Energy Research & Social Science 22 (2016) 1–6

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Short communication

Energy realities or modelling: Which is more useful in a world of internal contradictions?

Michael Jefferson

ESCP Europe Business School, 527 Finchley Road, London NW3 7BG, UK

ARTICLE INFO

Article history:
Received 17 August 2016
Accepted 17 August 2016

Keywords:
Energy modeling
Shell
Energy futures
Scenarios

ABSTRACT

For over forty years energy expectations have been riddled with internal contradictions, and all too often a failure to recognise complexity, the nature and scale of the challenges to be faced, and resultant uncertainty. Key elements of Shell's "World of Internal Contradictions" scenario, issued internally in October 1974, still hold good. Some other elements have since intruded, though they should not have been entirely unsuspected. The paper opens with a summary of the October 1974, risks then anticipated: another regional conflict in the Middle East; further serious threats to energy supplies; and another currency crisis and recession. Changes in social attitudes were thought likely to shift the emphasis from working for high achievement to 'takers and dreamers' having a more influential role. There were numerous internal contradictions anticipated in the evolution of this long-term scenario that have been apparent over the past forty years and seem likely to continue. Some fundamentals of the exploitation and use of energy resources were as apparent then as they are now. The future, like the past, seems likely to be riddled with internal contradictions and failure to find satisfactory resolution of important challenges for the human race. But the complexities, uncertainties and time horizons involved suggest modelling is a marginal option compared with other approaches.

1. Introduction

Shell had won high regard for its assessment of a likely first 'oil crisis' (although the timing was a little out), and so in October 1974, "Scenarios for the 1975 Planning Cycle" was issued internally. On pages 20–21 of that 100-page book key elements of a "World of Internal Contradictions" scenario were set out. Although members of the scenario group had different views on the emphasis to be placed on key features, the outstanding ones were:

> "It is thought another major regional conflict in the Middle East, further serious threats to energy supplies, or another major currency crisis and recession could well precipitate the world into this path rather than that of the alternative scenario we have called a New Belle Epoque".
> "In the energy sector the supply problem is perceived as imposing a constraint on growth."
> "Within most Societies expectations outstrip the achievement potential as the 'takers and dreamers have a more influential role."

Other features of this scenario included the holding back of economic growth rates and per capita incomes in countries other than those which were resource rich and able to trade "vibrantly"; a lack of incentives or rewards was likely to hold back productivity increases; and balance of payments were likely to become more problematic for countries heavily dependent upon imports. There was an expectation by some that these forces would support the rapid development of nuclear – a view which some countries took successfully on board (such as France), while others (such as Denmark) opted to go for coal to enhance supply security. For Shell the decision to enter the nuclear sector was marred by choice of partner, if nothing else. The scenario book also noted that solar energy represented a further vast energy resource, "of which the surface has been barely scratched."

Since an alternative "New Belle Epoque" scenario has been mentioned, it may be worth brief comment. There were one or two influential voices in the scenario team who had been close to Herman Kahn and the Hudson Institute for some years. It was the Hudson Institute which peddled the notion of a *Belle Epaque* or *La Deuxieme Belle Epoque* scenario, which even featured in the later Hudson Institute book: "World Economic Development: 1979 and Beyond" [1]. This was a scenario which other members of the scenario group regarded at the time (and since) as ludicrously over-optimistic – and, of course, most unfortunately timed in the case of

E-mail addresses: jeffers@dircon.co.uk, mjefferson@escpeurope.eu, michael.jefferson@buckingham.ac.uk

http://dx.doi.org/10.1016/j.erss.2016.08.006
2214-6296/

the book's publication. This issue and related ones have been discussed elsewhere [2]. As far as the Hudson Institute is concerned, the publication in 1974 of its doom-laden: "The United Kingdom in 1980" and three major illusions about North Sea oil was another masterpiece of timing which overlooked the rise to power of Margaret Thatcher [3].

Shell were diffident in October 1974, about future oil prices, although a return to low prices was not anticipated unless there were to be a world depression following 'accidents' such as international monetary instability or the eventual consequences (for a time) of turbulence in the Middle East. On the supply side oil was seen to be at a disadvantage in the heating and steaming markets, and although coal supplies could expand to satisfy these markets their short-term supply elasticity was recognized to be low. Conventional oil availability was not anticipated to prove a hurdle under the World of Internal Contradictions scenario before the end of the 20th Century, but there was full awareness of 'the oil mountain'.

Although Marion King Hubbert had been a Shell Oil employee in Houston when advancing his "bell curve" hypothesis in 1956, there was no mention of a bell curve despite an awareness of Hubbert's work. Instead, there was preference for the phrase "the oil mountain" – the shape of which could vary according to demand and the availability of alternatives, whether unconventional oil or other sources accessible for the transportation sector.

There has been a recent fashion to dismiss the 'peak oil' hypothesis as now redundant due to the onset of fracking of oil and gas. This suggests a misunderstanding about the nature of the 'peak oil' hypothesis which has been widely circulated over the past twenty years. Although the issue is out of chronological order here, it is now addressed. The hypothesis has always been about recoverable conventional oil, and there has never been any serious suggestion that non-conventional oil (or gas for that matter) did not exist or would not ultimately be developed. Although the topic was not addressed in the October 1974, Shell scenario book, Shell's "Exploratory Scenarios for the Long Term", issued in January 1977, was explicit. It was highly likely that ultimately recoverable conventional oil resources would exceed 2 trillion barrels, and a 25% chance of them exceeding 2.7 trillion barrels. There could be a further 600–700 billion barrels to be discovered "in the more speculative Deep Sea and Polar regions and in stratigraphic traps". The scenario book went on:

> "Furthermore, no allowance has been made for future recovery from unconventional sources such as tar sands or oil shales, neither of which is considered to contribute significantly to the world oil availability within the remainder of this century." (p.45)

Most commentators on 'peak oil' have excluded tar sands (e.g. Athabascan) and heavy oil (Venezuelan) from their definition of (the lighter) conventional crudes for the reason covered later here when the mid-1980s and OPEC production quotas are discussed. But there has been no denial of the existence of non-conventional oil and gas resources or of fracking (which can claim a 150-year history) although volumes and timing of exploitation have been debated [4].

Three other points may be made here before proceeding on to the implications of the World of Internal Contradictions scenario as events developed in the late 1970s. First, it has been claimed that "international political economy (IPE) of energy, a field with which scholars have only recently started to identify", was founded in the 1970s and born of the OPEC "crisis" [5]. This seems an odd claim. Numerous Shell people were familiar with issues of international political economy – not least in relation to the Middle East and North Africa. A number of Shell people had attended the Middle East Centre for Arab Studies in Shemlan from 1947. Wahhabism, Sunni-Shia tensions, and unrest in the Arabian Gulf, were familiar territory on which Shell people talked and wrote for many years even before 1973. Ian Skeet's "Muscat & Oman: the end of an era", published in 1974, reflects this for example [6]. There was also the notion, particularly associated with Maurice Adelman, that OPEC would quickly collapse as an organization, as US Trusts had done in the past. Few seemed to be aware of the long life of numerous European cartels in the past although Shell's planners were.

This highlights the importance of having a knowledge of history – social, political, religious, economic, climatic, scientific and technical. Paul David and Mark Thomas have stated as their central contention: "economics in some quarters, and more widely should become, an historical social science" [7]. In the energy field there are related themes in the journal *Energy Research & Social Science,* edited by Benjamin Sovacool. One thinks of papers written by Richard Hirsh and Christopher Jones [8], Daniel Spreng [9], Adonis Yatchew [10], and Benjamin Sovacool himself [11,12] in that journal. *Energy Policy* has covered some of the same ground from time to time – in a Special Issue edited by Roger Fouquet and Peter Pearson in 2012, for example [13]. More recently some of the papers published in the January 2014, and November 2015, issues of *Energy Policy* also emphasized the importance of history [14]. Charles Hall and others have referred to the need to 're-integrate the natural sciences with economics' in the journal *BioScience* [15]. Benjamin Sovacool has pointed out that, for every $1 spent in the USA on research into behavioural and demand-side energy research, $35 is spent on energy supply and infrastructure [16]. It should be obvious that energy economists are required to have knowledge of economic and social history, including financial and debt crises and past political and religious upheavals, as well as the history of energy transitions and basic energy concepts. An ability to engage in modelling such matters may be considered of secondary importance [17].

One area where a distinct difference of view existed within Shell's scenario group emerged from the idea that under the new conditions operating in the wake of the 1973 oil 'crisis' large sections of industrialized societies would opt for "Voluntary Simplicity". Financial pressures and resource constraints would assist in promoting the idea that less materialistic lifestyles would be a worthwhile goal. This idea was being strongly promoted by the Stanford Research Institute at the time [18]. For some of the scenario group's members it seemed to reflect unrealistic perceptions of human behaviour unlikely to be shared outside a small coterie of California's residents. The opposition to the idea of "Voluntary Simplicity" was not led by "hard core economists" as some have suggested, but by an economist who was also a social and economic historian, who had researched and written extensively on human behaviour, and was aware of the past record of similar thinking and small group initiatives over more than 2500 years.

The promoters of 'Voluntary Simplicity', within Shell at least, seemed unaware that the term derived from Richard Gregg's 1936 Pendle Hill Essay: "The Value of Voluntary Simplicity", which began by "reference to such great modern leaders as Lenin" [19]. The opponents of the concept of 'Voluntary Simplicity', while acknowledging that at some future point of time there may be involuntary simplicity forced by economic, population and environmental pressures, were familiar with 'the 150-year old Jevons' paradox' (or 'rebound effect' as it is now usually referred to), considered likely to undermine hopes of achieving 'Voluntary Simplicity'.

Another debate which for some of those involved has stood the test of time is the importance of not placing too much faith in modelling. Shell's 1974 global energy model contained over 3000 simultaneous equations and took over 19 h to run. It never achieved anything useful except, perhaps, in providing a firmer basis for 'mini-modelling' to test particular issues. It was finally handed over

gratis to Harvard University. In recent years Shell has revived a world energy model which is hopefully of greater practical value.

What was not anticipated was the widening of income and wealth disparities in some major economies (not least in the USA and UK) which began to emerge from the 1980s, and which has led to a vast outpouring of books on inequality over the past five years or so. For poorer folk this widening disparity has in part reflected rising energy costs due to the subsidizing of renewable energy schemes in numerous developed countries, and the impact on other expenditures has been felt well up the income scale. The incidence of fuel poverty has been rising even in a number of more prosperous industrialized countries (notably in Germany and the UK).

Another challenge which was not anticipated was anthropogenically-induced climatic change. In the mid-1970s the main focus of interest was cooling, not near surface warming. Hubert Lamb had founded the Climatic Research Unit (CRU) at the University of East Anglia, and he would occasionally visit Shell Centre in London (Shell International Petroleum had helped establish the CRU) and would discuss potential climatic change. At that time Professor Lamb believed that the world had entered a period of cooling, although he recognized that CO_2 and some other gases could cause warming. He considered even several years later that "the riddle of the lack of any demonstrable effect from the increase in carbon dioxide so far is that the expected warming has been offset by tendencies of the natural climate working in the opposite direction." (in "Climate, History and the Modern World", First Edition, 1982). However, by the time of the second edition in 1995 the Preface referred to: "Anxieties about the possibility of drastic warming of world climates resulting from the continual build-up of carbon dioxide (and other intrusions) in the atmosphere due to human activities have been forced upon the notice of politicians and industrial managements" [20]. It may also be recalled that the mid-1970s were years when Gordon Manley's "Central England temperature: monthly means 1659–1973" was published (in the Quarterly Journal of the Royal Meteorological Society, 1974); and John Eddy's paper on: "The Maunder Minimum" (*Science,* June 18, 1976, 192, 4245). When, in 1986, Shell first began to pick up on the subject of climatic change there were a number of people well placed to assess the debate and its implications.

How far the actual diversions from key oil sector issues were responsible for all too many people taking their eye off the ball within Shell can only be guessed at. But with so much effort being put into the notion of 'Voluntary Simplicity' and other work emanating from the Stanford Research Institute, as well as the preparation of a scenario dubbed "The Carter Miracle", it is perhaps not entirely surprising that the onset of the second oil 'crisis' in 1979 seemed to catch many unawares. This was an unnecessary failure.

2. The second oil crisis and its aftermath

A recently published (March 2016) book by David Howell, former UK Secretary of State for Energy (1979–1981): "Empires in Collision: The Green versus Black Struggle for our Energy Future" [21], relates on page 211 how:

> "In the summer of 1980 I was shown into a special research room at Shell's then Head Office at Shell-Mex House in the Strand [actually Shell UK's Head Office on the other side of the River Thames]. On the wall a large graph showed Shell's view about the evolution of oil prices over the next ten years – to 1990. There were three lines. The lower one showed oil reaching $60 a barrel by 1990, the middle line reached the $90 dollar figure. The top line touched $120 when the ten years were up."

Lord Howell goes on to explain that the consensus had closed around $90 per barrel. Finally, he points out: "On the same day ten years later, in 1990, the price for Brent Crude stood at $18!" It is difficult to imagine a clearer example of corporate internal contradictions being displayed.

From March 1976, it had become clear to some members of Shell's scenario group (those not dazzled by 'Voluntary Simplicity', the 'Carter Miracle' and suchlike) that the Shah of Iran faced deepening opposition and the likelihood of being forced from power. This period coincided with the bringing on of North Slope Alaskan and North Sea oil. To slightly disguise the Middle Eastern State where regime collapse was anticipated (by some) the prospect was named "Producer Miscalculation" – and it was never a fully-fledged scenario. On page 23 (Chart 4) of "Exploratory Scenarios for the Long Term", January 1977, were two Charts. In Money of the Day Crude Oil Prices (f.o.b. Persian Gulf) jumped from about $15 per barrel in 1978 to over $30 per barrel before starting to fall again around 1982 due to recessionary forces in oil-importing countries. It will no doubt be recalled that crude oil prices did begin to weaken in 1982 before falling more sharply in 1985.

At the same time that in Shell-Mex House David Howell was being regaled with $60 plus per barrel for crude oil, Shell's European Organisation had for at least six months previously been subjecting its mainland European Operating Companies to a "Hard Times" scenario. This scenario set out the recessionary forces at work which were highly likely to follow the 1979 oil 'crisis' (the Iranian Revolution had begun in January 1978, but the Shah held on for another twelve months), with crude oil prices expected to more than double – as had been recognized since 1976 – before falling again. This judgement had considerable effects, including profitable decision-taking, both in some Operating Companies and in Shell's Manufacturing Function.

It was not until December 1984, that Shell's Group Planning produced the first detailed paper to examine the consequences of oil price collapse. In May 1985, Shell's Committee of Managing Directors (CMD) sanctioned an exercise on oil prices collapsing to between $10 and $16 per barrel, and by January 1986, the main conclusions were discussed in detail with the CMD and major operating companies. However, as Paul Tempest pointed out in an internal Report dated April 1st, 1987, Shell International Petroleum's Supply and Marketing Function had already in January 1986, produced a Chart suggesting that crude oil prices were likely to continue weakening until June/July 1986, after which they were expected to recover close to $15 per barrel. Paul Tempest stated, from the work conducted through the first three months of 1986: "one has to conclude that, without claiming to know the future, Supply and Marketing [S&M] were more or less on the right lines." Indeed, S&M, by taking the view that crude oil prices would fluctuate between $15 and $20 per barrel for the rest of the decade, were also proved correct. It was a pity that Shell's then Group Planning scenario team missed another opportunity to demonstrate it was ahead of the game.

Meanwhile, however, OPEC had introduced production quotas, and these were to lead to the shift from defining proved recoverable conventional oil reserves as a 90% 'probability' to a 50% 'probability'. This led to a massive expansion of proved conventional oil reserves data for the Middle East OPEC Member countries in the main published sources, and led to debate about actual recoverable reserves, the likely gross overstatement of reserves, and one of the foundations on which more recent work on 'peak oil' conventional reserves has focused as indicated earlier. Thus for the five main Middle East OPEC Member countries sources such as the BP Statistical Review, the Oil & Gas Journal, the US Department of Energy, and OPEC all have proved conventional oil reserves figures which total some 775 billion barrels – far higher than pre-1984 figures would suggest. As no major finds have been made in these countries over the past

thirty years and offtake has been considerable, these numbers are greatly inflated. The inclusion of Venezuelan 'heavy' oil and Canadian Athabascan tar sands within the definition of 'conventional' oil was also disputed on differential quality grounds.

3. The rise of sustainable development issues

But other factors began to play an increasingly large role from the mid-1980s. Concerns about sustainable development had been focused upon in Stockholm some fifteen years earlier, although some thought that "acid rain" was the main concern at the time. These broader development and environmental issues were largely placed in abeyance due to the impacts of oil crises, but gained renewed prominence from 1986 as concerns grew about the potential impact of human activities on global climatic change. But sustainable development issues were not entirely ignored by Shell's scenario group members during the 1970s. Harrison Brown's "The Challenge of Man's Future" had appeared in 1954 [22] and Rachel Carson's "Silent Spring" in 1962 [23]. They were followed by a flurry of publications in the early 1970s with which Shell's scenario group members were mostly familiar: the Meadows' "The Limits to Growth" (1972), "A Blueprint for Survival" from *The Ecologist*, (1972), Barbara Ward's "Only One Earth" (1972), and E.F. Schumacher's "Small is Beautiful" (1973) [24–27].

Also of interest and relevance, especially to Shell's economists, were the works published by Resources for the Future on energy flows and balances (and those of materials more generally) written by Robert Ayres and others [28]; the contributions of Nicholas Georgescu-Roegen on what he termed "the entropy process" [29]; the works of Howard Odum on the need to take a "macroscopic" view of energy flows and their impacts upon the natural biosphere and human life [30]; and the insights of Piotr Kapista on the limits to energy conversion [31]. The import of these works has been reinforced by the subsequent research findings of Charles Hall and co-authors on "Energy and Resource Quality" [32], and subsequent publications of his and associates, such as listed in Refs. [33,34]. Then there is Vaclav Smil's impressive body of work on energy transitions and power density emphasizing the challenges of achieving major changes in energy systems either easily or quickly [35–42].

Behind the energy policy moves of the past twenty years an important role has been played by concerns about potential anthropogenic climatic change and the need to move to a low-carbon world. In the process of seeking to shift from the fossil fuels there have again been many examples of internal contradictions, in policies and resultant investments. Modern biomass and biofuels policies and schemes have all too often been in conflict with basic sustainable development criteria – resulting in the cutting down of forests, destruction of natural habitats and threats to species' survival, and diversion of agricultural output to biofuel with resultant food price rises and social turbulence, for example. Wind energy developments have all too often been placed in sub-optimal locations, and without sufficient acknowledgement of adverse local impacts whether on local human residents or other species. Solar energy developments have likewise taken too little account of location in relation to direct and indirect solar insolation. Promoters of estuarine barrages have similarly paid insufficient heed to ecological impacts – on bird, fish and some other species [43,44].

Other lessons do not appear to have been learned in considering potential climatic change. One leading climate economist has claimed that "our future lies not in the stars but in our models." Yet 111 out of the 114 climate models considered relevant by the IPCC in their Fifth Assessment have, in the IPCC's view, overstated recent warming. There is ongoing debate, some of it illtempered in quarters where objective scientific assessment should overrule all other considerations. Fundamental scientific debate continues, for example, on the influence of solar variation. Observing the past Grand Solar Minimums of Oort (1040–1080 CE), Wolff (1280–1350), Sporer (1450–1550), Maunder (1645–1715), Dalton (1790–1820), and Glassberg (1880–1914), can we be sure that further Grand Solar Minimums cannot occur in the future, which might even offset other warming factors in this century? Why have some leading climate scientists dismissed all solar variation other than the basic 11-year cycle and 95,000 to 125,000-year Milankovitch cycles? Various hypotheses exist about the impact of the Sun, and the main published sources stress the need for further research. Many serious researchers question why there is not greater emphasis on examining natural variability. Historical research raises questions about prospects for droughts, floods, and sea level rise, as well as temperature change. There is a large volume of relevant literature which appears to be largely ignored by those totally convinced about anthropogenic causation [45–54]. Some of these authors have emphasized that there is no definitive answer to whether solar variation causes climatic change (for example, 50). Others have concluded that although Grand Minimums exist their duration, and presumably impact, are essentially 'a random process' [55]. Nevertheless, this is a field which requires fuller understanding, as do other aspects of the causation and effects of climatic change.

These are complex matters and uncertainty therefore remains about them. Until such issues are resolved with a high degree of scientific certainty then sound precautionary measures are sensible. Regrettably, there is clear evidence that in relation to energy matters many policies, measures, and investments have not been optimal. Some have seen "the economist as saviour", yet their contribution has been very limited and frequently not useful or sound [56]. Vested interests have combined with scaremongering, bureaucratic meddling with economic decision-making. Instead, as Mike Hulme has suggested in several of his works, we need to take a calmer, broader, less politicized approach to the potential challenges of climatic change – and place it within a broader picture of how we can best seek "to ensure that the basic human needs of the world's growing population are adequately met", while seeking also to protect as far as is reasonable a range of other broad environmental and narrower ecological goals. "We are a long way short of displaying even the minimum attributes necessary for earth system governance. The current efforts to defuse the risks of climate change are leading us nowhere" [57].

4. Future challenges

Nearly 12 billion people are projected by the UN to populate the world by 2100, yet currently some 2.8 billion people remain dependent on traditional fuels for cooking, and about 1.4 billion are without electricity. We can all understand the importance of having access to modern energy services, but the idea that we can 'ensure universal access to affordable, reliable and modern energy services for all by 2030' (UN Sustainable Development Goal 7, 2015) is just fanciful.

Given the expectation of increased life expectancy and rising energy costs largely associated with accelerating renewable energy provision, it would seem likely that energy (fuel) 'poverty' will increase even in developed nations and among the hitherto relatively well-off.

The UN's latest Sustainable Development Goal 7 includes doubling the global rate of improvement in energy efficiency by 2030, but if one takes account of the likelihood that more people will travel by air or by motorized vehicles, more goods will be moved by efficient lorries and ships, and the impacts of 'the rebound effect' are not simply going to disappear, then however much we believe

that "less is more" it is unlikely to happen unless forced upon us by conflict or extreme measures.

"Energy transitions have been, and will continue to be, prolonged affairs" [28]. The transition to coal and then to oil were relatively faster than the shift towards gas. Renewable energy's contribution is rising, but there are some fundamental issues surrounding the relative efficacy of renewable energy when compared to the fossil fuels and nuclear. We need to look back about 150 years for the origins of the fuel cell and of solar photovoltaics, and over 100 years for the first CSP development. Our towns and cities are burdened with massive infrastructures which will take many decades to modify substantially, while the rapid moves to urbanization that have occurred and will continue (80% of the world's population is anticipated to be urbanized by 2100) will require a huge effort to install effective layouts and supporting infrastructures which will almost certainly only partly be fulfilled.

Renewable forms of energy contain a number of fundamental drawbacks once their low carbon benefits are recognized. Their power densities (Watts per square metre) are lower than those for the fossil fuels [42]. Apart from the variable placings of hydropower schemes, renewable forms of energy have relatively low Energy Return on Energy Invested (EROI) rates [33,34]. We humans, like most creatures, seek out the most convenient and closest resources to exploit first. As these resources are exploited so the marginal returns on their production decline. Energy is no exception to this rule, which can be traced back to the earliest efforts to feed ourselves as hunters and gatherers ([14], Jefferson) It remains no exception in the context of renewable energy.

The depletion, degradation, or exhaustion of many critical resources may well provide the basis for conflict. The lack of access to basic needs such as modern energy services, or inability to provide successfully for massive concentrations of urbanised populations, or simply a lack of food, could provoke upheaval with wide-ranging consequences. As Mike Hulme has written, we need to move away from regarding concerns about climatic change as 'a narrative of crisis', "the most important issue in human history", with "science demanding this or that", to a more rounded view. As he put it: "Our goal is surely to ensure that the basic human needs of the world's growing population are adequately met; that we move toward a development paradigm where we are living within our technological means and not beyond them; and that our societies are adequately equipped to withstand the risks and dangers that come from a changing climate. Distinguishing whether those risks and dangers are natural or not is hardly the point" [58].

5. Conclusion

The World of Internal Contradictions scenario forged over forty years ago in Shell has had a robust past and may well have a robust future. We cannot foretell the future, of course, and more optimistic scenarios may prove realistic. The assessments of 40 years ago highlighted unrealistic and over-optimistic assessments on the one hand, such as OPEC collapse and move to a bright 'Belle Epoque' future, with the associated claims of rapid transition to a new pattern of universal availability of modern energy services provided by renewable sources of energy. The reality was, and is, that mega-changes are never as easy or as quick as the optimists hope. Blame may often be attached to the short-sightedness of politicians looking to the next election, or the incompetence of bureaucrats, or the failures of business and final energy users to adopt effective new technologies and change habits. These are just some of the features of a World of Internal Contradictions.

The reasons why the World of Internal Contradictions scenario has proved so robust are because it reflected historical, social, political, behavioural, and industry realities. It did not rely upon energy modelling, which would have failed to encompass the complexities of this world.

For energy policy, the World of Internal Contradictions scenario reflected the reality that fundamental energy transitions take a long time – far longer than "the optimists" would have us believe. In the process the Law of Unintended Consequences is seen to operate in various renewable energy fields where environmental impacts are too often adverse and contributions sub-optimal in other ways. Research, policy and investments need to heed all the lessons we can learn from the past.

If the world fails to face up to these internal contradictions and their unintended consequences then it is not surprising that some have questioned the future of the human race and the possibility of the end of what has been termed the Anthropocene Age. For Shell's Group Planning scenario team 40 years ago the pressures seemed likely to be such that, instead of "Voluntary Simplicity", the survivors of the human race would need to turn involuntarily to a "Transformed Society". This "Transformed Society" would be characterised by less materialism, the seeking out of dependable and environmentally acceptable forms of renewable energy, and greater awareness of the need to protect our natural environment. Is this beginning to occur?

References

[1] Herman Kahn, World Economic Development: 1979 and Beyond, Westfield Press, Boulder, Colorado, 1975.
[2] Michael Jefferson, Shell scenarios: what really happened in the 1970, and what may be learned for current world prospects, Technol. Forecast. Social Change 79 (2012) 186–197.
[3] James Bellini, et al., The United Kingdom in 1980, Halsted Press, New York, 1974.
[4] Michael Jefferson, Win–Win strategies for tackling oil and natural gas constraints while expanding renewable energy use, in: F. Barbir, S. Ulgiati (Eds.), Sustainable Energy Production and Consumption, Springer, Dordrecht, 2008.
[5] Kathleen J. Hancock, Viado Vivoda, International political economy: a field born of the OPEC crisis returns to its energy roots, Energy Res. Social Sci. 1 (2014) 2016–2216.
[6] Ian Skeet, Muscat & Oman: The End of an Era, Faber & Faber, London, UK, 1974.
[7] The Economic Future in Historical Perspective, in: Paul David, Mark Thomas (Eds.), Oxford University Press, 2003, p. 10.
[8] Richard F. Hirsh, Christopher F. Jones, History's contribution to energy research and policy, Energy Res. Social Sci. 1 (2014) 106–111.
[9] Daniel Spreng, Transdisciplinary energy research ? Reflecting the context, Energy Res. Social Sci. 1 (2014) 65–73.
[10] Adonis Yatchew, Economics of energy, big ideas for the non-economist, Energy Res. Social Sci. 1 (2014) 74–82.
[11] Benjamin K. Sovacool, What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda, Energy Res. Social Sci. 1 (2014) 1–29.
[12] Benjamin K. Sovacool, et al., Integrating social science in energy research, Energy Res. Social Sci. 6 (2015) 95–99.
[13] Past and prospective energy transitions: insights from historyRoger Fouquet, Peter J.G. Pearson (Eds.), Energy Policy 50 (2012) 1–149 (In this Special Section of the journal papers by the following authors are of particular relevance: R. Fouquet and P. Pearson; A. Grubler; R.C. Allen; B. Turnheim and F.W. Geels; P. Rutter and J. Keirstead; C. Wilson; S.J. Bennett; and P. Pearson and T.J. Foxon).
[14] (a) R. Ayres, V. Voudouris, The economic growth enigma: capital, labour and useful energy, Energy Policy 64 (2014) 16–28;
(b) T. Trainer, Some inconvenient theses, Energy Policy 64 (2014) 168–174;
(c) M. Jefferson, There's nothing much new under the Sun: The challenges of exploiting and using energy and other resources through history, Energy Policy 86 (2015) 804–811.
[15] Charles Hall, et al., The need to reintegrate the natural sciences with economics, Bioscience 51 (8) (2001) 663–673.
[16] Benjamin Sovacool, Energy studies need social science, Nature 31 (July) (2014) 529–530.
[17] Michael Jefferson, Closing the gap between energy research and modelling, the social sciences, and modern realities, Energy Res. Social Sci. 4 (2014) 42–52.
[18] Arnold Mitchell and Duane Elgin Voluntary Simplicity, 1974, June, Stanford Research International, Menlo Park, California (Report No. 1004). See also: Duane Elgin and Arnold Mitchell: Voluntary Simplicity, 1977, *The Co-Evolution Quarterly*, 1977, Summer; Duane Elgin: Voluntary Simplicity: An Ecological Lifestyle that Promotes Personal and Social Renewal, 1981, William Morrow, New York. A second revised edition of Duane Elgin's book, with the

sub-title: Toward a Way of Life that is Outwardly Simple, Inwardly Rich was published in 2010.
[19] Richard B. Gregg The Value of Voluntary Simplicity, 1936, Pendle Hill Essays No. 3, Pendle Hill Quaker Center for Religious and Social Study, Wallingford, Pennsylvania.
[20] H.H. Lamb, Climate, History and the Modern World, second edition, Routledge, London, 1995 (page xxiii).
[21] David Howell, Empires in Collision: The Green versus Black Struggle for Our Energy Future, Gilgamesh Publishing, UK, 2016.
[22] Harrison Brown, The Challenge of Man's Future, Viking Press, New York, 1954.
[23] Rachel Carson, Silent Spring, Houghton Miffin/Riverside Press, Cambridge, Massachusetts, 1962.
[24] Donella H. Meadows, et al., The Limits to Growth, Earth Island/Potomac Associates, London, 1972.
[25] Editors of 'The Ecologist': A Blueprint for Survival, 1972, Penguin Harmondsworth, UK.
[26] Barbara Ward, Rene Dubos, Only One Earth: The Care and Maintenance of a Small Planet, Andre Deutsch, London, 1972.
[27] E.F. Schumacher, Small Is Beautiful: A Study of Economics as If People Mattered, Blond and Briggs, London, 1973 (and paperback edition by Penguin, Harmondsworth, UK, 1973).
[28] Robert U. Ayres, et al., Economics and the environment: a materials balance approach, Resour. Future (1970).
[29] Nicholas Georgescu-Roegen, The Entropy Law and the Economic Process, Harvard University Press, 1971.
[30] Howard T. Odum, Environment, Power and Society, John Wiley & Sons, New York, 1971.
[31] Piotr Kapitsa, Physics and the energy problem, New Sci. 72 (1976) 10–12.
[32] Charles A.S. Hall, et al., Energy and Resource Quality: The Ecology of the Economic Process, John Wiley & Sons, New York, 1986.
[33] Charles Hall, Kent Klitgaard, Energy and the Wealth of Nations: Understanding the Biophysical Economy, Springer, New York, 2012.
[34] (a) Charles A.S. Hall, et al., EROI of different fuels and the implications for society, Energy Policy 64 (2014) 141–152;
(b) Jessica Lambert, et al., Energy, EROI and quality of life, Energy Policy 64 (2014) 153–167.
[35] Vaclav Smil, Energy in World History, Westview Press, 1994.
[36] Vaclav Smil, Cycles of Life: Civiliztion and the Biosphere, Scientific Library, New York, 1997.
[37] Vaclav Smil, Energies: An Illustrated Guide to the Biosphere and Civilization, MIT Press, 1999.
[38] Vaclav Smil, Energy at the Crossroads: Global Perspectives and Uncertainties, MIT Press, 2005.
[39] Vaclav Smil, Global Catastrophes and Trends: The Next Fifty Years, MIT Press, 2008.
[40] Vaclav Smil, Energy Myths and Realities: Bringing Science to the Energy Policy Debate, AEI Press, 2010.
[41] Vaclav Smil, Energy Transitions: History, Requirements, Prospects, Praeger, 2010.
[42] Vaclav Smil, Power Density: A Key to Understanding Energy Sources and Uses, MIT Press, 2015.
[43] Charles McCombie, Michael Jefferson, Renewable and nuclear electricity: comparison of environmental impacts, Energy Policy 96 (2016) 758–769.
[44] Michael Jefferson, A renewable energy future? in: Roger Fouquet (Ed.), Handbook on Energy and Climate Change, Edward Elgar Cheltenham, UK, 2013, pp. 254–269.
[45] The New Solar Physics, in: John Eddy (Ed.), Westview Press, Boulder, Colorado, 1978 (AAAS Selected Symposium No. 17).
[46] John A. Eddy, The maunder minimum: a reappraisal Sol. Phys. 89 (1983) 195–207.
[47] Jean M. Grove, Little Ice Age, Methuen, 1988.
[48] Rudolph Kippenhahn, The Star by Which We Live: Discovering the Secrets of the Sun, Wiley, 1994.
[49] Nigel Calder, The Manic Sun: Weather Theories Confounded, Pilkington Press, 1997.
[50] Douglas V. Hoyt, Kenneth H. Schatten, The Role of the Sun in Climate Change, Oxford University Press, 1997.
[51] Willie Wei-Hock Soon, Steven H. Yaskell, The Maunder Minimum and the Variable Sun-Earth Connection, World Scientific, 2003.
[52] Henrik Svensmark, Nigel Calder, The Chilling Stars: A Cosmic View of Climate Change, Icon Books, 2007 (2nd Edition, 2008).
[53] Richard Cohen, Chasing the Sun, Simon Schuster, London, 2010.
[54] Nils-Axel Morner, The approaching new grand solar minimum and little ice age climate conditions, Natural Science 7 (2015) 510–518.
[55] I.G. Usoskin, et al., Grand minima and maxima of solar activity: new observational constraints, Astron. Astrophys. 471 (2007) 301–309.
[56] Michael Jefferson, Climate Economics: the literature and its utility, in: R. Ragiani (Ed.), International Seminar on Nuclear War and Planetary Emergencies: 45th Session, World Scientific, Singapore, 2013, pp. 141–159.
[57] Mike Hulme, Moving Beyond Climate Change, Environ. Mag. 52 (May/June (3)) (2010) 15–19.
[58] Mike Hulme, Why We Disagree About Climate Change: Understanding Controversy, Inaction and Opportunity, Cambridge University Press, 2009.