; Watt, R. N., Towards a synthesised network approach: an analysis of UK nuclear and renewable (wave) energy programmes 1939-85, (University of Birmingham, 1998, PhD thesis) p.41
[29] TNA, EG 16/124, ET 4/1/03, ‘ACORD consideration of Nationalised Industry R&D programmes 1978’, L H Leighton, 26 October 1977.
[30] Bevington, J., ‘Melville, Sir Harry Work (1908–2000)’, *Oxford Dictionary of National Biography*, Oxford University Press, Sept 2004; online edn, Jan 2009 [http://www.oxforddnb.com/view/article/74293, accessed 11 Nov 2009]. Another Scot.
[31] TNA, AB 48/1015, correspondence, Searsby to Moore, 11 July 1973; EG 16/4, ‘ACORD: Suggested changes in its way of working’, H. W. Melville; EG 16/4, ‘Sir Harry Melville’ letter, Leighton to PS/PUS, 13 February 1974.

to see whether it is well founded'. He commented rather acerbically that ACORD was 'to some extent isolated from the discussions on energy problems that *presumably* occur in DTI'.[32] Although his request for a meeting with the Minister was successful, the outcome was that little or no change was implemented at ACORD.[33] Denness, an official at the DoEn who also acted as a member of the secretariat of ACORD, had commented that 'it is probably fair to say that we are not entirely happy with all the suggested changes'. Discouragingly for Sir Harry, Denness went on to recommend that 'the Minister merely notes what he has to say, leaving it open for officials to report to the Minister at a later stage if and when it is considered that there should be fundamental changes in ACORD's modus operandi'.[34] The unmistakable impression given is that until the changes brought about in the organisation of UK energy policy after 1974, ACORD was clearly regarded by the ENT division as a very minor functionary in UK energy technology and as little more than a tool of the DTI.

The Energy Technology Support Unit (ETSU)

At the beginning of April 1974 the Energy Technology Support Unit was officially established by the new Labour Secretary of State at the DoEn, Eric Varley. ETSU formed the management hub of the UK renewable energy programme. It did not undertake any R&D work itself, but was given the task of identifying suitable renewables R&D, implementing and managing specific programmes, and advising the Secretary of State at the DoEn.[35] As the scale of the programme increased through the 1970s, ETSU created and coordinated several 'steering committees' that were concentrated on what were regarded as the 'most promising' renewable technologies of the period. These included the Wave Energy Steering Committee (WESC) created by ACORD in June 1975, and the Wind Energy Steering Committee (WISC) created in 1978.[36] Although central to the technical development of the programme it is debatable whether ETSU had any significant impact on policy. Certainly the reports it provided to the DoEn could affect the choice of technology, but these were routinely scrutinised by ACORD before reaching the Secretary of State and the Council was given the important task of 'advising' the department on renewable energy policy (see below). Despite this, the impact of ETSU must be carefully

[32] TNA, EG 16/4, 'ACORD: Suggested changes in its way of working', H. W. Melville . [my italics]
[33] EG 16/4, 'Sir Harry Melville' letter, Leighton to PS/PUS, 13 February 1974.
[34] TNA, EG 16/4, correspondence, Denness to APS/Minister for Industry, 6 June 1972
[35] TNA, AB 88/217, 'Energy Technology Support Unit: Proposals for the Initial Programme. J. K. Dawson' 8 February 1974
[36] TNA, EG 16/80, ET 4/3/01, FPRD(76) 9, Department of Energy, Advisory Council on Research and Development for Fuel and Power, 'A Programme for Wave Power: FPRD(76) 8'

considered in accounting for the evolution of the programme within the government's wider energy policy objectives.

ETSU was officially established in April 1974 at Harwell, which was home to the Atomic Energy Authority Research Establishment (AERE) and was one of the UK and Europe's biggest centres of scientific research.[37] The Attlee Government had established Harwell in 1945 as a 'research and experimental establishment covering all aspects of the use of atomic energy'.[38] However, for some years prior to 1974 it had been forced to diversify into what it termed 'non-nuclear' work in an attempt to secure its future amid the continuing uncertainties of the UK nuclear programme.[39] In what was a unique move for a government-funded research laboratory, Harwell began to seek out 'industrial partners' which would pay for specific R&D programmes.[40] Despite strong and wide-ranging opposition to the scheme (some from within Harwell itself) under the influence of its new and ambitious young director, Walter Marshall, the plan appeared to work and a range of non-nuclear research programmes were set-up.[41] These included work in ceramics, non-destructive testing, desalination, and carbon fibres. By 1974, Harwell's annual income from outside of the Atomic Energy Vote amounted to £8m, which represented about 40 per cent of its budget.[42]

In May 1972, Keith Dawson, who was to become the first Director of ETSU produced an internal study which he titled, 'Proposal For An Advanced Energy Technology Institute'.[43] Dawson was a senior scientist in the Applied Chemistry Division, and his proposal can be seen as a clear example of the diversification strategy to help safeguard the 'future' of Harwell.[44] The 'needs' which his proposal was based upon provide a further indication that an awareness of the shortcomings in energy policy were

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[37] Fishlock, D., 'Marshall the energy', *Nature*, vol. 254, 13 March 1975, p.94. The AERE employed 5,000 staff at Harwell in the mid-1970s. It had numbered around 6,000 ten years earlier.
[38] *Nature*, 'Twenty-one Years at Harwell', vol. 214, 22 April 1967, p.343
[39] TNA, AB 17/154, 'The changing role of Harwell', *ATOM*, monthly bulletin of the United Kingdom Atomic Energy Authority, number 196, February 1973; *Nature*, 'What to do about Harwell?', vol. 226, 23 May 1970, p.679
[40] Maddox, J., 'Diversification at Harwell', *Nature*, vol. 217, 17 February 1968, pp. 607-608
[41] Marshall went on to play a central role in UK energy policy, particularly during the 1970s. This is considered in detail in Chapter 5.
[42] Fishlock, 'Marshall', p.95
[43] TNA, AB 88/216. 'Advanced Energy Technology Institute', letter from J. K. Dawson to L. E. J. Roberts, 18 May 1972.
[44] Ibid.

becoming more widespread in the period. Furthermore, they also strongly reflect the growing influence of environmental issues at the time, mentioned in the previous chapter:

> (a) the need to formulate an overall U.K. energy policy which takes into account all the economic, sociological, environmental and political factors (this requires the provision and evaluation of advice particularly on the new technology that will be needed),
> (b) the need to control the use of energy sources for environmental reasons,
> (c) the need to conserve existing fuel reserves to prevent an energy famine in the early part of the 21st century, which is not further ahead than the time which has elapsed since the end of the Second World War,
> (d) the need to diversify the U.K. energy sources for political reasons.

The proposal, which anticipates much of the later structure of ETSU, unsurprisingly saw Harwell as the only possible location for such a unit in the UK. 'No other laboratory in the U.K. could take such a wide view of the situation, or bring such a powerful interdisciplinary approach to the range of problems involved.'[45] The work that Dawson considered that such an Institute should undertake betrayed an understandable personal bias towards new energy technology based on chemicals, such as fuel cells, advanced batteries, and synthetic fuels. No specific mention is made at this early stage of the renewable energy technologies (in particular wave energy) that would later become the focus of much of ETSU's early work.

A meeting was eventually held at Harwell in November 1972 to discuss Dawson's proposal.[46] There had been some suggestion that the Institute could be launched as an Applied Nuclear Programme, which appeared to be an attempt to lend the unit some credibility of continuity with Harwell's main function. However, at this meeting it was made clear that 'the Directorate would <u>not</u> support the presentation of this proposal as an Applied Nuclear programme'.[47] The Harwell Directorate seemed anxious that any new venture should be distanced from the 'weak commercial strategy' of current research in the Applied Nuclear field. It was agreed at this meeting that approaches should be made to DTI and Department of Environment (DoE) 'contacts' before any formal proposals were drawn up; however, the meeting was also reminded by Dr Dell of the pressing need for new programmes of work at Harwell.

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[45] TNA, AB 88/216. 'Proposal For An Advanced Energy Technology Institute' J. K. Dawson , 18 May 1972
[46] Ibid.
[47] Ibid. Underlining in original.

By early 1973, as the CPRS was preparing the launch of its first energy paper, the reach of Lord Rothschild on energy matters had extended to include Harwell. Rothschild made a direct approach to Walter Marshall 'to consider what part Harwell as a laboratory might play in the formulation of alternative strategies for energy supplies'.[48] The request from such an influential figure at the heart of government appears to have encouraged Harwell and further studies of its potential role in energy technology were produced.[49] A new 8 page study by Dawson contained a recasting of the 'needs' which closely reflect the influence of Rothschild's views on oil imports,

> There is a need to reverse the rise in dependence (currently 45% of total energy demand) of the U. K. on imported oil as an energy source for several reasons:
> (a) on a timescale of say 10 years, various factors will almost certainly lead to substantial increases in the price of oil, giving rise to adverse effects on the balance of payments and leading to a 'dear energy' regime which could affect many aspects of industry,
> (b) oil production will begin to decline within about 30 years and the gap between supply and demand will then increase rapidly, and
> (c) there are obvious political advantages to be gained by reducing the substantial dependence of the U.K. (and indeed Europe) on the Middle East as the primary source of oil.

This new set of 'needs' contrasts with the earlier version of May 1972 in several ways: first, it is clear that it was written in language that would have a more direct appeal to government, and in particular the DTI; second, although the 'new environmentalism' tone of the first version has been excised, in its place is a clear acceptance in (b) of the 'Limits to Growth' thesis of rapidly depleting oil reserves. Clearly, Harwell's 'contacts' within the DTI had had an influence on the presentation of the case for a new unit. However, much of the other content remained similar to that which Dawson had outlined in 1972. The research focus remained firmly centred on the development of synthetic fuels and advanced batteries. However, the report did include, for the first time, a brief discussion of 'New energy sources', which covered solar, wind, and tidal schemes. Ironically, these 'novel approaches' were however quickly dismissed by Dawson as 'impractical or uneconomic on close examination'.[50]

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[48] TNA, AB 88/216. Letter from L. E. J. Roberts to K. D. B. Johnson, 25 April 1973
[49] TNA, AB 88/216. 'Energy Strategy in the U.K.: Comments and some possible Harwell contributions' J. K. Dawson, 8 May 1973; 'Proposal for a review study on: "Sources and Utilization of Energy"' , G. F. Hewitt, 25 April 1973
[50] TNA, AB 88/216. 'Energy Strategy in the U.K.: Comments and some possible Harwell contributions' J. K. Dawson, 8 May 1973

Marshall forwarded Dawson's new paper to Rothschild in June 1973 and Dawson met with him shortly after the CPRS energy report had been produced. Rothschild's view was that the situation was probably more urgent than Dawson had suggested, and he thought that 'oil production could decline in considerably less than the 30 years…quoted'. During the meeting Rothschild indicated that he supported the idea of 'an assessment team on energy matters' being based at Harwell. Indeed, he had evidently given the matter some thought as he proposed to Dawson that such a unit should comprise a budget of £250,000 p.a. and a staff of 10.[51] Following on from the recommendations of the CPRS report, Rothschild believed that 'electric road vehicles' were a key element of any future energy R&D, and he emphasised this to Dawson.[52]

Clearly, by mid-1973 the establishment of an energy technology unit at Harwell had moved a significant step closer to reality, particularly with the recruitment of Rothschild to the Harwell cause. There appeared to be a growing realisation of the uncertainty in future energy supplies, and due mainly to the efforts of Rothschild, this recognition was beginning to spread to Government. Some evidence of this recognition is to be found in the report produced at the DTI in August 1973 into 'new energy forms and applications'. The report was produced in response to the 'possible need for the Department to adopt "a more positive stance" vis-à-vis the initiating and financing of research into new energy forms and applications'.[53] There are clear links to the CPRS in the report as the author adopts the CPRS's 'SCARCE' energy scenario as his framework. The 10 page report sets out to provide a brief summary of the state of R&D into 'New Sources of Primary Energy' both in the UK and worldwide, but remains largely fixated on coal and nuclear technologies. A short paragraph on solar, wind, and geothermal energy reaches similar conclusions to Dawson that these are 'economically highly unattractive'. This is followed by another short paragraph on wave and tidal schemes which reaches similar conclusions, 'Justification…would fall to be judged from the standpoint of an insurance option against the possibility of a nuclear mishap of such magnitude as to jeopardise acceptability of nuclear techniques for power generation'. The concept of an 'insurance option' would reappear repeatedly throughout the UK renewable energy

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[51] TNA, AB 88/216. 'Note for the Record on Discussion with Lord Rothschild, 13th June 1973'. J. K. Dawson, 15 June 1973

[52] *Nature*, 'Last?'. This profile of Rothschild concluded, 'It would be a fitting memorial to Lord Rothschild's quirky reign in Whitehall if he could get public acceptance of a slow, small economical battery-driven urban runabout'

[53] TNA, AB 88/216, Leighton to Secretary (Industry), 30 August 1973

programme (see chapter 4). The report concludes with the judgement that even 'against a background of the CPRS "Scarce" scenario…the prospects are not such as to justify the mounting of new R&D activities'.[54]

Leonard Williams was a Deputy Secretary at the DTI with a special interest in energy matters, and he transferred over to the new DoEn in January 1974. Whilst at the DTI, Williams had arranged a meeting with Keith Dawson to discuss his proposal for an energy technology institute at Harwell. The claim by Rothschild to Marshall that he had 'suggested the matter be discussed in a high place' seems to have borne fruit for Harwell.[55] The meeting, on 6 December 1973, took place at the offices of the DTI in London. It was made clear at this meeting, by the official from the DTI, that Dawson's proposals had 'fallen on fertile ground' and the establishment of an 'Advanced Energy Technology Centre' was 'introduced tentatively'.[56] Five days later, Leonard Williams, visited F. J. Doggett, the Deputy Chairman of the UKAEA, to report that the DTI wanted to make use of 'a team at Harwell (building up to 20-30 strong)' to establish an energy '*think tank*'.[57] In a subsequent letter to Doggett from Williams there is some evidence that the impetus to establish the unit quickly stemmed from Government pressure to make positive statements on energy policy, as he suggests that it would 'be of great advantage if we could make an early announcement of these new arrangements'.[58] Walter Marshall wrote to Lord Rothschild to inform him of this approach and to thank him 'for whatever part you have taken behind the scenes in bringing this about', and rather fawningly assuring him that 'Harwell shall try and do a good job for you'.[59]

At the beginning of January 1974 a series of meetings were held involving the DTI (after 12th January the DoEn) and selected figures from Harwell. Now that an energy technology unit at Harwell had been agreed in principle, it was left to sort out the structure, and budget of the new unit. Williams negotiated with the Treasury staffing levels of 12-20, and for a likely budget of £300,000, but added that the new unit would cost £15,000 in

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[54] TNA, AB 88/216. 'Research Into New Sources of Primary Energy', L. H. Leighton, 30 August 1973.
[55] TNA, AB 88/216, Letter from Lord Rothschild to Walter Marshall, 26 September 1973.
[56] TNA, AB 88/216. 'Meeting to discuss Energy Research topics held at D.T. I. (Abell House) on 6th December, 1973' 7 December 1973
[57] TNA, AB 88/216. F. J. Doggett to Chairman (UKAEA), 11 December 1973 . My italics. The reference to an energy 'think tank' provides further evidence of Rothschild's influence in the creation of ETSU.
[58] TNA, AB 88/217. L. Williams to F. J. Doggett, 17 December 1973
[59] TNA, AB 88/217. Walter Marshall to Lord Rothschild, 14 December 1973.

1973/4 and £200,000 in 1974/5. [60] Perhaps significantly, this was not far away from Rothschild's earlier estimates. However, a clear public statement of the aims and guidelines of the new unit would also be required. Despite some misgivings about the control that the DTI would exert over the work programme at Harwell,[61] Doggett wrote officially to Williams in early January welcoming the DTI proposals and agreeing that the unit should be established quickly.[62] Marshall attended an initial meeting at the DTI with Williams on 8th January before flying to India on business for a few weeks. After this it was left to Roberts, Marshall's deputy, and Keith Dawson, to sort out the details of the new arrangement. Progress was made at meetings held throughout January, and possibly as a further sign of the government's anxiety to show evidence of action on energy some hints about the creation of the new unit were leaked to the press. A short article, 'Harwell may do coal and gas research' appeared in the *Daily Telegraph* on 10 January.[63] However, despite the wishes of the DTI to make a quick announcement, political events temporarily stalled the creation of ETSU. From mid-January rumours that Heath was going to call an early election abounded, and finally on 7 February the announcement was made that an election would be held on 28 February.[64] Dawson, and ETSU, would have to wait a little longer.

Soon after the general election, as the new Labour government under Harold Wilson somewhat unexpectedly regained power, the creation of ETSU was back on the table at the DoEn. The new Minister, Eric Varley (sponsored as an MP by the NUM) was at the helm. The January meetings had hammered out most of the key issues surrounding the role of ETSU, and once the agreement of Varley had been obtained, the process of establishing the unit began. In April the staffing levels and budget for ETSU were set, and the DoEn made the official announcement of the unit on 9 April. For the remainder of 1973/4 the budget was fixed at £15,000, and for 1974/5 it was agreed at £200,000. Dawson, as head of the unit was given the authority to allocate only 10 per cent of the budget without first consulting the Management Committee, which was chaired by Leonard Williams.[65] It was also agreed that initially the unit should comprise around a dozen people, perhaps building in the future to twenty or so. Naturally, Dawson was given

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[60] TNA, T 319/2945. Williams to Pliatzky, 11 January 1974.
[61] TNA, AB 88/217. Doggett to Marshall, 21 December 1973; Marshall to Doggett, 3 January 1974
[62] TNA, AB 88/217. Doggett to Williams, 4 January 1974
[63] Dover, C., ''Harwell may do coal and gas research', The Daily Telegraph, 10 January 1974
[64] T. Benn, *Against the Tide: Diaries 1973-76* (London: Arrow Books, 1990) pp. 90-105
[65] TNA, AB 88/218. Leighton to Todd, 10 April 1974

the job as head of ETSU, and he and L. E. J. Roberts (Deputy Director, AERE) were the Harwell representatives on the Management Committee.

The role that Dawson had envisaged for an 'Advanced Energy Technology Institute' in May 1972 had altered somewhat over the two years leading to the creation of ETSU. His original focus on fuel cells, advanced batteries, and synthetic fuels, and his total rejection of renewables were substituted by a rather different set of initial DoEn priorities for the unit.

> '(a) to assess and report on the applicability of wind and geothermal energy systems in the UK;
> (b) to assess and report on the methods of utilisation of solar energy as an energy source in the UK;
> (c) to assess and report on the hydrogen economy and its competitive position with respect to SNG and methanol;
> (d) to maintain liaison with – and assess as required - R & D work on waste heat and nuclear process heat applications;
> (e) to put in hand a study of energy utilisation in the industrial sector and advise on the investigational work and assessment work that would be required in order to arrive at a realistic appreciation of the scope for energy savings through changes in industrial practices;
> (f) to assist, at the request of the Department, in assessing proposals from outside sources for Government support of R & D projects.'[66]

The first two items on the list, in particular, make clear the DoEn's objectives for ETSU, as Dawson's original research focus was largely swept aside. Investigations into the potential of wind, geothermal and solar energy sources were to form the initial work of the unit. Much of this is explained by the sensitivity within the DoEn over the rivalry that existed between the nationalised energy industries, and in particular, their own R&D programmes. During the discussions which established ETSU consideration was given to the likely response of the coal, gas, and electricity industries to what might be seen as a duplication of existing research efforts: this would have an obvious potential impact on the R&D budgets of the nationalised energy industries. 'The need for care' was emphasised, so that the work of the unit should not 'cut across the direct responsibility of the nationalised industries to mount...R&D programmes'.[67] This anxiety gives some insight into the powerful position occupied by the nationalised energy industries. Moreover, the government was already spending vast amounts on energy-related R&D and the Treasury

[66] Ibid.
[67] TNA, AB 88/218, 'Energy Technology Support Unit: Note of a meeting in Mr L Williams room, Department of Energy at 11 am on 14 January 1974', J. L. Drinkwater , 16 January 1974

was not keen on further spending within similar research fields (see Table 3.1).[68] This led the DoEn to emphasise the difference between the work of ETSU and that which was already underway – or that which could be considered to form part of an existing research programme. In addition to this the budget agreed for ETSU was relatively small when compared to other energy R&D in the UK. Much less consideration was given to the likely reaction of ACORD, and this is discussed in detail below. Dawson had envisaged a unit that would eventually take on practical research programmes *within* the organisation, but it was clear that at the levels of funding and manpower agreed by DoEn, that ETSU would remain largely an advisory body for the new Department.

Table 3.1

Department of Energy (DoEn) Research Expenditure, (1972-73)

Electricity Council (incl. CEGB)	£19,800,000
UK Atomic Energy Authority	£64,000,000
Gas Corporation	£8,964,000
National Coal Board	£4,800,000
British Nuclear Fuels (incl. centrifuge)	£4,000,000
Safety in Mines Research Establishment	£1,301,000
South of Scotland Electricity Board	£808,364
North of Scotland Electricity Board	£119,449
Total	**£103,792,813**

Source: D. Fishlock, 'Practical avenues for energy research', *Financial Times,* 6 February 1974

'Harwell?' [69]

Despite the location of ETSU at the heart of the UKAEA's research establishment the choice attracted little comment at the time, other than by some members of ACORD which will be discussed below.[70] This is perhaps partially explained by low expectations for alternative sources of energy and the limited interest in the programme at the time. However, as the programme began to falter in the early 1980s, particularly after the closure of the Wave Energy Programme, increasing speculation was directed at the independence of Harwell in controlling R&D into renewable energy (see chapter 4). The account above

[68] TNA, T 319/2945. Pliatzky to Harrop, 17 January 1974: Pliatzky to Williams. 1 February 1974

[69] HC Deb, 25 October 1985, vol. 84, col. 587. Comment by Nigel Spearing (Newham, South). Eleven years after the creation of ETSU at Harwell it was clearly news to some MPs.

[70] *New Scientist*, 'Energy research starts to expand',18 April 1974. p.121. This rare comment stated that the critics suggested that such a unit placed within a nuclear research facility could never be 'truly independent'.

of the establishment of ETSU shows that Harwell scientists always regarded it as the most suitable location for energy R&D and this was agreed at the time by *New Scientist* which pointed to the absence of any alternatives. It stated that the universities had 'no obvious candidate' to compete with Harwell, and moreover their 'independence' could also be brought into question.[71] It was only following the protests surrounding the controversial closure of the Wave Energy Programme in 1982 discussed at length in chapter 4, that the role of ETSU at Harwell became more of an issue. Speaking in a day-long House of Commons debate on renewable energy in 1985, Alex Eadie, who had been Under-Secretary of State at the DoEn during the 1970s said,

> The claim is that the wave energy activity at Harwell is independent. Perhaps the Minister will reply to that question. There is a feeling abroad that it is all wrong, that nuclear and wave research should be done together but that objectivity is being blocked. That might be a gross slander but that feeling is abroad in the industry. [72]

This mood of suspicion was echoed in the same debate by Malcolm Bruce, who stated more directly 'the suspicion cannot be avoided that Harwell has an interest ultimately in ensuring the continuation of nuclear-related research. It therefore does not appear to have the same commitment to securing the viability of alternatives'.[73] In addition to the critical questioning of the role of Harwell in parliament, the wave energy community was also sceptical. Wave pioneer, Stephen Salter, was understandably frustrated by the closure of the programme and in evidence to a House of Lords inquiry into alternative energy in 1988 he wrote that ETSU had 'uncomfortably close links with nuclear technology'.[74] He was more outspoken that same year when he wrote in *Environment Now* that 'The control of renewable energy must be taken away from the UKAEA. The UKAEA are not only ETSU's landlord, but are also its paymaster'.[75]

Although the focus of criticism centred on Harwell as the location for the management structure of the government's renewables programme, it is clear that the real question (addressed by Salter) was about the potentially negative influence of the UKAEA

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[71] *New Scientist*, 'Energy research'
[72] HC Deb, 25 October 1985, vol. 84, col. 589. His comments clearly overlook the fact that it was the Labour Government that established the unit at Harwell.
[73] HC Deb, 25 October 1985, vol. 84, col. 593
[74] House of Lords, HL Paper 88, Select Committee on the European Communities, Session 1987-88, 16th Report, *Alternative Energy Sources.* p.190
[75] Quoted in Tasker, A., 'The role of the Energy technology Support Unit', *ATOM,* 390 (April 1989)

on the programme. However, defenders of ETSU and Harwell pointed to two mitigating factors. First, ETSU did not carry out any R&D at Harwell itself. The programme was coordinated and managed by Harwell staff, and even the sternest critics such as Salter conceded that ETSU staff generally acted in the best interests of the programme.[76] This was a view echoed later by Elliott in his extensive work on the UK renewable energy programme.[77] Second, as discussed in detail above, the AERE at Harwell had for some time depended on non-nuclear work for its survival. And indeed the evidence above suggests that it was probably the intervention of Lord Rothschild that ensured that the new unit went to Harwell. This suggested that it would be in the interests of Harwell to maintain and *increase* the volume of work on renewable energy rather than see it ended. I would argue that the debate that emerged surrounding the choice of Harwell highlights the misunderstanding that arose during the period over the closure of the wave energy programme in particular. It suggests a UKAEA conspiracy to sink the wave programme just as it was showing economic and technical viability. This misses the point. The UKAEA was only one part, though a powerful part, of the much wider techno-institutional complex which acted as a perpetual barrier to renewable energy.

ACORD and ETSU

During the negotiations between Harwell and the DTI to create ETSU, as noted above, some consideration was given to the nationalised industries, and their possible reaction to the implications of the creation of a new government energy R&D unit.[78] However, it appears that no such thought was given to the reaction of ACORD and the council learnt officially about the creation of ETSU from officials of the new DoEn at a council meeting on the 12 February 1974. E. C. Williams, who had been appointed Chief Scientist at the DoEn attended the meeting and was invited by Sir Harry Melville to outline the changes at the new Department of Energy. Williams explained that the new department was similar to the old Ministry of Power (familiar to many of the long-standing ACORD members) but with the important addition of responsibility for nuclear power. The Energy Technology division (ENT) would remain under the supervision of Len Leighton, who would in turn

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[76] House of Lords, HL Paper 88, Select Committee on the European Communities, Session 1987-88, 16th Report, *Alternative Energy Sources.* p.190. He wrote that 'the former nuclear engineers appointed to run things, in particular Clive Grove-Palmer, were so convincingly enthusiastic about waves that our doubts were stilled'.

[77] Elliott, D., *Renewables: Past, Present and Future: The UK Renewable Energy Programme,* NATTA (Milton Keynes, 1997)

[78] TNA, AB 88/277, correspondence, L.E.J. Roberts to W. Marshall, 7 January 1974. Roberts wrote ' We need close and good relations with the energy supply industries.'

report to Williams on 'professional matters' (Williams did not elaborate on what this might actually mean) and to another senior official, Peter Le Cheminant, on administration and energy policy. Despite the inclusion of nuclear energy within the ambit of the new DoEn, Williams explained carefully that he saw the 'task of ENT division, in conjunction with the Council, as reviewing the whole energy technology field, *excluding the UKAEA's nuclear programme*'. [79]

Williams, joined by Leighton who was also in attendance at the meeting, then immediately announced the creation of ETSU, which he presented as 'a simple extension' of the ENT division.[80] He explained that,

> ...the changed situation on oil price and availability called for a fresh assessment of technological options in the energy field to determine whether or not the Government should re-enter directly the R&D field from which it withdrew some ten years ago when supplies of conventional primary energy were in surplus at low prices. [81]

Williams went on to say that the decision had been taken to 'tap the capability at Harwell' rather than extend the manpower of the ENT division to carry out this function on the basis of expediency; describing Harwell as 'the UKAEA's centre for non-nuclear R&D'. Len Leighton backed Williams up by stressing the 'need for such a unit' and 'the need to have more people looking at what Government should be doing on research on long-range problems'. He added, perhaps in an attempt to close off any final criticism, that Treasury approval had been received.[82]

For ACORD the announcement was a stark reflection of the limited role that it represented in advising the Secretary of State on matters concerning energy R&D in the UK. Sir Harry Melville was 'incensed' by the announcement, and the representatives of the nationalised industries were similarly perturbed by the news. Clearly, the members of ACORD saw this as a further weakening of their perceived position within energy policy in the UK. Grainger, the NCB representative, complained that the 'comparatively narrow

[79] TNA, EG 16/1, 'Minutes of meeting held in room 144, Dean Bradley House, on Tuesday 12 February 1974' , Advisory Council on Research and Development for Fuel and Power, Department of Energy.
[80] TNA, AB 88/217, 'Notes for the Record', R. L. R. Nicholson, 12 February 1974. Nicholson's notes of the meeting suggest a degree of arrogance about the delivery of Williams' remarks. He wrote 'Mr. E. C. Williams "announced" the setting up of the Unit…'.
[81] TNA, AB 88/217, 'Notes for the Record', R. L. R. Nicholson, 12 February 1974
[82] Ibid.

experience of Harwell staff made them unsuitable for such wide-ranging assessments'. He suggested instead that the ENT division should be expanded to fulfill this role. Professor Beer, an independent member of ACORD, accepted the creation of ETSU 'on the grounds of expediency', but he also alluded to Harwell's role in suggesting that he would have preferred 'a completely independent and objective body' to be appointed. Indeed, the focus of criticism was not specifically about the creation of the unit per se, but on the choice of Harwell as its centre. Nicholson, who was attending the meeting on behalf of the UKAEA later summarised the objections,

> The Gas Council, Electricity Council, CEGB and the National Coal Board all had objections which fell into the following categories: -
> (a) they are not being consulted;
> (b) AEA people at Harwell were not necessarily competent outside the nuclear field;
> (c) they would be biased. [83]

In his notes of the meeting, Nicholson went on to write that he 'challenged the members on their assumptions of ignorance and bias' and pointed out that Harwell had undertaken R&D contract work for all of the nationalised energy industries in recent years.

In the correspondence surrounding the creation of ETSU there is no consideration of a role for ACORD in the alternative energy programme and the reaction of the council took Williams and Leighton completely by surprise. Leighton conceded to Nicholson after the meeting that the matter had 'not been handled right both in terms of timing and the content of the letter' (which had been sent to the nationalised industries prior to the meeting).[84] Despite being forced to accept that there was little they could do to prevent the establishment of ETSU at Harwell, the members of ACORD did wring what would prove to be a crucial concession from Williams at the meeting. Nicholson recorded,

> The Department of Energy agreed to these strings, namely:-
> (1) that the Unit's work would be reported to ACORD
> (2) that the Unit was a measure of expediency and that before it was used as a basis for building up a permanent energy policy unit, the whole matter would be further discussed at ACORD, among other places. (Mr. Leighton has said that the contract was for one year).

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[83] TNA, AB 88/217, 'Notes for the Record', R. L. R. Nicholson, 12 February 1974
[84] Ibid.

Although the second point was largely disingenuous and could be understood largely as an apology to ACORD, the first of these ad hoc 'strings' had the effect of maneuvering the Council into a powerful position between ETSU and the DoEn. After not being mentioned at all in the initial establishment of ETSU, ACORD would become the body which assessed and co-ordinated the work of the Unit. Eventually this would lead ACORD to become central to the controversial decision to close down the Wave Energy Programme in 1982 (chapter 4). Integral to the increased profile of ACORD after 1974 was the role of Walter Marshall, the aforementioned director of Harwell, and his towering, though brief, impact on the formation of the UK renewable energy programme.

'Marshall the energy'[85]

Soon after the creation of the Department of Energy in 1974 Sir Harry Melville was replaced as chairman of ACORD by the rising star of the UK energy scene, Dr. Walter Marshall,[86] and in the three years until he stood down as Chief Scientist in 1977 he dominated the UK energy scene.[87] Marshall was respected both as a scientist and a science administrator. He was a brilliant physicist (elected to the Royal Society in his thirties) who began his career with the UKAEA at Harwell in 1954. There he rose very quickly through the management ranks becoming deputy director in 1966 and then, two years later (at the age of thirty-six), its Director. By the age of forty Marshall had been appointed to the board of the UKAEA.[88] During the summer of 1974 Marshall accepted the offer from the Secretary of State to take up the post of Chief Scientist at the new 'science-starved' DoEn, on the condition that he could retain his role as Director at Harwell.[89] Thus, one of the leading figures in the UK nuclear industry became the Government's top scientific adviser (albeit on a part-time, unpaid basis) on energy policy. In addition, Marshall insisted that as part of his new role at the DoEn he himself should assume the chairman's role on both the new Offshore Energy Technology Board (OETB) and, as mentioned, ACORD.[90] As Chart

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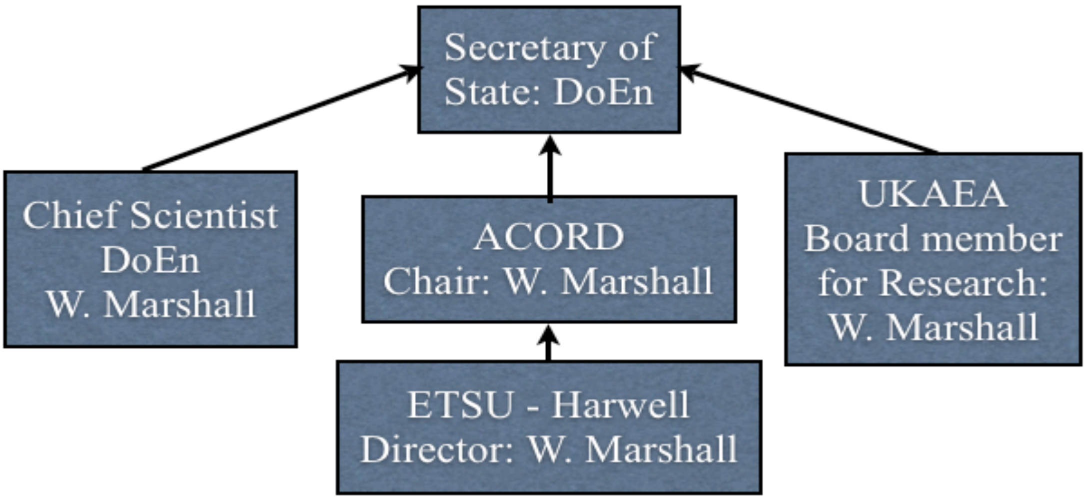
[85] Fishlock, D., 'Marshall the energy', *Nature*, vol. 254, 13 March 1975. pp. 95-6
[86] TNA, EG 16/1, Minutes of ACORD Meeting, 16 July 1974
[87] *Nature*, 'Getting at the truth about Dr Marshall', editorial, vol. 268, 7 July 1977, pp. 1-2
[88] Roberts, L. E. J., 'Marshall, Walter Charles, Baron Marshall of Goring (1932–1996)', *Oxford Dictionary of National Biography*, Oxford University Press, 2004 [http://www.oxforddnb.com/view/article/62150, accessed 11 Nov 2009]
[89] Fishlock, 'Marshall', p. 95.
[90] Fishlock, 'Marshall', p. 95. Fishlock pointed out that there was a precedent for this. Sir John Cockcroft, founder and director of Harwell in the 1950s, was appointed as Chief Scientific Adviser to the Cabinet (also part-time). Although Fishlock states that his influence was 'so slight' that 'few today even recall that Cockcroft held the post in Whitehall'.

1 shows this placed Marshall in a uniquely powerful position to influence the future direction of UK energy policy.

Chart 3.1

Advisory structure 1974-77 - Department of Energy and Walter Marshall



Although Marshall was clearly a 'nuclear man', as explained above, the consideration of the UKAEA's R&D fell (and would continue to fall) outwith the remit of ACORD. The UKAEA formed the DoEn's largest sector of energy R&D - in terms of scale and investment - and accordingly, Sir John Hill the Chairman of the UKAEA, also enjoyed a close advisory relationship with the Secretary of State. In the past this had served to weaken ACORD's influence on wider energy policy, but clearly Marshall occupied a unique position, not only as the DoEn's Chief Scientist, but also as the UKAEA board member for research. As such his influence briefly spread to every corner of UK energy policy. Writing in *Nature* in 1975, David Fishlock observed that Marshall and Sir John Hill had '...devised the kind of formula that can work only between two people in closest rapport, to avoid mutual interference within each other's parish in advising the Secretary of State for Energy.'[91] This may indeed have been the case, but arguably the source of many of Hill's views on nuclear R&D could be traced back the UKAEA's board member for research.

The potential for conflict of interest was ultimately to cost Marshall his role as Chief Scientist in June 1977 as the Secretary of State for Energy, Tony Benn, grew increasingly sceptical about nuclear energy and particularly the role of the UKAEA.[92] Ironically, Benn had himself promoted Marshall to the post of Deputy Chairman of the UKAEA in 1975, despite Marshall's own uncertainties of perceived conflict of interest, thus further increasing the nuclear profile of the DoEn's Chief Scientist.[93] During 1974, when Marshall was first appointed, public interest in the nuclear power programme was just beginning to emerge when, as Williams described, the debate shifted from 'private to public'.[94] Also in the same period, following the publication of the influential Flowers Report in 1976, many key individuals such as Lord Rothschild began to reconsider the wisdom of relying so overwhelmingly on nuclear energy for the future.[95] Clearly, by 1977 with the Windscale Inquiry looming, Marshall's position was becoming increasingly untenable and he 'stepped down' from his role as Chief Scientist. Subsequently, he went on to become Chairman of the UKAEA in 1981, before being knighted in 1982 and moving on to become the CEGB Chairman the same year. In a comment perhaps designed to highlight Marshall's predilections, Benn praised his contribution and the 'high regard in which I hold Dr. Walter Marshall' before emphasising 'the role which he can and must play in the decisions which must be reached in the nuclear industry within the AEA'.[96]

The role of Walter Marshall in the formative years of the UK renewable energy programme serves as a useful example for the larger theme of this thesis: that of the UK energy TIC dominating and constraining renewable energy development. In 1977, after carefully pointing to Marshall's pro-nuclear views, Benn went on to praise the work that he had done in advancing 'the potential of alternative sources of energy', and it is clear that

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[91] Fishlock, 'Marshall', p. 95.
[92] Walgate, R., 'UK atomic authority 'was a great mistake' - Benn', *Nature,* vol. 278, 15 March 1979. p.201
[93] *Nature*, 'Getting at the truth about Dr Marshall', editorial, vol. 268, 7 July 1977, pp. 1-2
[94] Williams, *Decisions*
[95] Royal Commission on Environmental Pollution, 'Nuclear Power and the Environment', Cmnd. 6618. 1976;
[96] HC Deb 28 June 1977 vol. 934 col. 294

Marshall was crucial in pushing forward the early programme.[97] The archives show that Marshall's views on the potential of renewable energy were no more pessimistic than any of those involved in policy making at the time. Indeed, he was responsible for launching the Wave Energy Programme in 1975 and through his dual roles he recommended several increases in renewables funding. There is certainly no evidence of Marshall conspiring to end the renewables R&D programme. There are two straightforward explanations for this, of course. First, Marshall was director of Harwell and had been responsible for its 'survival' diversification programme from the 1960s onwards. Not only did ETSU attract funding to Harwell, but it also served to raise the profile of the establishment as the UK's centre for energy R&D. Second, Marshall was first and foremost a scientist, and he was interested in maintaining and promoting funding for scientific R&D in the UK. I would argue though that overlaying both of these explanations, there is a strong sense for Marshall of the unassailable dominance of the existing structure of energy supply in the UK, and in particular the UKAEA.

Conclusions

This thesis sets out to develop an argument that Government-funded renewable energy development in the UK during the period 1974-88 was dominated and constrained by an energy TIC. This chapter has shown how the institutional structure of the renewables programme was established within the TIC and controlled by interests close to the traditional energy industries, particularly the UKAEA. Despite the attraction of the simpler explanations for such domination, such as the roles of Harwell and Walter Marshall in the period, it has attempted to address the question of influence based on the actual evidence that this thesis has examined. This shows quite clearly that, despite earlier pessimism about the prospects for renewable energy, ETSU acted to evaluate the R&D efforts of the various programmes in a largely fair and balanced manner. A complex network of independent consultants was contracted to provide ETSU with progress reports on all aspects of the work of the device teams. As stated above, even the most outspoken critics of the overall programme regarded ETSU as, at least, scientifically rigorous. This would suggest that any outstanding breakthroughs achieved in renewable energy development in the period would have been favourably supported at Harwell. It also shows, as argued above, that Walter Marshall supported the initiative to explore all new forms of energy and this included

[97] HC Deb 28 June 1977 vol. 934 col. 294

renewable sources. Clearly, there was science-based support for renewable energy R&D in the UK.

The evidence therefore appears to challenge the view that renewable energy was explicitly sabotaged by the energy TIC at the level of the programme itself. What remains is a view which posits that other factors acted to constrain the successful development of renewable sources in the UK. At one level these are factors of scale and scope and would include the level of funding that was awarded and the targets that were set. The following chapter will demonstrate that there is strong evidence to support the argument that these factors were crucial in limiting the effectiveness of the programme. These elements of the programme were more closely influenced by ACORD, and by the attitude of the DoEn and the Government towards energy policy. This thesis argues that it was this wider, macro-level influence on the renewables programme that limited its success.

Chapter 4
The UK Wave Energy Programme, 1975-82

'The first stage of a full technical and economic appraisal of harnessing wave power for electricity generation should be put in hand at once' [1]

This brief recommendation by Lord Rothschild's Central Policy Review Staff (CPRS), and contained in its 'Energy Conservation' report to the government in the depths of the oil crisis in January 1974, set the pattern of renewable energy R&D in the UK until the early 1980s. The report set out to consider the possible solutions to Britain's energy crisis, and as a part of that exercise, it had considered the contribution of 'inexhaustible' sources of energy, which included hydro-electric schemes, tidal power, wave power, solar energy, and nuclear fusion. Although paying some attention to each of these different energy sources in the appendix section of the 75-page report, the three pages that summarised the report's recommendations contained only the brief statement above under the heading 'Electricity Generation'. Reflecting the influence that the CPRS enjoyed in government circles (discussed in chapter 3), particularly during the early 1970s, this statement was repeated continually over the next few years as the justification for unprecedented levels of government spending on R&D on renewable energy, and in particular on wave power.

The UK renewable energy programme was focussed on wave energy throughout the 1970s. Inspired by the early work of Gordon Goodwin at the Department of Industry (later of the DoEn) and the recommendation of Lord Rothschild's Think Tank, wave power was judged to offer the best prospects of all of the renewable sources of energy for the country. Serendipity played its part too, as the groundbreaking discoveries of Stephen Salter coincided with the urgent new interest in alternative sources of power. Wave energy quickly gathered supporters, in ETSU, ACORD, and the DoEn, who proved to be powerful allies for its development. Two of the DoEn's Chief Scientists, Walter Marshall and Sir Herman Bondi, did much to advance the cause of wave energy and their influence extended to ACORD and the DoEn. Within the ENT division at the DoEn, Don Gore (the head of the unit) and Gordon Goodwin worked tirelessly to establish a wave energy

[1] TNA, PREM 16/253, 'Energy Conservation', Central Policy Review Staff:, January 1974, p. 5. My italics

programme and senior figures at Harwell such as Freddie Clarke and more notably, Clive Grove-Palmer, became firm advocates for wave power. It appeared that wave energy was unassailable - and this chapter will present strong evidence to show the damage that this view was to have on wave energy development in the UK.

The cracks began to appear at the Heathrow Wave Energy Conference in 1978. High relative costs and technical challenges - perfectly understandable for such a new technology - began to weaken official support for wave energy. ACORD began to look more closely at wave energy, and at alternative sources of renewable energy development, particularly wind. Wind power was a mature technology in comparison to waves, the technical challenges less daunting and therefore the costs easier to estimate. The years following Heathrow proved difficult for the Wave Energy Programme (WEP). Despite massive improvements in the technology and concomitant reductions in cost, the failure to settle on a single device proved fatal for wave energy. The new Government after 1979 had little patience for a long-term publicly funded R&D programme such as wave power required. It demanded results, something concrete that could be plugged in to the National Grid and produce electricity at something close to the cost of the conventional sources. The decisions of the March 1982 meeting of ACORD to close the wave programme reflected this change.

The UK WEP illustrates some of the key aspects in the evolution of Government-funded renewables R&D in the UK. Before the ascendancy of wind energy in the early 1980s, wave power appeared to offer the best prospects as an ‘alternative source of energy’ and quickly became what a later Select Committee would describe as the DoEn’s ‘favourite horse’ during the 1970s. The programme therefore attracted much of the funding for renewable energy R&D and nearly all of the political and media attention during the 1970s. It began amid the (almost) heady optimism of the mid-1970s programme and effectively ended in the harsher fiscal spotlight of the Thatcher government. Along the way, the unfolding story of the WEP highlights many of the challenges that all renewable energy technologies faced during this period. I will show that these challenges were created through an understanding of energy that was dominated by the traditional industries and seen within the problem frame of UK energy policy at that time. The principal theme of this view was the persistence of the traditional understanding of energy created by a belief in the history of great energy transitions: animal to coal, coal to oil, and oil to nuclear. This was despite the fact that closer examination of history would have revealed that from the time of the first Industrial Revolution Britain had been a mixed-fuel economy. Despite this, throughout the period and beyond, policymakers always considered renewable energy sources in terms of their potential to *replace* an existing fuel source, be it oil, coal or nuclear energy. Renewable energy (in this case wave power) was therefore routinely understood and described as an 'insurance technology', an illuminating description which neatly summarises the overwhelming attitude to its anticipated potential. The widespread use of the term was clarified at length by ETSU in 1979 and is worth quoting in its entirety.

> The concept of insurance is important. Even if a country plans to achieve a particular pattern of energy supply and use, it might for a number of reasons find itself having to adopt some different pattern. Current assessments of future likely events and technical progress could be profoundly mistaken. There might be unexpectedly high world energy prices or restrictions on trade, including sudden embargoes, or restrictions on the use of certain energy sources. For example, nuclear power might be limited for environmental or social reasons, or concern about the effects of increasing levels of carbon dioxide in the world's atmosphere could lead to limits being set on fossil fuel combustion well within a 50 year time horizon.
>
> Different technologies can provide a hedge against different risks. A robust RD&D strategy must ensure that technologies that might need to be used as an insurance are brought to an appropriate stage of development, so that if required they can play their insurance role. To be important as an insurance a technology does not have to be cost competitive with those which it might have to compete in normal circumstances. *Wave energy, for example, may never be competitive against nuclear power; but if for any reason nuclear power were not able to be used, wave energy could be an important alternative*.[2]

As well as an interesting early reference to climate change and carbon limits, the quote above highlights the clear fact that nuclear power was the priority of UK energy policy throughout this period. This is well-established and unsurprising. Much less well understood, and more pertinent to my central thesis is the understanding of energy that underlies this policy priority: that energy policy could and should be based on a limited mix of fuels. Another key issue that the above statement highlights, and which was to become central to the debates over wave energy, was the concept of 'an appropriate stage of development'. After the initial enthusiasm for wave energy had subsided, particularly following the Heathrow Conference in 1978, the question of development became the

[2] Department of Energy, *Energy Technologies for the United Kingdom,* Energy Paper 39 (London: HMSO, 1979) My italics.

centre of debate in the WEP. On one hand the wave energy device teams (and the WESC) were keen to develop the scale of the programme towards working wave energy devices by the mid-1980s, whereas the DoEn and ACORD were daunted by the inevitably huge costs of such an undertaking. As we shall see, by 1982 the government judged controversially that wave energy had reached a stage in its development that was 'appropriate' within the UK's wider energy policy.

This was the background against which renewable energy was developed during the 1970s. The WEP began as a serious attempt to examine the long-term potential of wave energy in the UK, but I will show that it was undermined by constantly shifting expectations which only accelerated after the election of the Conservative Government in 1979. Rather than fully endorsing the view that the WEP was the victim of a nuclear-inspired conspiracy in the early 1980s, I will argue for a more subtle explanation. My research shows that the wave energy community misunderstood the weight and pervasiveness of the government's energy problem frame during the 1970s. The widespread publicity that the programme attracted, and the enthusiastic endorsement of many key figures within the energy policy community, led the supporters of wave energy to believe that it occupied a key position in the UK's energy future. This was mistaken. Rather, all of the evidence points to the fact that wave energy was never seen as anything more than 'insurance' by the government. The early programme set out 'to examine the potential of wave energy devices' and by the early 1980s, in the view of the government, the WEP had largely fulfilled these initial goals. By general agreement the next stage of the WEP, demonstration in the open seas, required much more significant sums, and this was an investment that the Conservative government was simply not prepared to make for a rather uncertain insurance policy.

The wave resource

The UK - mainly in Scotland - has the best wave energy resources in Europe, and among the best in the world. However, the actual figures attributed to the potential of the resource varied during the course of the WEP, primarily to suit the argument - for or against wave energy - being advanced at the time. However, by the mid-1980s it was assumed that offshore wave energy could provide in the order of 50 - 66 TWh per year of electricity, or approximately 20 Mtce.[3] At the time this represented roughly twenty-five percent of total electricity consumption in the UK, which in 1980 stood at 241 TWh.[4] In contrast, the suggested total potential for wind energy in the UK increased greatly through the period, beginning early in 1973 with estimates in the region of 4 TWh, when wave was initially estimated at a staggering 900 TWh.[5] By the mid-1980s developments in wind energy had raised these estimates to a figure much closer to that estimated for wave energy and wind was seen as having an onshore potential of around 45 TWh.[6] The huge early figure for wave energy was produced in March 1973 by the Energy Technology Unit (ENT) at the DTI and was based on existing wave data.[7] It extrapolated these figures from the entire 1700 miles of UK coastline which resulted in such impressive looking numbers. This basic approach was also adopted by the more rigorous NEL report on wave energy that appeared in 1975 although in this case the total potential was estimated at 500 TWh.[8] Clearly, these early estimates varied greatly from the eventual agreed potential for wave of around 50 TWh. How is this explained?

The very first estimates for renewable energy in the UK concentrated on the physical scale of the resource. The subsequent reductions in the figures for wave are explained by the investigation that took place during the first phase of the WEP to determine the *technically feasible* scale of the resource. Clearly, the working NEL assumption of an unbroken line of wave energy devices ringing Britain, ten miles out to sea, was not practicable. Moreover, neither was the implicit assumption that all of the energy contained in the waves could be captured and sent to shore without any transmission losses. Therefore, the first job of the new WEP was to determine this new figure and this is where we shall move to considering the first phase of the programme.

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[3] Department of Energy, *Renewable Energy in the UK: The Way Forward,* Energy Paper 55 (London: HMSO, 1988) Annex 7; Department of Energy, ETSU, ETSU R30, HL85/1364, *Prospects for the exploitation of the renewable energy technologies in the United Kingdom* (Harwell, May 1985) p.58

[4] Department for Business, Enterprise & Regulatory Reform, *UK Energy in Brief July 2007*

[5] TNA, EG 16/13, Department of Trade and Industry, Energy Technology Division, 'New Forms of Energy in the UK' 21 March 1973.

[6] Department of Energy, ETSU, ETSU R30, HL85/1364, *Prospects for the exploitation of the renewable energy technologies in the United Kingdom* (Harwell, May 1985) p.63 ; Department of Energy, *Renewable Energy in the UK: The Way Forward,* Energy Paper 55 (London: HMSO, 1988) Annex 3. The figure for offshore wind was estimated at 140 TWh.

[7] TNA, EG 16/13, Department of Trade and Industry, Energy Technology Division, 'New Forms of Energy in the UK' 21 March 1973.

[8] Leishman, J.M. and Scobie, G., *The development of wave power; A techno-economic study* (East Kilbride, National Engineering Laboratory, 1976)

The Wave Energy Programme

Although most accounts, including this one, identify Rothschild's CPRS report as the starting point of the UK's wave energy R&D programme, there was already some impetus within the government to explore the potential of wave power. The DTI report referred to above was produced in March 1973 and provided some of the inspiration to the later CPRS study. Indeed, Rothschild consulted the author of the earlier report, Gordon Goodwin of the Energy Technology division (ENT) at the DTI, and used his investigations into wave energy extensively.[9] Goodwin was a scientist by training, and became fascinated by the potential of wave energy in 1973. He played a key 'behind the scenes' role in developing wave energy in the UK (described in more detail in chapter 5). Prior to the official appearance of the CPRS report (although obviously aware of its content) the DTI had already commissioned the National Engineering Laboratory (NEL) at East Kilbride to produce a detailed techno-economic appraisal of the state of global wave power technology.[10] The high public profile of Rothschild's Think Tank attracted publicity to wave energy and provided the initial boost that it required, but it was the recommendations of the NEL report that provided the evidence required for the establishment of the wave energy programme after 1975.[11]

The NEL report: 'preliminary assessment'

The stated objective of the NEL report was to 'assess the economic and technical viability of wave power generation in the UK', but its focus was overwhelmingly on the technical challenges of wave energy.[12] Although the report did suggest that electricity could be produced from wave energy 'at about 1p/kWh' within the summary of its findings the report conceded that it was unable to fully assess the economic potential of wave energy owing to the uncertain technical development of wave energy devices.

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[9] Gordon Goodwin was to play a key 'behind the scenes' role in establishing and maintaining the Wave Energy throughout the 1970s. Chapter 5 will examine his role in more detail.

[10] TNA, EG 16/13, ET 51/03, correspondence Gore to Scholes, 24 January 1974.

[11] TNA, EG 16/48, *Private Eye*, 'Government Backs Power from Waves Plan', 18 October 1974. This spoof article contributed by 'Sir Solly Wong-Number' (Sir Solly Zuckerman) provides a humorous example of this connection with the Rothschild and also gives some insight of the scepticism that surrounded both wave energy and the work of the Think Tank. 'The project, described as "the brain-child of Lord Rothschild" has been pioneered by top scientists working round the clock at the Grocer Heath Robinson Institute. It involves the harnessing of the waves in the Think Tank to provide enough electricity to light a small light bulb'.

[12] TNA 16/13, NEL, Economic Assessment Unit, 'Proposal for an Economic and Technical Study of Wave Power Generation', 25 January 1974.

> No undue emphasis should be placed on these cost estimates as the assessment did not and could not determine the costs of structures and components whose detailed design requires extensive investigation. [13]

Despite this, the recommendation of the report was that 'The UK should maintain an interest in the development of power generation from sea-wave energy'. Notwithstanding its shortcomings, Ross, perhaps the strongest and most widely published critic of the UK WEP, described the NEL report as the 'standard work' on wave energy and it formed the basis for the Wave Energy Programme (WEP). Gordon Goodwin was less impressed however. Ross quotes an interview with Goodwin in the early 1980s where he describes the report in much more negative terms.

> We granted them £13000 to produce this and they had access to Salter's work. It is horrible. It is rubbish. It is paper ideas. I had argued that water would not do what you expected. I thought we should get our feet wet. I was over-ruled and work went on at the NEL.[14]

Goodwin was enthusiastic about the potential for wave energy and had been instrumental in putting it on the agenda of the DTI, and subsequently the CPRS, through 1973. He had written the March 1973 DTI study and had contributed to Rothschild's report. However, his comments were made as the WEP was facing closure in the early 1980s. Ross concluded that his harsh comments arose because NEL shifted through time from supporting the work of Salter at Edinburgh University towards a different wave device - the oscillating water column - based on a design originated by Masuda in Japan. Goodwin had been closely associated with the Salter team from late 1973 (see chapter 5). This then may partly explain his damning assessment of the NEL report. However, I would add the view that he was frustrated at that lack of progress in wave energy and placed some of the blame for this on the initial eighteen-month delay caused by the wait for the NEL report. The report undoubtedly set the tone for the WEP and following its recommendations in its first phase this focussed on 'study': device development in the labs and test tanks of the device teams - with no 'wet feet'. This first phase will be explored next.

[13] TNA 16/13, NEL, Economic Assessment Unit, 'Proposal for an Economic and Technical Study of Wave Power Generation', 25 January 1974. Underlined in original.
[14] Ross, *Energy,* p.43

'Phase one: Study'

In 1985, with the convenience of hindsight, a government report mapped out the evolution of the development of the WEP.[15] This official version presented the NEL Report as the 'Preliminary Assessment' stage lasting until early 1976 which then introduced a two-year 'Study' phase of the programme. In late 1978 this was followed by 'Reference Designs'; this part of the WEP, when device teams worked towards the design of a 2GW generating station, which, as it turned out would last until the programme was drastically reduced and effectively shut-down in March 1982. The government report termed the phase after 1982 as the 'Reduced Ongoing Programme'. At the time this was written in 1985, the government was still coming under criticism for what some saw as the premature abandonment of wave energy R&D, and the above can be seen on one level as a clear attempt to emphasise the structural logic of the WEP and to emphasise the government's assessment that the programme had reached 'an appropriate stage of development'. The clear gap in the otherwise detailed NEL study was in the cost of generating electricity from the sea waves, and this therefore had to be a priority for the programme. This section will focus on the 'Study' phase of the programme which began formally in April 1976 and lasted until the Heathrow Wave Energy Conference in November 1978.

Following the favourable conclusions of the NEL report in 1975 the formal decision was taken by ACORD in June of that year to establish a Wave Energy Steering Committee (WESC).[16] The initial task of this committee was;

> • to draw up and agree a national programme of work for the study of wave energy
> • to advise on the implementation and management of that programme
> • to advise on the technical briefing of UK delegates to international meetings on wave energy
> • to report to the Chief Scientist, Department of Energy on matters relating to wave energy.[17]

WESC began to meet formally from August 1975. Despite the claim that 'members of the WESC were drawn from industry, academic institutions, consultants, officials, and

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[15] Department of Energy, ETSU, ETSU R26, *Wave Energy: The Department of Energy's R&D Programme 1974-83* (March 1985)
[16] TNA, EG 16/80, ET 4/3/01, FPRD(76) 9, Department of Energy, Advisory Council on Research and Development in Fuel and Power
[17] Department of Energy, ETSU, ETSU R26, *Wave Energy: The Department of Energy's R&D Programme 1974-83* (March 1985) p.111

ETSU'[18], in fact, as table 1 shows, the initial membership was dominated by the last two of these groups, ETSU and the DoEn. The pace of initial developments was quickened by the DoEn's Chief Scientist, Walter Marshall, who was very anxious to work 'urgently on progressing Wave Power R and D'.[19] This was partly explained by his recent uncomfortable appearance in front of the Select Committee for Science and Technology (SCST) which, in common with many other aspects of energy policy, was sharply critical of the lack of progress in renewable energy technology.[20] The initial challenge lay mainly in funding the programme, as the relatively new and small DoEn was slow in establishing its R&D budgets.[21] Late in 1974 this had already led to the Salter wave energy device secure its initial funding from the rival DTI through the recently established Mechanical Engineering and Machine Tools Requirements Board (MEMTRB) (see chapter 5). Shortage of DoEn funds meant that the same body also initially funded the WESC.

Table 4.1

Wave Energy Steering Committee Membership, 1975-76 [22]

L. E J. Roberts (Chairman)	ETSU (Harwell)
F. J. P. Clarke (Chairman - from July 1976)	ETSU (Harwell)
J. K. Dawson	ETSU (Harwell)
G. Goodwin	DoEn
D. Gore	DoEn
R. Hancock	NEL
G. Potter	Science Research Council (SRC)
J. K. Wright	CEGB
C. Grove-Palmer (Secretary)	ETSU (Harwell)

The ENT division at the DoEn had prepared a paper for the ACORD meeting in June 1975 which suggested funding for a wave programme 'should be about £400,000 per

[18] Department of Energy, ETSU, ETSU R26, *Wave Energy: The Department of Energy's R&D Programme 1974-83* (March 1985)
[19] TNA, EG 16/80, Skipper to Marshall, 1 July 1975.
[20] TNA, EG 16/48, HC, Minutes of Evidence taken before The Committee on Science and Technology (Energy Resources Sub-Committee) 12 February 1975
[21] McInnes, 'Policy Networks', p.21
[22] TNA, EG 16/64, Appendix 1

annum at present, rising to perhaps £2 million in three or four years time'.[23] The first option was to consider diverting some of the existing ETSU budget, however for 1975/6 this had been agreed at a total of £300,000 - with perhaps only around £100,000 being available for the wave energy programme.[24] At the early meetings of WESC it soon became apparent that a figure much closer to the ENT recommendation would be required for a two-year programme. Wave energy was continuing to attract publicity and this added to the pressure that Walter Marshall felt to demonstrate serious intent in energy R&D. By April 1976, when the official wave energy programme was launched £1m was the amount allocated by the DoEn for the two-year study.

By January 1976 the WESC had formulated a plan for the first stage of the formal Wave Energy Programme. This set out a two-year programme lasting until the end of 1978, which was to include 'nine major areas of work.'[25] This included four 'Specific Wave Energy Convertor Projects' and five identified areas of 'Generic work'. The original four wave energy devices included were:

- Salter's Duck (University of Edinburgh)
- Cockerell's Raft (Wavepower Ltd.)
- Masuda's buoy - the Oscillating Water Column (NEL)
- Russell's Rectifier (Hydraulics Research Station)

Each of these devices featured prominently in the NEL report, and as already mentioned in the case of 'Salter's ducks' government R&D funding of £65,000 was already in place through the DTI (see chapter 5). The publicity that surrounded wave energy during 1974, and resulted in the funding for Salter, was also assisted by the prominence given to Sir Christopher Cockerell's work on wave energy. Cockerell, through his work on developing the Hovercraft, was one of the best-known and respected British scientist/inventors and his presence undoubtedly attracted further attention to wave energy. Cockerell was optimistic about wave energy, and as early as October 1974 he had been interviewed by the BBC on its prospects. In the interview he suggested that the wave energy 'which at the moment just bashes the shore and goes to waste' could meet all of our

[23] TNA, EG 16/1, ET 4/10/012, FPRD(75) 26, Department of Energy, Advisory Council on Research and Development for Fuel and Power, 'Wave Energy: Note by ENT division'.
[24] TNA, EG 16/80, Leighton to Marshall, 17 June 1975
[25] TNA, EG 16/64, WESC(75)P24, 'A Programme for Wave Power. Summary paper for the Chief Scientist', undated

electricity consumption needs. [26] Along with Salter, Cockerell and his raft device had been under development since late in 1973. Cockerell had formed a new company, Wavepower Limited, with some funding from British Hovercraft Ltd. to develop the device, and the DoEn had indicated early in 1974 that government R&D funding would be allocated to his new device.[27]

The other two wave energy devices that feature in the initial programme were also given their prominence in the WESC recommendations by the NEL report. The Masuda buoy was the most well established of all the devices proposed for the programme and the NEL report identified it as 'the most promising scheme'.[28] Yoshio Masuda had been developing his floating buoy wave energy device since the Second World War and it was therefore the only device to have achieved any commercial development. The remaining, and least well-developed device, known as the Russell rectifier, was based at the Government's own Hydraulics Research Station (HRS) at Wallingford. Like the Masuda device the fundamental idea had been developed prior to the 1970s, owing its development to earlier work during the 1950s on wave energy by Walton Bott. Bott gained his experience in energy working on hydroelectric schemes in Scotland before relocating to Mauritius in 1953 to set up an electricity board. Bott developed a shoreline wave energy device which was later taken up by Robert Russell, a scientist based at Wallingford. These devices, along with the Raft and the Duck, then appeared to WESC to be the most promising of the early wave energy devices.

The other element of the initial wave energy programme proposed by WESC was five areas of 'Generic Work' (see below). This would eventually result in the creation of the Technical Advisory Groups (TAGs) that were directly responsible for assessing different elements of the programme. This area of the programme was to prove crucial in developing and assessing the work of the device teams, though some, including Salter, felt that they sometimes slowed progress with unnecessary extra work (see chapter 5 for more discussion on this point).

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[26] TNA, EG 16/51, ET 51/48/01, Transcript, BBC Radio 4, *The World at One*, 'Energy from the Waves', 7 October 1974

[27] TNA, EG 16/13, Leighton to Gore, 12 February 1974

[28] TNA 16/13, NEL, Economic Assessment Unit, 'Proposal for an Economic and Technical Study of Wave Power Generation', 25 January 1974. p.5

- ✦ Wave data
- ✦ Wave loading and the behaviour of Structures
- ✦ Anchoring and Mooring
- ✦ Energy conversion and Transmission
- ✦ Environmental studies and external relations.[29]

The summary paper proposed the initial programme as a 'feasibility study' and went on to say clearly that '*If*, when the feasibility study has been completed, the idea of wave energy continues to look attractive, it will be necessary to build larger scale models for more extensive tank trials' (my italics). WESC planned to 'take at least two devices' to this next stage, and have 'at least one 1 MW prototype operating at sea within the next ten years'. Significantly for the future programme the WESC went on to suggest that the anticipated cost of such an ongoing programme 'is unlikely to be less than £25m'. This shows quite clearly that from the outset of the renewable energy programme considerable funding was anticipated in order that devices could be developed fully. As has been shown, wave energy was seen as the major contender in this period. This arose from the assessment of its potential contribution as a major energy source. In contrast to the small contribution traditionally expected from renewable energy, wave energy showed early promise as a potentially significant contributor to UK electricity consumption. Even bodies thought of as hostile to renewable energy sources such as the CEGB suggested that it could provide 'nearly five times the average demand on the CEGB'.[30] This helps to explain much of the early enthusiasm for wave power.

On April 29 1976 Alex Eadie, the Under-Secretary of State for Energy, responding to a written question announced the launch of the Government's 'national research and development programme into wave energy'. The WESC recommendations had been adopted without any alteration and a two-year £1m programme to establish the 'feasibility of large-scale extraction of power from the sea-waves' was formally created.[31] In preparation for the announcement Eadie had made a public visit to see Salter's work at Edinburgh during March that year and was personally impressed by the potential of the resource.[32] Although WESC was careful not to indicate any favourites among the competing wave energy devices, the Salter team was allocated the largest slice of the

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[29] TNA, EG 16/64, WESC(75)P24, 'A Programme for Wave Power. Summary paper for the Chief Scientist', undated

[30] Glendenning, I., 'Energy from the sea', *Chemistry and Industry* (1977) pp. 588-99

[31] HC Deb 29 April 1976, vol. 910 cc. 150-1W

[32] TNA, EG 16/50, 'Alex Eadie to visit wave energy research project - Edinburgh University' February 27 1976; Frazer, F., "Ruling the waves' *The Scotsman,* 2 March 1976, p.11

proposed budget.[33] This was partly due to the advanced development of the duck in comparison with the other devices, but also reflected the high public profile of Salter as a wave energy pioneer.

The 'study' phase of the programme went very much according to the proposed WESC plan. The National Engineering Laboratory at East Kilbride were given the task of developing the Masuda device, which after a brief spell as the 'Pelican' became more widely known as the oscillating water column (OWC) and each of the device teams set about the initial development task of producing designs for a 1MW generating station. Very early in the programme (in fact, *prior* to the official programme) the Salter team at Edinburgh formed a partnership with Lanchester Polytechnic and industrial partners, Ready Mixed Concrete (UK) Ltd. and Insituform (Pipes and Structures).[34] They formed a limited company called Sea Energy Associates (SEA) to help develop the Duck concept which received separate funding from the WEP. This was an interesting example of an early university/industry/government initiative which is dealt with in greater depth in chapter 5.

By April 1977, only a year after the launch of the official programme, the DoEn announced an increase in funding to £2.5m. [35] Although this was partly due to the dramatic impact of inflation at the time (averaging around 16% in the period) it was also a reflection of the rapid development and testing of the wave devices.[36] The earlier funding received by the Salter team meant that the WEP did not begin from a standing start, as the Edinburgh lab had already assembled a suitable testing tank for the four first generation devices. With the first 1:100 scale tests completed, the DoEn and some of the teams were keen to scale up their devices and get them into the open-water. Very quickly this was to lead to conflict between Salter and the Lanchester team, specifically over open water trials of Salter's Duck in Loch Ness during 1977.[37] Salter favoured more tank testing, but the Lanchester team led by Norman Bellamy (and encouraged by the WESC) was keen to test a 1:10th

[33] TNA, EG 16/64, WESC(75)P24, 'A Programme for Wave Power. Summary paper for the Chief Scientist', Table 1, p.7, undated
[34] Salter Archive, P. L. Young to J. W. Midgley, letter dated 19 December 1975.
[35] HC Deb 05 April 1977 vol. 929 c392W; TNA, EG 16/80, ET 172/20/01, Reference no. 133, Department of Energy, Press Notice, 'Increased spending on wave energy R & D' 5 April 1977.
[36] TNA, EG 16/80, WESC(76)P99, 'Revised Funding for the Wave Power Programme: November 1976', C. O. J. Grove-Palmer, hand-dated 11 November 1976.
[37] Salter Archive, Minutes of technical meeting of Sea Energy Associates Ltd. held at Lanchester Polytechnic at 11.00 a.m. 23rd June 1976.

scale model in open-water. This gave rise to some bitter exchanges, covered in more detail in chapter 5, which give some early indication of concern over the direction of the WEP.

By the end of the two-year study phase of the programme, and despite Salter's strong objections, open water trials had taken place in Loch Ness of the Salter device and the Cockerell Raft in the Solent. Allowances had been made within the WEP budget for additional devices to be included, and by the end of the two-year programme more devices were beginning to receive DoEn R&D funding.

Heathrow 1978

A first Wave Energy Conference at Heathrow marked the end of the two-year study phase of the programme in November 1978 and attracted over 300 delegates, including many from overseas keen to hear about the initial successes of the UK wave energy programme.[38] The conference brought together all of the wave device teams, the Technical Advisory Groups (TAGs), government, and the press to review the results of the feasibility study. Despite the commitment of the DoEn earlier in 1978 to fund the programme for a further two years, most commentators identify the Heathrow Conference as the crucial turning point away from wave energy in the UK.[39] Unfortunately little archive material exists on what this thesis regards as the pivotal moment in the period. This account therefore will rely on the conference programme and the personal recollection of some of its participants.

Although the conference produced clear evidence of tremendous technical advances in wave energy data and devices, the estimated costs of generating electricity that were unveiled at Heathrow deflated early enthusiasm. The crest that the wave energy community had been riding right up until the conference dipped into a trough from which it could not recover. One purpose of the feasibility study had been to identify the most promising wave energy devices for further funding and development, and the device teams all had plenty of technical progress to report on at the conference. However, the study

[38] Ross, D., 'Scuppering the Waves', Network for Alternative Technology and Technology Assessment, Energy and Environmental Research Unit, Faculty of Technology, The Open University (Milton Keynes: May 2001) p.6

[39] Ross, *Waves,* pp. 103-107; Ross, D., *Power from the Waves* (Oxford: Oxford University Press, 1995) pp. 52-60; Ross, 'Scuppering the Waves', p.6; Watt, R. N., 'Towards a synthesised network approach: an analysis of UK nuclear and renewable (wave) energy programmes 1939-85', (University of Birmingham, 1998, PhD thesis); Department of Energy, ETSU, ETSU R26, *Wave Energy: The Department of Energy's R&D Programme 1974-83* (March 1985) p.7. This Government review of the WEP stated that costs presented at Heathrow were 'disappointingly high'.

phase of the programme was also given the task of estimating the likely cost of wave power - something that the NEL report had been unable to do. It was these results - the economics of wave power - that caused significant and lasting damage to the reputation of wave energy.

The omens were bad for wave energy when Freddie Clarke, chairman of the WESC and research director at Harwell, opened the conference on the 22 November in somewhat gloomy terms, '...there is usually a stage in the research and development of technology at which the problems loom larger than the solutions and things appear to change from month to month and possibly from week to week. Wave energy is currently at this stage.' He gave a very brief review of the first two years of the programme, in which he highlighted what he regarded as its three main achievements. The first of these was the 'team of some 150 people all over the country...who are gaining a grip on this new and difficult technology of wave power.' The second was the shift from 'elementary testing in laboratory to very sophisticated testing that simulates in miniature real sea conditions' adding that the 'films of these are very striking indeed.' This technological development was 'a substantial step forward in our knowledge' but in introducing his third point he judged that it was 'still not great enough'. The last 'achievement' was what Clarke termed 'a proper engineering evaluation of concepts'. This final point referred to the role that Rendell, Palmer and Tritton (RPT), a key consultant to the WEP, played in assessing and evaluating the devices in the programme. He explained that RPT, working closely with the teams, had produced 'so-called reference designs, and have costed them. *So it is that we are today able to give some costings for the first generation of wave energy machines*.' [40] He then concluded his opening remarks under the heading 'The high costs of the early designs'. Whilst conceding that some 'important designs and concepts' were hoping for a figure of 10p per kWh, he estimated average generation costs in a 'very high' range of 20-50p per kWh, compared to the average electricity generation cost at that time of 2p per kWh. This was a million miles from the 1p per kWh that the NEL report had tentatively suggested in its report.

Speaking later in the conference, Clive Grove-Palmer the WEP manager was more upbeat about the prospects for wave energy. Both revealing the hubris of the wave energy

[40] Salter Archive, 'Clarke, F. J. P., Introduction to the Conference, Proceedings: Wave Energy Conference, Heathrow Hotel, London. 22-23 November 1978. Sponsored by the Department of Energy. Organised by the Energy Technology Support Unit, Harwell.' p.5 (my italics)

community and anticipating the unfavourable reaction to the Heathrow figures, he rather naively suggested that although the 'cost analysis' could be seen as 'a hatchet job' he thought that '...there is nothing quite like the thought of an execution to concentrate the mind.' Ross later wrote that most of the journalists and foreign buyers had left the meeting after the first day when the technical challenges and high predicted costs for wave energy were unveiled and emphasised.[41] Certainly in the media there was evidence of a notable shift away from the largely positive views on wave energy immediately following Heathrow. Writing in the *Observer* Jeremy Bugler, referring to the RPT report suggested that 'A 3-volume gale hits the wave energy men'.[42] In *The Scotsman,* Frank Frazer focussed on the 'environmental and social aspects of wavepower' with the 'routing [sic] of pylons across the Isle of Skye'.[43] In a letter to Salter on the publication of the Heathrow proceedings, Grove-Palmer observed that it '...presents a rather gloomy picture of the prospects for wave energy and that fact has not escaped the press.'[44]

It appeared from Grove-Palmer's remarks at Heathrow that the goodwill of the Government and public support for alternative energy had been taken too easily for granted. Four years of R&D on wave energy, including the previous two years of official backing had lent the programme a feeling of invincibility. Much of this was perfectly understandable, of course. In the early part of 1978, following the success of the early programme and before the two years of the 'study phase' were completed, the Government had agreed funding for a further two years of wave energy R&D; at an increased rate. And Glyn England, chairman of the CEGB which was often seen as a strong advocate for the expansion of nuclear power, speaking at Fawley power station in July that same year said,

> As we see it at present wave power is the most promising of the renewable energy sources...Averaged over the year there is about 80 kilowatts of power in each metre of wave front approaching Britain from the North Atlantic. This implies a total annual availability of 120,000 megawatts (120 gigawatts) of power along Britain's Atlantic Coast. However, not all the power could be harnessed. There would inevitably be substantial power losses in conversion, and transmission losses, too, so that probably only about one third could actually be got to the electricity consumer. *Nevertheless this is still a substantial amount of power - enough, in fact, to*

[41] Ross, *Power,* p.58
[42] Salter Archive, Bugler, J. 'A 3-volume gale hits the wave energy men' *Observer,* 26 November 1978
[43] Salter Archive, Frazer, F., 'Problems of power from waves', *The Scotsman,* 24 November 1978.
[44] SA, Grove-Palmer to Salter, 20 November 1979.

supply the whole of Britain with electricity at the present rate of consumption. [45]

Added to the official endorsements of wave power was the positive, widespread and ongoing media coverage that wave energy received prior to the Heathrow Conference. The launch of the WEP was covered extensively in the UK and abroad.[46] This coverage reflected the official enthusiasm for wave energy and continued throughout the 'study' phase of the programme, as progress was covered positively by the press and trade journals. This included gushing reports of the opening of a new £100,000 wave energy tank at the University of Edinburgh,[47] and the first open-water trials of the Duck at Loch Ness in 1977.[48]

Phase two: 'Reference Designs'

In the first phase of the programme the WESC operated within a set of loosely defined long-term targets for the wave energy device teams. Their initial report to the Chief Scientist in 1976 had suggested that the teams should work towards having a 1MW prototype 'operating at sea' by the mid-1980s.[49] More clearly defined were the short-term two-year technical targets of the programme, and ironically, the Heathrow Conference provided evidence that these had been achieved successfully. This element of success led to a reconsideration of the scale of the target that the teams were set, and when the funding was increased early in 1977 the 'reference design' that the teams were working towards was also increased dramatically to 2GW (2000 MW) power station.[50] In addition to reflecting the success of the device teams, this new target says something about the attitude of the DoEn towards new energy sources. Echoing the comments by the CEGB on the

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[45] His July 1978 speech was reprinted as, England, G., 'Renewable Sources of Energy - the prospect for electricity' *Atom,* 264, October 1978.

[46] Some examples are: Dover, C., '£1m Study of Britain's Wave Power', *The Daily Telegraph,* 30 April 1976; *The New York Times,* 'British Will Tap Waves for Power', 15 October 1976; Delin, J., 'Sea Wave Power 'in 10 years'' *The Daily Telegraph,* July 1975; Silcock, B., 'Britain's Search for Wave Power', *The Washington Post,* 24 October 1976; *Offshore Engineer,* 'Wave power gets the nod from DoE', December 1976

[47] Faux, R., 'Wave power testing tank opened for research', *The Times,* 12 July 1978; Fishlock, D., 'Wave-testing tank holds key to future energy research', *Financial Times,* 12 July 1978; Linklater, J., 'Scots aid UK to plug in waves power', *Glasgow Herald,* 12 July 1978

[48] Thackway, C., 'Research into energy from waves ready for tests at Loch Ness', *The Scotsman,* 23 November 1976;

[49] TNA, EG 16/64, WESC(75)P24, 'A Programme for Wave Power. Summary paper for the Chief Scientist', undated. p.6

[50] Department of Energy, ETSU, ETSU R26, *Wave Energy: The Department of Energy's R&D Programme 1974-83* (March 1985) p.7. 'In order to ensure that device teams were working to a common basis they were asked to optimise their respective designs to meet the criterion of a 2 GW wave power station off South Uist in the Hebrides and to estimate the cost of electricity generated by such a station'.

scale of the resource it illustrates the government's pressing need for alternative energy sources to demonstrate their potential as major fuel providers according to the dominant energy paradigm. Although accepted with little comment at the time (again, perhaps a reflection of the hubris of the wave energy community) the change in the scale of the reference designs created problems for the device teams from the Heathrow Conference onwards. During this new phase of the programme the consultants RPT were set the task by the WESC of estimating the cost per kWh of the much larger station. Later, Salter would repeatedly complain that this was like trying to estimate the cost of air travel in the 1980s based on data available in 1910.[51]

By the end of 1978, at the start of the next phase of the wave energy programme, the range of devices receiving DoEn funding had increased significantly. Joining what became known as the four 'first generation' devices, were a number of new devices listed below.

- ✦ the Flexible Bag (University of Lancaster)
- ✦ the Clam (Lanchester Polytechnic and Sea Energy Associates)
- ✦ the Triplate (Royal Military College of Science)
- ✦ the Cylinder (University of Bristol)

The greatly increased number of devices indicated a number of things. First, from a technological point of view it was an illustration of the rapid spread and transfer of new technology within UK research establishments. This was aided and encouraged by the wide press coverage but must also have indicated the existence of some form of technology R&D network within the UK. Certainly also the number of devices increased in proportion to the funding available for wave energy within the DoEn. Interestingly the device teams rarely, if ever, complained about the extent of funding available. On the contrary, after the official programme was established Salter wrote regularly that his research was 'well provided for'. Rather, bitter complaints were reserved for the administrative process that accompanied the funds discussed in detail below.

A second important issue that arises from the increase in devices is the uncertainty that this indicates from WESC, particularly about the potential of first generation devices. Chapter 1 discussed the long history of wave energy converters, in particular the large number of wave device patents - a point emphasised in the NEL report. In that history of

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[51] Salter, 'Looking Back', p.25. 'in 1983 it was as wrong as giving Bleriot the specifications for a Boeing 747'.

devices a wide variety of approaches had been taken to extracting energy from the sea waves. Famously, Salter had invented his basic but highly efficient Duck device within a few short months by going '...round to Woolworth's...[and buying]...sixpen'orth of Balsa...'[52] adding another method to the already long list of wave energy devices. In short it appeared that there were a number of methods for extracting power from the waves, and in each case the fundamental principle and design of the devices was arguably the least of the technological challenges facing the teams.[53]

It was the ease with which new wave energy conversion devices could be devised that made the initial study phase of the programme a success, as each concept was tested in the controlled environment of the laboratory tank. The Heathrow Conference had gone beyond the test-tank to imagine each device operating in the open sea - and this is where the real challenges lay. Donald Swift-Hook, a senior CEGB scientist who worked on wave energy in the 1970s, later argued that the actual device selected was almost irrelevant: each device converted wave energy at high efficiencies. The key lay in collecting the energy and transmitting it to the National Grid.[54] Although perhaps understandably disagreeing with his point over the irrelevance of converters, Salter was aware of this general issue and this helps to explain his resistance to what he viewed as premature testing in open water at Loch Ness in 1977.[55] However, the WESC decision to include yet more wave energy devices shows some misunderstanding of the importance of this point. Unfortunately, the decision to include additional devices also resulted in some nervousness and criticism from ACORD over the scope of the programme, and this led directly to a series of retreats from the WEP that ultimately resulted in the closure of the programme by 1982.

The first official signal of a retreat from the WEP resulted from the ACORD meeting in March 1980. At this point it may be worthwhile to describe the way in which the overall DoEn management of the programme was structured, which Salter referred to as a 'tortuous chain of command'.[56] As outlined in chapter 3, ACORD had the task of advising the DoEn on its energy R&D programmes. Although, controversially nuclear energy lay outside the remit of ACORD, after 1974 the renewable energy programme was

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[52] Ross, *Power,* p.46
[53] Ross, *Power,* p.118. On this point, Ross quotes one of the wave device developers, Michael French of Lancaster University, as saying that 'anyone could invent two wave energy devices before breakfast'.
[54] Interview with Donald Swift-Hook, July 2008
[55] Interview with Stephen Salter, 31 July 2008
[56] TNA, EG 16/50, ET 51/03, Salter to Goodwin, 5 February 1976. 'I sometimes feel wave power is too young to have such a tortuous chain of command.'

added to its advisory responsibilities. ETSU provided the next link in the management and advisory chain and it reported on the range of individual renewables programmes to ACORD on an annual basis. WESC reported progress on the WEP to both ETSU and ACORD. Ultimately, it was ACORD who would make recommendations to the Secretary of State, and they had a strong influence on outcomes as was discussed in chapter 3. The difficulties arose in the timing of progress reports and advice. Salter described it thus:

> The cycle of events began with the Treasury Financial Year in April. There had to be time for the Department of Energy officials to consider the ACORD advice and for ACORD to approve its own minutes. This meant that the advice must be given at an ACORD meeting in February. The proposals put forward to ACORD had to be discussed by one meeting of WESC and modified for approval by a second. This meant that WESC must have all the information it needed in early December. The most important piece of information required was the report by the Consultants. If they worked flat out they could finalise reports on a number of devices in about a month, but this meant that they must bring down the chopper on the work of the device teams by the beginning of November. Everything they saw was a flash photograph of the position in October. There is no chance of a device team saying “There. It is finished. Nothing can improve it. We have spoken.” The drawings and graphs carried long streaks as the paper was wrenched from beneath their pencils at 23.59 on October 31st.
>
> After April the Department of Energy would tell the Programme Manager how much he would have to spend. This would be unlikely to be the same as the amount he wanted and so he would have to talk with device teams, Project Officers, Consultants and TAGS and arrive at a new revised programme. If he worked with the tireless devotion for which programme managers are selected he might have this done by the end of May, ready for discussions by WESC in June and for modifications and re-approval in July. The sums of money involved exceeded the amount which could be authorised without signature by officials of the Department of Energy, who are of course on holiday in August. But when they returned in September it took no time at all to authorise and issue the formal contracts from the Harwell contracts branch. It was just possible to get one out by mid-October, leaving two weeks for the ordering of equipment and the recruitment if not the training of staff before the consultants’ axe descended. A single hiccup in any part of the procedure could make the official working time go negative and often did. When the contracts arrived they could be amazingly complicated. In one the work programme was split into four time periods and four different work topics giving sixteen different pots of money and no certainty that it could be transferred between them. [57]

[57] Salter, ‘Looking Back’, p.21

Even allowing for the frustration that Salter felt as part of the device teams at the sharp end of this process, it clearly placed severe constraints on the work of the WEP. Bellamy, of the SEA/Lanchester Polytechnic team shared Salter's concerns. In April 1978 he wrote to Clarke,

> What is not acceptable is the inflexibility of the yearly go/no-go decisions on device team existence which particularly applies to educational institutions. Even with the intention of continuity from year to year, the time scales of reports leading to proposals leading to contracts cannot be achieved without disruption. Something should be done to put future programmes on a businesslike basis.

Despite the complaints of the device teams and the efforts of WESC and the Chief Scientist, Sir Herman Bondi, the Treasury were firm that the basis of government funded R&D should remain on yearly contracts. They pointed out that 'This policy is adopted for all Government R&D work of this nature, including entire weapons systems costing several hundred millions of pounds to develop.' Although confessing not to 'be fully aware of all the details' of the WEP, the Treasury went on to explain that yearly contracts 'allow the Government to limit their involvement in the event of (i) public expenditure cuts or (ii) a desire to terminate the work either because the technological feasibility of completing the work becomes doubtful or because the market prospects change adversely to such an extent that continued funding cannot be justified.'[58] This was to prove to be an uncanny prediction of the fate of the WEP.

After what can now be seen as the high point of the WEP between 1976 and 1978, the disappointing economic assessments of wave energy presented at the Heathrow Conference and the proliferation of devices eventually caused ACORD to look more closely at the programme. Increased funding for 1978/79 of £2.9m had been agreed by ACORD early in 1978 (before Heathrow) but clearly the enthusiasm for waves was beginning to wane.[59] The case for wave energy was not helped by the publication later in 1979 of the Heathrow Conference Proceedings, the appearance of the DoEn's Energy Paper 42 on the wave energy programme, and the election of a new government committed to cuts in public expenditure. Unfortunately for the device teams, despite significant

[58] TNA, EG 16/80, 'Continuity in Wave Power Contracts', Heathcote (Treasury) to Chief Scientist (DoEn) 19 May 1978

[59] TNA, EG 16/80, Skipper (Head, Chief Scientist's Branch, DoEn) to Kemp (Treasury), 14 March 1978. This new funding included £300,000 for a collaborative project 'with the Japanese and others through the International Energy Agency'.

improvements in cost per kWh since Heathrow, Energy Paper 42 reproduced the earlier higher figures from Heathrow. However, by the time these publications appeared, and prior to the election of the Thatcher government in May 1979, the March 1979 meeting of ACORD had approved an increased budget of £4.9m for wave energy in 1979/80.[60]

ACORD March 1980

Wind energy, which had been largely dismissed up until this point, began to look more favourable to the DoEn and by the March 1980 meeting of ACORD official impatience with wave energy was increasing. From June 1978, under invitation from Sir Herman Bondi, a Wind Energy Steering Group (WISC) had begun to meet (also under the chairmanship of WESC chairman, Freddie Clarke) to develop a wind energy programme (see chapter 6).[61] Despite this, in January 1980 ETSU produced its fifth annual report for ACORD which was full of praise for the 'considerable progress' made by the WEP during 1979. Referring to the 'very high' costs estimated at Heathrow (and repeated in Energy Paper 42) it noted that 'all these factors have been improved significantly during 1979'. Instead of the wide 20-50 p/kWh range, costs on a range of devices had been reduced to 5-15 p/kWh, with the promise of further reductions.[62] These figures were repeated in the WESC report for ACORD, and both reports painted a very promising picture for wave energy.

Alluding to another primary criticism of the WEP by ACORD, the WESC report also stated that '...a diversity of devices is still seen as an important feature of the ongoing programme…'.[63] However, by 1980 ACORD judged that the programme had become too diverse and Grove-Palmer was asked to return to ACORD in June 1980 with a radically revised wave programme featuring only two devices. At the time, Sir Hermann Bondi observed that there existed a fundamental difference between WESC and ACORD on the approach to wave energy. ACORD saw the programme in terms of wave *devices*, whereas WESC saw it as a set of broader technical and economic challenges that were being addressed through the work of all of the device teams.[64] The structure of the WEP reflected

[60] TNA, EG 16/80, 'Alternative Energy Sources', Bondi to Permanent Under Secretary (DoEn), 9 March 1979
[61] TNA, EG 16/150, WISC(78)M1, Wind Energy Steering Committee, Minutes of the 1st meeting held at the Department of Energy, London on 14 June 1978 at 10.00 hours
[62] TNA, EG 16/305, Fifth Annual Report of the Energy Technology Support Unit, J. K. Dawson, January 1980
[63] Ibid.
[64] Watt, *Towards,* p.46

the WESC objectives, as the consultants and TAGs surveyed all of the device development. Arguably, misunderstanding over this point also caused the WEP to begin to unravel.

Nevertheless, Grove-Palmer returned to ACORD with a new proposal featuring just two devices, the Flexible Bag and the Oscillating Cylinder. After some discussion ACORD added a third device, the Oscillating Water Column, which was being developed by NEL. Accordingly, from 1980 funding for three devices, the Rectifier, the Triplate, and the Raft was stopped completely, while the remaining teams, the Duck and the Clam, continued on (with greatly reduced funding) as contributing elements of the wider wave energy programme. The ongoing WEP was therefore eventually agreed by ACORD as a two-year programme concentrating on three devices. In September 1980, John Moore, the Under-Secretary of State for Energy opened the WEP's new test tank facility at Cockerell's Wavepower in Southampton. Despite the decision a few months earlier to drop Wavepower's Raft from the list of devices under development (the tank would continue to be used by the programme) Moore reassured his audience that 'I am confident that if solutions are possible our wave energy researchers will find them. Whatever other problems they may face, *lack of Government support will not be among them*.' [65]

ACORD March 1981

Despite John Moore's words, by the time of the next ACORD meeting on wave energy in March 1981 the WEP appeared doomed. Rumours, strenuously denied, appeared in the press that the decision had already been taken to close the programme.[66] Added to diminishing official faith in wave energy as a method of providing for future energy demand, the advocates for waves had suffered a blow in 1980 when the Chief Scientist, Sir Herman Bondi, was replaced as Chief Scientist (and therefore also as Chairman of ACORD). Sir Herman was known to keenly support the development of renewable energy sources, and was convinced about the potential of wave energy. He was replaced with Dr Anthony Challis from ICI. Although a chemist by training Challis was brought into the DoEn for his commercial experience. As well as Bondi's enforced departure from the

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[65] Ross, *Power,* p.136. My italics

[66] Ross, *Power,* pp. 136-138. Ross recounts an exchange in the *Financial Times* in May 1981 between the journalist David Fishlock and the Chief Scientist, Anthony Challis. Challis responded to Fishlock's report predicting the closure of the wave programme. 'Fishlock's report is well off track. […] ...there are grounds for cautious optimism'

scene, Freddie Clarke also left WESC during 1980.[67] Thus, by the time of the March 1981 meeting wave energy had lost two of its most influential supporters.

By this stage the earlier confidence of WESC in the long-term future of the programme had been shaken by the 1980 ACORD reaction. In the short time between reaching agreement on a new two-year programme (in June 1980) and the March 1981 meeting of ACORD there had been little opportunity to demonstrate any significant progress in wave energy that might reassure the committee. Despite the two-year programme (lasting until 1982) Grove-Palmer was now aware that ACORD was rapidly losing patience with wave energy, and he recorded after the 1981 meeting that 'there was a substantial body of opinion which was in favour of stopping the programme now.'[68] Despite the majority view on ACORD favouring immediate closure, approval was given to complete the two-year programme eventually agreed in 1980. Grove-Palmer immediately held a meeting with the device teams which laid out clearly the challenges ahead. March 1982 was looming as a crucial date for the WEP as ACORD had insisted that a 'recommended way forward' for the programme be presented by then. After consultation with WESC, Grove-Palmer saw that the programme now had only three options.

(1) Building a demonstration module at near full size of a system which could produce power of value to the UK National Grid, or
(2) Build a demonstration module at near full size of a system which could provide interest to smaller power consumers, or
(3) Stop work on wave energy.[69]

His discussion paper for the meeting emphasised that by March 1982 'there would be no request for a further extension to try and get more answers before making a decision about the future' and he warned the device teams that 'the decision date is not the subject of discussion *it has been fixed*.' Coming less than three years after Heathrow a new cost target of below 5p kWh was set for March 1982 and WESC and the device teams worked on achieving this. Clearly, Grove-Palmer now felt that the best prospects for maintaining

[67] He was replaced as Chairman of WESC by Dr Peter Iredale, who had been the head of Harwell's long-standing Marine Technology Support Unit (MATSU).
[68] SA, 'Objectives, Criteria and Weightings; A note for discussion on 3 March 1981', Grove-Palmer, 2 March 1981, p.2
[69] SA, 'Objectives, Criteria and Weightings; A note for discussion on 3 March 1981', Grove-Palmer, 2 March 1981, p.2

the WEP lay in seeking funding that focussed on a single device, and he implored the device teams to work together on selecting what he termed 'the chosen one.' [70]

WESC were understandably concerned over the short time available before the 1982 meeting to put a convincing case for wave energy before ACORD. Therefore, in December 1981 Grove-Palmer arranged for all of the device teams to give a presentation to the new Chief Scientist, Dr Challis.[71] Clearly the intention was to win over Bondi's replacement (as Chief Scientist *and* chairman of ACORD) and demonstrate the progress and potential for the wave energy programme prior to the March meeting. Grove-Palmer stressed to the teams that they must emphasise reductions in cost achieved since 1979 (5 - 15p kWh) and 'explain why you believe that your device has the potential to become economically viable'. He also asked that the teams 'discuss why you believe that your device should be the one first selected to be used as the basis for a sea-trial of a megawatt sized module'.

ACORD March 1982: 'Reduced Ongoing Programme'

The Wave Energy Programme was officially closed down at the ACORD meeting on 19 March 1982, although as discussed the signs had not been good for the WEP for some time. The meeting itself took place in the wider context of a greatly reduced DoEn budget for renewables, of which the programme managers were made aware. Funding of over £17m in 1981-82 was to be restricted to around £11m in 1982-83: cuts would have to be made. As was the custom for ACORD meetings, each of the individual programmes submitted reports to the council through ETSU which outlined the progress made in the previous year and a suggested programme (and accompanying budget) for the next year. As a result of the ending of the two-year programme, and the recently difficult passage of its proposals through ACORD, wave energy was given particularly close attention. It had, after all, been the DoEn's favoured renewable technology for the previous seven years. The minutes of the ACORD meeting show that the council considered three approaches in reaching its decisions.[72] The first was to ask that the budget be increased to allow the present programmes to continue, the second to make 'pro rata cuts across each

[70] SA, 'Objectives, Criteria and Weightings; A note for discussion on 3 March 1981', Grove-Palmer, 2 March 1981, p.3

[71] SA, 'Presentation of device team work to the Chief Scientist on 14 December 1981 in Room 1145, Department of Energy, Thames House South', Grove-Palmer to Salter, 12 November 1981

[72] ET 4/1/046, FPRD(82) 2nd Meeting, Department of Energy, Advisory Council for Fuel and Power, Minutes of the meeting held on Friday 19th March in Northcote Lecture Theatre 1, Civil Service College, Sunningdale.

programme', and the third to select 'a number of more-promising renewable energy technologies'. Recognising the 'constraints to which all parts of the public sector were being subjected' and with the prompting of the chairman, Dr Challis, the council agreed that the third option 'offered the best opportunity to formulate sound recommendations on the future of the development of renewable energy sources and technologies for the UK.'

With its task established the council then went on to consider a daunting list of twelve programmes in turn; Passive Solar Design, Solar Water Heating, Active Solar Space Heating, Geothermal Aquifers, Geothermal Hot Dry Rocks, Biofuels: Combustion, Biofuels: Anaerobic Digestion for Animal Waste, Biofuels: Anaerobic Digesters for Vegetable Materials, Biofuels: Thermal Processing, Onshore Windpower, Offshore Wind, before concluding with its discussion of Wave Power.[73] For proposal after proposal of the smaller budget programmes, and perhaps anticipating the savings to be made by closing the wave programme, ACORD recommended that 'work should continue broadly along the lines planned at or about the proposed level of expenditure.' It was only when the council reached the final three programmes on its agenda that the recommendations started to vary.

The wind energy programme had been gathering pace for some time, and in the months leading up to the ACORD meeting agreement had been reached with the DoEn to fund a very large 3MW demonstration turbine on Orkney (see chapter 6). The council noted that 'onshore windpower seemed currently to offer the best prospects for bulk electricity generation of any of the renewable energy sources being studied by the Department.' However, they were much less sure about offshore wind, judging it to be 'technically and economically more risky' than onshore wind. The onshore windpower programme was therefore approved, and given priority over the offshore programme, which should only then be developed 'budget permitting'.

Finally, the council turned to the wave power programme, though by this time, an observer would have noted two things. First, wind power had been recognised by ACORD

[73] Writing about ACORD Salter later remarked, 'It gave advice on fission, fusion, oil, gas, coal, tidal, geothermal, wind, hydro and wave power, and, one also hopes, conservation. As it met quarterly and as its membership was selected from the busiest, most senior experts, one can readily calculate how much time could have been devoted to any one topic'. Salter, 'Looking Back', p.19. Interestingly, he was wrong in one important regard, as chapter 3 discussed ACORD never gave advice to the government on fission or fusion R&D.

as the 'most promising' of the renewable technologies, and second, by the time the council came to consider Wave Power the DoEn renewables budget had, theoretically at least, been allocated. The numbers for wave energy disappointed ACORD. Despite much larger earlier (and later) estimates, the size of the resource was now put at 'about 20 TWh'. Much less than Glyn England of the CEGB had spoken of in 1978. Frustratingly for the device teams, the council was also unimpressed by the latest cost estimates for wave energy, which now fell in the range of 4 - 12p kWh. The teams had been given a 'target' of 5p kWh for 1982. But despite this representing a huge improvement over the three and a half years since the Heathrow Conference, the council was unmoved. Obviously referring to wind energy, the council judged that it 'did not accept that wave power could become economically competitive against other electricity generating technologies expected to be available over the strategic review period (1981-2025)'. Clearly, wave energy was doomed.

The final**,** and arguably most significant, criticism of the WEP focussed on the wave energy devices. As shown above, Grove-Palmer and WESC had been aware that the ACORD review would require evidence that a single device had been identified that could be taken forward to sea-trials. Unfortunately, the ENT report on the WEP supplied to ACORD was equivocal on devices.[74] It identified two devices - the 'Edinburgh Duck and the Lanchester Clam' - as having 'a clear lead' but was quick to point out the 'development problems' of each.

> The Edinburgh Duck depends on the proving of the reliability of the sophisticated, but complete, power take-off system, while the Lanchester Clam has less, but not insignificant, need for component development but offers rather more expensive power. [75]

It was therefore not surprising that the council would decide that 'no single device had emerged as having all the required technical features'. However, subsequent comments cast doubt on whether a clearly identified single wave energy device would have made any difference to the ACORD decision.

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[74] ET 4/1/046, FPRD(82)P15, Department of Energy, Advisory Council on Research and Development for Fuel and Power, 'The Department of Energy's Wave R&D Programme - Progress Report and Proposed Future Work' 5 March 1982

[75] ET 4/1/046, FPRD(82)P15, Department of Energy, Advisory Council on Research and Development for Fuel and Power, 'The Department of Energy's Wave R&D Programme - Progress Report and Proposed Future Work' 5 March 1982

> Members also considered, as part of the wave power review the implications for the other parts of the renewable energy R & D programme if it were decided to go ahead to the full-scale demonstration of a wave power device in the open sea, estimated to cost £10 million. The Council agreed that in order to make way for further wave power work, Departmental support for other *more promising* renewable energy technologies would have to be abandoned. This would result in a change of balance in the Department's efforts which the Council considered would have unacceptable consequences for the development of renewable energy sources for the UK. [76]

Clearly, wind power had now galloped onto centre stage as the 'Department's favourite horse'. In the end it provided what wave energy had failed to; a single, clear, and large-scale example of the technology in action, producing electricity. ACORD recommended starkly, 'that no new development work on wave power should be supported from the Department's R&D budget'. Although they were keen that the results of the seven-year WEP should be 'prepared for publication...in a tidy form so that the work supported to date would be available to Government and the private sector should it be decided to re-consider the role of wave power in the UK energy economy'. Some funding trickled on for the WEP (around £300k) to allow for the 'tidying up' of the programme, but after a difficult few years Government-funded wave energy R&D was finally ended in March 1982.

Conclusions

ACORD were aware that there would be much 'public interest' over their recommendations. This proved to be the case and their decision created controversy; and has continued to do so. Criticisms focussed on the 'facts' of wave energy as presented to ACORD and the exclusion from the meeting (for the first time) of the WEP programme manager, Grove-Palmer. Allegations of secrecy and 'stitch-ups' abounded. The device teams were incensed that the reports supplied to ACORD had been withheld from them, and it was only several months after the decision had been taken that they became available. They argued that crucial figures had been deliberately miscalculated and in the case of the Duck a key consultants' report had allegedly been changed after it was written. In Parliament during the 1980s wave energy was discussed in two heated debates and

[76] ET 4/1/046, FPRD(82) 2nd Meeting, Department of Energy, Advisory Council for Fuel and Power, Minutes of the meeting held on Friday 19th March in Northcote Lecture Theatre 1, Civil Service College, Sunningdale. p.23

criticism of the Government's decision to end the programme was strong, as MPs asked, when the WEP had achieved the cost targets set why did ACORD pull the plug? Looking closely at the evidence surrounding the ACORD decision it is clear that many of the criticisms of the process are valid. Based on a year to year assessment of wave energy, the programme should have been continued. Significant technical progress had been made and cost targets achieved.

This then leads to a wider explanation for the closure of the programme that has been advanced: the nuclear conspiracy theory. Some commentators have suggested that the WEP was 'scuppered' by the powerful nuclear industry, fearful of the increasing viability of wave energy. The evidence for this is largely circumstantial and contextual. ETSU, and therefore WESC, was situated at Harwell, as discussed in chapter 3. The Chief Scientist, Walter Marshall, was clearly a 'nuclear man'. Nuclear energy R&D funding dominated the DoEn's R&D budget throughout the period. Nuclear debates had, as Williams wrote, moved from the private sphere to the public arena during the 1970s and public awareness and criticism of nuclear power was growing.[77] There is no doubt that the nuclear industry was increasingly sensitive to criticism from the 1970s onwards. Again, although direct evidence is harder to locate there is some validity in this argument.

However, despite the validity of the more conventional explanations for the closure of the WEP I would suggest that this chapter presents clear evidence for two alternative interpretations: one at the meso-level, one at the macro-level. First, at the meso-level, from the outset the device teams were clear that a long process of R&D would be an essential element of the programme. Despite the proliferation of wave energy device patents from the past, developing a viable large-scale wave energy device would require a substantial programme of theoretical work and tank-testing before any device would make it to the open sea. However, rapid early progress resulted in open-water trials in Loch Ness and the Solent during 1977 and the disastrous Heathrow Conference followed this. I believe that this shifted the expectations of ACORD and the DoEn. Despite earlier acceptance of the caution advocated by the device teams, the government now had examples of wave energy in the water and evidence (at Heathrow) for the high estimated costs. From this point the attitude of ACORD and the DoEn towards wave energy changed. It was no longer a promise of 'what is to come', but rather a demonstration of the technical and economic

[77] Williams, *Decisions*

limitations of wave power as a viable future energy source for the UK. Patience with R&D evaporated and ACORD sought results - a clear ‘winner’ among the devices and an economically viable wave machine in the open sea. The WEP could not provide this, however, wind energy could.

The second, macro-level, resides in placing the events of the WEP within a broader understanding of the dominant energy paradigm of the period. Despite the gradual shift to oil in overall postwar UK energy demand, electricity generation was still dominated by coal burning, as it had been for nearly a century. Thus the pattern of production in electricity was firmly based on one big fuel source. From the 1950s nuclear energy held out some promise as a complement, and ultimately replacement, for coal. The CEGB, who made the decisions about which type of power stations to build, needed to have long-term confidence in the available fuels. Their initial hesitancy over oil-fired and nuclear power stations through the 1950s and early 1960s illustrates this point. Thus, UK energy policy became dominated by the view that fuel supply must be secure, dependable, and most importantly large scale. This framed the development of renewable energy, in this case wave power, within an energy policy that demanded proven reliability and scale. By March 1982 the DoEn lost confidence in wave power to meet this demand.

Chapter 5
Case Study: Salter's Duck and Sea Energy Associates

The discussion of the creation and organisation of the UK renewable energy programme in Chapter 3 was followed in Chapter 4 with a close analysis of the evolution and eventual demise of the UK Wave Energy Programme (WEP). This chapter will explore some further elements of the programme by considering the individual case of the wave energy pioneer at Edinburgh University, Stephen Salter. This will focus on the involvement of private industry in the WEP by considering the creation and evolution of Sea Energy Associates Limited (SEA); a company formed with the financial backing of Ready Mixed Concrete Limited (RMC) to exploit the commercial potential of wave energy. Salter's involvement and interest in wave energy spanned the entire WEP coinciding with the very earliest formation of the UK renewable energy programme in 1974. Indeed, in many senses it was his initial research, culminating in the publication of an influential 1974 article in *Nature* that helped to kick-start the WEP.[1] His invention, the Duck, was featured among the four 'first generation' wave energy devices in the programme and he remained a key, and persistently vocal, part of the WEP through the 1970s and 1980s.[2]

The Salter Duck

When Stephen Salter, an academic at Edinburgh University, wrote to Peter Walker, the Secretary of State at the DTI, in December 1973 about his developments in wave power technology he could not have anticipated the content of the yet to be published CPRS report, *Energy Conservation,* which would give the potential of wave energy such a prominent endorsement.[3] In his letter he modestly offered some idea of the 'promising' nature of his research, before solemnly wishing Walker best wishes 'in your present difficulties'.[4] In an oft-repeated anecdote, Salter would explain that just a few months

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[1] Salter, S. H., *Nature*, 'Wave Power', 249, 21 June 1974, pp. 720- 724

[2] During this time he amassed a considerable personal archive relating to his participation in the WEP, to which he has generously allowed this researcher full and unlimited access. The accompanying footnotes to this research give some indication of the extent of this resource and its value to the historical record .

[3] TNA, PREM 16/253, 'Energy Conservation', Central Policy Review Staff:, January 1974

[4] TNA, EG 16/13, Salter to Walker (DTI), 10 December 1973

earlier, with a heavy cold and amid the gloom of the oil crisis he had been inspired by his wife 'to solve the energy crisis'.[5]

> What she wanted was something which would provide the vast amounts needed, which would be clean and safe, would work in the winter in Scotland and would last forever. It is a good thing for an engineer to have the design objective clearly specified.[6]

He quickly set to work on his domestically inspired design challenge. Gordon Goodwin later commented on Salter's 'extraordinary position of an established lecturer with no lecturing responsibilities' and this allowed him the freedom to pursue his ideas with vigour (and the resources of the University of Edinburgh).[7] He already had a 'lavishly equipped toolroom and electronics laboratory' and his work within the University's research departments also allowed him access to a small test tank with a basic wave-maker.[8] After some preliminary research on the characteristics of waves and some calculations on the likely scale of the resource, he began to experiment with devices to extract energy from the sea waves (see fig.5.1). Beginning with a simple ball-cock float device (fig.5.1, 2.1A), he estimated that he was able to extract around 15 per cent of the available energy. Later, by hinging the mechanism below the surface of the water (fig.1, 2.1B) he was able to improve this figure to nearer 60 per cent. As he wrote later 'It looked as if the to and fro movement was better than the more obvious up and down'. After some experimentation with flaps in the water, Salter had a couple of initial designs which he called the Kite (fig.5.1, 2.1D) and the Tadpole (fig.5.1, 2.1E) after each of their shapes. At this point Salter realised that he needed to know much more about waves. Britain's sea-faring traditions mean that it was well served with wave data, and Salter met with Laurie Draper, from the British Oceanographic Data Service, who was by coincidence visiting Edinburgh around the time. Earlier in that same year, Draper had also advised Goodwin on the potential of wave energy. Greatly encouraged by his discussions with Draper, it was at this point that Salter wrote to the DTI.

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[5] TNA, EG 16/48, 'Light from the Face of the Deep?', *University of Edinburgh Bulletin,* 11:2, October 1974; TNA, EG 16/49, BBC, Radio 4, *Today Programme,* interview, Desmond Lynam with Stephen Salter, 29 October 1974

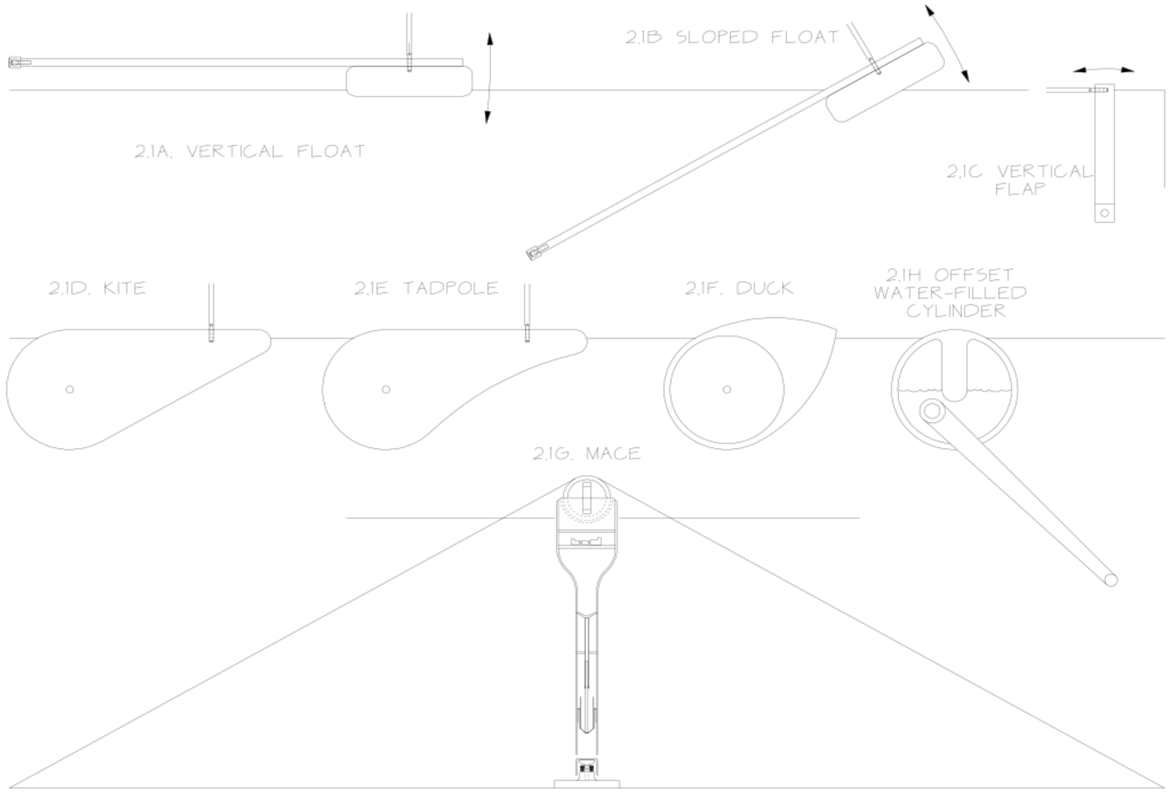
[6] TNA, EG 16/48, 'Light from the Face of the Deep?'

[7] TNA, EG 16/13, Note for the file, 'Wave Power - Visit to Mr Salter at University of Edinburgh' p.1

[8] TNA, EG 16/13, Note for the file, 'Wave Power', p.1; EG 16/48, 'Light from the Face of the Deep?'

Figure 5.1

The evolution of Salter's wave power device designs



Source: Salter, S., 'Looking Back', in Cruz, J (ed.), *Ocean Wave Energy: Current Status and Future Prospects* (Springer: Heidelberg, 2008) Fig. 2.1, p.9

Salter's letter to Peter Walker included a brief four-page summary of his work so far on wave power. At that time Salter was working in the Bionics Research Laboratory at Edinburgh's School of Artificial Intelligence, and he later speculated about the likely bewildering effect that this might have on the reception that his letter received.[9] Before Christmas 1973 Salter received a prompt and courteous reply from the DTI thanking him for his letter, and noting that 'the points which you make, and the figures quoted in the accompanying paper, are both interesting and striking'.[10] Happily for Salter, his letter and report were then passed to Gordon Goodwin, who also had responsibility within the DTI for dealing with what he called the 'oddball enquiries'.[11] Despite being put off by what he dismissed as some 'distracting facetiousness' within Salter's report, Goodwin recognised

[9] Ross, *Power*, p.43. In an interview with Ross, Gordon Goodwin confirmed that he treated Salter's letter with skepticism at first, owing to its unusual sounding origins. He went so far as to telephone the Edinburgh University switchboard to check that Salter existed and ensure that he was not the victim of an elaborate departmental hoax.

[10] TNA, EG 16/13, DTI to Salter, 17 December 1973

[11] Ross, *Power*, p.43

the 'sound and original thinking' that it contained: particularly, as Salter's initial claims for the potential of wave energy appeared to confirm his own earlier estimates.[12]

'As a matter of urgency' Goodwin visited Salter at Edinburgh in late January 1974 to see for himself the developments that had been made.[13] He was greatly impressed by Salter's work and reassured (and it appears, relieved) that many of his own calculations of device efficiency produced for the CPRS report were confirmed by Salter during this visit. During the period between writing his initial letter and Goodwin's visit, Salter had been working steadily on improving his designs. With the help of colleagues, such as the mathematician Denis Mollinson at Heriot-Watt University, he had been working towards an 'optimal shape' for his device. Quite quickly he arrived at a basic varnished balsa wood model that he initially called the 'pregnant Duck' (fig.5.1, 2.1F). To his delight and amazement he found that this shape could achieve a staggering energy conversion efficiency of around 90 per cent.[14]

Goodwin's account of his visit betrays both a scientist's enthusiasm (Goodwin was trained as a biologist) for the potential of wave power technology, and some mixed personal views about Salter's own understanding of that potential. He describes Salter as 'a man of impressive ability' and 'outstanding talent'. Noting that 'some of the pieces of his work I saw were of astonishing quality, both in conception and finish.' However, he then goes on to write 'At this point the adulation has to stop, as Mr Salter's imagination appears to stop, at the boundaries of his device.' Introducing what was to become a recurrent theme in the development of renewables in the UK, Goodwin explains that Salter,

> …tends towards the grandiose and panacea like in his thinking and has difficulties in appreciating that any major undertaking has to fit in with existing economic structure, must be costed on a totally comprehensive basis, and has to compete with other dominant calls upon National [sic] resources. [15]

Notwithstanding this critical view of some aspects of Salter's thinking Goodwin judged that Salter 'had a great deal to offer' and recommended to the Department that

[12] TNA, EG 16/13, Note for the file, 'Wave Power'. '…as a matter of incident much of his approach paralleled my own ideas on the subject of wave energy extraction'
[13] TNA, EG 16/13, Note for the file, 'Wave Power'
[14] TNA, EG 16/48, 'Light from the Face of the Deep?'
[15] TNA, EG 16/13, Note for the file, 'Wave Power'

Salter be given support to carry out his research 'either directly or through NEL'.[16] During his visit he made Salter aware that a report on wave energy had been commissioned from NEL and encouraged Salter to consult with them. Following the visit, responding to a specific request from Salter, Goodwin set out in a subsequent letter the 'official' position of the new DoEn on his work; 'we are impressed by your work and hope that you will be kind enough to keep us informed of the progress you make'. Salter had also asked for confirmation that the DoEn 'would be happy' to let the DoEn's position on his work 'be known publicly', and Goodwin was able to confirm this.

With a delay in any possible funding from the DoEn, Salter was keen to be allowed the freedom to pursue alternative sources of funding. This is an example of Salter's keen awareness of the value of publicity for his work, which was to recur throughout the WEP. Another recurring, and arguably more crucial theme, in Goodwin's letter was the focus on the economics of wave power. He took the opportunity to remind Salter of the 'next essential step in the furtherance of your ideas...a comprehensively based costing of the power that could be produced by such a scheme'.[17] For the moment however, it was clear that the commissioning of the NEL wave power study placed constraints on the DoEn when it came to the funding of wave R&D projects until the study had produced its recommendations.

'Distracting facetiousness'?

Goodwin clearly found some of the content in Salter's four-page outline of his initial findings irritating. This probably refers to the brief introduction and the closing sentence of what otherwise was an overwhelmingly impenetrable (for the non-science trained reader) document. The final sentence in the report could perhaps be charitably forgiven as a weak attempt at humour. Here, among the acknowledgements, Salter thanked 'Sheikh Ahmed Zaki Yemeni and OPEC for their continuing support'. Evidently Salter had more confidence in this particular joke as it was later repeated in the conclusions of his highly regarded *Nature* paper.[18] Probably more annoying to Goodwin was Salter's - again, widely repeated - reference in the introduction to the environmental arguments for renewable energy. Salter had written, 'There are people, until recently regarded as eccentric, who

[16] TNA, EG 16/13, Note for the file, 'Wave Power'
[17] TNA, EG 16/13, Goodwin to Salter, 12 February 1974
[18] SA, Salter to Piper, 28 May 1974. In this letter to *Nature* over corrections to his article, Salter thanks the editor for 'leaving me my Sheikh.'

question our practice of treating as income those resources which our descendants will regard as capital.'[19]

As discussed in chapter 2, a key strand of the new environmental movement of the early 1970s was the famous 'limits to growth' thesis advanced by the Meadows team at MIT, and in the UK by *The Ecologist* magazine's*, Blueprint for Survival.*[20] Each of these publications strongly rejected the 'solution' to energy resource depletion offered by nuclear power on the grounds of safety and waste disposal, and the fledgling environmental groups, such as Friends of the Earth UK (FoEUK) campaigned against nuclear energy. Therefore in the early part of the 1970s (and until very recently) to adopt an environmental stance was equated with being 'anti-nuclear', and arguably this is the message that Goodwin would have taken from Salter's opening statement.

Despite this, what would become notable throughout the government's early renewable energy programme was the absence of explicit references to environmental arguments. Arguably less surprising is the total lack of criticism of nuclear energy, although during the 1970s and 1980s the two issues - renewable energy and nuclear energy - seemed inextricably linked through constant economic comparison. Earlier comments (see chapter 3) made it clear that the renewables programme was an 'insurance' against failure in nuclear development. Therefore, this lack of criticism is explained on one hand by the pervasive involvement of the UK nuclear community in the renewable energy programme, both by location (Harwell) and influence (ETSU and Walter Marshall). However, it is also explained by the continuing official faith in nuclear energy as the energy of the future, despite a problematic history of development.[21] Therefore, before the widespread awareness and acceptance of climate change emerged in the 1990s the official drivers for renewable energy resided mainly in their potential to meet UK energy needs in a cost-effective way and (as explained in chapter 3) more specifically as an 'insurance option' against failure in the nuclear programme.

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[19] TNA, EG 16/13, 'Wave Power: by Stephen Salter, School of Artificial Intelligence, University of Edinburgh' This phrase reappeared in the introduction to Salter's funding applications to the Science Research Council and the Wolfson Foundation in 1974. TNA, EG 16/13, 'Power for the Sea Waves – A Proposal to the Science Research Council', S. Salter, March 1974;
[20] Goldsmith, *Blueprint*; Meadows et al., *Limits.*
[21] Williams, *Decisions.*

During November 1973, as he was forming his ideas on wave energy, Salter had attended a conference at the Royal Society in London on ‘Energy in the Eighties’ addressed by among others, Peter Walker (perhaps planting the idea for his subsequent letter). At the conference Salter came across a copy of a pamphlet, *World Energy - Facts, Issues and Opinions*, written by Amory Lovins of the recently formed UK branch of Friends of the Earth (FoEUK) that had been actively promoted by the new environmental group during the conference.[22] He sought out Lovins at the conference and discussed his ideas for wave energy.[23] Salter wrote later that the pamphlet ‘influenced me profoundly’. It clearly satisfied his academic and scientific sensibilities with its ‘meticulous detail’ and ‘hundreds of references’ and set out ’how long [energy] might last, and what might be the side effects’. It was a pivotal moment for Salter. He wrote that after reading the pamphlet ‘*energy research was no longer a bit of a joke for me to fill in between projects. It was time, if the light water pressure-vessel designers will forgive the expression, to get cracking*’.[24]

Salter’s private correspondence particularly through the 1970s is peppered with references to his strong anti-nuclear beliefs.[25] In one letter he stated plainly that ‘...my motivation for carrying out this research project is based on my fear of nuclear power’[26] and in another that this was ‘...a strong motivation to the whole of our team…’[27] His resistance to a nuclear future was repeatedly made plain, built on a growing public awareness of the problems of nuclear energy, focussing on safety, decommissioning, and waste disposal. But he was persistently meticulous in his care to avoid any public statements or connections with anti-nuclear groups or sentiments.[28] He received repeated invitations to address environmental groups, but declined all of these politely, always stressing the sensitive nature of his position within the UK energy establishment; ‘to attract the attention of the very powerful nuclear establishment in this country would be unwise at this stage and so I am not able to say everything that I feel about the nuclear industry.’[29]

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[22] Patterson, W., ‘A Decade of Friendship: The first ten years’, in Wilson, D. (ed.), *The Environmental Crisis: A Handbook for all Friends of the Earth,* (London: Heinemann, 1984) p.145
[23] SA, Salter to Lovins, 29 April 1974
[24] TNA, EG 16/13, ‘Wave Power: by Stephen Salter’. My italics. At the time the American- designed Light Water Reactor was at the centre of the debates over reactor-choice for the UK. It was regarded by its critics as unsafe.
[25] Some examples among very many include, SA, Salter to Davies, 7 January 1975; Salter to Morgan-Grenville, 20 January 1975; Salter to Cookson, 12 May 1976; Salter to Orlowski, 26 September 1975
[26] SA, Salter to Cookson, 12 May 1976
[27] SA, Salter to Boles, 15 July 1976.
[28] SA, Salter to Cookson, 12 May 1976. ‘I would be very reluctant for this to be stated publicly…’
[29] SA, Salter to Orlowski, 26 September 1975.

Despite this care, from the moment of his first contact, it was perhaps clear to some within the DoEn that Salter was motivated by somewhat differing aims than those of the wider programme. Equally clear was Salter's eloquence and skill in dealing with the media. This would help to explain Goodwin's repeated insistence on 'cost-effectiveness' and his discomfort with Salter's quasi-environmental statements.

Initial funding

By March 1974 Salter, realising that no research funding was likely to come directly from the DoEn in the meantime, submitted proposals for funding to the Science Research Council (SRC) and to the Wolfson Foundation.[30] The SRC proposal sought funding of £66k over three years, whilst an almost identical proposal to the Wolfson was for £74k over the same period. Salter sent copies of the proposals to Goodwin and provided him with regular updates on his work. He mentioned some of the individuals that he had been consulting with, such as Michael Longuet-Higgins ('the top wave man'), as useful names to mention if Goodwin felt 'able to influence SRC'.[31] By early July, after seeking the advice of the DoEn, the SRC responded to Salter's proposal with an offer of just £6,900 over 2 years, which Salter declined.[32] The SRC were frightened off by the large capital investment that Salter's proposals involved (£30k) and suggested that he should undertake a 'more thorough examination of the theoretical aspects and engineering feasibility' before launching the larger-scale experiments that his proposal suggested. This was a disappointment for Salter and Goodwin, who both felt that the NEL report would provide much of what the SRC recommended and that what was needed from Salter was a more experimental approach.[33] Disappointingly for Salter and Goodwin, the Wolfson Foundation reached similar conclusions.

Whilst awaiting the outcome of his grant proposals Salter had continued his wave power research at Edinburgh. The establishment of ETSU had heightened interest in renewable energy during the mid-part of the year, and Salter had published what proved to be a much-cited article on wave power in the respected journal *Nature* in June 1974.[34]

[30] TNA, EG 16/13, 'Power for the Sea Waves – A Proposal to the Science Research Council', S. Salter, March 1974;
[31] TNA, EG 16/14, Salter to Goodwin, 2 April 1974
[32] TNA, EG 16/14, SRC to Salter, 9 July 1974
[33] Ross, *Power,* p.46. Goodwin also noted later that the SRC had previously provided substantial funding (£2.5m) for a project by a team at Edinburgh (featuring Salter) which had ended in a rather embarrassing failure.
[34] *Nature*, 'Wave Power', S. H. Salter, 249, 21 June 1974, pp. 720-4

This was picked up by some of the popular media newly obsessed by energy, and articles began to appear on the government's investigations at NEL into wave power potential.[35] Attracted by the publicity, and by the recommendations of the CPRS report, the CEGB also began to consider the possibilities of wave power around the same time. Don Gore, Deputy Chief Scientific Officer at the DoEn (and Goodwin's immediate superior), wrote to Salter in June 1974 to advise him that Donald Swift-Hook from the CEGB's Marchwood Laboratory in Southampton was heading a programme of research into the potential of wave power.[36] He suggested to Salter that this could result in some CEGB funding for his research.

When the news of Salter's largely unsuccessful applications to the SRC and the Wolfson Foundation emerged in July, the DoEn acted swiftly to locate other sources of funding for his research. Undoubtedly the main motivation for this was the belief – mainly from Goodwin and now Gore – that wave power research had some value, but political considerations were also important. With the recent launch of ETSU and the media interest in wave power inspired by the publication of the CPRS report (also in June 1974), it was important that the DoEn was seen to be moving forward in its efforts to seek solutions to the energy crisis: and it was to ETSU that Gore turned first. In a revealing letter he referred to the 'sordid' difficulties that surrounded the funding of the NEL report (due to the reorganisation of the DTI at that time) and the continuing problems in finding funds for the 'kind of work' that Salter was doing. He indicated that Salter had claimed that he would have to halt his research on wave power and that the respected *New Scientist* wanted to publish a 'sob article, no doubt inspired by Salter, on the lack of Government support'. Gore asked Dawson for 'a few thousand pounds (Salter suggested £8,000)' from the 'ETSU or Harwell budget', and revealed that he has already had the approval, in principle, of Walter Marshall.[37] A few weeks later Dawson replied, highlighting the limitations of the ETSU budget, but with an offer of £4,000 and the chance of further funding when subsequent ETSU budgets were set.[38]

Realising that only limited funding could be extracted from the limited ETSU budget, the ENT division of the DoEn decided on an alternative approach. Len Leighton

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[35] *The Daily Mail,* 'Britain probe wave power', Daily Mail reporter, I July 1974; *The Guardian*, 'Coupling of swells', Anthony Tucker, 5 July 1974
[36] TNA, EG 16/14, Gore to Salter, 25 June 1974
[37] TNA, EG 16/14, Gore to Dawson, 25 July 1974
[38] TNA, EG 16/14, Dawson to Gore, 19 August 1974

wrote to Maddock, the Chief Scientist at the DoI, in July to make him aware of the situation with Salter's SRC application, and to advise that NEL had agreed to work with Salter on any future wave power R&D that he might undertake.[39] NEL was a highly regarded section of the DoI at this time. Salter himself had already written to Maddock in February as part of his personal campaign to raise awareness of wave energy.[40] After advising that they themselves had no funds for this type of project, Leighton suggested to Maddock that the natural result of any developments would result in 'hardware development in the engineering field' and would therefore be 'right in your court'.[41] The DoEn had earlier expressed some anxiety over retaining control over wave power R&D amid the gathering publicity that Salter's work was receiving, and this approach to a 'rival' department illustrates the risks that Gore, Goodwin, and others were prepared to take in order that the research be continued.[42]

In the event, the positive response of NEL to Salter's work proved to be decisive.[43] In August 1974 a series of meetings were held at NEL in East Kilbride and at Salter's lab at Edinburgh University, attended by representatives from the DoEn and the DoI at which Salter gave 'a particularly impressive demonstration of his experimental approach and of his self made equipment.[44] Another creation of the Heath government, along with the CPRS (see chapter 3), had been the Requirements Boards. These were set up within key government departments to control the funding of new projects. For wave power the Mechanical Engineering and Machine Tools Requirements Board (MEMTRB) was regarded as the most relevant body, and accordingly they were invited along to these initial meetings. Verbal assurances of support from DoI were given to Salter at the meeting itself, and by October 1974 the official announcement was made that he was to receive support of £66k over three years (the amount he had originally sought from the SRC) through the MEMTRB. This represented the start of government-funded wave power R&D in the UK,

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[39] TNA, EG 16/14, Leighton to Maddock, 31 July 1974
[40] SA, Salter to Maddock, 24 February 1974. The letter was a typical example of Salter's self-deprecating approach. He begins 'The present paper shortage has been attributed to the great number of inventors sending in helpful suggestions for the solution of our energy problems, which could perhaps be solved by their efficient incineration.'
[41] TNA, EG 16/14, Leighton to Maddock, 31 July 1974
[42] TNA, EG 16/14, Gore to Leighton, 26 June 1974. In a handwritten addition to the letter, Gore expresses the fear that the involvement of the CEGB and ACORD may mean that the DoEn 'may not be seen as being in a key position'.
[43] TNA, EG 16/14, Leishman (NEL) to Gore, 25 July 1974; Summerfield (MEMTRB) to Leishman (NEL), 12 August 1974
[44] TNA, EG 16/14, Note for the file 'Wave Energy –Support for S H Salter at Edinburgh University', 9 September 1974. This note contains Goodwin's brief account of the two meetings.

achieved in large part by a partnership of Salter's impressive technical ability and ingenuity and Goodwin's indefatigable search for funding.

Leading from the rear:[45] *Gordon Goodwin*

Gordon Goodwin was a key figure in the development of wave power in the UK, and his role raises the question of 'influence' and 'influential figures' in the renewable energy programme. In previous chapters I have emphasised the roles that high-status figures such as Lord Rothschild and Walter Marshall played in the development of wave power. Both of these individuals, by nature of their contrasting positions, were able to bring about the creation of the WEP, and as such they could both be judged as influential. In the case of Marshall, much of this influence was due to his wide-ranging responsibilities as Chief Scientist, chair of ACORD, and director of Harwell. In this sense he acted both as a symbolic and physical link between groups and was able to bring pressure to bear on a number of diverse groups. I would suggest that Goodwin played a similar, and arguably more important, role in this regard. Although in comparison to Marshall, he occupied a junior position within the DoEn, Goodwin's long civil service experience provided him with a network through which he was able to steer and establish the early wave programme.

In contrast with Salter, who actively sought publicity for the benefit of his work on wave power (and for a brief period in the 1970s became a familiar face in the media) Gordon Goodwin remained a behind-the-scenes figure throughout the WEP. Ross provides an interesting portrait of Goodwin 'a man withdrawn and taciturn' in his book, *Power from the Waves,* where he describes him as 'the best ally of wave energy inside the Civil Service.[46] Certainly from the evidence it appears that within government Goodwin had waged a subtle one-man campaign for wave energy since he compiled his first report for the DTI early in 1973. As noted previously he was largely responsible for the inclusion, if not the prominence, of the recommendation for wave power R&D included in the CPRS report. All of the existing correspondence in the archives on wave energy from the commissioning of the NEL report to the closure of the programme features significant input from Goodwin. Despite misgivings over aspects of Salter's personality, he worked

[45] TNA, EG 16/14, ET 51/03, Goodwin to Gore, 16 August 1974. In an illuminating comment, referring to the way forward for wave energy Goodwin stated 'I would wish to lead from the rear however.' This reflects some personal modesty perhaps, but also emphasises an awareness of the importance of his role in advancing the case for wave power.

[46] Ross, *Power,* pp. 43-51

tirelessly through 1974 to secure funding for his wave energy research, and it is largely through his creative approach, and the enlistment of more senior support within the DoEn, that funding was eventually secured. Following the establishment of the WEP this effort was no longer required, but Goodwin remained a key figure at the heart of wave energy throughout, via his insider position as a member of WESC and his role as secretary of ACORD.

'We are on our way'[47]

The announcement of funding for Salter attracted a good deal of attention. Both he and Sir Christopher Cockerell were interviewed on BBC Radio 4 news programmes, and various stories appeared in the press.[48] Salter already knew Cockerell reasonably well having spent some time as an apprentice engineer at British Hovercraft.[49] On the 7 October 1974 *The Times* reported the news of Salter's funding on the front page of the newspaper.[50] Cockerell had also been working on devices to harness wave power for around the same time as Salter, although he later commented rather sourly that Salter had the advantage of a university laboratory to advance his work, whereas he had been left to fund any initial research privately. During 1974 Cockerell had been in touch with the DoEn, providing them with updates on the progress of his design for a floating raft device. As early as February 1974 the DoEn had noted that he would soon be in touch looking for funding, and indicated that this would likely be forthcoming.[51]

In this period prior to the founding of the WEP, other wave power projects had also joined the research effort, drawing on a range of funds. In a memo dated 16 August 1974 Goodwin outlined the institutions that were either 'actively working in this field or have test facilities and an expressed interest in making a contribution'.[52] They included;

[47] SA, Salter to Austin, 6 August 1975. 'W****w**d B**n says that wave power is the next best thing after nuclear. We are on our way.'
[48] TNA, EG 16/51m, BBC R4 'The World at One', interview with Sir Christopher Cockerell, 7 October 1974; TNA, EG 16/49, BBC R4 'Today', interview with Salter, 29 October 1974; *The Sunday Times,* 'Harnessing white-horse power', Bryan Silcock, 13 October 1974; *The Guardian,* 'Power research waved on'. Anthony Tucker, 29 October 1974;
[49] SA, Salter to Ross, 29 May 1978. Salter wrote that British Hovercraft 'taught me just as much as Cambridge'.
[50] *The Times,* 'Government approves project for power form sea waves' Michael Bailey and Pierce Wright, 7 October 1974
[51] TNA, EG 16/13, Leighton to Gore, 12 February 1974
[52] TNA, EG 16/14, ET51/03, Goodwin to Gore, 16 August 1974

- NEL - East Kilbride
- CEGB Marchwood Laboratories – team led by Dr D Swift-Hook
- S. H. Salter - University of Edinburgh
- Gifford & Partners – test tank work in collaboration with British Hovercraft Corporation (Sir Christopher Cockerell)
- NPL Ships Division - Feltham
- Hydraulics Research Station - Wallingford
- British Hydrodynamics Research Association – Cranfield
- Admiralty Research Laboratories - Teddington [53]

The extent of interest gives some indication of what Gore described as the 'infectious nature of wave energy R&D'.[54] Ironically, given the difficulty in securing funds for Salter, most of these projects would have been funded indirectly by the Treasury, through each institution's annual budget. The most notable example being the CEGB team under Swift-Hook which by this time had allocated £50,000 for a 'practical programme' on wave energy that sought to 'supplement rather than duplicate' the work of Salter and NEL.[55] Therefore, even before the official launch of a wave power programme the government funded R&D effort in wave energy had expanded. In this way the WEP can be understood as an obvious next step in co-ordination.

With government funding in place Salter was able to continue development of what had now become known, more simply, as the Duck (fig.5.1, 2.1F).[56] Having arrived with speed at an optimal shape for his wave energy device, the Edinburgh team now turned its attention to fine-tuning the other aspects of the device. Their three-year plan was focussed mainly on perfecting and extending the single Duck to a 'multi-vane' model arranged along a single spine or 'backbone'. Typical of the month-by-month plan was the entry for May-July 1976 'Analysis, Writing, Thinking, trying anti-bending moment tricks'. Also included was the plan to build a dedicated wave maker, which would be housed in a new building at Edinburgh University.[57] Arising from its pole position in wave energy R&D, Edinburgh was to have enviable test-tank facilities throughout the WEP - often much to Salter's annoyance, as this inevitably created a stream of requests to use the facilities or to

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[53] Ibid.
[54] TNA, EG, 16/14, ET 51/03, Gore to Leighton, 26 June 1974
[55] Ibid.
[56] Salter et al, 'The architecture of nodding duck wave power generators', *The Naval Architect,* January 1976. 'The reason for the choice of the term 'duck' is not entirely frivolous; new ideas need new names and it is well to keep them short and descriptive.' p.21
[57] SA, First Year Interim Report on Edinburgh Wave Power Project "Study of Mechanisms for Extracting Power from Sea Waves" September 1975, Department of Mechanical Engineering, University of Edinburgh

simply look.[58] Salter wrote that, 'There seem to be more than 365 people in the world who feel entitled to a day's outing to look at wave models.'[59] The constant parade of observers was eventually to include television crews, Government ministers, Select Committees, and even royalty (the Duke of Edinburgh).

In his first-year report dated September 1975 the Edinburgh team showed good progress on the agreed plan, despite the illness (causing temporary paralysis below the waist) of David Jeffrey, Salter's trusted assistant. Salter reported that much of the work on apparatus scheduled for early 1976 had been completed, and that the 'second-phase' of the work on the wave maker building (scheduled initially for January 1977) could be brought forward. High inflation was having an impact on the programme, and he noted that he had been forced to 'defer orders since June to avoid overspending'. Included in his report was a section on 'new cost planning'. With perhaps a nod to Goodwin, Salter ended his report with a low-key reference to economics, couched in recognisably civil service terms, 'On the basis of one year's work I can say that the possibility of economic power from sea waves has not been excluded.' [60]

Commercial partners: Sea Energy Associates

At the end of the 1980s, as the Government was clearly backing away from further public expenditure on renewable energy, much was made of the need for 'industry' to become 'increasingly involved in research, development and demonstration activities, *eventually taking these functions over from Government*.' [61]This was somewhat misleading as commercial involvement had been a notable aspect of the UK renewable energy programme from the 1970s, particularly, as will be seen in chapter 6, for wind energy. Wave energy was also developed from the outset with the aid of a range of partners from 'industry'. Previous chapters have referred to a 'government' programme, and indeed the WEP was managed and derived the majority of its funding from the DoEn budget. However, throughout the programme commercial capital and expertise featured prominently - particularly within the two leading wave device teams of Salter and Cockerell.

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[58] SA, Salter to Dundas (Information Officer, Edinburgh University) 16 January 1975
[59] SA, Salter to Gregory, 25 February 1975
[60] SA, First Year Interim Report on Edinburgh Wave Power Project "Study of Mechanisms for Extracting Power from Sea Waves" September 1975, Department of Mechanical Engineering, University of Edinburgh
[61] Department of Energy, *Renewable Energy in the UK: The Way Forward,* Energy Paper 55 (London: HMSO, 1988) p. iii

Sir Christopher Cockerell had formed one of the earliest wave energy firms, Wavepower Limited, by February 1974; made up of a consortium of McAlpines, Gifford and Partners, British Hovercraft, and Cockerell himself.[62] When the WEP was launched in 1976, Wavepower Ltd formed a public/private partnership with the DoEn, which along with SEA Ltd routinely attracted the largest portion of the programme's budget. Salter also recognised the advantages that could be gained, both financially and technically, through the inclusion of industrial partners and from early on he sought out suitable candidates.

Salter complained (to an industrialist) in 1972 that his 'big problem' was 'finding intelligent sympathetic industrialists'.[63] From late 1973 he had been in touch with a number of commercial firms, seeking funding and support for his wave work.[64] This included a disastrous exchange with *Shell* which resulted in Salter travelling to the *Shell* research facility in Rijswijk in the Netherlands only to be mistaken, to his great displeasure, for a job applicant.[65] However, by mid-1975, after 'some rather disappointing discussions with Lithgows, Langs [sic] (and […] Taylor Woodrow)' [66], he had managed to secure interest in supporting his work from Ready Mixed Concrete (UK) Ltd (RMC). As Salter proposed that the full-scale Ducks should be constructed from concrete this was perhaps a logical tie-in for all concerned. The contact arose through an 'inventive' engineer at the civil engineering firm, Edmund Nuttall Ltd., called Eric Wood.[67] Stimulated by the publicity for wave power during 1974 Wood was inspired to make contact with Salter and explore the possibilities of collaboration and commercial exploitation. He was responsible for developing the contact with RMC, and for bringing Norman Bellamy (his cousin) based at Lanchester Polytechnic, into wave energy.[68] However, the latter step would prove to be the source of bitter disagreements with Salter that would eventually end the SEA partnership.

[62] TNA, EG 16/13, Leighton to Gore, 12 February 1974
[63] SA, Salter to Huffan Ltd., 27 November 1972
[64] Some examples include, SA, Salter to Trelevan (Annfield Engineering) 9 January 1974; Salter to Rodgers (Shell), 6 December 1973; Salter to Marsh (Procter & Lavender Ltd., 28 January 1974; Salter to Wright (John Laing) 8 August 1975; Salter to McCullough (I. J. McCullough Inc. USA) 10 August 1975; Salter to Davies (Taylor Woodrow Construction Ltd.), 15 January 1976
[65] SA, Salter to Rodgers (Shell), 6 December 1973; Salter to Starling (Shell), 11 April 1974; Salter to Bellis (Shell), 17 June 1974. In his letter to Bellis, after insisting that he be recompensed for his time at his 'normal consulting rate of £30 per hour' , he concluded by asking "I would like to know the name of the person who instigated the visit and what precisely he hoped to achieve'.
[66] TNA, EG 16/80, WESC(76)P81, 'Organisation of Wave Power Programme by C. O. J. Palmer', 1976. Grove-Palmer notes that none 'were agreeable to putting in their own funds'.
[67] TNA, EG 16/80, WESC(76)P81, 'Organisation of Wave Power Programme by C. O. J. Palmer', 1976. p.3
[68] Salter interview

Prior to the announcement of the DoEn's £1m wave energy programme, Wood and Bellamy had themselves submitted a joint proposal for funding to MEMTRB. This had also been the source of Salter's earlier funding, and the initial deliberations of the Wave Energy Steering Committee (WESC) clearly identified this as the primary funding source for UK wave power development. However, the minutes of the meeting which considered the Wood/Bellamy proposal record that it received a fairly hostile reception. Goodwin noted,

> In seeking their presentation the WESC representatives had the evident goodwill of both the board secretariat and the chairman. Despite this the board came close at times to a unanimous rejection of the proposals and quite an amount of this goodwill was used up. [69]

Eventually MEMTRB approved funding by 'reluctant consensus, but by no means unanimous, agreement'. In the end, this uncomfortable meeting was perhaps unnecessary as the DoEn soon after took over wave power funding. However, it established the credibility of Wood and Bellamy and resulted in the formation of Sea Energy Associates Limited.

During the Wood/Bellamy presentation to MEMTRB the issue of commercial interest in wave energy was raised, as the Chairman read a letter from RMC 'declaring their interest in contributing a 50% stake'. The reaction of the meeting illustrates a developing awareness of the advantages of early industrial partnerships in government-sponsored R&D and an example of the declinist thinking that pervaded Britain during the 1970s.

> The Chairman suggested that industrial participation might be premature. There was a chorus of disagreement with this sentiment as being quite opposed to the objectives and function of the board. It was strongly asserted that industrial failure to exploit innovatory ideas was a marked feature of poor UK economic performance.[70]

The possibility of commercial involvement immediately raised the question of patent ownership. During his earlier visit to London when he experienced his renewable energy

[69] TNA, EG 16/64, WESC(75)P31, Note 'Presentation to MEMTRB of LPI application' , G. A. Goodwin, 1 December 1975
[70] TNA, EG 16/64, WESC(75)P31, Note 'Presentation to MEMTRB of LPI application' , G. A. Goodwin, 1 December 1975

epiphany Salter had filed a provisional patent for his wave device, which he subsequently assigned to Edinburgh University in May 1974.[71] Edinburgh University wrote to Peter Young, Director of RMC, in October 1975 to assure him that 'the University certainly considers that it is the legal owner of the original Salter patent' and although they confirmed that they had applied for Government funding none 'was forthcoming' to support his original work.[72] RMC were obviously reassured and by December 1975 the registered company, Sea Energy Associates Limited (SEA), had been formed. Although initially wholly owned by RMC, agreement had been reached that 49 per cent of the shares would be transferred to another company 'probably to be called Marenco' which would be jointly owned by another commercial partner, Insituform Ltd. (a division of Edmund Nuttall Ltd.), as well as Salter, and Norman Bellamy.[73] Young confirmed that,

> RMC have agreed to support (subject to certain safeguards) research expenditure totalling £230,000 over the first two years, and are, in principle, prepared to support much higher expenditure to finance the construction of a quarter scale model commencing in the third year and, of course, assuming satisfactory technical progress to that stage. Expenditure from year three onwards will run into many hundreds of thousands of pounds. It is hoped that the Government will contribute 50% of the expenditure referred to above during the first two years' development programme.[74]

Despite the seeming good fortune in attracting commercial interest and significant capital at such an early stage in wave energy development, Salter had a prickly relationship with industry. He explained in a letter '...as an engineer I enjoy a love-hate relationship with technology. It only goes sour when the commercial people become too powerful. We must find ways of saving the good bits.'[75] Therefore it was perhaps not surprising that his involvement with SEA was quickly to prove troubled and acrimonious. Crucial to Salter, as the comment above suggests, was retaining control of the R&D, and this quickly emerged as the source of his disagreements within SEA. Perhaps only his distrust of Government involvement outweighed his distaste for 'commercial people.' During negotiations with RMC he wrote to a friend 'Wave Power is racing ahead and if we can get some private finance the Government will contribute an equal amount and allow us to keep

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[71] SA, Salter to Grove-Palmer, 28 March 1977
[72] SA, Midgley to Young, 8 October 1975. This was an issue that was to reappear for Salter as the WEP was wound down after 1982.
[73] SA, Young to Midgley, 19 December 1975
[74] SA, Young to Midgley, 19 December 1975
[75] SA, Salter to Morgan-Grenville, 20 January 1975

control. Otherwise they will finance the whole of it and take over themselves.'[76] The involvement of RMC appeared at the time to have achieved this goal for Salter.

By late 1975 the Government's involvement in wave energy had accelerated with the establishment of WESC, followed soon after by Alex Eadie's announcement of a £1m wave energy programme (as discussed in chapter 4). Research funding for wave energy shifted from the convoluted and difficult process that was necessary to fund Salter initially, to an explicit Government programme for wave power. Salter's earlier fears over Government involvement seemed to have been realised and he wrote 'The vested interests of the establishment have jumped onto the bandwagon fairly hard and things seem to be getting out of control. I am reminded of the poem about somebody riding a tiger.' He went on to state that with the involvement of RMC 'we could go independent if necessary'.[77] However, it was unthinkable at the time that the high-profile Salter device would not feature prominently in any new Government wave energy programme. Despite continued development by Cockerell's team and new work by NEL on the Masuda device, Salter remained at the leading edge of UK wave power R&D. Accordingly, early in March 1976, and prior to the official launch of the wave power programme, an innovative private/public contract was eventually drawn up between SEA and the DoEn.[78]

It was clear that the inclusion of a commercial partner was something of a departure for the DoEn, 'The existence of [SEA] made it necessary to negotiate commercial terms quite different from those which would be normal for a University type contract.'[79] After a 'protracted series of negotiations'[80] a jointly funded programme was agreed with each party contributing £202,000 (later increased to £230,000 due to inflation) over two years for the 'development and exploitation of wave power devices based substantially on the Salter and SEA patents'.[81] The DoEn pressed for control of the intellectual property rights, but 'conceded' these to SEA on the basis that 'it was an

[76] SA, Salter to Brown, 8 August 1975
[77] SA, Salter to Disney, 5 July 1976
[78] TNA, EG 16/50,ET 51/013, Note of a Meeting on 4 march 1976 at Harwell on Salter's Ducks
[79] TNA, EG 16/100, WESC(76)P59, Contracts for Wave Power
[80] TNA, EG 16/100, WESC(76)P59, Contracts for Wave Power. 'The difficulties which have been encountered in negotiating and drawing up the wave energy contracts for R & D work have been most severe in the case of SEA,…'
[81] TNA, EG 16/50, 'Wave Power: Revised Draft Heads of Agreement', undated.

unimportant matter so long as HMG had free use for their own purposes and adequate control over the rights to grant licences.'[82] A WESC report stated,

> It would be difficult to summarise the whole agreement in a few words but it is sufficient to say that: (a) HMG now has secured a position in which there will be a fair return on the National investment if it should prove possible to make any profit out of the SEA/Salter system; (b) HMG has the right to veto overseas licensing if they consider it unnecessary; (c) ETSU will have Project management control to ensure that the objectives of the feasibility study are achieved. [83]

A meeting of SEA Ltd. took place in June 1976 as the initial WEP was being put together and reveals some sensitivity about the role that SEA would play in the new programme. The minutes stated that,

> ...difficulty with dealing with various other investigating bodies and advisory groups acting on behalf of the Wave Power Steering Committee was discussed. It was agreed that these parties had no contractual standing with SEA and that in future these bodies should not be given any commercially useful information. It was stressed that many of the parties investigating had their own commercial interests and that several of these parties were certainly being more commercial than SEA in keeping their secrets close to their chests. [84]

A key issue arose at this meeting that would ultimately prove to be the cause of Salter's relationship with SEA, and more specifically with Bellamy's Lanchester team, descending into acrimony. Bellamy tabled a paper at the meeting entitled 'Revised Wave Power Development Programme'.[85] Bellamy was keen to construct 'a model of working ducks' immediately, rather than first concentrating efforts (as Salter preferred) on further development work on some aspects of the 'backbone' of the device within the testing tanks. For Bellamy 'engineering experimentation' was important at this stage of the programme. Salter was also keen to test the device in open water and favoured 'a one metre diameter model sited near Inch Keith on the Firth of Forth' but Bellamy was insistent that a larger-scale model in 'a more protected inland water where current problems would not be met and where the working environment would be safer' was the best way forward. He had already begun conducting tests on 1:60 scale 6-metre string of

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[82] TNA, EG 16/50,ET 51/013, Note of a Meeting on 4 march 1976 at Harwell on Salter's Ducks
[83] TNA, EG 16/100, WESC(76)P59, Contracts for Wave Power
[84] SA, Minutes of Technical Meeting of Sea Energy Associates Ltd. held at Lanchester Polytechnic at 11.00 am, 23rd June 1976.
[85] SA, Revised Wave Power Programme, 2nd draft, July 1976

Ducks at Draycot reservoir, but he was keen to extend this to a 1:15 scale model 50-metre string.[86] He mentioned Loch Ness as a possible site, though he acknowledged the unwelcome slant that the choice of this site may give to the publicity.[87] The minutes record that 'the matter was not completely resolved'.

In the months following the meeting Salter and Bellamy made some attempt to resolve their differences. For his part, Salter stated that he was 'wholeheartedly in accord' with Bellamy on several points. The main one being that 'our ultimate aim is to produce cheap electricity'. However, in what was to become a familiar Salter argument over wave R&D, he went on to point out that he made a 'crucial distinction' between 'the ultimate aim, and the objectives in the earlier stage of development'.[88] Salter's stated strategy from the outset had been to 'maximise credibility in the shortest time'.[89] His comments also reveal that Goodwin's insistence on the crucial role of sound economics in wave power had taken hold.

> What we must aim for now is to maximise information. And we must do this precisely in order that, later on, we can be efficient in the sense that we can do the job as cheaply as possible. So we must distinguish between sophistication in the early stages in order to gain information and sophistication in the final design. If we are sophisticated now we shall know how to be cheap later. I consider this principle is the key to the success of the project. Do you accept it? [90]

Evidently, as events would prove, Bellamy evidently did not accept this principle. Much later, in 1979, after the SEA partnership had disintegrated, Salter reminded the Maidenhead Wave Energy Conference of the deceptive attraction of 'simplicity' in new technology.[91] Referring to Bellamy's contention (with whom, by this time, relations were very poor) that 'simplicity should be the over-riding design principle', Salter responded in typical fashion. After a lengthy quote from the Oxford English Dictionary defining 'simplicity', he wrote,

[86] TNA, EG 16/80, ET 172/20/01, Report to ACORD Programme Committee from the Wave Energy Steering Committee, December 1976. p.3
[87] This proved, not unexpectedly, an accurate prediction. For an example see, Ross, D., 'It's shocking...after years of entertaining the world, they're taking Nessie's power away', *Daily Express,* 29 November 1976.
[88] SA, Salter to Bellamy, 27 December 1976
[89] TNA, EG/49, Salter to Midgley, 30 July 1975
[90] SA, Salter to Bellamy, 27 December 1976. Underlining in original
[91] DoEn, ETSU R9, 'Wave Energy Steering Committee, Proceedings of a workshop on wave energy, Maidenhead, 16-18 December, 1979'.

> It seems to me that 'simple' is not a simple word. While I do not argue that simplicity is for simpletons, I believe that it is an irrelevant factor, I want to get things right whether rightness comes from simplicity or complexity. The history of technology has many examples of designs which were 'right'. Very often, these 'right' designs are elegant.[92]

By the time that Salter had written to Bellamy in December 1976 the decision over Loch Ness had already been taken by SEA. During a visit to Lanchester Polytechnic earlier that month, Alex Eadie, no doubt keen to demonstrate visible early progress on wave energy, had announced that trials of the Duck would take place in Loch Ness during the summer of 1977.[93] Salter thought that this was a grave error and he was placed in a very uncomfortable position by the announcement. He wrote, 'I am sorry about the Loch Ness announcements which resulted from a visit by Eadie to the Lanchester people. It is much better to say what you have done rather than what you hope to do but it may get all of the monster headlines out of the way early on.'[94] The SEA partnership had been formed around Salter's device and the Loch Ness trials would be of his Duck design, yet in the end - and through his own choice - he had little involvement with it. He continued work at Edinburgh on improvements to the backbone of the Duck and the construction of a new wide tank, whilst, as predicted, the press and television were drawn to Loch Ness to see 'Salter's Ducks'.

After the establishment of the WEP and two years of funding from the DoI, the control of Salter's team passed from NEL (Jim Leishman at NEL had been managing Salter's team) to WESC and Clive Grove-Palmer. Salter's second-year report for the DoI had shown evidence of continued progress and he had been able to report once more 'we can say that the possibility of economic power from the sea waves has still not been excluded.'[95] He wrote in January 1977 that 'the duck is still the favourite device' and reported that 'we have a budget of £180,000 for the next two years with a contribution from an industrial group which brings the total up to nearly £500,000.' [96] Clearly, despite his difficulties with Lanchester and the Loch Ness trial, his confidence in the future of

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[92] DoEn, ETSU R9, 'Wave Energy Steering Committee, Proceedings of a workshop on wave energy, Maidenhead, 16-18 December, 1979'. Underlining in original
[93] *Offshore Engineer*, 'Wave power gets the nod from DoE' , December 1976, p.77; Thackway, C., 'Research into energy from waves ready for tests at Loch Ness', *The Scotsman,* 23 November 1976; Ross, D., 'It's shocking...after years of entertaining the world, they're taking Nessie's power away', *Daily Express,* 29 November 1976.
[94] SA, Salter to Churcher, 8 December 1976
[95] SA, 'Second Year Interim Report on Edinburgh Wave Power Project "Study of Mechanisms for Extracting Power from Sea Waves" September 1976'
[96] SA. Salter to Keller, 10 January 1977. Salter was responding to Keller's enquiry about a post on the team.

government backing for wave energy research remained high and he wrote 'There are quite strong political pressures to give us a higher budget *and immense amounts of goodwill*.'[97] Through 1977 Salter focused on the construction of a new wide testing tank at Edinburgh which he saw as the next logical step in the development of a robust and economic wave energy device.

Grove-Palmer had officially agreed his proposals for the wide tank in March 1977 and construction began late in 1977. Up until this point the Edinburgh team had been testing designs in a borrowed narrow wave tank that resembled an elongated fish tank. This had allowed 1:100 scale testing of a single device, but clearly could not accommodate the testing of a string of devices that would be required. Salter had designed the Duck as a modular device, which could then be incorporated into long strings, forming wave power stations of varying size. This would allow strings of Ducks to be added or removed from future installations. Many of the early wave devices (such as the Raft) shared this modular design, and it was regarded as a positive feature of wave energy. From the beginning Salter had been pushing to build a wide testing tank at Edinburgh. He regarded this as an essential step in perfecting the design of wave power devices, contrary to the views of Bellamy at Lanchester who, as stated above, pressed for the development of scaled-up devices in the water. It was clear to Salter that of equal, if not greater, importance than the wave device design itself was the design of the mechanism that would couple the devices together. In the case of the Duck this was the spine or backbone. The wide tank would allow Salter to develop a reliable backbone at 1:150 scale, which he regarded as an optimal testing scale. Salter had earlier hired a 1:10 scale tank for a week to test his Duck design but concluded that 'Everything was far slower and more expensive but, for shapes like those of most wave devices, no more accurate [than the 1:100 tests]'.[98]

Funding for the wide tank was capped at £100,000 as this was the amount that Grove-Palmer, as WESC programme manager, could approve without seeking further approval from ACORD and the DoEn; not to mention the inevitable delays that the pursuit of greater funding would create. The Salter team had therefore to 'design backwards from £100,000'.[99] A new building had to be constructed at Edinburgh University to house the wide tank, but with the purchase of scrap parts and a great deal of ingenuity the team was

[97] SA. Salter to Keller, 10 January 1977. My italics.
[98] Salter, 'Looking Back', p.18
[99] Ibid.

able to stay within the tight budget. The tank was eventually filled with 350 tons of water in January 1978 and was 'officially' opened in July 1978 by Alex Eadie, just prior to the Heathrow Conference.[100] It comprised of 89 wavemakers and could reproduce (at 1:150 scale) an area of sea 3 km wide and 1 km long (see fig. 5.2). In the wide tank, using around 90 1:150 scale Ducks, the Salter team would be able to reproduce a scale model of the 2GW wave power station that the WEP had set as its 'reference design' (see chapter 4). In the event it was a rival team that first used the tank from February 1978.

[100] Fishlock, D., 'Wave-testing tank holds the key to future energy source', *The Financial TImes,* 12 July 1978; Faux. R. 'Wave power testing tank opened for research', *The Times,* 12 July 1978; Linklater, J., 'Scots aid UK to plug in waves power', *Glasgow Herald,* 12 July 1978

Figure 5.2:

The Edinburgh wide tank

Source: Salter, S., 'Looking Back', in Cruz, J (ed.), *Ocean Wave Energy: Current Status and Future Prospects* (Springer: Heidelberg, 2008) Fig. 211., p.27

Salter was distracted from his focus on device development during the construction and equipping of the wide tank. In addition, his attention was repeatedly drawn to the problems of SEA, Lanchester, and the Loch Ness Trials. Recognising the difficulties, Grove-Palmer wrote to SEA in March 1978 that 'The Ducks project is in danger of going off the rails and something must be done quickly to put it back on course'. He noted that there was 'an almost total lack of communication between SEA and Salter.' [101] Despite the attempts to resolve their differences it was clear that Salter and Bellamy had fundamentally irreconcilable views on the direction of wave energy development. After the announcement of the Loch Ness trials, soon after the formation of SEA, Salter took little part in the SEA/DoEn project. The Edinburgh team continued to receive separate DoEn funding (£35,000 per annum) for its tank work, and Salter devoted himself to this aspect of the work. As early as June 1977 Salter was writing about a 'crisis in the organisation and planning of the [SEA] project'.[102] Soon after he began to openly question the 'competence' of the Lanchester team and warned Peter Young, the RMC director of SEA, that 'we are headed for an expensive disaster'. He elaborated,

> I am sure that you must be aware that on several occasions we have questioned the competence with which the various Lanchester activities have been conducted. Each of the steps from computer simulation to Draycote to Loch Ness have followed an identical pattern. They find that a problem is harder than they supposed and, instead of solving it, they abandon it and move on to a yet more ambitious goal. The present Loch Ness model has the wrong shape of duck with the wrong moment of inertia and centre of gravity, a spine which is too stiff, inadequate control of spine alignment and power take-off and unreliable information on the directional characteristics of the waves. [103]

By December 1977 the 'crisis' had evolved into a 'rift'[104], and finally become a 'split'.[105] By May 1978 Salter stated plainly that 'I have no faith in the competence of the Lanchester team and cannot be involved in any of their future work.'[106] For him the ultimate folly of the Loch Ness trial lay in the harm that it could do to the image of wave power. The RMC people involved in SEA agreed with Salter that the Bellamy trials at Loch Ness were over-ambitious, but regarded this as a mistake in the time-scales

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[101] SA, Grove-Palmer to Young, 8 March 1978.
[102] SA, Salter to Wood, 16 June 1977
[103] SA, Salter to Young, 17 November 1977.
[104] SA, Salter to Soper (RMC), 21 November 1977
[105] SA, Salter to Goodwin, 8 December 1977
[106] SA, Salter to Soper (RMC), 9 May 1978

envisaged for the work; '...we have been trying to go too fast'.[107] Certainly the Loch Ness trials were dogged with difficulties and delays. Problems between NEL, who were collaborating on aspects of the project, and Lanchester, meant that vital parts for the trial were severely delayed. When these parts did arrive, winter conditions had also arrived on Loch Ness, and the bad weather (which included parts of the loch freezing over) hampered the SEA team further. This pushed the work - to have been completed in the summer of 1977 - into the next year, and by May 1978 an extension to the SEA/DoEn project was agreed by WESC. An additional £330k was allocated to the trials and the proposed completion date was extended until 31 October 1978. Significantly, WESC required that SEA make certain alterations to the model - the centre of gravity and moment of inertia - which echoed some of Salter's earlier criticisms.[108]

Through the summer of 1978 WESC made repeated attempts to heal the rift between Edinburgh and Lanchester, noting that 'Salter and Bellamy have not been working fully in harness'. They urged that the Loch Ness trials should go 'hand in hand' with the wide tank work at Edinburgh.[109] However, it was clear that Salter would not be persuaded. During 1978 the SEA/Lanchester trials continued at Loch Ness and the interim results of the tests were reported at the Heathrow Conference in November that year (see chapter 4). The technical challenges that had been thrown up by the trials formed a major part of the rather gloomy prospects for wave energy which were presented at the conference. In particular, the SEA team had encountered real challenges with the bending 'spine' of the device, and in the power 'take-off' mechanism. These were problems that Salter had recognised, and judged would be best tackled at 1:150 scale in the new wide tank.

Following the Heathrow Wave Energy Conference official enthusiasm for wave energy dipped. The technical challenges and associated costs revealed at the conference served to dent the initial surge of optimism shown by government and, consequently, by private industry. The 'immense amounts of goodwill' that Salter had referred to, only one year earlier, vanished quickly. Shortly after Heathrow, after the first two years of the SEA project, RMC reviewed their involvement in wave energy. They were clearly concerned by

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[107] SA, Soper to Salter, 18 November 1977. In replying to this comment, Salter's wrote 'You say that the troubles have been caused by trying to go too fast. I agree. But the point is that accuracy in estimating time and costs for a project is an important requirement for a project manager. Nobody set deadlines for Lanchester. They were all self-imposed.' Salter to Soper, 21 November, 1977

[108] SA, 'Notes of a Meeting at Chesham Place held on 31st May 1978 to discuss future funding of the SEA Limited's programme on Salter Ducks'

[109] SA, Clarke (WESC) to Young (SEA/RMC), 7 June 1978

the technical challenges revealed by the Loch Ness trials, and probably disappointed and disconcerted by the lack of commitment that Salter had shown the project.

A meeting of SEA was arranged for January 1979 to discuss a way forward for the project, and a paper circulated by Peter Young of SEA/RMC prior to the meeting made the position abundantly clear.

> This paper has been written in an attempt to assess the commercial future of wave power and SEA Ltd's chances of benefiting from it. RPT's [consultant] latest cost estimates are analysed and it is concluded that wave power is unlikely to be competitive as a source of electrical power for the grid within a commercially viable time scale. An alternative route - energy farming - is discussed, but with wind and tidal energy likely to be more competitive in this scenario it seems again that time is not on our side. *The conclusion is that we should not invest further funds in wave power* and that any future commitment should be on a fully funded basis, hopefully with a management fee to provide a worthwhile profit. [110]

SEA were concerned about the emerging understanding of the development time-scales for wave energy, and how this would affect their investment. Young elaborated,

> Patents last for 15 years. Some of ours are already one or two years old. We should therefore be in a position to cash in within 8 years at most if we are to see much return. With the sort of problems now being thrown up, and the speed at which ETSU functions, it appears unlikely that a full-scale prototype of any device will be built within 8 years, let alone one on which we have patent rights.

The meeting signalled the end of RMC's involvement in wave energy, and the winding down of SEA Ltd. The arrangement had lasted for nearly three years and had focussed on trials of the Duck at 1:10 scale in Loch Ness. The DoEn and RMC had invested heavily in the project and the results had been largely discouraging. Bellamy reported at the January meeting that 'The work had demonstrated beyond doubt that a duck string could absorb substantial amounts of power', but the cost predictions and reliability figures loomed large. Also, by this stage Bellamy was losing interest in Duck development and had submitted separate funding applications to WESC for his new 'Clam' wave device. So, from early 1979 the Duck would return to the test tank of Stephen Salter and his team at the University of Edinburgh.

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[110] SA, Soper to Salter, 23 January, 1979. Paper enclosure, 'The Future for SEA Ltd. in Wave Power', P. Young. My italics.

Conclusions

This chapter has examined an early attempt at the commercial development of wave energy. It has shown how this began in 1975 with Stephen Salter's search for industrial partners to aid in the development process, and resulted in the formation of Sea Energy Associates Ltd in 1976. Despite regular complaints over the administration of DoEn funding, Salter remained generally satisfied (throughout the early WEP) that the *levels* of that funding were adequate, and even generous, for his R&D work on the Duck. Therefore his motivation for including commercial partners can be seen to have been derived mainly from awareness that large-scale engineering expertise would ultimately be required for the successful development of wave energy in the UK. At full-scale the Ducks would be constructed of concrete and each Duck would be in the order of 3 metres across. Ready Mixed Concrete Ltd. appeared to be an ideal partner; not only for their expertise in concrete but also their willingness to invest significant amounts of time and capital in the project.

Very quickly it emerged that Salter and SEA had fundamentally different ideas about the way in which the Duck should be developed. Although Salter focused his disagreements over the direction of the project on the Bellamy team's 'competence' - it was clear that RMC, anxious over patent exploitation, were also keen to hasten the development process. As has been seen, Salter maintained that the future viability of the Duck would be best served by thorough laboratory testing prior to up-scaling and testing in the open water. This fundamental disagreement sealed the fate of the SEA partnership almost from the outset.

Another key theme that emerges in this chapter was the influence of new environmentalism, in particular ant-nuclearism that lay at the heart of Salter's motivation to develop a renewable energy source. Though clearly stimulated by the oil crisis (and Mrs Salter) to consider renewable energy sources, it is plain that Salter was greatly influenced by his early encounter with Amory Lovins and the new UK branch of Friends of the Earth. The challenge for Salter was to create a renewable energy device that would serve as a genuine alternative to the continued expansion of nuclear power in the UK. This long-term hope, that Goodwin had termed 'grandiose and panacea like thinking' for the potential of renewable energy arguably caused Salter to approach the development of wave energy in a careful and considered way, which was at odds with the frantic pace encouraged by short-lived enthusiasm of the DoEn; and the clash with Bellamy over the Duck trials at Loch Ness illustrates this well. This chapter emphasises that Salter remained committed throughout the WEP to protecting the credibility of wave power as a valid alternative to nuclear power. It would perhaps to be too ambitious to claim that, at the time, Salter had a sense that the energy TIC would ensure the failure of renewable energy technology by forcing the pace of development towards unrealistic targets; although this is certainly a view that he reached later.[111]

What damage, if any, did the SEA project do to the UK WEP? The evidence suggests that the Heathrow Conference was a major watershed in wave energy in the UK. Chapter 4 showed that the cost estimates and technical challenges unveiled at the conference did lasting harm to the image of wave energy, and began a gradual process of retreat culminating in the closure of the WEP in March 1982. Before Heathrow, the Salter Duck was the leading wave energy device, attracting much of the funding and media interest in renewable energy. The disappointing results from the widely publicised Loch Ness trials served to emphasise the unexpected scale of the challenges that faced the programme and, as such, harmed the future of UK wave energy development. In this, Salter's anxiety over the damage that premature 1:10 scale testing could inflict was proved correct.

Previous chapters refer to the 'hubris' of the wave energy community prior to Heathrow. This boundless confidence in the potential for wave energy among developers and those close to the WEP was encouraged before 1979 by consistently positive statements on wave energy from within the government and the CEGB. I would argue that this led many developers towards the perfectly understandable belief that the DoEn would remain committed to wave power in the medium to long term whatever the challenges. Consequently, this belief encouraged leading developers such as SEA and Cockerell's Wavepower Ltd, to push forward to larger-scale sea trials without due consideration of the potentially damaging impact of short-term failures; a risk that Salter alone had recognised. In *Power from the Waves* Ross argues that despite drawbacks there was some merit in this approach, as it allowed developers an opportunity to uncover some of the challenges of

[111] Interview, Salter, S., July 2008

larger-scale power generation.[112] However, this overlooks the lasting damage that perceptions of failure had on the wider wave energy programme.

[112] Ross, *Power*

Chapter 6
Rising Wind

'*Variability, unpredictability and high capital costs make [wind] a non-runner*'[1]

This chapter will consider the gradual evolution of the UK wind energy programme from its inception in 1978 until the privatisation of the electricity industry in 1989. Despite the surprisingly vast numbers of wave energy patents mentioned in previous chapters, the technology of wind energy was much more firmly established by the 1970s than that of wave energy. Various projects from the late nineteenth century and throughout the twentieth century, most notably in the US and Denmark, had advanced the development of efficient and effective wind turbines.[2] Perhaps owing to this the technical challenges of wind power generation were significantly less than for wave power: a fact emphasised starkly for wave by the proceedings of the Heathrow Conference.

The previous two chapters dealt primarily with the evolution and eventual closure of the UK wave energy programme (WEP) between 1974 and 1982. It was seen that during the early years of the WEP, wave energy was routinely considered by the DoEn as the front-runner among the potential renewable energy technologies in the UK. Chapters 4 & 5 showed how this position of preeminence began to shift after the abortive Heathrow Wave Energy Conference of November 1978. Prior to this, as the quotation above illustrates, wind energy had been given a much lower priority and effectively discounted within the government's wider renewable energy programme. However, the cost estimates and technical challenges for wave energy revealed at Heathrow, plus a substantial wind energy programme in the US, placed wind energy in a much more favoured position from 1979 onwards.

In a sense, the appeal of wave energy had lain in the scale and uniqueness of the technological challenge that it presented to the UK government. In this way it resembled the early nuclear programme. Edgerton and others have argued that the nuclear programme was driven by the enthusiasm and specialist technical expertise of engineers. Politicians could not be expected to fully understand nuclear technology and therefore the UKAEA

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[1] TNA, EG 16/13, DTI, Energy Technology Division, 'New Forms of Energy in the UK', 21 March 1973
[2] Although interestingly the ancient competition between vertical and horizontal turbines remained to be fully resolved (see chapter 1).

developed as a uniquely powerful and autonomous organisation within the UK energy scene.[3] Wave energy presented a similar array of complex technical challenges (only understood fully by a limited number of 'engineers') which required a similarly huge and long-term capital investment. However, with nuclear energy continuing to represent, however uncertainly, the UK's energy future the government was ultimately not prepared to gamble on another speculative and expensive energy technology. This chapter shows that wind power soon came to be seen as a much safer and perhaps cheaper renewables option for the UK.

The UK Wind Energy Programme

In the early years of the UK renewables programme the development of wind energy was routinely rejected. This was despite the fact that the original ETSU objectives *included* wind energy (and *not* wave) as a primary area for R&D (see chapter 3).[4] However, as previously discussed, the weight of the 1974 CPRS recommendation strongly influenced the initial shape of the UK renewables effort in this regard. This was not helped by the fact that the influential Lord Rothschild was also quoted as being sceptical about the prospects for wind energy in the UK.[5] It was not until 1978, four years after the creation of ETSU that a Wind Energy Steering Committee (WISC) was set up. How can this initial hesitation to explore the potential of wind energy in the UK - arguably the most 'conventional' of the alternative energy sources - be more fully explained?

Some explanation for the initial reluctance to invest in wind energy in the UK can be traced back to the attitude of ACORD before 1978. At a meeting in December 1975 the council considered an early ETSU report on 'The Prospects for Wind Energy in the UK'.[6] The report had considered only 'large machines' and the council noted that the accompanying 'Wind-maps' showed that the areas of 'greatest wind' were 'away from the areas of greatest demand'. More pointedly ACORD observed that periods of calm meant that wind could not be considered a 'firm power source'. This was despite the fact that wave energy shared both of these characteristics. The council though appeared to accept

[3] This was the focus of Benn's criticism of the UKAEA from the late 1970s onwards.
[4] TNA, AB 88/218. Leighton to Todd, 10 April 1974
[5] TNA, AB 88/290, 1089/13, ETSU visit notice: Note for the record. 17 July 1974. Dr Bruckner, a visiting US scientist interested in wind energy systems, commented on a visit to ETSU for support that he had approached Lord Rothschild and was 'disconcerted by [Lord Rothschild's] unfavourable view on Wind Power'.
[6] TNA, EG 16/1, ET 4/153/019, FPRD(75) 9th Meeting, Department of Energy, Advisory Council on Research and Development for Fuel and Power, Minutes of meeting 9 December 1975.

that a suggested capital investment of between £2m - £5m would ‘save’ one million tonnes of oil per annum, or the equivalent of ‘one or two’ coal fired power stations. However, further objections were raised which perhaps better explain the delayed investment in wind energy development in the UK. First, the council anticipated that the ‘environmental aspects’ of erecting 10,000 ‘of these machines’ would create ‘intense opposition’.[7] Second, the meeting noted that the US was proposing to spend $30m on wind technology over 5 years and it might be better to await the outcome and ‘buy in’ US technology. Although the council observed that it might be unacceptable to the IEA ‘if the UK put in no effort’ rather interestingly it noted that ‘wave power work might be offered in exchange’.[8] The meeting concluded that there was no need to establish a steering committee for wind energy ‘until more accurate cost estimates were available which indicated a valid option’.[9]

Clearly, the minutes of the 1975 meeting show that ACORD had little interest in the development of wind energy, and ETSU appeared to do little to encourage its development in the UK. Interestingly many of ACORD’s objections could be applied equally to wave energy but the momentum created by Lord Rothschild had forced wave energy into the renewable energy spotlight. Indeed many of their key objections on location, intermittency, and uncertain costs were perhaps even more telling for wave energy than for wind: though this may have been intended as a thinly veiled criticism of all renewable energy sources from ACORD. Despite this, perhaps as a stalling tactic within the wider UK renewables programme, ACORD asked that ETSU revise their proposals for wind energy.

By April 1976 an ad-hoc group led by ETSU, and including representation from the Energy Technology Unit (ENT) at the DoEn, produced a report titled ‘A Strategy for Energy R&D in the UK’.[10] ETSU had been established for two years by this time and took the opportunity to reflect on its initial experience, and to develop a wider energy R&D plan for the medium term in conjunction with the DoEn. It was a comprehensive and lengthy

[7] TNA, EG 16/1, ET 4/153/019, FPRD(75) 9th Meeting, Department of Energy, Advisory Council on Research and Development for Fuel and Power, Minutes of meeting 9 December 1975. The figure of 10,000 wind turbines appears in several of the early discussions of wind energy. This appears to have been based on nothing more than the estimates that the UK had once had around 10,000 windmills in operation.
[8] Ibid. This provides further evidence of the widespread confidence in the potential of wave energy R&D in the UK during this period.
[9] Ibid.
[10] TNA, EG 16/55, ET 4/1/018, FPRD (76) 16, ‘A Strategy for Energy R&D in the United Kingdom, ACORD draft.

report which covered all UK energy sources, and included an overview of the renewable sources. The section on wind energy immediately followed a positive assessment of the potential of wave power; ‘probably the most attractive naturally occurring energy source in the UK’.[11] The report suggests that the ‘upper limit’ for a UK wind energy programme would (again) be ‘10,000 generators each of 1MW rating’ (a figure derived from the earlier ETSU study) and that this would represent an annual energy saving of 8 mtce. This contrasts with the figures given for wave in the report which suggest an energy saving of 15 mtce in 2000, rising to 50 mtce by 2025. However, the environmental aspects of wind energy were stressed once again and described as ‘considerable’. The report states that ‘a modern aerogenerator has more in common with an electricity transmission tower than with the picturesque, old-fashioned windmills.’[12]

This report is a clear example of renewable energy sources set within the dominant UK energy problem frame. Wind and wave were considered in terms of their potential contribution to a national energy mix which contains a limited number of energy sources. Coal, oil, and nuclear energy were the main components in this mix, and the renewable sources were seen as insurance mainly against a so-called ‘Limit on Nuclear’ scenario. Therefore, their contribution had to be shown as significant and cost-effective (compared to nuclear) to be worthy of consideration. In the mid-1970s the uncertainty that surrounded wave energy helped to suggest that it had the potential to fulfill these conditions, whereas wind energy (where the technology was much better established) appeared initially to fall short of the requirements. This helps to explain both the initial rejection of wind energy and its eventual appearance in the UK renewables programme as the technical challenges of wave energy grew over the course of the Wave Energy Programme (WEP) described in chapter 4.

Despite the lack of enthusiasm for wind energy within ACORD and the DoEn, ETSU continued to investigate its potential and published what proved to be the seminal report on wind energy in the UK, Energy Paper 21, in June 1977 ‘The prospects for the generation of electricity from wind energy in the United Kingdom’.[13] This first

[11] TNA, EG 16/55, ET 4/1/018, FPRD (76) 16, ‘Strategy’, Appendix 2, pp. 20-21
[12] Ibid.
[13] TNA, EG 2/325, Energy Paper 21, ‘The prospects for the generation of electricity from wind energy in the United Kingdom’, A report prepared for the Department of Energy by the Energy Technology Support Unit, Harwell (London, HMSO: 1977)

comprehensive study of the potential for wind energy overturned the earlier assumptions about its potential in the UK and concluded,

> Whilst no clear economic case can be made at the present time for utilising wind energy for the large scale generation of electricity, *the potential contribution from this source has a significance that is too large to ignore.* Further, aerogenerators can produce energy in its most useful and high grade form, namely a.c. electricity: in which form it is readily and efficiently transmitted and converted to light, heat and motive power. Also, it is compatible with the existing distribution system fed by conventional power plant.[14]

The report stopped short of recommending what it called ‘a large development programme’ but did suggest that in addition to continued support for ongoing wind energy research at the university level, the DoEN should support the commercial development of ‘medium size aerogenerators of around 100kW’. ETSU noted that this would ‘ensure a British presence in the potential home and export markets for this form of energy *saving* equipment.’[15] Energy Paper 21 represented the first detailed consideration of the potential of wind energy in the UK and led directly to the first commercial wind energy proposal.

Hawker Siddeley Dynamics proposal: 1977

Prior to publication of Energy Paper 21, ACORD had considered and approved a draft of the ETSU report in its meeting of November 1976 and the conditions for industrial participation were established.[16] In January 1977 an ‘independently formed industrial group’ led by the British multinational Hawker Siddeley Dynamics Ltd submitted a proposal to the DoEn which sought to ‘resolve’ some of the ‘uncertainties’ surrounding the exploitation of wind energy in the UK.[17] The consortium included leading industrial partners, Electrical Research Association Ltd, Cleveland Bridge & Engineering Co. Ltd, and Taylor Woodrow Construction Ltd. Also included was a small contribution totalling £10,000 from the South of Scotland Electricity Board (SSEB) and the North of Scotland Hydro-Electric Board (NSHEB). The proposal did not aim to produce a prototype turbine, but rather to seek the ‘configuration and cost of a machine optimised for minimum energy

[14] TNA, EG 2/325, Energy Paper 21, ‘Prospects’, p.50. My italics
[15] My italics. This illustrates the continued identification of renewable energy sources with the preservation of conventional fuel sources.
[16] TNA 16/118, FPRD(77) 12, Department of Energy: Advisory Council for Research and Development for Fuel and Power, ‘Wind Power: Note by the Chairman of ACORD Programme Committee’.
[17] TNA, EG 16/118, Hawker Siddeley Dynamics Limited (Mechanical Equipment and Systems Division, ‘The Development of large wind turbine generators: A proposal for a joint industry/Government programme’. Technical Proposal No. 379, Issue 1, January 1977.

cost' and the 'total costs associated with site construction and grid connection of an installation at several representative sites'. The costs of the study were estimated at £160,000 (including the contribution from the Boards) and government funding of £75,000, matching the total contribution of the industrial partners, was requested. The proposal from the consortium firmly rejected the earlier ACORD notion that the UK should simply wait for the US developments in wind turbine technology. It suggested that American developments were 'over-sophisticated' and their manufacture in the UK would involve 'high capital expenditure'. Furthermore it stated vaguely that US machines were 'not suitable for optimum exploitation of the highest merit sites available in the UK and overseas', before making the rather more salient and persuasive political point that a 'home initiative will maximise employment of the required skills that already exist in UK industry'.[18]

The February 1977 meeting of ACORD considered the consortium's proposal.[19] Despite the appearance that wind energy was gaining official support in this period, the November 1976 meeting had given ETSU the rather negative task of defining 'the *minimum* Department of Energy programme to ensure that its overall position on the subject was defensible'.[20] Advice to ACORD further illustrated the tokenistic nature of the initiative. The Chairman of the ACORD Programme Committee pointed out that it had already been established that wind energy 'may be economic on a few remote sites', but emphasised that this was 'still a long way from any thought of series ordering which must be the option of interest to the Department.' However, in accordance with the 'defensible' position desired by the DoEn the advice recommended that ACORD should 'welcome the active participation of industry, including commitment of finance, in a small on-going programme *without any commitment whatsoever to prototype construction.*' [21]

ACORD followed this advice closely and supported the Hawker Siddeley proposal, albeit in overwhelmingly negative terms. The council echoed the view that the study would add little to that which was already known about wind energy on 'prime sites' and would not 'demonstrate whether or not wind energy could be economic on a more general basis…'. Moreover it re-stated the view that the environmental impact of 'the large

[18] TNA, EG 16/118, Hawker Siddeley Dynamics Limited. p.2
[19] TNA, EG 16/118, ET 4/1/021, FPRD(77) 2nd Meeting, Department of Energy, Advisory Council for Research and Development for Fuel and Power, Minutes of meeting, 8 February 1977.
[20] TNA 16/118, FPRD(77) 12. My italics
[21] TNA 16/118, FPRD(77) 12, My italics

numbers of machines required to make any significant contribution...would in all probability prevent wind power exploitation.’ [22] Walter Marshall added the typically trenchant observation that ‘He, himself, doubted that wind power could be proved an economic option’ but conceded that ‘it was important to assess its economic viability in an objective and responsible manner’.[23] Perhaps, he could also have added ‘defensible’ to this list.

By early 1978 the consortium had completed its feasibility study. During 1977 Hawker Siddeley Dynamics had been nationalised as a leading part of the new British Aerospace under the *Aircraft and Shipbuilding Industries Act 1977* following a manifesto commitment by the Labour Government in 1974. Despite earlier reluctance to move to a prototype, the study recommended that as a next stage in the investigation of wind energy a demonstration turbine should be constructed on an appropriate site in Scotland. The suggested prototype was a massive 3.7 MW turbine with a blade diameter spanning 60 metres, at a time when the largest successfully demonstrated machines (such as in the Netherlands) spanned around 23 metres. Clearly the scale of this prototype did not daunt the DoEn and a further 12-month study costing £341,000 was funded to refine the design of the turbine and to investigate potential sites. Evidently, the enthusiasm for wind power was increasing during 1978 as the DoEn also commissioned a further study of the potential for offshore wind. How can this shift in attitudes be understood?

There are perhaps a number of key factors that help to explain the increasing attention paid to wind energy in the UK at the end of the 1970s. First, and perhaps most important, was the example of the US wind energy R&D programme. From 1974 the US had committed millions of dollars to developing reliable onshore wind technology. As noted above, ACORD was aware of the scale of the US programme and was initially tempted to allow the Americans to bear the cost, and some of the potential first-mover advantages, of wind energy development. However, pressures from influential industrial partners such as Hawker Siddeley over the impact on British technology jobs forced the DoEn to reconsider its position. Also the apparent commitment in the US to develop domestic wind energy capacity, and the introduction of legislation favourable to renewable

[22] TNA, EG 16/118, ET 4/1/021, FPRD(77)
[23] Ibid.

energy sources, offered a valuable export opportunity to UK industry at a time of serious balance of payments pressures.[24]

Second, the interest and involvement of the Electricity Boards encouraged the DoEn to reconsider the potential of wind energy. As well as the commitment of the SSEB and the NSHEB to the initial Hawker Siddeley study, the CEGB also began actively pursuing the feasibility of onshore and offshore wind energy during this period. The electricity boards were attracted by the advanced technological development of wind turbines, and by the examples of its exploitation by electricity providers in other countries. Closely related to this for the Scottish Boards was the involvement of leading UK industrial firms in wind energy. The interest and financial commitment of leading companies such as Hawker Siddeley Dynamics and Taylor Woodrow in wind energy encouraged confidence among the Boards for the potential of wind energy.

Third, as previous chapters have shown, was the growing realisation that wave energy development would take longer and prove more costly than originally envisaged. The impetus for wave energy advocated by the CPRS recommendation in 1974 and Salter's groundbreaking work coincided serendipitously to create an initial enthusiasm for this exciting new energy source. Staggering conversion efficiencies demonstrated by Salter, and confirmed by the CEGB among others, suggested that by scaling up a wave device tremendous amounts of electricity could be captured. However technical challenges were emerging that cast some doubt on the economic feasibility of wave energy which were fully revealed at the Heathrow Wave Energy Conference in 1978. Wind energy technology was on the other hand much less technically challenging and therefore a cheaper option. Whilst Britain pioneered the development of wave energy (and bore the costs of this) wind energy had been developed internationally and the UK could benefit from this established expertise.

Set against these factors for the development of wind energy was the repeated concern over the environmental impact of large-scale deployment of wind turbines. After the initial temptation to allow the US to do the 'donkey work' on wind power was

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[24] For an account of the effect of the new legislation on renewable energy development in the United States see, Russo, M. V., 'Institutions, Exchange Relations, and the Emergence of New Fields: Regulatory Policies and Independent Power Production in America, 1978-1992', *Administrative Science Quarterly,* 46 (2001), pp. 57-86; Thompson, E., 'The Rapid Transformation of Intergovernmental Energy Relations', *Publius: The Journal of Federalism,* 13 (Fall 1983)

overturned, the only consistent argument against wind energy in the UK was focused on its environmental impact and the potential reaction of the public to this visual intrusion. Among countless examples, Freddie Clarke, Research Director at Harwell (and subsequent Chairman of the Wind Energy Steering Committee) stated,

> It will be noticed that [windy sites] do not generally coincide with the areas of maximum industrial or domestic demand for electricity. Indeed they tend to lie in the more remote areas of natural beauty. [25]

Glyn England, the CEGB chairman, doubted whether 'the public would welcome the intrusion of these gaunt, massive structures into the landscape'.[26] Official government assessments of renewable energy also routinely cited environmental factors as a primary impediment to wind energy.

Wind Energy Steering Committee

In June 1978 the Wind Energy Steering Committee (WISC) was set up at Harwell. Despite the earlier reluctance on the part of ACORD to establish a steering committee for wind energy, the increased activity following the recommendations of Energy Paper 21 and the subsequent Hawker Siddeley study eventually sealed the case for its creation.[27] Although perhaps the removal of the wind-sceptical Walter Marshall as Chief Scientist at the DoEn (and chairman of ACORD) in 1977 and his replacement in both roles with the arguably more sympathetic Sir Herman Bondi also had some impact. As a reflection of the importance of the new committee, Harwell's research director, Freddie Clarke, took up the role of WISC chairman. The committee initially was comprised of representatives from ETSU, Government departments and the CEGB, but WISC signalled at the first meeting that it was anxious to have representatives from industry join the committee as soon as possible.[28] The main functions of the committee were similar to those of the previously established Wave Energy Steering Committee (WESC) and its main role was,

[25] Clarke, F. J. P., 'Status Report on the Alternative Energy Sources', *ATOM,* 252, October 1977.
[26] England, G., 'Renewable Sources of Energy - The Prospects for Electricity', *ATOM,* 264, October 1978, pp. 271-272.
[27] The acronym 'WISC' was chosen as the Wave Energy Steering Committee had already adopted the 'WESC' acronym.
[28] TNA, EG 16/150, WISC(78) M1, Wind Energy Steering Committee, 'Minutes of the 1st Meeting', 14 June 1978.

> To advise upon the formulation and management of a Government Programme on wind energy and to consider and make recommendations for support on individual proposals. [29]

The minutes of the early meetings of WISC reveal a vigour that was perhaps absent when considering the deliberations of WESC at a similar stage. The focus of WESC had been, and largely remained, on the identification of the most appropriate wave energy device to take forward to the demonstration phase. For WISC the more advanced state of experience with the technology and the reduced scale of technical challenges placed the committee much closer to demonstration of wind energy. The earlier Hawker Siddeley study had already produced a single reference design and two further tranches of Government funding had also been approved for further work on the construction of a 3.7MW turbine. In many senses WISC was simply taking up the reins of a programme which already had a significant degree of momentum.

As stated above the first task of the committee was to formulate a ‘Government Programme’ for wind energy in similar terms to the earlier Wave Energy Programme (WEP) described in chapter 4. While work by the industrial consortium[30] on the design, construction and siting of the 3.7MW demonstration turbine continued through 1979, the committee regularly reviewed the progress of the study. By February 1979 ACORD had agreed the detailed strategy for the wind energy programme which was set within the overall aim,

> ...to establish the total feasibility of both land based and offshore sited aerogenerators, and the nature and size of the contribution they might make to the UK energy supply. [31]

During 1979 there was a marked increase in activity on wind energy in the UK. WISC added selected industrial partners to the steering committee, and in December 1979 appointed a full-time wind energy programme manager, Len Bedford from Harwell. The committee reported to ACORD in March 1980 that ‘In the UK, during the past year, there has been an increasing level of optimism regarding the prospects for wind energy

[29] Ibid.
[30] The consortium for this second study was the same as the earlier study. It comprised, British Aerospace (formerly Hawker Siddeley Dynamics), Cleveland Bridge Engineering Ltd, Taylor Woodrow Ltd, and ERA Ltd.
[31] TNA, EG 16/305, FPRD (80) 7, Department of Energy, Advisory Council on Research and Development for Fuel and Power, ‘Wind Energy Programme: Report from the Wind Energy Steering Committee’, March 1980.

becoming a viable alternative source of energy.'[32] Perhaps this was partly as a result of the disappointment surrounding the discussions at the Heathrow Wave Energy Conference, but it is also explained by the total abandonment of the earlier ACORD notion that the UK should allow other nations to take the lead in wind energy development. The WISC progress report for 1979/80 described a range of DoEn-funded wind energy studies set in progress during the year.[33]

The main thrust of the new Wind Energy Programme (WEG) remained focused on the reference design for a 3.7MW turbine recommended by the earlier Hawker Siddeley study. Although the new report had not yet been completed, the preliminary conclusion suggested that the 'report will largely confirm the conclusions reached by the feasibility study.' Moreover, a suitable site for the demonstration turbine had been identified at Bennan Hill in Ayrshire, Scotland.[34] Also as a further indication of serious intent, during 1979 WISC had appointed W.S. Atkins and Partners as technical consultants to the wind programme, and through 1980 Atkins prepared an assessment of the consortium's overall turbine design.

In addition to this, the DoEn were now funding a range of other wind energy initiatives. Although the horizontal axis wind turbine (HAWT) favoured by the consortium was coming to dominate wind energy development both in the UK and abroad, there remained a significant interest in the alternative design of the vertical axis wind turbine (VAWT). Peter Musgrove, an important pioneer of UK wind energy in the 1970s, was an advocate of the VAWT and the DoEn was funding a study led (again) by British Aerospace and Taylor Woodrow Ltd (key members of the 3.7MW HAWT turbine consortium) into the potential of the VAWT, with Musgrove acting as a consultant.

The verdict on the Musgrove study has some interesting parallels with the development of wave energy. The 1980 WISC report stated that despite some promising wind tunnel results, the Musgrove turbine was 'a new concept originating from the UK'. This was clearly seen as a negative assessment. Given the 'considerable amount of experience' already gained with the HAWT and the 'knowledge that MW size machines were already planned or under construction in other countries' WISC were hesitant about

[32] Ibid. p.1
[33] Ibid.
[34] This site would eventually be rejected in favour of the eventual site in Orkney (see below)

funding a megawatt-sized Musgrove turbine. Instead they recommended that an 'intermediate size machine of about 25 to 30m diameter, and 100 to 250kW rated output, should be taken to the reference design stage.' [35] Clearly in the case of the VAWT, as with wave energy devices, innovation in renewable energy sources was seen as too great a risk for the DoEn.

CEGB

A further important stimulus to wind energy in the UK in the late 1970s was the active interest of the CEGB.[36] As was seen in previous chapters, the CEGB had also taken an early interest in wave energy. Don Swift-Hook from the CEGB was a very early visitor to Salter's workshop in Edinburgh and the CEGB had invested time and money into wave energy R&D from 1975 onwards. This was not entirely surprising as both wave and wind were primary electricity-producing renewable technologies. And although the CEGB, like the Government, retained an abiding faith in the nuclear option it was seen as sensible to investigate the long-term potential of the renewable options. Indeed it may well have appeared attractive to the CEGB to have some control over 'fuels' after decades of wrestling with the government, the NCB, and the UKAEA over supply. Certainly the early estimates of renewable energy potential seemed to offer some encouragement to the CEGB, demonstrated most famously in the speech of the CEGB chairman, Glyn England, at Fawley Power Station in 1978. He said,

> ...in planning how to meet any future shortage of fossil fuels for electricity generation, we are not nailing our colours to the nuclear mast alone. We expect that, in time, nuclear power will be augmented by energy from some of the renewable sources. [37]

Although in the same speech England described wave energy 'as the most promising of the renewable energy sources' and promised that the CEGB were 'not daunted' by the technical challenges, as already discussed the scale of these challenges was beginning to dent enthusiasm for wave energy.

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[35] TNA, EG 16/305, FPRD (80) 7. p.3

[36] TNA, EG 16/305, FPRD (80) 7. p.7. The report refers to the 'wish [of the CEGB] to see the potential of wind energy properly explored'.

[37] England, G., 'Renewable Sources of Energy - The Prospects for Electricity', *ATOM,* 264, October 1978, pp. 271-272.

During 1979, no doubt in part encouraged by government activity in wind energy and perhaps equally discouraged by the disappointment of wave energy at Heathrow, the CEGB began its own studies of both onshore and offshore wind energy and collaborated with many of the other government programmes. Swift-Hook who had worked on earlier studies of wave energy now switched his focus to wind technology.[38] The CEGB worked on a number of different aspects of wind energy during this period. One of these was offshore siting, which many regarded as the best response to the widely discussed and imagined environmental problems of onshore wind. This study was conducted in collaboration with Taywood Engineering Ltd, ERA Technology Ltd, and Newcastle University. Musgrove also acted as a consultant on this element of the programme. The initial results of this study were very encouraging and the report considered offshore siting was 'feasible for a 60m diameter machine'. The study also confirmed earlier estimates that a total 200 TWh/year, at a cost of around 4p per kWh, could be generated from offshore wind. The cost in particular contrasts very favourably with the wave energy estimates from Heathrow which were in the 'very high range' of 20-50p per kWh (see chapter 4).[39]

In addition to the work on offshore wind, the CEGB also examined other important aspects of wind energy development. In particular, this was focused on two important areas; turbine cluster spacing and perhaps most crucially, integration into the National Grid. A central theme of this thesis is the techno-institutional barrier that existed in the UK and constrained the development and deployment of renewable energy technologies during the period. The primary technical barrier discussed was the National Grid and its historical creation on a model of large, centrally located power stations. I have suggested that this served to create a dominant energy problem-frame that discouraged innovation in small to medium scale energy sources in the UK, due in part to the perceived technical challenges, and perhaps the lack of will, in connecting these sources to the National Grid. The nature of the CEGB's involvement in wind energy addresses some of these claims.

It is clear that the research into wind energy carried out by the CEGB after 1979 recognised that integration into the Grid would be a key issue for this new technology. The accepted scale of the resource, and the low projected generating costs, encouraged a 'next

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[38] Swift-Hook eventually left the CEGB after a long career and through the formation of the British Wind Energy Association (BWEA) became a leading advocate for wind energy in the UK.
[39] Salter Archive, 'Clarke, F. J. P., Introduction to the Conference, Proceedings: Wave Energy Conference, Heathrow Hotel, London. 22-23 November 1978. Sponsored by the Department of Energy. Organised by the Energy Technology Support Unit, Harwell.'

stage' study of Grid integration that had been absent in wave energy. And WISC reported that the CEGB had concluded that it would be 'unlikely' for there to be any 'major operational difficulties in incorporating aerogenerator capacity' into the Grid. This was, of course, greatly encouraging for all of the renewable technologies, but the favourable cost estimates for wind energy had by this time shifted the focus firmly towards wind power.

Although, as has been seen, wider research activity in wind energy intensified through 1979, the 'main plank' of the UK Wind Energy Programme remained the construction of the 3.7MW reference design turbine at an initial estimated cost of £5.4m. Relative to other elements within the wider UK renewables programme this represented a significant investment by the government in a single demonstration project; by 1980 a total of around £17m had been spent on the entire programme since inception. This provides further evidence of the extent of the DoEn's newly-discovered faith in wind energy at the time. Moreover, as the new Conservative Government took up office in May 1979 with a pledge to make cuts in public expenditure, it makes the subsequent decision to cut the wave energy programme appear inevitable.

In 1979, the DoEn's 'Briefs for Incoming Ministers' were telling for the fate of the renewable energy programme.[40] Reflecting Thatcher's stated intentions for the new government, a 'Tory version' of a key document titled 'The scope for cuts in public expenditure' outlined the possible areas where savings could be made.[41] For the major element of its expenditure, the DoEn rejected the idea that any possible 'good housekeeping cuts' could be made to the nuclear programme without the requirement for 'explicit policy decisions on major programmes.' Similarly, other key elements of the DoEn budget were seen as yielding little in the way of savings. The exception highlighted in the brief is 'non-nuclear research and development' and 'energy conservation'. For conservation the DoEn estimated that £7m could be saved by 1982/83 'if the entire programme were terminated'. Whilst in 'non-nuclear' (the renewable energy programme) the brief stated that there could be 'small savings in early years, rising to about £18 million by 1982/83 if programmes are sacrificed.'[42]

[40] TNA, EG 16/298/1 & 2, General Election 'Briefs for Incoming Ministers'
[41] TNA, EG 16/298/1, FB 10/51, "Election Briefing' Covering letter. G. G. Campbell, 2 May 1979.
[42] TNA, EG 16/298/2, 'Energy Technologies for the United Kingdom: An appraisal for R, D&D planning', Volume 1, 27 March 1979. pp. 96-97.

Accompanying the 'Briefs for Incoming Ministers' at the DoEn was the paper 'Energy Technologies for the United Kingdom' which would be published that same year as Energy Paper 39, which was prepared by ETSU. Following a similar publication from ETSU in 1976, Energy Paper 11, this represented a major appraisal of the UK's 'R, D & D planning', and it gives some insight into the shift in focus from wave energy to wind energy which had accelerated by 1979. The renewable technologies were categorised in the report in terms of their likely contribution to the UK's energy future. They were described as either being a 'supplementary technology' to those needs, or falling into the more familiar and less important 'insurance technology' category. The document reflects the disappointment over wave energy development and quoting figures produced at Heathrow it concluded that hopes for a 'near full-scale prototype operating by the mid 1980s are […] unlikely to be realised.' Wave energy was accordingly classified as an 'insurance technology'.

By contrast, wind energy, largely dismissed in Energy Paper 11, was described in the newer report in much more positive terms. The estimated costs for wind turbines (£320 - £380 per kW of installed capacity *including* maintenance and transmission costs) were in stark contrast to the frighteningly high costs for wave devices (estimated at Heathrow at a staggering £4000 - £9000 per kW installed capacity, without including maintenance and transmission). Furthermore, the report made clear that wind turbine technology was at a much more advanced stage than many of the other renewable energy technologies, and the 3.7MW demonstration machine 'suitable for mass production' would be constructed within 'the next few years'.

Orkney Turbine: 'the star attraction' [43]

In January 1981, the Secretary of State for Energy, David Howell, formally announced the government's plan to build 'a 60 meter blade diameter' wind turbine 'of about 3 megawatts' at Burgar Hill, Orkney. The government hoped to have the machine in operation and connected to the island's electricity supply by 1983-84. Financial support of up to £4.6m would be provided by the government, with a further £1m (and the provision of the site) coming from the NSHEB. Howell also confirmed that a smaller 20-metre machine (250kW) would 'share the site' and was expected to be in operation by October

[43] TNA, EG 16/124, 'The Department's Wind Energy Programme - proposal to construct a 3.7MW horizontal axis turbine', Note for ACORD, Appendix I, Chief Scientist's Branch, 10 October 1980.

1981.[44] Since the completion of the first Hawker Siddeley study in 1978, the proposed site for the demonstration turbine had been Bennan Hill in Ayrshire. Through 1979 and 1980 detailed site investigations had been carried out and negotiations with the relevant Board (SSEB) had been ongoing. What explains this change to a more remote island site after nearly two years of planning for another location, and what does this tell us about the development of wind energy in the UK?

Two main factors came into play which caused a last minute change to the site of the proposed demonstration turbine. Most important of these was the rapidly accelerating development of wind energy in the United States and in Europe. By late 1979 WISC noted that 'the US wind energy RD&D programme is 4 to 5 years ahead of the UK programme.[45] WISC member, Dr R. H. Taylor (CEGB) had visited a US wind energy workshop in October 1979 and returned to report the scale of the US programme to the committee. He stated that the US Department of Energy was spending \$56.9m on the wind power programme alone in 1979, and had budgeted for \$63.4m in 1980. His breakdown of the figures showed that the bulk of US spending in 1979 would be on 'Engineering development', but that in 1980 this would shift significantly in favour of 'Capital equipment and construction'. Taylor went on to report President Carter's announcement that a target of 20% of US energy should be provided by 'solar energy' by 2000.[46] He noted that this had caused the US wind power programme to accelerate and there was a plan to achieve 500MW of installed capacity by 1986, which would require a \$1bn programme.[47]

During his stay, Taylor had also visited two leading US companies involved in the US wind power programme; GEC and Westinghouse. GEC had submitted evidence to the US Government that the target should be much higher, at 750MW. Whilst two other leading aerospace firms interested in wind energy, Boeing and Hamilton Standard, suggested even higher targets of 1000MW and 1500MW respectively.[48] Similar to the UK, it is notable that leading industrial firms were expressing interest and spending money on wind energy development in the period. Similar too, but perhaps unsurprising, is that these

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[44] HC Deb 27 January 1981 vol. 997 c345W

[45] TNA, EG 16/150, ET 20/3/038, WISC (79) M7, Wind Energy Steering Committee, Minutes of the 9th meeting, 15 November 1979.

[46] In the US the convention was to refer to all renewable sources as 'solar energy'.

[47] TNA, EG 16/150, ET 20/3/038, WISC (79) M7.

[48] Ibid

firms were concentrated in the aerospace and electrical engineering sectors of industry. What is more unexpected is the ambitious scale of their hopes for wind energy development. WISC noted that this initiative would 'bring down the unit cost of wind power and will demonstrate to US utilities that machines can operate reliably in the grid.'[49] These developments in the US caused the wider energy community in the UK to take serious notice of wind energy.

Closely related to the scale and rapid development of the US wind power programme was the reaction it created among the electricity Boards in the UK. Significantly it had been the CEGB representative on WISC who had made the trip to the US, and the Scottish Boards also began to take notice of the increasing interest and participation of US utilities in wind energy. For the CEGB, with its greater resources and facilities, this acted as a catalyst for its expansion of wind energy RD&D in the UK. In addition to its representation on WISC and its involvement in some of the DoEn sponsored studies, the CEGB also made plans to construct its own demonstration turbine, independently of the UK Wind Energy Programme. The Scottish Boards could not match the resource base of the CEGB in this regard, and therefore pressed the DoEn to forge ahead with wind energy developments. In particular, the NSHEB had been active since 1977 in examining the potential of wind energy for remote island sites.

The Scottish islands relied mainly on diesel oil for electricity generation, and were therefore a notable casualty of the high oil prices that prevailed during the 1970s. This problem had been recognised by the DoEn and there were several mentions throughout the period about the particular energy 'problems' of remote island sites. In 1978 the Chief Scientist advised that despite the DoEn not having 'primary responsibility' for energy supply to the Scottish islands, 'it would probably be to the Department's advantage to be able to claim the interest in the social advantage that development of better energy supplies could bring to small communities.'[50] The NSHEB were understandably even more acutely aware of the problem and this caused their early involvement in the potential of wind energy.

[49] TNA, EG 16/150, ET 20/3/038, WISC (79) M7, p.6
[50] TNA, EG 16/132, Linacre (Chief Scientist's Branch) to Skipper, 17 April 1978.

The consortium had recommended the site for a demonstration turbine at Bennan Hill on the Scottish mainland (and within the SSEB area) based both on an assessment of its position (a windy hilltop site) and its accessibility, and WISC had accepted this advice.[51] The choice made sound economic sense as it would keep construction and transport costs down. However the NSHEB were determined that the demonstration turbine should be built on Orkney. Through 1980, as WISC ironed out plans for the construction at Bennan Hill, Alex Murray, Chief Engineer at the NSHEB keep constant pressure on the DoEn (supported by the consortium[52]) to reconsider its decision; eventually threatening to buy wind turbines from abroad to fulfill its requirements. The pressure worked and WISC began to hesitate over its initial choice of site. At a meeting in 1980 the NSHEB was described as ‘a real customer’ and WISC looked more closely at Orkney as a potential site for the 3.7MW turbine. The SSEB on the other hand had access to a range of conventional power stations within its area including the nuclear power station at Hunterston. This meant that the SSEB had a less pressing need to explore alternatives.

Meetings of WISC through 1980 considered closely the proposals to relocate the demonstration turbine on Orkney. Although their discussions were finely balanced between the ‘definite requirement for the machine on Orkney to solve an immediate economic problem’ and the ‘greater difficulties for the construction, commissioning and operation of a prototype machine’, the committee made the decision to recommend to ACORD that the 3.7MW demonstration turbine should still be built at Bennan Hill in Ayrshire.[53] In the meantime the NSHEB had formed its own plans to construct a smaller 250kW turbine on Orkney in collaboration with Taylor Woodrow Construction Ltd at a proposed cost of £1m. WISC had recommended that the DoEn should fund 30% of the cost of this smaller machine.[54] In 1980 ACORD considered the WISC recommendations for the 3.7MW turbine as ‘the major item’ of its October meeting.[55] Although WISC favoured the plan to build the 3.7MW at Bennan Hill and the 250kW machine on Orkney, reflecting the fine balance within its deliberations it also offered the alternative proposal to ACORD that *both* machines could be built on Orkney. WISC estimated that the additional costs of siting

[51] Bennan Hill lay approximately 30 miles south of Glasgow.
[52] TNA EG 16/316/2, Moore (DoEn) to Fletcher (Scottish Office), 31 December 1980.
[53] TNA, EG 16/150, ET 20/3/038, WISC (80) M7.
[54] TNA, EG 16/150, ET 20/3/038, WISC (80) M7.
[55] TNA EG 16/124. ET 4/1/039, FPRD(80) 6th Meeting, Department of Energy, Advisory Council on Research and Development for Fuel and Power, Chairman’s Brief, 14 October 1980.

the 3.7MW on Orkney could amount to an estimated £225,000, where the total cost of each option offered by WISC ranged around a figure of £7m.

This was a difficult decision for ACORD and its new chairman (and also newly appointed Chief Scientist), Dr Anthony Challis. The briefing note for the chairman highlights two aspects of the proposals in particular. First, on a positive level was the confidence of the DoEn in the new wind energy consortium led by Taylor Woodrow, which the note suggested was 'likely to perform much more satisfactorily' than earlier 'insufficiently well directed industrial partners'. Second was the 'sheer size of the programme' in terms of cost. This would mean 'juggling the spend profile to accommodate this and all our other projects in the R&D budget'.[56] This clearly had direct implications for the Wave Energy Programme among others. ACORD made the decision to recommend to the DoEn that the wind energy programme should go ahead with the construction of both machines on Orkney. The most immediate concern for ACORD in deciding against Bennan Hill and the SSEB was the recognition that 'the Consortium would gain valuable experience through being involved with a customer (NSHEB) that *needed* the electricity generated…'.[57] The suggestion from the NSHEB that they 'might eventually order a further 5-10 large aerogenerators' also helped to convince ACORD.[58]

The ACORD decision to construct the DoEn's large demonstration turbine on Orkney was also driven by a variety of wider considerations. The emergence of a strong industrial consortium and the perceived 'failure' of the Wave Energy Programme were important in this regard. Arguably more crucial though to the progress of wind energy in the UK were the dual impact of the US wind energy programme and the probable emergence of an international market for wind turbines. Vast amounts of spending on wind energy development in the US appeared to convince the DoEn that it was the most promising of the renewable energy technologies in the period. The strong support for wind energy development by the NSHEB and the CEGB seemed to confirm this view. This signalled a change in the direction of the UK renewable energy programme. In part this was undoubtedly ideologically-driven by a new Conservative Government committed to a move away from publicly-funded energy R&D, but I would argue that it also demonstrates

[56] TNA EG 16/124. ET 4/1/039, FPRD(80), p.3.
[57] TNA, EG 16/316/2, Annex, 'Proposal to construct a 60 metre diameter aerogenerator on Orkney'. My emphasis.
[58] TNA EG 16/316/2, Moore (DoEn) to Fletcher (Scottish Office), 31 December 1980.

a fundamental lack of confidence in British innovation. It was widely acknowledged within the DoEn that the UK occupied the lead position in wave energy, whilst it remained ‘4 to 5 years’ behind the US lead in wind technology. Despite this advantage the DoEn was daunted by the scale of the investment required to develop wave energy. The enthusiastic participation of a range of leading industrial partners in wind energy, the existence of ‘real customers’ in the NSHEB and possibly the CEGB, and the prospects for export swayed the DoEn towards the safer option of wind energy.

‘Large Scale Wind Power Comes of Age on Orkney’ [59]

In November 1987, almost ten years after the initial reference design for a 3.7MW demonstration turbine was formulated, the Secretary of State for Energy, Cecil Parkinson, finally ‘inaugurated the UK’s largest wind turbine’ on Orkney. Changes to the design meant that that the two-bladed 60m turbine now had an output of 3MW - ‘enough power for 2000 homes’.[60] However, during the ten years between conception and construction the international wind energy scene had gone through some crucial changes, and in many senses the Orkney turbine had become passé even before its blades started to turn. The United States, the main external driver for Britain’s wind energy programme, had experienced a frenzy of activity between 1980-85. In particular, changes to legislation and the introduction of financial incentives for wind energy developers in California had seen a flurry of new ‘wind farms’ appearing after 1980 in a ‘Californian wind rush’. But at the end of December 1985 the financial incentives were greatly reduced and caused an almost immediate drop-off in wind development in the United States. Suddenly the prime export market for UK wind turbines largely disappeared.[61] Furthermore, technical problems on many of the US wind-farms cast some doubts over the economics and reliability of wind energy. Just as the US wind energy industry went into a decline, the DoEn unveiled its ‘star attraction’.

Following David Howell’s announcement in February 1980 negotiations began between the DoEn, NSHEB, and the consortium of Taylor Woodrow, British Aerospace, and GEC (soon after the consortium formed a new enterprise for the project called the Wind Energy Group). Relations became fraught at times as the NSHEB grew impatient

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[59] TNA, EG 4/1437, Department of Energy, *Review: The quarterly journal of renewable energy,* Issue 2, January 1988

[60] Ibid.

[61] Interview, Peter Jamieson (formerly of Howden Engineering Ltd), 28 April 2008

with the pace of the project, threatening at one point to withdraw from the agreement and instead buy its wind turbines from Sweden.[62] Some of the initial delay was due to contractual disputes between the DoEn and the Wind Energy Group (WEG) over funding and ownership issues. WEG was very keen to place limits on their liability on Orkney, and pressed the DoEn to offer guarantees that all of their costs (including profit) would be reimbursed by the government. The DoEn resisted the idea that WEG should have a 'risk-free' part in the project, and negotiations slowed accordingly.

An essential element of the Orkney project was the construction of the smaller 20 metre 250kW turbine prior to the larger machine. This contract had already been agreed separately between NSHEB, WEG and the DoEn, but it now came to be included in the overall project. Whilst the DoEn and NHSEB were funding the cost of the larger machine (the DoEn were contributing £4.6m, whilst the NSHEB contribution was £1m) the smaller machine included a financial commitment from WEG. This 20-metre machine was now estimated at £1.1m, with a WEG contribution of £225,000. WEG now emphasised the importance of the 20m turbine to the successful construction of the larger turbine, and they argued that this constituted a financial commitment to the success of the overall project. Eventually, after WEG refused to proceed with the 20-metre turbine until guarantees were forthcoming for the 60 metre machine, the DoEn was persuaded and the Government took on the bulk of the risks associated with the project. Finally in August 1982, after nearly two years of negotiations, the contracts were signed and final design and installation work could begin.[63]

Other Developments (I): CEGB

Whilst the DoEn was locked in the protracted contractual negotiations over the Orkney project, other developments in wind energy were taking place in the UK. Around the same time as the Orkney announcement was made the CEGB announced that it intended to build its own demonstration wind turbine in the UK. This came as a complete surprise to WISC and the DoEn, and caused some degree of annoyance as the CEGB was a key member of WISC (it was Dr Taylor of the CEGB that had travelled to the US in 1977 to assess the developments in wind energy for WISC). WISC had repeatedly asked the CEGB to clarify its position on *wind e*nergy R&D in recent years, but they had always been non-committal,

[62] TNA, EG 16/316/1, Murray (NSHEB) to Challis (Chief Scientist), 28 May 1981.
[63] Salter Archive, 'The Orkney 60 metre Horizontal Axis Wind Turbine Generator - A Progress Report', Seventh BWEA Wind Energy Conference, Oxford, 27-29 March 1985.

or at least low-key, about any plans to develop their own wind programme. The CEGB chairman denied to the Chief Scientist that they had any firm plans to develop wind turbines, but in fact site investigations had been taking place from the end of 1980.[64]

Throughout the early wind energy programme the CEGB had remained an interested, and often active, participant in the DoEn developments. It had contributed to the earlier DoEn sponsored studies on offshore siting and carried out important research on clustering and Grid connection at its Leatherhead laboratory (under the direction of Don Swift-Hook). Dr Taylor was a founding member of WISC, but the CEGB took no part in the flagship 3.7MW demonstration turbine project, other than its role within WISC. During an earlier energy crisis, in the early 1950s, the CEGB had attempted to construct a demonstration wind turbine on the Lleyn Peninsula in Wales. This was eventually overturned by 'intense local opposition' on environmental grounds by the affected community.[65] Now the CEGB planned to resurrect its plans for a demonstration turbine outwith the DoEn programme. By January 1981 a site was chosen next to its existing Carmarthen Bay power station in Wales.[66] Rather than developing their own design the CEGB made the decision to 'buy a proven commercial design when such machines become available'.[67] It was proposed by the CEGB Chairman, Glyn England that an initial 'medium sized generator' would lead to the development of wind turbine installations at other CEGB sites in the UK; and they named three possible sites for their first wind farm.[68] The tendering process considered five proposals and the CEGB settled on an American-designed 24 metre 200kW HAWT turbine to be manufactured in the UK by the Glasgow engineering firm, James Howden Ltd., at an estimated cost of £500,000.[69] In contrast to the protracted and ongoing negotiations over the Orkney project, the CEGB's wind turbine was constructed quickly and was 'switched on' by November 1982. Ironically, it was the recently installed CEGB Chairman, (now) Sir Walter Marshall accompanied by Lady Marshall, who carried out the ceremonial duty. He said of the experimental turbine,

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[64] TNA, FG 5/330, PR 693, 'CEGB to search for inland wind-power site', Central Electricity Generating Board, CEGB Press Information, 13 August 1980.
[65] TNA, FG 5/330, CEGB, England, G., 'Power in the Wind', A talk to the British Wind Energy Association at their annual conference at Cranfield, Bedfordshire, 9 April 1981
[66] TNA, FG 5/330, PR 704, 'CEGB selects wind power site', Central Electricity Generating Board, CEGB Press Information, 12 January 1981
[67] TNA, FG 5/330, PR 693.
[68] TNA, FG 5/330, PR 704. These sites were at Wigsley, Bradwell nuclear power station, and Richborough power station. They were all owned by the CEGB.
[69] TNA, FG/330, PR 735, CEGB Press Information, 'CEGB to buy wind generator', 26 August 1981.

> It will enable us to gain valuable experience of operation and maintenance and help us to find out how a much greater amount of wind energy could be integrated into the public electricity supply system. […] If our economic targets can be met, and if our programme has public support, wind energy on lowland sites could begin to make some contribution to public electricity supplies in the 1990s, with a progressively greater contribution thereafter. [70]

Marshall also stressed that the CEGB was not 'exclusively preoccupied with coal and nuclear energy, but was interested in all forms of energy which showed promise of producing economical supplies of electricity'. In the event the Carmarthen Bay turbine was an unsuccessful experiment although this did not deter the CEGB from announcing in May 1983 that it intended to press ahead with a much larger turbine.[71] Blade problems with the American-designed machine (first revealed in the US) meant that it only operated for a total of 400 hours between November 1982 and January the following year. Despite this, Marshall announced plans to build a massive 90-metre 4MW machine at the chosen site of Richborough in Kent with the possibility that 'a cluster of up to ten large wind turbines of proven design' could follow.[72]

What does the role of the CEGB tell us about the development of wind energy in the UK during this period? There are two aspects that are perhaps worth highlighting. First, the independence of the CEGB initiative can be explained most simply by its limited access to suitably windy sites. It had been well established since the most rudimentary wind maps were produced that the best sites for wind energy in the UK, and therefore the most economical, were located in Scotland. This meant that the DoEn wind programme was formed around the development of hilltop sites that would be of little use to the CEGB. This forced the CEGB to investigate the potential of lowland sites. Second, was the determination of the CEGB to press ahead with wind energy development using large-scale machines despite the failure of its experimental turbine at Carmarthen Bay. On the one hand, this again illustrated the influence of developments elsewhere (particularly in the US) where wind energy was fast gaining acceptance as a viable alternative energy source. Moreover, it also emphasised the continuing influence in the UK of the dominant energy problem-frame, which required large-scale solutions to energy needs. The CEGB plan to construct huge wind turbines, of a size far greater than anything currently operating, shows an understanding of energy sources based entirely on the conventional power systems. The

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[70] TNA, FG/330, PR 757, CEGB Press Information, 'Power from the wind', 16 November 1982.
[71] TNA, FG/330, PR 765, CEGB Press Information, 'Site chosen for Large Wind Turbine', 16 May 1983.
[72] Ibid.

proposal for Richborough was that 10 turbines could provide 400MW of electricity - comparable to coal-fired power station. Though admittedly some of this push towards this early model of wind farms was driven by the anticipated environmental objections to their construction, the CEGB approach (in common with the Orkney Project) emphasises the mistaken assumption that ‘size mattered’ in the development of wind energy in the UK.

Other Developments (II): James Howden Ltd.

Also operating largely outwith the DoEn wind programme through the 1980s was the Glasgow engineering firm, James Howden Ltd.[73] During the 1970s Howden had enjoyed a very profitable spell working on a range of engineering projects (including nuclear power) and it was keen to explore lucrative new avenues in developing its range of engineering activities. After a meeting with the NSHEB in the winter of 1979, and no doubt intrigued by the involvement of other leading UK engineering firms in the potential of wind energy, from around 1980 Howden began to examine the possibilities of involvement in this emerging new sector. The initial plan was for Howden to buy out an existing turbine manufacturer but enquiries revealed that only one private firm in the UK, Sir Henry Lawson-Tancred, had developed a working wind turbine (a 100kW machine) with any immediate commercial potential. After a visit by two of its senior engineers Howden made an attempt to buy out the company.

When the independent-minded Sir Henry resisted this Howden shifted its attention abroad and bought out the US company, Wind Technology Generation (WTG) who had designed and manufactured a 300kW HWAT. Unfortunately for Howden, the WTG turbine design of large steel blades had major weaknesses due to stress, which were only revealed after installation. It was this machine design that the CEGB commissioned from Howden at Carmarthen Bay, which failed soon after it went into operation. After this initially unhappy experience Howden were undeterred and made an approach to the NSHEB to construct and test out an amended design of its HAWT on Orkney. Using its own expertise in engineering design a team of four engineers from Howden soon produced an alternative turbine blade from scratch, manufactured from a wood polymer. As the

[73] Interview with Peter Jamieson (formerly of Howden Engineering Ltd), 28 April 2008. Much of the material for this section on the role of Howden was derived from interviews with Peter Jamieson. A senior engineer at the firm during the period, Jamieson was at the centre of Howden’s brief involvement with wind energy. I am very grateful for his generous contribution to this research.

DoEn/WEG negotiations ground on, Howden successfully installed and tested their new 22m 300kW turbine on Orkney during 1983.[74]

Perhaps realising the glacial pace of progress in wind energy development in the UK, particularly when compared to the US, Howden began to make approaches to American wind farm developers in California to exploit the growing opportunities becoming available. Danish turbine manufacturers had already made significant progress in the US and Howden also saw the chance for a lucrative new export market. The breakthrough came in 1984 with a single machine built for Southern Californian Edison. This 26m 330kW machine led directly to a massive order for the major US wind farm development at Altamont Pass in California, where Howden secured a deal for seventy-five 330kW turbines, ten 15m 60kW rated machines, and a further single 45m 750kW turbine.[75] In 1985 the price of blades was roughly £10 per kilo, making the cost of a single Howden blade around £10,000. The Altamont deal amounted to 225 blades making this a significant job for Howden.[76]

Unfortunately the blades experienced problems right from testing. These were technical issues related to inadequate quality control which eventually resulted in all of the Howden/Edison blades breaking. Musgrove estimates that the total cost of this breakdown, including loss of electricity sales and the redesign and replacement of the blades, totaled more than £13m.[77] As a result, in 1986-87 Howden made a loss on its new wind energy division. Howden blamed the subcontractors but Peter Jamieson (who had helped to design the blades and was closely involved with the Altamont job) thought that the problems originated in Howden's rush to complete this major order without adequate testing. The new system of US tax credits for wind farms was due to terminate at the end of 1985 and was unlikely to be renewed. Just as in the UK a change of government in the US signalled a shift in attitudes towards public subsidies and this directly affected the renewable energy programmes. Awareness of the looming deadline caused Howden and others to reconsider their participation in the disappearing US wind energy market.

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[74] Musgrove, *Wind Power*, pp. 151-2
[75] Musgrove, *Wind Power,* pp. 151-2
[76] Interview, Peter Jamieson, 28 April 2008.
[77] Musgrove, *Wind Power,* pp. 151-2

This change of mood, and the experience of heavy losses, signalled the demise of Howden's interest in wind energy. They constructed three more turbines (750Kw HAWTs) over the next couple of years - one of these for the CEGB at their new site at Richborough - before in April 1989 withdrawing completely from the wind energy business. Peter Jamieson, who had been closely involved with wind energy at Howden from the outset, cites the lack of any real support from the government for wind energy development in the UK as a key factor in Howden's decision. He compared the UK unfavourably with Denmark where he claimed there existed a concept of growing a new wind energy industry. The reliance on what he termed 'the purist free market agenda' severely constrained any prospect of developing a viable wind energy sector in the UK.

Conclusions

The inauguration of the Orkney turbine in 1987 proved to be the conclusion of the UK government's involvement in wind energy and was the last act of the UK renewable energy programme. As its blades began to rotate slowly in the Orcadian wind the government announced its plans for electricity privatisation. From 1989 onwards renewable energy would cease to receive any direct government funding and would instead be encouraged through the new Non-Fossil Fuel Obligation (NFFO). By this time Danish turbine manufactures had demonstrated that any immediate potential for wind energy lay in machines somewhat smaller than the massive 3MW WEG machine, which quickly transformed into an elegant white elephant. By this time, Howden, the UK's only viable commercial manufacturer of wind turbines had pulled out of the industry after its unhappy experience in the US. However, the CEGB retained some faith in the future for wind energy in the UK. Howden's final involvement in wind energy (following its announcement to withdraw from the industry) was to complete the turbine at Richborough for the CEGB, and in February 1988, one month after privatisation was announced, Walter Marshall unveiled plans to build three wind farms in the UK. The CEGB plan was for each wind farm to comprise 25 turbines with a capacity of about 8MW. In the event only one of these, at Cold Northcott in Cornwall, was ever built.[78]

The UK's involvement with wind energy was radically different from its earlier interest in the development of wave energy. From the outset this more mature technology provided an opportunity for the UK to exploit its own vast wind resource and to encourage

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[78] Musgrove, *Wind Power,* p. 155

the development of manufacturing capability which could take advantage of the export opportunities provide by the burgeoning US market. Relative to other countries in Europe such as Denmark, Germany, and Sweden, the UK made a late start on its wind energy programme. Recognition of this fact forced the DoEn to ditch other renewables programmes, most controversially wave, in order that resources could be concentrated on wind energy. However, rather than recognising that the commercial potential lay in machines rated 1MW and less the UK concentrated its attention on the huge 3MW demonstration machine on Orkney. Moreover, as had been seen, extended contractual difficulties meant that it took the government more than five years to construct the Orkney turbine. During this time Howden had entered the industry, designed and developed its own machine, and sold and built its machines in the US. Also the CEGB had built and tested its own machine at Carmarthen Bay.

Energy Paper 55 'Renewable Energy in the UK: The Way Forward' set out the government's new approach to renewable energy in the UK.[79] The Non-Fossil Fuel Obligation (NFFO) would be used to encourage commercial exploitation of renewable energy in the UK and government involvement (and expenditure) would gradually decline. However for wind energy the decision of Howden makes it clear that industry was not attracted to the commercial potential. Despite the CEGB announcement to build three wind farms the interest of industry was practically non-existent. Only WEG (the consortium of Taylor Woodrow, British Aerospace, and GEC) would continue its involvement in wind energy. Indeed it is arguable that wind energy and renewables more generally would have disappeared at the end of the 1980s were it not for the discovery of the science of climate change. The imperatives of rising oil prices, security of supply, and dwindling fossil fuel reserves that had driven renewable energy since 1974 were increasing replaced after 1989 with the new incentive of reducing carbon emissions.

[79] Department of Energy, *Renewable Energy in the UK: The Way Forward,* Energy Paper 55 (London: HMSO, 1988

Chapter 7

Some economic aspects of the UK Renewable Energy Programme

This account of the development of renewable energy sources in the UK in the period following the first global oil crisis presented in the foregoing chapters has focused on the political and social aspects of the story. This is explained with reference to the primary assumption of this thesis that it was these two factors that combined to create, maintain, and ultimately end the UK renewable energy programme. Throughout this account this thesis has sought to emphasise how social movements and political imperatives dominated energy debates in the UK during the 1970s and how these profoundly influenced the impact of economic assessment of renewable energy sources in particular. It is also central to the hypothesis proposed here that socio-political factors took precedence over economic considerations in government policy on renewable energy sources. However, it important to the development of this thesis that the economic elements of the period are considered and this chapter will explore some of the key economic aspects of the development of renewable energy sources during the period 1974-88. It is not a suggestion of this thesis that costs were unimportant. This chapter will show that the estimated generating costs for renewable energy (in particular wave energy) were constantly used to appraise the programme. Rather, it is advanced that during this time it was widely accepted that energy prices were generally unreliable as a guide in UK energy policy.

Although many of the central economic issues appear in the main body of this thesis, this chapter will gather this information together and consider the wider socio-economic conditions against which the programme operated during the period. This will include the role of the UK government in R&D and in creating prices during this period. The chapter will begin by revisiting the theme of government intervention in energy matters and the constructed nature of fuel pricing explored elsewhere in this thesis. It will continue with a general discussion of the role that economics played in the evolution of renewable energy programmes during the period before moving on to highlight many of the key issues using a case study of the economics of wave energy during the 1970s. Some consideration will also be give to the impact of externalities that play such a large part in current economic assessments of renewable energy. Through the use of a case study of the WEP this chapter will focus on the challenges that confronted those involved in the development of renewable energy when it came to calculations of estimated cost. The huge variation in estimates between groups and the over time will give some insight into the limits and politics of economic evaluation during the period. This will also go some way to explaining the rationale behind the focus of this thesis on socio-political factors.

As I have shown in Chapter 3 the UK government's renewable energy programme was created in large part as a reaction to the increased price of oil after 1973. The key element of that programme, the Wave Energy Programme (WEP), was constantly evaluated in economic terms in what seemed to be an objective measure: the price per kWh of generating electricity. The 'objective measure', however, proved contentious. In 1978 the Heathrow Conference revealed the findings of the consultants RPT. These dealt with the technical and economic challenges that faced wave energy – and as was shown the estimated costs caused the government to back away from wave energy. Later, after the WEP was closed down, Stephen Salter consistently challenged the government's estimated costs, offering revised versions of the cost per kWh. Following the WEP, the wind energy programme again was focused on cost throughout its short-lived existence prior to the privatisation of electricity in the late 1980s.

So in many respects the history of this period of the development of renewable energy in the UK could be regarded as a quite simple tale of economic imperatives. The narrative could go something like this: *The government experimented with the development of alternative forms of energy following the oil crisis, but these proved too costly*. However, this thesis has rejected this view of the period and regards it as (to use a phrase of Salter's) *simplistic* rather than simple.[1] This deterministic view might be more acceptable if we accepted that decisions about energy were based entirely on cost; however I hope to have shown in the foregoing that this was not the case in the UK during the twentieth century. Chick wrote that national energy policy not always 'a matter of rational economic calculation' and as this quote from a 1970s Energy Commission paper demonstrates energy prices were a product of a rather more complex set of circumstances.[2]

[1] See p.147. DoEn, ETSU R9, 'Wave Energy Steering Committee, Proceedings of a workshop on wave energy, Maidenhead, 16-18 December, 1979'.
[2] Chick, Electricity, p.18

> Current energy prices are the product of the varying circumstances and histories of the individual industries….Coal, gas and electricity are not internationally traded to the same extent as oil. There is greater freedom of manoeuvre to determine, in the context of energy policy, the principles which should underlie their pricing…The general principle of relating price to the costs of supply […] may be difficult to apply in practice.[3]

The fact that fuel prices are created by more than their related costs of discovery, extraction, transport and conversion is not surprising. It was widely accepted that the 'market' for energy in the UK as something less than efficient. Michael Posner stated that fuel policy was 'tendentious' and went on to claim that,

> …all the energy industries were operating in a market of which the characteristics were, in part, artificially determined not just by the permanent elements of imperfect competition, but by government trying to play God in the system without having divine knowledge or divine power.[4]

This was a view echoed by the governments own White Paper on Energy in 1967:

> National fuel policy is presumably meant to overcome the deficiencies of an imperfect market by imposing on its dominant institutions decisions that serve the public interest better than those they would otherwise make. The record makes it appear doubtful whether that purpose was either achieved or achievable.[5]

In addition the fact that electricity prices are further complicated by government choices over generation methods is equally widely known (see chapter 3). These conclusions over the uncertain relationship between energy costs and energy prices for mature fuels such as oil, gas and coal suggest that it would be challenging to integrate a 'new' fuel into this complex network of 'varying circumstances and histories'.[6] This thesis suggests that this was indeed the case for renewable resources in general during the period 1974-88, and certainly for wave energy during the 1970s.

The central contention here is that the development of renewable energy resources after 1973, partially instigated through social movements, was maintained and encouraged by social and political imperatives. This was explored in detail in Chapter 2 and is echoed

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[3] Energy Commission, Working Document on Energy Policy, Paper Number 1. Annex 4, 'Instruments for implementing energy policy', pp.79-80
[4] Quoted in Ashworth, Coal, p.55
[5] Ashworth, Coal, p.58
[6] Energy Commission, Working Document, pp.79-80

throughout this thesis. 'Disrupters of institutionalised arrangements' kept continual pressure on the government to explore alternative sources of energy, based mainly on an opposition to nuclear energy.[7] Throughout the post-war period the UK government made largely political decisions on fuel and energy policy. The most obvious example of this, discussed in Chapters 1 and 2, was the UK nuclear industry. Based on a perceived need for energy security and a post-war thirst for big science, the government created a succession of highly expensive nuclear programmes in the UK. Scholars have agreed that this programme was not driven by its economic attractions, but rather by political goals.[8] This political nature of energy decisions applied equally to the renewables programme after 1973 and explains the overwhelming focus on these issues in this thesis.

Externalities

It is difficult, from the viewpoint of the twenty-first century, to think of renewable energy resources separately from climate change. Much, if not all, of the enthusiasm for renewable sources of energy appear to emanate from concern about the impact of carbon emissions. This close relationship has certainly encouraged the subsequent development of renewables through post-privatisation instruments such as the Non-Fossil Fuel Obligation (NFFO) and the later Renewables Obligation (RO). As discussed at length in Chapter 2 the 1970s was the period when the 'environment' began to creep into the consciousness of the developed world through the appearance of landmark publications such as *The Limits to Growth* (LTG) and the first *UN Conference on the Human Environment* in 1972. Important social movements such as *Friends of the Earth* and *Greenpeace* were created during the 1970s and all campaigned hard on environmental issues. As discussed, energy *did* appear at the margins of this debate but did not occupy the key role that it has for these same groups today. Energy-related environmental concerns during the 1970s were instead focused on one main issue: depletion. Emanating from the LTG thesis of rapid depletion of fossil fuels the focus of environmental concern was on renewable energy as an inexhaustible energy supply, rather than (necessarily) a *clean* supply. During the 1970s the science of climate change was developing. Below is an early, and highly unusual, mention in an official government publication of carbon emissions but this made little impact on thinking about renewable energy resources until later in the 1980s:

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7 Sine and Lee, 'Tilting', p.124

8 Williams, *Nuclear Power Decisions*; Patterson, *Nuclear Power*: Patterson, *Critical*

> …concern about the effects of increasing levels of carbon dioxide in the world's atmosphere could lead to limits being set on fossil fuel combustion well within a 50 year time horizon.[9]

During the 1970s environmental groups were preoccupied with the impact of pollution. This was a direct result of the publication at the beginning of the 1960s of Rachel Carson's seminal *Silent Spring*. Throughout the 1970s environmental groups and publications such as *The Ecologist* magazine in the UK concentrated on issues such as acid rain and air pollution. The link to energy was not well developed other than through attention to the pollution emitted by the coal-burning power stations. The other key area of concern for environmental groups at this time (and still today) was nuclear energy. The harmful effects of radiation and the problems of waste disposal were key concerns of many environmentalists from the outset and, as discussed in Chapter 2, these issues encouraged both the creation and development of many social movements from the 1950s. These concerns about nuclear energy encouraged support for *clean* renewable energy sources from environmental groups during the 1970s. This added to the social and political pressure for renewable energy, rather than being included in any economic assessment.

The Wave Energy Programme

As mentioned above, from its inception in 1974 until well after its closure in 1982, the cost of the new technology (defined as the cost of producing electricity from wave energy) within the Wave Energy Programme (WEP) was continually scrutinised by the government, mainly through ACORD (as described in chapter 4). This formed a key part of the general assessment process which all the renewables programmes were subject to in 'Phase 1' of the governments plan.[10] Although the plan appears in Energy Paper 55 as a rather neat and ordered programme of 'research, development and demonstration' from the UK government it was in fact devised roughly two-thirds of the way through that programme. Phase 1 (Mid 70s to mid 80s) which focused on wave energy was described thus:

> The programme identified feasible technologies, their costs, their technical potential as contributors to UK energy supply and the possible timescale of

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[9] Department of Energy, Energy Technologies for the United Kingdom, Energy Paper 39 (London: HMSO, 1979)

[10] Department of Energy, Renewable Energy in the UK: The Way Forward, Energy Paper 55 (London: HMSO, 1988), Phase 1 – Mid 70s to mid 80s. p.2

> that contribution. This phase was conducted mainly by analysis and experiment without heavy financial commitment to technology development at full scale. Further expenditure on those technologies unlikely to contribute significantly in the UK was curtailed and increased effort focused on the more promising ones. [11]

Therefore alongside cost, the other early considerations for the government were the technical potential of the resource and the state of the technology. Of course both of these additional elements for investigation were in fact very much related to cost. The scale of the potential resource and its location and accessibility would have a direct impact on cost, as would the developmental stage of wave technology. Therefore each of these elements, expressed as disparate issues by the government, could all be measured by cost. It is no surprise then that cost (in terms of electricity generation) was central to both the initial enthusiasm and the eventual gloom of the WEP, although it was a 'cost' that as both constructed and contested.

From before the creation of the WEP, economics featured strongly in the dialogue surrounding wave energy. Gordon Goodwin made several mentions during his very first visit to Salter's workshop of his view that…

> …any major undertaking has to fit in with existing economic structure, must be costed on a totally comprehensive basis, and has to compete with other dominant calls upon National [sic] resources. [12]

Although Salter was completely absorbed by the technical challenges of wave energy he had a clear understanding that wave energy must be 'economic' in order that it be adopted more widely.[13] The challenge for developers and for the government in a very uncertain environment was to make an accurate assessment of what the costs might be

The calculation of the cost of wave energy

Although he does not appear in the period during which decisions were made initially, an important figure in the development of accurate costs estimates for wave energy was Tom Thorpe. Thorpe was a senior scientist at ETSU and he produced two lengthy reports on wave energy during the 1990s; one in 1992 and the other in 1999. These reports were

[11] Ibid
[12] TNA, EG 16/13, Note for the file, 'Wave Power'
[13] SA, First Year Interim Report on Edinburgh Wave Power Project "Study of Mechanisms for Extracting Power from Sea Waves" September 1975, Department of Mechanical Engineering, University of Edinburgh

commissioned by the government (through the DTI) in response to the increasing evidence of the existence and impact of climate change and growing pressure from environmental groups and Select Committees to reconsider the potential of wave energy.[14] Thorpe had the benefit of being some distance from the controversy surrounding the closure on the WEP on economic grounds in 1982, so was able to take a detached and clinical look at such facts that were available. His 1999 report summarises all of the officially generated costs for wave energy from 1983 onwards and gives a useful insight into the challenges of calculating the costs of new and uncertain technology.[15] As Thorpe himself put it in his 1992 report.

> …until the technology matures, estimates of the cost of power from wave energy devices represent a snapshot of the status and costs of the designs at (the current) stages of their development.[16]

In 1999 he was still keen to emphasise the 'considerable uncertainty' associated with his cost estimates and went on to suggest that predicted generating costs 'could vary by up to ±20%'.[17]

The 'cost' of the early wave energy schemes was calculated on the relatively simple basis of capital costs (annuitized over the lifetime of the plant), fuel costs, and the operation and maintenance (O&M) costs, essentially the same kinds of cost estimates deployed for more traditional sources of energy from fossil fuels. More recent and helpful concepts such as energy coefficients were absent in these simplified calculations. As already mentioned in the introduction this approach caused a number of challenges for wave energy. Firstly, although the energy in the waves is free, the capital costs of establishing very uncertain technology can be difficult or impossible to calculate accurately. As Thorpe noted above these were never more than a 'snapshot' during periods of rapid technological progress in the 1970s. For mature technologies the elements of the calculation were well established and reasonably predictable. To further complicate matters, as mentioned above, the established energy industries drew on a range of subsidies that obscured the true cost of fossil fuels.

[14] Ross, D., 'Scuppering' p.16
[15] Thorpe, T. W., 'A Review of Wave Energy', ETSU Report number R-120 for the DTI (May 1999)
[16] Thorpe, T. W., 'A Review of Wave Energy', Vols. 1 and 2, ETSU Report number R-72 (December 1992)
[17] Thorpe, 'Wave Energy', (May 1999). Executive summary p.iv

Discount rates

An important element of the calculations was the discount rates applied and the concomitant estimated plant life. Although an important element of any calculation of cost, in the period it was less of an issue for wave energy. Although arguable, plant life for wave devices was estimated to be similar than that for fossil fuel plants at 25-30 years. Of more importance to the fate of wave energy was the discount rate that was applied. Over the period this was the same for wave as for fossil fuels – varying from 8% (public sector) to 15% (commercial rates) over the period. Small changes in the discount rate can have a major impact on total cost – and marginal differences in the base cost can be magnified over time. However the major challenge for renewables in general and wave energy in particular is that by far the largest proportion of total cost for a 'free' fuel resides in the capital plant and the Operation and Maintenance (O&M) costs. The benefit of free fuel can be swamped by larger capital costs discounted over the life of the plant. This was a particularly so as the impact of hugely uncertain prices over time for fossil fuels in the calculations should have allowed a tremendous advantage to renewable energy sources. Therefore the need to arrive at as accurate a figure as possible for construction of the physical plant is crucial to the perceived cost-effectiveness of renewables. Unsurprisingly it was in this area that most of the disagreements between the wave device developers and the government appeared.

Ross provided some examples of the disputes that arose with the government over capital costs.

> It was assumed that a non-return valve in a wind turbine would fail once in a million hours while the same valve in a wave energy device would fail 68 times during the same period. The cost of the steel canister and concrete casing of the Duck caused extraordinary diversity. Salter's team obtained estimates of £208 per tonne. The RPT figure was £10,000 per tonne. The difference added up top £2.7 million per Duck. RPT calculated the 'average' cost of wave power by comparing all the devices, including those assessed as the most expensive. So if one device was costed at 4p and the most expensive at 12p, then the average would automatically be 8p. But if someone introduced a spendthrift invention costed at, say, 24p, then the average would automatically have gone up to 14p. Salter was not the only protester. Professor Michael French of Lancaster University, who had invented an inflatable air bag to generate wave-electricity, proposed to use scrap iron as ballast. The official estimate put it at £3,000 a tonne. The normal price was £100.[18]

[18] Ross, 'Scuppering the Waves', p.15

For wave energy these uncertainties and disputes over the factors involved in the estimation of generating costs remained (and still remain?) problematic. The vast complexity of variables led to some very imprecise calculations, which was prevalent throughout the 1970s. Furthermore, the general unreliability of these figures was widely acknowledged at the time. However, what was beyond dispute was the fact that, even allowing for wide variations in estimates, the cost of wave energy was significantly above that of the cheapest generating fuel – coal. At the time of the Heathrow Conference coal averaged 2p/kWh compared to the 20p-50p/kWh estimated for wave.

Thorpe (1999) and the Edinburgh Duck

This subsection examines a much later assessment of wave energy. The intention is that this will illustrate two facts about wave energy relevant to this thesis. First, it will show the huge challenges that the developers and the government faced in determining an accurate indication of the generating cost for wave energy. Second, it will show the dramatic fall in generating costs as the technology developed over a 15-year period. The evidence here would suggest that the cost estimates for wave energy during the 1970s were subject to even greater inaccuracy and variation. This then leads back to a central contention of this thesis that estimated generating costs formed only one element of the process in the decision to close down the wave programme. Developers and the government (through ACORD, ETSU, and the consultants RPT) knew that estimates of generating costs were as Thorpe late put it 'snapshots' of the technology. More relevant to the government at the time was the scale of its commitment to an uncertain new technology. Wave energy clearly had many years of development ahead – a point Salter was always anxious to make (see Chapter 5). Faced with cuts to the energy R&D budget, ACORD made the understandable decision to invest in wind energy, a much more mature renewable technology. However, this thesis argues that this was not based on finely balanced economic estimates, but rather on much broader numbers. A clear example of this was in Energy Paper 3, prepared by ETSU, which showed low estimated costs of £320-£380 per kW of installed capacity (including operation and maintenance) for wind.[19] This contrasted sharply with the figures for wave presented at Heathrow of £4000-£9000 per kW of installed capacity (*excluding* operation and maintenance). This vast gulf in the cost of installed capacity and the

[19] TNA, EG 16/298/2, 'Energy Technologies for the United Kingdom: An appraisal for R, D&D planning', Volume 1, 27 March 1979.

investment of time and money needed to develop wave that it suggested were arguably more pertinent than the accepted unreliability of generation cost estimates.

In 1999 Tom Thorpe produced his second report on wave energy within 10 years for the DTI. In the report he summarised the current state of wave energy development and offered some assessment of the economic and technical potential of the resource. His 1992 report concluded that ‘optimistic expectations for the original wave energy devices were unfounded’, but by 1999 ‘the same review methodology now indicates that wave energy could become a useful source of energy’.[20] As this later date falls outside the focus of my research it is somewhat of a moot point. What is useful to this thesis is the methodology that Thorpe adopts to calculate the generating costs of wave energy. The complexity of his calculations reveals the challenges that faced developers and consultants in the 1970s. This is further emphasised by the margin for error referred to above (±20%).

Under a heading ‘Economic Assessment’ Thorpe builds a model of the variables that make up the capital cost estimates for wave energy. These divide into two main categories as shown in Table 7.1. The table expresses the complexity involved in estimating generation costs for wave energy. The range of variables in the table is concentrated on the issues of site selection and the device itself. For each of these categories a further list of variables was added. The challenges were increased in the case of the Duck, ‘which would exploit the maximum amount of wave energy resource in deep water’. As Thorpe pointed out,

> This required the Duck to operate under more energetic wave regimes, which would place great technical demands on the device. The Edinburgh team has acknowledged that the Duck would require a long R&D programme…[21]

[20] Thorpe, ‘Wave Energy’, (May 1999) Executive summary. p.iii
[21] Thorpe, ‘Wave Energy’, (May 1999) p.53

Table 7.1 Methodology for Economic appraisal

⇒ Site Selection	Wave Power resource ⇒	Power levels in the sea ⇓
⇒	Directionality factor ⇒	Available wave power ⇓
	Capture efficiency ⇒	Captured wave power ⇓
⇒	Power chain efficiency ⇒	Maximum annual output ⇓
⇒ Device selection	Availability ⇒ ⇓	Actual annual output ⇓
⇒	O&M costs ⇒ ⇓	Cost of electricity
	⇑ Annual cost	
⇒	⇑ ⇑ Capital costs ⇒	

Source: Thorpe, ‘Wave Energy’ (May 1999)

In his 1999 report Thorpe looked at three versions of the Duck: the 1983, the 1991, and the 1998 version. He charted the technical improvements that the Edinburgh team had made over nearly three decades of development and provided a summary of the dramatic reductions in estimated generating costs. This variation over fifteen years from a high of 83p/kWh in 1983 to a figure of 5.3p/kWh in 1998 gave some indication of the effects of the ‘long R&D programme’ that the Edinburgh team had always envisaged (see Table 7.2). Interestingly the 1998 figure of 5.3p/kWh was the target that ACORD had set for wave energy in 1982 prior to closure (see p.120).

Table 7.2

Costs of Generating Electricity for the Edinburgh Duck, 1983-98.

	Generating Costs	
	8% discount rate	15% discount rate
1983 Duck	57p/kWh	83p/kWh
1991 Duck	17p/kWh	26p/kWh
1998 Duck	5.3p/kWh	8p/kWh

Source: Thorpe, 'Wave Energy' (May 1999)

Conclusions

This chapter has explored some of the economic issues of the renewable energy programme in the period 1974-88. It has shown how energy prices in the UK were subject to 'varying circumstances' and that the link between cost and price was not always clear. For renewable energy this may have offered an opportunity to enter an energy market that was less concerned with costs (at least initially). In theory the government could have taken a decision to set a low *price* for wave energy as a route to rapid development. This thesis has shown that prior to the Heathrow Conference in 1978 this may have been a possibility amid the unbounded enthusiasm for wave energy. However following Heathrow it was clear that the estimated generating costs for wave energy were frighteningly high, which undermined any thought of short-term subsidy. Estimates (that Thorpe showed later were actually hugely optimistic) of 20p-50p/kWh – ten to twenty-five times the average generation cost of the time - scuppered any enthusiasm for wave energy. The emergence of a more reliable and mature renewable energy technology - wind – in the early 1980s sealed the fate of wave energy. Wind had better short-term prospects and much lower capital costs at the time, and it had the added appeal of being promoted in the United States. This gave the UK government more faith in the technology and relieved it of the pressure of 'going it alone' on wave energy.

This thesis has argued that the development of renewable energy after 1974 was the result of a range of factors. Energy security was a key aspect. Chapter 1 discussed the response to the Suez crisis in 1957 with a trebling of the UK nuclear programme at the time. It was suggested that this was repeated after the 1973 oil crisis, both in the United States (with Project Independence) and the UK. Official reports, from Rothschild's CPRS onwards, repeatedly emphasised the need to move away form a reliance on imports of foreign oil. Clearly for the government the main solution to this challenge was as it had been in 1957 - the UK's nuclear programme. This thesis has shown how the renewables programme was consistently regarded by the government as an 'insurance option' and it was generally compared in any official economic assessments with nuclear energy.[22] Given the heavily subsidised nature of nuclear energy and the uncertainty over the costs of wave energy discussed above this was a rather troublesome financial comparison. Therefore this suggests that the decisions on wave energy were taken as they were in other areas of energy policy at the time – on mainly social and political grounds.

[22] Department of Energy, Energy Technologies for the United Kingdom, Energy Paper 39 (London: HMSO, 1979)

Conclusions

The central hypothesis examined in this thesis is the idea that decisions on renewable energy sources taken by the UK government are driven largely by socio-political factors – with economic issues playing a more minor role than might be expected. It was suggested in the introduction that the period 1974-88 was clear evidence of the early evolution of this approach with the Wave Energy Programme (WEP) providing a useful case-study of an R&D programme which was created, maintained, and eventually closed by socio-political policymaking. It was made clear in the introduction that this task would be achieved within a broadly based historical narrative and analysis of some of the key political, economic and social events of the programme, thus avoiding the narrower debates on technology and politics that have characterised the subject so far. Therefore what is put forward here is an account of renewable energy that considers the key social and political factors for its creation and some of the reasons for its demise which cuts across the existing technical and political literature. In doing so it has explored a central theme, first suggested by Langdon Winner, that artifacts have politics.[1]

It has examined the evolution of renewable energy in the UK in terms of the social and political imperatives that in some cases drove change and in others encouraged continuity. Central to this has a been a new consideration of the role of the 'new environmentalism' in pressing for the development of alternative, and benign, sources of energy. In their role as what Sine and Lee have described as 'disrupters of institutions', environmental organisations and publications continually nagged at the government during the early 1970s to look at alternatives to traditional energy sources and, in particular, to nuclear energy.[2] This largely informal social pressure acted to alert the government to the potential of renewable energy, and as I have shown, provided ideological inspiration to innovators such as Stephen Salter in seeking to create alternatives to nuclear power. Although a natural link between environmentalism and renewable energy is often (wrongly) assumed, this thesis has shown, in particular by a close analysis of the content of *The Ecologist* magazine during the period, just how environmentalism began to embrace the debates on energy during the early 1970s.

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[1] Winner, L., 'Do Artifacts Have Politics?', *Daedalus,* 109:1, Modern Technology: Problem or Opportunity? (Winter 1980) pp. 121-136
[2] Sine and Lee, 'Tilting', p.124

As the vast majority of renewable sources are used directly to produce electricity, this analysis began with a brief consideration of the historical development of electricity networks in the UK. This addressed the first of the major themes of this thesis – government involvement and intervention in energy matters in the UK.[3] Since the early days of electricity supply in the UK, government and municipalities recognised its importance for economic and social development and largely took control of the fledgling industry. The eventual result was the creation of a national distribution grid in the 1930s and the subsequent nationalisation of the electricity industry in 1948. One important consequence of this was that thereafter the evolution of energy technology in the UK was overwhelmingly dictated by the socio-political demands of the postwar era, and this influence continued through to the UK renewables programme of the 1970s and 1980s. After nationalisation all of the UK's energy industries became integrated monopolies and the market remained distant from energy in the UK until a series of privatisations in the later 1980s. As Helm put it,

> The nationalised coal industry dug coal primarily for the nationalised electricity industry, which built enough power stations to secure supply. Customers, with nowhere else to go, paid the costs. When North Sea oil and gas were discovered, the Gas Council (and the British Gas Corporation, BGC, at it became known) built the National Transmission System (NTS), converted households to natural gas and signed long-term contracts for gas to flow through its planned network. The British National Oil Company (BNOC) completed the picture, set up in 1976 to give the state a direct hand in the North Sea, complementing the oil interests of British Gas.[4]

When the Government did intervene on energy it was often on what it perceived as matters of national security, such as during the Suez crisis when its motivations were overtly political. Chick described this as the 'patriotic cloak' of national energy security, when alongside the infamous trebling of the UK's nuclear programme, the crisis also pushed the country away from cheap oil imports towards protectionism for the coal industry, as domestic employment triumphed over cheap energy.[5] Despite these occasional interventions, during the two decades following the Second World War, energy forecasting and planning was largely left to the nationalised giants of the CEGB, the NCB, and the UKAEA, and as Hannah pointed out, within these organisations the 'engineers'

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[3] Introduction. pp.17-1p
[4] Helm, Energy, p.14
[5] Chick, Electricity.

dominated.[6] Within the framework of statutory monopoly and integration inhabited by the nationalised energy industries during the period this was to lead to an approach to energy that was dominated by a constrained technological development (mainly in nuclear) and which paid little attention to the cost of electricity.

Bound up in the general disregard of cost to the electricity consumer during this period were the political decisions over fuel choice, which were a more central concern of this thesis. The CEGB remained throughout the postwar period the most important customer for coal, and as the quote from Helm (above) illustrates, its decisions over fuel were always dictated by the needs of at least one other nationalised energy industry - usually coal. In the postwar golden age of increasing prosperity, domestic consumers were keen to switch from 'dirty' coal heating to electric heating and the survival of the coal industry depended entirely on the CEGB's decision to burn coal to provide that electricity.[7] This, exacerbated by the Government's concerns over energy security following Suez, further restricted the opportunity for the CEGB to take advantage of cheaper oil-fired power stations. This situation was made worse by the troubled development of nuclear energy in the UK. Once more, energy security and the dominance of the engineers in energy supply meant that the huge costs of nuclear power development were absorbed by the cost per therm to the consumer, as the UK repeatedly tried, and largely failed, to establish a dependable nuclear programme. This approach resulted in what Baumgartner and Midttun termed the 'haphazard' UK policy before 1974, during which there was 'no serious attempt to explore the longer term energy future of the UK'.[8]

In 1973 the global oil crisis shook the UK government's complacency on energy policy. It responded immediately by creating a Department of Energy and turning its attention to energy forecasting and attempted for the first time to create plans for the medium and long term energy needs of the UK. For the next fifteen years, until privatisation, the UK Government made various attempts to formulate an energy policy. This was a unique period in UK energy policy during the twentieth century when the Government attempted to directly control and guide the development of energy planning in the UK. Although focused on the traditional fuels of coal and nuclear, as well as the

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[6] Hannah, *Engineers*.
[7] Ashworth, *Coal : Volume 5,* p.43
[8] Baumgartner, T., and Midttun, A. (eds.), *The Politics of Energy Forecasting: A Comparative Study of Energy Forecasting in Western Europe and North America* (Oxford: Clarendon Press, 1987) p. 115

'newer' North Sea oil and gas, this new attempt at formulating a UK energy policy also extended to energy conservation and renewable energy sources. With the sensational publication of *Limits to Growth* and the growing profile of the new environmentalist lobby in the UK, the Government was alerted to the potential of the 'alternative' sources within its wider energy strategy.

Another theme examined in this thesis was the idea of energy morality. This described a new social interest in matters relating to energy taken up by the newly emerging environmental groups of the 1970s. The influence of the new environmental movement was crucial in advancing the case for renewable energy sources during the early part of the 1970s. Emerging from the swirl of anti-establishment, anti-capitalist, anti-industrialist counter culture of the late 1960s, the UK environmental movement advocated the development of alternative energy sources, mainly as an alternative to nuclear energy. Through influential publications such as *The Ecologist* and the newly formed, more radical, environmental organisations such as Friends of the Earth UK (FoEUK) the ideological case for renewable energy was pushed into the mainstream. This thesis has shown that this not only attracted the attention of developers, but it also prompted the government to respond in some way. As several recent accounts of the 1970s have shown, during this period the government was keenly aware of the growth and perceived dangers of radical thought.[9] Turner and others have shown in detail how the government became fixated on responding to these threats to the established order, and how the 'muesli-eaters, ecology freaks, loony leftists and other nutters' in many ways typified these new and dangerous elements in British society during the period.[10] This indicates that the new environmental movement had gathered sufficient momentum to represent a threat to the government, and that the UK renewables programme can be seen in some ways as a response, and a token, for this new section of society.

Alongside the social pressure created by the formation and growth of the new environmental movement was the important political influence of Lord Rothschild and his Central Policy Review Staff (CPRS). This thesis has shown how during 1974 Rothschild and the CPRS occupied, albeit temporarily, a vacuum in UK energy policy following the

[9] Beckett, A., *When the Lights Went Out: What Really Happened to Britain in the Seventies* (London: Faber and Faber, 2009); Turner, A. W., *Crisis? What Crisis? Britain in the 1970s* (London: Aurum Press, 2008); Wheen, F., *Strange Days Indeed: The Golden Age of Paranoia* (London: Fourth Estate, 2009)
[10] Turner, *Crisis*, p. 50

oil crisis. Amid political upheaval, which included two UK general elections in that year, Rothschild's views on energy arguably set the tone for UK energy policy at least until the new Conservative Government of 1979, and perhaps even until privatisation in 1989. His overall strategy of attention to coal, nuclear and conservation (known as CoCoNuke), included a key recommendation on wave energy. This specific recommendation had arisen following a study carried out by an official in the Department of Industry, who then used Rothschild's high profile report to advance the case for a detailed R&D programme on wave energy. The serendipity continued as Stephen Salter's early work on wave energy provided a startling example of the potential for wave power. Therefore, renewable energy, beginning with wave energy, emerged, almost from nowhere, to form a key part of the Government's new energy policy after 1974.

The need for diversification in nuclear energy R&D helped to encourage the UK renewable energy programme. This was explained by the efforts, led by Keith Dawson of the UKAEA, to establish an energy technology centre at its Harwell R&D facility. This was part of a larger effort by Harwell director, Walter Marshall, to ensure the survival of Harwell through the 1960s when research on nuclear energy was scaled back as the technology matured. From 1972 Dawson had been submitting plans to establish a new unit at Harwell, and the oil crisis (and the intervention of Rothschild) provided the final impetus to the Government to agree the creation of a new unit, to be called the Energy Technology Support Unit (ETSU). Working within the new Department of Energy, ETSU became the central coordinating body for the UK renewable energy programme. Although the location of ETSU at Harwell was eventually to draw some understandable criticism, it was clear that the motivation for the unit was based on the needs of the UKAEA rather than as a direct response to any exogenous growth in renewable energy technology. This provides some evidence for the conclusions of this thesis that renewable energy development in the UK during this period is also partly explained by a greater understanding of the needs of the UKAEA, and the wider political imperatives of the UK government. The influential demands of the UKAEA during this time leads to one of the themes examined in this thesis, the domination of energy policy by key energy institutions through an energy techno-institutional complex (TIC).

Within the analysis of social and political pressure on the course of technological development this thesis has explored the theme, suggested by the work of Laird for the US, of an energy techno-institutional (TIC) complex in the UK. One effect of the energy TIC was the existence of powerful interest groups within the UK energy scene, chiefly created through nationalisation as discussed above. This included the monopolies of the National Coal Board, the British Gas Council and the Central Electricity Generating Board which combined to dominate energy policy in the UK. However, the attention of this thesis has been drawn to a close analysis of the role of one powerful group in particular, the UK Atomic Energy Authority (UKAEA). From the time of its creation in the early 1950s, the UKAEA represented a key element of UK energy planning. During this period the technological promise of nuclear energy was bound up in complexity and mystery. Nuclear technology represented a weapon for postwar Governments, both in the military sense and as a method of ensuring self-sufficiency in energy terms. The military aspects of the project allowed nuclear energy to simultaneously hide behind a veil of national security and to attract huge amounts of Government funding with little public accountability. Nuclear energy was ‘big science’ and the UKAEA grew quickly to dominate UK energy R&D. Thereafter, ‘new’ energy technology came to be mediated through the UKAEA, and this was shown in Chapter 4 in the negotiations to establish the Energy Technology Support Unit (ETSU) and the subsequent control of renewable energy R&D by the nuclear establishment at Harwell.

A defining characteristic of the UK energy TIC was the representation of energy policy in the UK through a dominant energy paradigm. This paradigm understood energy in specific terms. First, it accepted the false notion of the historical energy transitions of industrialisation. These were understood as the great energy revolutions from water to coal at the beginning of the nineteenth century; coal to oil in the first half of the twentieth century; and then, most probably, oil to nuclear in the future. This was despite the evidence to the contrary which this thesis has emphasised. For each of these ‘transitions’ the reality was much less ‘historic’. It has been shown that in the textile industry water power lingered well into the twentieth century; that coal remains to the present day the major source of the world’s primary energy supply; and that the latter transition to nuclear energy remains unfulfilled. However, this paradigm had a direct impact on the renewable energy programme in the UK. This thesis has shown that renewable energy sources were routinely judged by their capacity to *replace* existing fuels, and the economic measure for renewable energy was an unreliable comparison with the cost per kWh of nuclear energy. This revealed an essential misunderstanding of the nature of renewable energy sources that could only result in the failure of its development. Now we understand renewable energy as *complementary* to fossil fuel and nuclear as part of a much wider energy mix. The dominant energy paradigm of the period had a much narrower conception of this mix derived from an essentially Whiggish belief in energy transitions.

Set within the dominant energy paradigm this historical analysis of the UK renewables programme has suggested that the programme was characterised mainly by fundamentally mistaken assumptions and the consequently misguided programmes. The rationale for launching a renewable energy R&D programme during the early 1970s was based almost entirely on social and political pressure. The government, through the DoEn, was too readily convinced by the advocates of alternatives in the period that renewable sources could make a significant contribution to the UK's energy mix in the short to medium term. However, although conceived in a socio-political vacuum, the programme came to be judged, ostensibly, on economic and technical grounds. Very quickly, initially through the Wave Energy Programme, the huge technical challenges that confronted the developers became plain as the tantalising initial estimates for the potential contribution of renewables receded into myth. It became clear to the Government that both significant amounts of time and money would be needed to realise this potential. The much more tangible and shorter term solutions of North Sea oil and gas, and to some extent nuclear power, were clearly of far more relevance to UK energy policy at this time. Setting out from a position of mistaken assumptions, the UK renewables programmes were soon assailed by a series of retreats and ill-timed changes in direction. As this thesis has described, the Wave Energy Programme was halted just as it began to achieve the ambitious and continually revised targets on cost, and a wholesale shift towards wind energy replaced it as the centre-piece of the UK renewables programme.

In conclusion, although this thesis has focused on a UK renewables programme that extended until the end of the 1980s and ended with the advent of privatisation in the energy industries, it is in many senses a story of the 1970s. The programme was established by a Labour government amid the particular social and political context of the 1970s, which was undergoing the slow transition from postwar consensus to the free market ideology encapsulated by the Thatcher government after 1979. The new government inherited the renewables programme, and has been seen, set about reducing expenditure on renewable energy R&D. It can also be seen that the wind energy programme was conducted with a somewhat different approach than its predecessor in wave energy. The attempted commercialisation of wind power, and the inclusion of industrial partners, was much more of a priority for wind power. In contrast, in wave energy industrial partnerships were viewed with an element of unfamiliarity, and even suspicion. In a sense therefore, this thesis represents an analysis of the long 1970s, rather than the 1980s.

Further historical research which focuses on the transition in renewable energy at the end of the 1980s and into the 1990s would be useful in examining the shift from directly funded R&D to the provision of incentives for renewables development. After 1990 the UK government introduced a scheme that obliged electricity suppliers to purchase a percentage of their generation from 'non-fossil fuel' sources. Commentators have pointed out how this careful definition allowed the inclusion of nuclear energy as a 'non-fossil fuel' and the negative impact that this had on the development of renewable energy. Eventually, this criticism resulted in the later introduction of a new scheme of specific Renewables Obligations (ROs) in the UK. Again, an historical account based on archival sources would be important in examining this crucial change in approach in the development of renewables in Britain.

This thesis has examined one aspect of the UK government's relatively brief flirtation with energy policy during the twentieth century, and has focused on the UK renewables programme when the imperatives of state and society temporarily quashed the economic and technological rationality of the period. The detailed analysis of this period showed that social pressure from the emergent environmental movement in the UK, the survival instincts of the UKAEA at Harwell, the influence of several key individuals at the heart of government, and the lead of the United States in 'alternative energy' R&D encouraged the UK government to suspend disbelief in the potential of renewable energy and then to fund a wide-ranging programme. This thesis has therefore presented the UK renewables programme as an essentially tokenistic gesture by the Government, keen to be seen as reflecting both the mood of society and also acting responsibly in exploring the potential of 'alternatives' in pursuit of wider energy security. Government studies produced in the early 1970s showed clearly that despite the widely fluctuating estimates for the overall potential of renewable energy sources in the UK the economic and technical challenges were considerable. The failure to engage widespread commercial interest in renewable energy and the lukewarm attitude of its main customer, the CEGB, reflected the limits to the development of renewable energy in the period.

Appendix I

Primary and Secondary Energy Sources

It is important to emphasise the important distinction between **primary** and **secondary** energy sources. Primary sources of energy are those which 'contain' energy- the original source - and consequently they are the most important element of any energy system. In modern energy systems fossil fuels - coal, oil, and natural gas - are the most commonly used primary energy sources. However, this category also includes biofuels such as wood, straw, and dried dung which even today constitute the key source of energy (mainly for heating and cooking) for many parts of the world.[1] Also included among the primary energy sources is nuclear energy, created from uranium. All forms of renewable energy also represent primary energy sources. The sun, the waves, the action of the tides, and the wind are the most commonly utilised sources of primary renewable energy. Ramage and Everett highlight the 'rather arbitrary nature of the definition' of primary energy giving the example of solar energy, which is only 'counted' if it is used in solar panels or photovoltaic cells. This overlooks the contribution of solar energy in 'warming and illuminating our buildings.' [2]

Secondary energy sources are those which use a primary source and convert that energy into an alternative, often more usable, form. This can take a number of different forms and examples include the conversion of coal to gas (town gas) and oil; gas to oil; and oil to gas. Although examples of secondary energy sources these are essentially the conversion of one primary fuel to another primary fuel driven by demand and availability. The most recognisable and dominant secondary source of energy is electricity. Since the development of mains electricity in the 1880s it has come to dominate our energy needs. Strictly speaking, electricity is not in fact an energy source but a method for converting primary *energy* into a source of *power*. Indeed Patterson, whose work exposes our common misunderstandings of energy, claims that 'for more than a century we have treated electricity as though it were a fuel'.[3] In many respects this has served to conceal the

[1] The persistence of 'old' technologies in many parts of the world is emphasised most recently in, Edgerton, D., *The Shock of the Old: Technology and global history since 1900* (London: Profile Books, 2006)
[2] Ramage, J. and Everett, B., 'Primary Energy' in Boyle, G., Everett,B., and Ramage, J. (eds.) *Energy Systems and Sustainability: Power for a Sustainable Future* (Oxford: Oxford University Press, 2003) p. 57
[3] Patterson, *Keeping,* p.55

actual fuels that feed our power stations. Electrical output is delivered in measurable and controllable quantities known as watts which further suggests the view of electricity as a commodity or 'substance'.[4] Its rapid success was due to its clear advantages over the incumbent energy technologies, most notably town gas. As Everett observed, 'It could supply lighting with less smell than town gas, drive electric motors that were more convenient than steam, gas or petrol engines and could be used in the steadily developing world-wide telegraph network.'[5]

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[4] Ibid.
[5] Everett, B., 'Electricity' in Boyle et al (eds.), *Energy Systems,* p.333

Appendix II

Renewable and Non-Renewable Energy Sources

A further key distinction demanded in the interests of clarity is the fundamental difference between **renewable** and **non-renewabl**e primary energy sources. This is particularly crucial to this thesis as it forms the basis of the entire debate over renewable energy. Energy is described as 'renewable' if it is 'continuously replenished by natural systems'.[1] Thus, it provides an endless and unlimited flow of primary energy. However, no effective means have yet been devised that can **store** this continuous flow of renewable energy.[2] Renewable energy sources include solar energy, wind power, wave power, bioenergy, tidal energy, and geothermal energy. Non-renewable primary energy sources are, on the other hand, a form of highly concentrated **stored** energy. These sources, such as coal, oil, gas, and uranium will not be replenished on a continuous basis. Mostly (with the exception of uranium) they have been formed by natural processes of fossilisation occurring over millions of years. Ultimately they too will be replenished, but only after the passage of many millennia. Therefore, this means that the fossil fuels - coal, oil, and gas - are *finite* sources of primary energy. Over time the reserves will be depleted - and this applies also to uranium, the mineral that is the primary energy source for nuclear power.

This ultimate weakness of fossil fuel as a primary energy source also represents its greatest strength and accounts for its dominance in modern energy systems. It means that it can be used where and when it is needed and for as long as it is needed (notwithstanding its eventual depletion). It can effectively be turned on and off at will. It is transportable, predictable and flexible, and as energy technology has developed over the twentieth century the uses of its by-products are also multifarious. As well as providing the energy source that this thesis examines, it also has a myriad of other applications from transport to chemicals. Coal, and more particularly oil, are fundamental ingredients in the modern world, particularly in plastics. However, it is the nature of fossil fuels as a *stored* form of energy that makes them most irresistible. Renewable sources of primary energy are by definition not stored - as stated above; they are continuous flows of energy. Therefore they

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[1] Patterson, *Transforming,* p.186
[2] There are however ongoing developments in battery technology in this area. See, Ter-Gazarian, A. *Energy storage for power systems*. IEE Energy Series 6. (London: Peter Peregrinus Ltd., 1994)

cannot be turned on and off at will, and they are not generally predictable in any reliable sense. Furthermore, renewable energy provides nothing but the energy itself: it has no useful by-product. In fact, renewable energy is the purest form of primary energy. Arguably, fossil fuels are the *repository* of energy rather than primary sources in themselves. The energy has already been naturally converted into a fuel, deep under the earth in a process taking millions of years. With renewables that first stage of conversion to a usable form has not taken place and the energy remains to be harnessed. Therefore the problems of storage remain to be solved. Much effort has been put into battery and hydrogen storage technology in an attempt to address this fundamental feature of renewable energy, but the innovation remains well short of the massive requirements of modern energy systems. The only renewable energy resource that confronts this issue is hydropower, where the energy can be ‘stored’ in reservoirs and used when required. This also helps to explain the success of hydropower when compared with the other renewable energy sources.

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