



Perspective

A History of Energy and Societal Scenarios for a World in Transition: Fifty Years of Personal Experience with Shell and Other Organisations

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ABSTRACT

No-one can foresee the future with certainty. However, the development and use of alternative scenarios can help to highlight opportunities and challenges, greater or lesser realism, physical and technological options and barriers, and compatibility with other goals of sustainable development. Imagining and assessing relevant scenario elements ideally requires putting together small multidisciplinary and multi-talented teams.

Over the past fifty years Shell's scenario work has envisaged energy transition – in 1971 towards greater reliance on nuclear and coal, from 1973 in response to ecological concerns, and from 1974 exploitation of solar energy resources as the single most promising 'new' renewable source. Hydro and hydrogen also got a mention. By 1977 particular emphasis was being placed on solar PV, while enthusiasm for coal was waning by 1975 and support for nuclear more equivocal by 1976 and withdrawn by Shell in 1978 due to the long lead times involved. In the 1977 scenario books wind, wave, ocean thermal, and biomass sources were also considered. Then in April 1986 a study of "The Greenhouse Effect" was first issued. The need to balance growing environmental concerns while providing energy services to meet increasing world demand became a growing concern.

From this concern flowed support for the rapid expansion of the availability and use of renewable forms of energy in some quarters, but scepticism in others - reflected in the scenario books issued in 1975 and 1976. This apparent scepticism reflected concerns about 'new' renewable forms of energy being insufficiently effective due to their low power density and issues of intermittency and needed storage, rather than opposition to transition in principle, despite likely impacts on oil demand. Interest in investigating the potential of the main forms of renewable energy and their scope for energy transition continued.

Here is considered the relevance of past scenarios, particularly those produced by Shell, but also the World Energy Council, UNDP, the IPCC, and others with which the author has had an involvement over the past fifty years. A list of scenario reports, related publications, and suggestions on what knowledge and skills are likely to be helpful for those involved with energy scenarios, are provided in the Annexes. It is concluded that seeking to consider a wide range of possible opportunities and threats incorporated into alternative scenarios should be of great value for individuals, business corporations and society. However, the history of the use of past scenarios is mixed: there are examples where signals were heeded, and others where they have not been – yet.

1. Introduction

It is over fifty years since I first came across the concept of producing alternative scenarios in order to improve the capacity of organisations and individuals to prepare for an uncertain, and often unknowable, future.

In my case this was due to working with Sir David Barran, Chairman of the Shell Transport and Trading Company from 1967 until 1972, and Chairman of the Industrial Policy Group from 1969 until 1972. I was

Deputy Director of the Industrial Policy Group at the time. For reasons I never fully understood Sir David got involved with a new European Economic Foundation and asked me to assist - which resulted in the two of us having many discussions on oil industry matters, Middle Eastern affairs, economic issues and geopolitical pressures, and other issues current at the time, while we travelled around mainland Europe. My own background was a bit unusual. My Father had worked in Bahrain and in the oil industry. He worked after retirement from the Bahrain Petroleum Company in the industrial relations field with a group of

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former Palestinians who had a consultancy in that field. My own history covered a miscellany of things from economics, industrial and social history, and a close interest in oil and Middle Eastern affairs (from 1955), to weather and climatic change (also from 1955), and pandemics (since experiencing the Asian flu pandemic of 1957/58). Sir David had worked in the Middle East, and with the Tehran Agreement and growing concerns about what might subsequently evolve, it was not surprising that we would discuss OPEC, oil availability and prices, and possible oil supply disruptions intensively. It later emerged that Sir David had signalled to relevant colleagues that he wished me to be invited to join Shell as its Chief Economist and a member of its scenario group whose work had been developing since 1968 under the guiding hand of Jimmy Davidson as Head of Group Planning. Sir David's signal had been passed on to his successor as Chairman of Shell Transport and Trading, Frank McFadzean, who had also joined the Industrial Policy Group. When I let it be known that I was considering leaving that Group I was offered the post of chief economist and joined Shell in January 1974. The Yom Kippur or October War of 1973 had only just ended, supply embargoes were still in place, and things had turned out pretty much as I, and Sir David, had expected. The oil price rise was in line with what we had anticipated, so higher than many had considered likely, while real GDP and inflation rates were hit more severely than Shell's Operating Companies had anticipated. Even those OPEC Member countries which emerged with large "surplus" oil export revenues had no serious problems in recycling them, contrary to what many in Shell (including my non-economist scenario team colleagues) and elsewhere seemed likely.

Many issues emerged as a result of this hiatus. Shell's ability to draw on the concept and application of alternative futures in order to understand and cope with an unknown future was a huge advantage. In the last few months of 1971 Sir David had discussed with the UK's Prime Minister some of the original scenario work within Shell. This was, and has long continued to be, very wide ranging. The focus here is on energy transitions - especially transitioning from heavy global oil and coal dependency to other forms of affordable and cleaner energy forms required to provide needed or wished for energy services. Nevertheless, when focussing on energy transitions it is important to remember that they link back and forward to a multiplicity of geopolitical, economic, social and ecological factors. Arriving in Shell fifty years ago I quickly became familiar with some new terms: among the broad background factors were those already "in the pipeline" and therefore "pre-determined elements"; a number of these were potentially significant "building blocks"; one could refer to "subjective probability" as distinct from the statistical; and "those who foretell the future lie, even when they tell the truth". But there were some important elements which were understated in Shell's corporate and planning perceptions of the economic consequences following the Yom Kippur War despite the earlier (May 1973) appearance of a single scenario warning of challenges in the pipeline.

This paper is the account of the author's fifty years of personal experience with scenarios, first when responsible for covering economic, geopolitical and societal aspects in Shell International's Group Planning scenario team; then over ten years in planning, oil supply, and trading posts; ten years as Deputy Secretary-General of the World Energy Council; and then, rather more remotely, as a consultant and finally as an academic over the past fifteen years. Along the way there has been relevant involvement with various international (including several UN) organisations, and the Intergovernmental Panel on Climate Change. Over this fifty-year period a large number and wide variety of major concerns and themes have come up, which to maintain chronological order are picked up here as they occurred rather than placed under specific topics. These are, of course, my personal memories and reflections which, as will occasionally be mentioned below, differ from some others involved.

2. The early energy scenarios (1971–1990)

Shell's interest in the use of scenarios had been spurred on by the

work of Herman Kahn and the Hudson Institute, which Ted Newland got closely involved in as a Shell executive from 1968 working with Jimmy Davidson. They were joined from Shell Francaise by Pierre Wack in 1971, whose presentational skills were formidable but whose absorption of more pessimistic views of economic and social elements were less evident. Pierre and other early scenario team members are briefly described in Chapter 5 of Thomas Chermack: "Foundations of Scenario Planning: The Story of Pierre Wack" [1]. With all the uncertainties emerging in the global oil sector, especially in North Africa and the Middle East from the later 1960s, it had become clear to senior Shell personnel that the development of scenarios could play an important role, although energy was not a field in which the Hudson Institute could offer much.

The central purpose of developing and detailing scenarios was to help Shell employees think creatively about both potential opportunities and threats for Shell's businesses. They were not predictions but were intended to be plausible. Unlike the then standard forecast-based projections common at the time, and which still continue in some quarters, they were innovative "exploratory scenarios". The year 1971 had begun in the January with Shell producing: "A Probabilistic Approach to the Forecasting of Upstream-Government Take on Crude Oil Exports" which, though having a section on "The Technique of Scenario-Writing" and referring to "subjective estimates" apparently could not conceive of oil prices rising above US\$ 2.75 per barrel by 1975 (or \$3.50 by 1985!). Sir David Barran had asked Shell's Group Planners the question: "What will oil prices be in the longer-term after expiry of the Tehran Agreement in 1976?" It was only later that I discovered this, having given Sir David my best guess of \$10–\$12. As far as energy transition was concerned, there was reference to "the discovery and active development of a cheap new energy source" but this was not specified and was regarded as having only a slightly rising likelihood in the period to 1985. There was also mention of electric vehicles emerging in Western Europe and Japan.

During 1971 and 1972 more scenario work was done, but even the January 1973 scenario book: "Scenarios for 1973 Planning Cycle" still only had crude oil prices rising to \$6.15 per barrel in the highest scenario – the "Energy Crisis". There was, nevertheless, a clear indication of concern about what might happen in that January 1973 book. Its aim was "to define a number of different futures which the oil companies may have to face and to provide sufficient detail to enable strategies to be developed so that a company such as Shell can adapt itself to survive in a wide range of futures" (page 5). Discontinuities in oil price and its availability were expected to take place before 1980 in the three 'A' scenarios (page 9).

Things were indeed about to change quickly. In May 1973, Shell's Group Planning team issued: "The Impact on the World Economy of Developments in the Market for Oil", in which a single scenario was proposed that "merits particular attention because it involves a threat to the well-being and progress of the industrialised world." The authors (it was largely written by Guy Jillings) accepted this was "an extreme assumption" but urged governments to direct their urgent attention to the potential issues of energy policy involved. This 38-page document led on to the introduction of two long-term scenarios – World of Internal Contradictions and A New Belle Epoque – in the 100-page report: "Scenarios for the 1975 Planning Cycle" issued in October 1974. Here was introduced 'the Rapids' – a term conjured up by Gareth Price to flag the expectation that the world was headed for a period of major turbulence [2]. The "New Belle Epoque" scenario was taken seriously by Pierre Wack and Ted Newland, the rest of the scenario group were more sceptical, believing the "World of Internal Contradictions" provided a more realistic scenario. This reference to a "New Belle Epoque" tried to hark back to that period between 1875 and 1905 when Europe appeared to enjoy peace, prosperity, and great European (especially French) influence. The majority of us in the scenario group saw no – or few – grounds for such optimism, being aware of clouds gathering much as they had a century earlier.

I regarded the GDP and inflation estimates circulating in January

1974 as over-optimistic and did not hesitate to point this out. Most of the scenario group were very mindful of Gro Harlem Brundtland's World Commission on Environment and Development's urging in "Our Common Future" of the need for a global agenda for change, and proposal back in 1967 for long-term environmental strategies for achieving sustainable development by the year 2020 and beyond. It had been followed in 1972 by the desperate messages in "A Blueprint for Survival" of what was needed if the world was to survive much beyond the year 2020.

Already the scenario work had begun to influence decisions relating to Shell's energy strategy, though not quite in the direction many might have expected. One of the 1971 scenarios, Scenario IV, had been entitled "Other Energy-Intensive Scenario". This envisaged a greatly increased share of global energy supply coming from coal and nuclear energy, largely reflecting a lower demand for energy to provide required services (22% lower than in two of the other scenarios, and 15% lower than in the fourth) [3]. The "required services" from energy included heating, cooling, lighting, cooking and mobility. The January 1971 scenario book had considered that higher oil prices would encourage a range of fossil fuel resources to come on stream, especially coal, but also nuclear – which led to the costly 50% purchase in 1973 by Shell of Gulf General Atomics, which had a high temperature gas-cooled reactor. In 1981 Gulf bought out Shell's interest, the latter having concluded that it could not be constructed profitably at realistic prices. Jimmy Davidson later recalled the work of Ted Newland and his close colleagues had "resulted directly in the Group's investment in the fields of coal and nuclear." Even in 1971 there were some others who perceived clear warnings that lengthy construction and other lead time issues existed for nuclear, as well as safety and grid integration ones. The environmental and health hazards of coal exploitation were also obvious to some of their colleagues. Differences of view are, of course, endemic in human nature. However, electric vehicles did make a one-sentence appearance.

Attitudes towards environmental concerns and their implications for an energy transition also varied, with some highly sensitive to the need to address environmental issues and others less so. There is a first mention in the January 1973 scenario book of "efforts to improve the ecological environment" which assumed "this would contribute to the overall level of economic activity" (page 11), whereas the May 1973 scenario book referred to "assuming the environmental lobby is successful in insisting on high cost and energy wasting measures to overcome pollution, much of it from energy sources". Although the overall costs were deemed like to be relatively small as a proportion of future Gross National Product: "Nevertheless it would represent a very considerable deployment of resources" (page 34). This was a reference to the obvious fact that although a small percentage of Gross National Product energy supplies and usage are crucial for the workings of whole economies. Brief references to ecology and environmental concerns rumbled on too, though briefly, suggesting that at least some of the scenario group considered these were unlikely to go away. Views were divided on the extent to which "voluntary simplicity" would be acceptable to the majority of the world's people or even those in the more prosperous economies.

Shell's October 1974 scenario book: "Scenarios for the 1975 Planning Cycle", had provided the view that "hydroelectricity, geothermal, and solar energy etc." would expand, but only with an expectation of a *maximum* (stress as in the original) availability of 10–12 million barrels of oil equivalent - roughly 12–14% of total world primary energy demand in 1973 (page 5). In terms of electricity generation, however, the prospects for non-fossil fuels were considered more promising, rising from an estimated 30% in 1973 (of which nuclear contributed only 4%) to 45% in the World of Internal Contradictions scenario and 42% in the Belle Epoque by 1980.

Looking beyond 1990, however, the scenario book referred to solar energy as representing "a further vast energy resource, of which the surface has been barely scratched. Various pilot schemes exist for collecting and utilising solar energy, particularly for space heating and

cooling" (page 42). Hydro-electric power received the largest coverage in space terms of the renewables mentioned in this scenario book, followed by geothermal energy, but even hydrogen got a brief mention (page 87). This focus on non-oil sources of energy was promoted primarily because of concerns about the reliability of oil supplies and their cost (further oil supply embargoes might occur in future) rather than about remaining reserves (the scenario team considered descending "the Oil Mountain" from its "Peak" was unlikely to begin until early in the 21st century).

In June 1975 the focus returned once more to the next five years with: "Scenarios for 'The Rapids' 1975–1980" which admitted that the world, or at least Shell, could be in for a disappointment with "Alternative Energies are Stagnant" (page 17). The thinking behind this was that "the alternative energy programmes consist largely of empty words and paper tigers." Nuclear plants were being deferred or cancelled and little had been done in the coal sector, facts far removed from the expectations "in the dark days of the oil embargo"! There had been a return to optimism about sustained recovery in Shell's markets, and this particularly began to influence its chemicals sector where a major expansion of investment to meet demand recovery was considered. In meetings with Shell International Chemicals planners I was able to convince them that the encouraging signs were down to inventory recovery and not general market recovery, a view assisted by work on the medium-term scenarios.

In January 1976 "Scenarios for the Eighties – An Update" appeared, and with it a further signal that enthusiasm for nuclear might be fading in some quarters. Although nuclear "is expected to approach 50% of electricity generation by 1990" there was also "a 'nuclear disappointment' case (which) is considered to reflect increasing doubts about the success of nuclear programmes." But in the latter case the "demand for oil and especially coal would be considerably higher" (page 1). The book admitted that: "Solar energy, and other 'exotics' (sic) would be increasingly introduced in the 1980s but were not expected to exceed one million barrels of oil equivalent per day before 1990" (page 16).

The May 1976 scenario book, "Scenarios for 'The Rapids' – A Review", maintained the optimistic view of nuclear energy's prospects – increasing by a factor of three by 1980 (page 26), although it cautioned that the high growth rate assumed "automatically makes the projections extremely sensitive." It was at this time that Pierre took up with enthusiasm the notion of "Voluntary Simplicity" which had emerged at the Stanford Research Institute under the directorship of Willis Harman, among whose colleagues was Peter Schwartz. I was familiar with the concept, which Richard Gregg had come up with in 1936 but reflecting a far longer history among a select few. My own view was highly sceptical of the real value of the concept for scenario purposes. For me the *Jeavons' Paradox* or 'rebound effect' was likely to be of much greater relevance for scenario planning in the energy field. (*Annex II to this paper provides further details.*)

Then in January 1977 came: "Exploratory Scenarios for the Long Term", which had a corporate and business environment planning horizon of the year 2000. There, solar PV was considered the most likely of the non-oil energy sources to challenge nuclear and coal, but the rate of change would not be high enough to have a major impact before the first few decades of the 21st Century (page 33). This was despite the view that solar PV was the only non-oil source of energy expected to show a steeply falling cost curve in suitable locations. Solar PV costs, it was suggested, might only be 10% of 1985 levels by the year 2000 (US\$ 12–40 per barrel of oil equivalent in 1976\$). On the same page appeared some ideas of costs for other renewable energy sources: ocean thermal and wave power (\$60) and wind for electricity generation (\$50). Biomass also got a mention in the context of thermal energy, with costs offered of \$40 derived from energy crops and \$50 derived from straw. Solar energy was referred to as the major challenger in 'decentralised' systems which emphasised community and individual supply – but not local solar insolation levels (page 33).

The next scenario book for the 'Rapids' appeared in May 1977, and

noted that: “Like Shell, a number of companies are interested in the development of solar energy, notably Exxon, Mobil and (the French company) CFP” (page 43). No mention was made of BP, which was to make a major effort in Spain before retreating. Nowhere in any of Shell's scenario books was there mention of the Desertec concept of transmitting solar PV generated electricity from North Africa to Western Europe by high voltage direct current transmission lines. This idea had emerged from the German Space Agency in the mid-1950s but, after much talk, suffered a severe blow with the Arab Spring of December 2010–December 2011 and its aftermath.

In June 1978 appeared: “Scenarios for the Next Five Years: 1978–1983”, where it was concluded that significant advance of nuclear programmes was infeasible due to its long lead times. Hydro-electric power again got a mention, but this time the stress was on its deviations due to variable precipitation levels. For the careful reader, however, something much more important was afoot: a political ‘accident’ such as a coup d'état in Saudi Arabia or Iran. Here was the beginning of a leak to a wider audience of my hunch, suddenly hitting me during a trans-Atlantic flight in March 1976, that opposition to the Shah of Iran would eventually lead to his overthrow. This hunch, for that was all it was despite reports of unrest in Abadan and elsewhere exacerbated by violent countermeasures, failed to gain support from other members of the Shell scenario team with the sole exception of Hans DuMoulin, who headed the energy analysis side [4]. Despite the warnings, and likely repercussions of major oil price hikes leading to severe disruptions and then oil price falls as economic recessions took hold, only Hans was on side. He and his co-author, John Eyre, hinted at trouble ahead in a paper published in *Energy Economics* in April 1979 not considering it wise to point their fingers solely at change in Iran [5]. Hans, as well as some other experienced oil sector colleagues, were also aware that crude oil supplies were finite, and were familiar with the work done by M. King Hubbert (a former Shell Oil employee) on “the oil mountain” although they had a much longer time perspective on potential crude oil supplies.

Shell's two most senior scenario planners, Pierre Wack and Ted Newland (both of whom retired in 1982) failed to take due notice of the emerging risks of Middle East instability, oil price rises and their effects on oil-importing economies. They did not prepare soon enough for the consequences of a later oil price collapse [6]. Art Kleiner was to head a published paper: “The Man Who Saw the Future” about Pierre Wack, but this regrettably had proved not to be the case [7]. Both Pierre and Ted were incorrigible optimists in their planning contributions, and Pierre at an early stage had taken up the idea of a coming New Belle Epoque from Willis Harman at the Stanford Research Institute. Ted quickly followed as Tom Chermack has recalled [1]. Many others were surprised by the events that followed the Shah's demise. Five years of more pessimistic economic, geopolitical, and societal assessments by at least three of their Group Planning colleagues had been either ignored or belatedly accepted. As former Group Planning Coordinator Jimmy Davidson put it in an email to the author: “It is very good that you have drawn attention to the fact that although Pierre was a wonderful presenter, and simulator of his people, this was not a one man show and credit should be given to those who were doing all the research and a lot of the thinking. It was unfortunate that Pierre was not given to lavishing praise on the contributions by his staff” (Email of November 28, 2011). Jimmy was referring to [4].

I felt it was time to make a move, having greatly enjoyed over five years as a participant in scenario development at the centre of Shell. Hans DuMoulin and Gareth Price appeared to be the only colleagues sympathetic to the idea that what Amory Lovins at the time referred to as a “Soft Energy Path”, replacing coal and “forestalling” nuclear, was desirable even if the journey was likely to be much harder and longer than Lovins thought [6].

Three of my colleagues in Shell's central scenario planning group had been involved with the Workshop on Alternative Energy Strategies, a project sponsored by the Massachusetts Institute of Technology (and

initially also Churchill College, Cambridge, UK), which reported in 1977 (“Global Prospects 1985–2000”). They were Hans DuMoulin, Gareth Price, and Alan Clarke, and the project was supported professionally and financially by Shell International Petroleum Ltd. and the Royal Dutch/Shell Group. The final report considered that, other than hydroelectric power, renewable energy resources (solar, wind and wave power were mentioned) were unlikely to contribute significant quantities of additional energy during the 20th century. “They are likely to become increasingly important in the 21st century” (page 3).

There were many other examples of scenario group members liaising with people in other organisations – UN agencies, the International Energy Agency, national governments, and academic specialists – not just in the energy field (climate research was just one of several). Perhaps one of the most telling had come in March 1975 when my Shell colleague Guy Jillings and I visited the then US Federal Energy Agency in Washington, DC. The visit had been arranged for us by Shell's associate company in New York, Asiatic Petroleum. We arrived about 10.00 am and were ushered into a small office close to the reception desk. It had no curtains, and the carpet covered only part of the floor. This was not a good sign, but the Federal Energy Agency employee quickly asked if he could make a telephone call. We did not object, of course. He spoke to a senior colleague explaining we had not come up from Houston seeking a Federal Government subsidy. We wished to introduce Shell's latest global scenarios. We were asked whether we could come back that afternoon. We could. We were then ushered through double doors into a large auditorium, where nearly 250 people had been got together – in the space of about 4 h. They listened with close attention. The Shell scenario team also had a major influence on corporate decisions in the company's oil refining, chemicals, and some other fields – but mainly, in my experience, to cool ill-founded optimism for heavy investment because prospects were considered less than propitious.

I moved to Shell's mainland European Organisation, based in The Hague, in April 1979 where the responsibility was appraisal of short-term future oil supplies and prices, to which more general planning was soon added. In that latter capacity there was responsibility for the generation of scenarios, each of which – helped by what had occurred over the previous three or four years and their likely repercussions – covered the oil price rise and expected (by me) subsequent fall. A Shell Europe ‘Hard Times’ scenario was issued in November 1979, giving central focus to the implications for Shell's business in the region of the sharp oil price rise and anticipated eventual fall in oil prices before their subsequent modest recovery – a pattern which was reflected in events over the next seven years. In March 1981 Shell's Group Planning also issued a scenario named ‘Hard Times’, although the previous April they had issued two ‘Crisis’ scenarios – one ‘Manageable’ the other ‘Unmanageable’ – as well as ‘Fragile Accommodation’ and ‘OPEC Compromises’.

It was also in 1981 that I came across the name Professor Bert Bolin, who was to become the first Chairman of the Intergovernmental Panel on Climate Change, during a visit to Sweden (I was responsible for oil supply and trading for Svenska Shell from March 1982 until August 1984). Shell had helped fund a SCOPE Workshop in Germany in 1977, the results of which were published in 1979 as: Bolin, B. et al. eds.: “The Global Carbon Cycle” with a wide-ranging review of the topic by Professor Bolin and three colleagues. Nevertheless, and not surprisingly, the focus of Shell's scenarios in the early 1980s was primarily on oil demand, supply and prices as they might impact on Shell's business and customers, rather than climatic change, although from the mid-1980s this was to shift.

For those with a broader interest in scenarios and their practical value, it may be worth mentioning that in the 1980s they proved very helpful to me while occupying five different posts. In 1981 Shell's oil refining business planners were being encouraged by their senior management to provide the rationale for expansion. I was able in the European planning role to discourage this (successfully) based on the “Hard Times” scenario. Providing crude oil supplies for Shell's refinery

in Sweden the scenario work provided much of the rationale for switching crude oil supplies from Soviet Russia, as they would advance or delay arrival of tanker cargoes of their Soviet Export Blend depending on whether they thought prices were about to rise or fall regardless of our refinery schedules. Brought in at short notice to address the problems which Shell's bitumen business in the UK was experiencing due to the age and condition of that part of its Stanlow refinery, scenario elements were found relevant to exiting that part of the business. In seeking to assess oil price movements as they collapsed at the end of 1985 and began to recover in third-quarter 1986 (Shell International Petroleum Supply & Marketing: "Oil Review: 1986–1990", February 1986) the elements of the "Hard Times" scenario were highly relevant. This concern with oil price movements was due to their implications for Shell's competitiveness and customers' demands. In planning for Shell UK in the late 1980s a longstanding interest in potential climatic change and relevance to scenario thinking also proved highly relevant, in which I was enthusiastically joined by my colleague Mark Scott.

By 1986 longstanding worries about the effects of 'acid rain' had been added to by widening concerns about 'greenhouse' gases and their potential implications for climatic change. An 87-page internal Shell study: "The Greenhouse Effect" was initially completed on 28 November 1985, with further work reported on the following April and wider circulation given in May 1988. On page 18 of the latter overall energy (or power) density was highlighted as an important variable seconded by competition between different fuels.

These issues and others were highlighted in a two-volume report by Shell UK: "Towards 2010: Scenarios for the long-term UK business outlook" issued in October 1986. It was stated: "Some minor contributions from 'renewable' energies may occur, probably in a higher energy price scenario" (Volume 1, page 86). Wind power was "likely to make a small, but growing, contribution by the end of the scenario period." There was also reference to a Severn Barrage, an idea which I had followed the history of, and the often rather dubious support it has been given over the years – ever since 1849.

More significantly, a whole section of Volume 2 was given over to "Weather and Climate Change" where the outcomes of the 1985 World Meteorological Programme Conference were summarised. The Shell UK scenario book focussed on what it considered as indicating the then current consensus of scientific understanding and some of its implications. It was a field that had long been of interest, ever since my boarding school days when for a time I would check the weather recording instruments early every morning. I still have on my book-shelves books on the history of climate acquired during that Autumn term of 1955. Interest in this subject resulted in invitations to join lunches in Shell Centre with the well-known meteorologist Professor Hubert Lamb in the 1970s and working with some of his colleagues at the Climate Research Unit, University of Anglia, in the early 1990s. It also led to my involvement with the Intergovernmental Panel on Climate Change from 1991 to 2015 in various roles. This knowledge and experience have proved very helpful over the years.

Over the period 1987 to 1990 climatic change and the extent to which non-fossil fuels (particularly renewables) would emerge to become major sources for needed energy services attracted the attention of Shell's planners, both at the centre and in some Operating Companies. By October 1989 there were two conflicting Group Planning scenarios: "Global Mercantilism", in which economic concerns would be given priority, and "Sustainable World", where environmental pressures would lead to industry restructuring. This publication coincided with Shell UK's November 1989 report: "UK Scenarios: Has The Biggest Challenge Begun?" which gave more weight to the "Sustainable World" scenario and "the importance and fragility of the global environment" (page 4).

There were some clear messages being publicly expressed, such as: "the 'sustainable world' view presumes that global environmental issues will be on the international agenda by the mid-1990s." This was in Ged Davis' article in *Scientific American*, Ged being head of energy in Shell's

Group Planning at the time [8].

These issues also led to some practical research on my part. In the UK, for instance, there was interest in checking the wind sector as some (but not all) of the country experienced relatively high mean wind speeds. Every actual and planned onshore wind energy development in England, Wales and most of Scotland was visited and its likely contribution assessed (the location, windspeed maps if available, model of turbines installed or planned, and likely load – sometimes referred to as capacity – factors estimated). Other potential renewable energy sources were also considered – and background details relating to a potential Severn barrage, its history and tidal barrage schemes elsewhere (in France at La Rance, and in Canada), potential geophysical schemes in Cornwall, and the Desertec solar idea, examined. Concepts such as Betz's law, intermittency, solar insolation, load (or capacity) factors, and power densities were explored.

As the 1980s were ending Shell warned in a Selected Paper that global warming had been identified as "a vital challenge to policy-makers", though a number of other challenges also had to be addressed [8]. This was a period when Shell began to undertake country and regional focussed scenarios. The Chinese, Indian, and some Latin American economies were growing. At the country level, in November 1989 Shell UK Planning issued: "UK Scenarios: Has The Biggest Challenge Begun?", where it was stated: "The global context of the greenhouse effect in particular will require global institutions and remedial action" (page 4). The report considered: "The key issue is the action required to make economic development sustainable", and "concerns about global warming and depletion will depress production of fossil fuels, their market share declining as renewables are actively promoted" (page 34). Among the implications were: "electricity looks towards conservation and renewables rather than large new greenfield projects or refurbishment of existing stations" (page 6). The concerns would be multiple, and "extend to the appearance of the countryside".

It was time to move on, but a scenario related job was not on offer. The two posts within Shell I was offered did not seem to be a good match as far as I was concerned (heading up crude oil acquisition in Nigeria and No. 2 for Shell International's public relations department) and, therefore, when I was approached to become Deputy Secretary-General of the World Energy Council on secondment from Shell I accepted with alacrity.

3. Scenarios for international organisations 1990–2000

Shell continued to engage in scenario development, by which time I was an external observer though in regular contact with some of Shell's scenario planners and a reader of their ongoing work. Building on the 'Global Mercantilism' and 'Sustainable World' scenarios of three years earlier, the 1992 Shell Group "Global Scenarios 1992–2020" were produced in the wake of the break-up of the Soviet Union. I participated in the prior discussions having recently been in Russia, Kyrgyzstan, and Uzbekistan.

Liberalisation was considered to lead either to 'New Frontiers' and faster growth in energy demand or a more divided world in which the poor are marginalised, markets constricted, and energy markets were constrained or threatened by crisis such as another Middle East one. This scenario was named 'Barricades'. Although in 'Barricades' some countries might mandate accelerating the introduction of electric vehicles, it was in 'New Frontiers' that: "By 2020, in many places it is possible to generate electricity more cheaply through photovoltaics and other renewable sources than from fossil fuels." But there was a warning: "Global agreements on environmental issues are both more necessary and harder to achieve, in part because developing countries argue that they should be allowed a fair chance for economic development before being burdened with international standards" (page 8). This view was to receive confirmation in the run-up to, and Chairman Estrada's handling of, the Kyoto Protocol sessions in 1997 [9]. The Shell Group scenarios for 1995–2020, 'Just Do It' and 'Big Me' (translated from the Chinese 'Da

Wo') seemed to have less energy transitions related content in them than usual, but Shell's summary version may have missed some relevant detail available in the original two-volume report, although there was a reference to declining energy intensities (page 11).

Shell's global scenarios for 1998–2020 were named 'The New Game' and 'People Power'. In 'The New Game' "Kyoto works" with consensus about the environment (pages 14–15). In 'People Power' the EU ratified the Kyoto Protocol but the USA did not. Among the results were increasingly effective NGOs and individual action targeting coal, oil, and car companies. Corporations came under closer scrutiny and encouraged to aim at higher standards; tougher action was encouraged against polluters, including drivers of gas-guzzling cars (page 23). This scenario book clearly had closer resonance with pressure for energy transition than its immediate predecessor.

Meanwhile, since 1990 I had been at the World Energy Council, where I was immediately plunged into the work of its Commission: Energy for Tomorrow's World – the Realities, the Real Options and the Agenda for Achievement. I wrote the final report, assisted by Michael Schomberg, on behalf of the Commission's 48 distinguished members [10].

The Commission's report had five items under an Agenda for Action:

1. The reduction of poverty by extending access to energy services, and by improving the efficiency and reducing the environmental impacts of its use;
2. Expanding the supply availability of acceptable traditional forms of energy and to diversify and increase the availability of non-fossil fuels;
3. Promoting technological innovation and its diffusion through raising efficiency in energy use, encouraging energy conservation, promoting international co-operation and effective government support;
4. Curbing harmful emissions from energy provision and use; and
5. Institutional change appropriate to global needs and local circumstances.

There were four energy 'cases', or scenarios. All four envisaged energy intensity reductions; increase in technology transfers; energy efficiency improvements; and institutional improvements. The Commission's Report stressed in its Foreword that it no more had a crystal ball which permitted it to foretell the future than anyone else.

Concurrently, the World Energy Council had a Renewable Energy Resources Committee at work. In 1994 its 379-page report: "New Renewable Energy Resources: A Guide to the Future" was published, jointly edited by Jack Darnell (USA) and me [11]. In the Foreword the editors mentioned that 80 specialists from many countries had contributed to the book which they claimed: "we believe represents a constructive, sympathetic, balanced, and realistic step forward in the technical, economic and environmental understanding of the place which these energy forms could occupy in the future." They added: "Inevitably, at this stage in the development of new renewable energy, there are areas of considerable uncertainty – not least in relation to future technological developments and costs."

Two cases were used ('Current Policies' and 'Ecologically Driven'), and the general tenor of the book was favourable to expanding the contribution of 'new' renewables with the main time horizon 2020. The intermittency of solar was covered (solar irradiance or insolation in rather surprising geographical detail). The availability of construction materials in solar PV systems was covered in the context of silicon but not more extensively, and more recent surveys would probably pay more attention to 'rare' earth metals. On wind energy the impacts on bird life, visual intrusion, telecommunications interference, and noise were covered, as well as some discussion of the wind energy resource (mainly by reference to the then available wind energy atlases), and load factors likely to be achievable.

Other chapters covered geothermal energy (rather optimistically), modern biomass (rather uncritically because it arguably understated the

potential adverse implications for food and water availability), ocean (tidal, wave and ocean thermal), and small hydropower. Tidal power, where it involved barrages and significant destruction of natural habitat, came under adverse criticism – directed at Canada's Bay of Fundy schemes (as they then were); the Severn estuary between England and Wales (where the promoters' motivations have been claimed to be solely financial); and France's La Rance scheme (which subsequent research found had adverse environmental consequences). Wave and Ocean Thermal were regarded as too immature to be worthy of serious consideration. The constraints to the development of small hydro were regarded as "numerous and challenging" (page 377). It was considered that under an 'Ecologically Driven' scenario total renewables (to include traditional biomass and large hydro) could account for 29.6% of total energy demand in 2020.

Various World Energy Council reports were published in the following five years – I wrote eleven between April 1974 and November 1998 on successive INC and United Framework Convention on Climate Change meetings with the support of some WEC colleagues and strong backing from WEC Chairman, 1995–1998, Sir John Baker; and on "Global Transport and Energy Development: The Scope for Change", 1998, for which I was Study Director, for example. The latter concluded that "for the next 25 years transportation energy use will continue to rise rapidly – a trend which is considered incompatible with many environmental protection objectives in the long-term" (page 43). These reports attracted strong support from many WEC national committees, but not from the US Energy Association, the WEC's US national committee, where organisations such as the Global Climate Coalition, the US Climate Council, and the American Petroleum Institute (in the person of William O'Keefe) were adversely and stridently critical without demonstrating awareness of the large body of WEC publications which had a different slant from theirs and had received general backing.

As Professor Bolin put it: "The World Energy Council, led by Michael Jefferson from the UK was another key international organisation that responded early to the potential threat of a human-induced climate change. Its attitude towards the issue was a much more constructive one" ([12], page 92). This attitude Professor Bolin differed specifically from two people he named: Donald Pearlman, of the US Climate Council; and John Shlaes of the Global Climate Coalition, both of whom had links to General Dick Lawson, President of the US National Coal Association ([12], pages 85, 92, 103, and 130).

Professor Bolin mentioned in his book the WEC's three scenarios in its 1993 Commission Report and subsequent work including scenarios taking possibilities out to 2050 and 2100 in collaboration with the International Institute for Applied Systems Analysis (IIASA). But he also mentioned that I was "sharply critical" of the first draft of the chapter on scenario development in the IPCC's 1994 Special Report and, Bert added: "admittedly the World Energy Council scenarios were more informative" ([12], page 93). As the WEC's Report No. 2: "Post-Rio '92 – Developments Relating to Climate Change" stated: "The WEC has made various criticisms of the IPCC draft reports received. However, in general these documents have so far been received on the basis of not being cited or quoted, and thus are not detailed here" (Report No. 2, page 7). In WEC Report No. 4: "Potential Climate Change", September 1995 I wrote that much of the IPCC's Second Assessment was "preliminary, non-original and rather academic in nature" so far as climate mitigation and adaptation were concerned, and contained "no new developments or insights, but also nothing to invalidate the need for precautionary measures satisfying a 'Minimum Regret' criterion" (page 16). Nevertheless, I added: "Our review does not in any way detract from the intrinsic value, high quality, and great interest of the IPCC's scientific work. Indeed, the contribution of Working Group I to the Second Assessment shows promise of being an outstanding contribution to our understanding of past and present climate and will help to shed light on future possibilities" (page 17).

Two World Energy Council reports were published after I had left the organisation with which I had been involved. In August 2001 there

appeared: “Energy Technologies for the Twenty-First Century”, a joint effort by IIASA and the WEC, directed by Nebojsa Nakicenovic. I was one of the Lead Authors along with Arnulf Grubler and several others. IIASA’s earlier links with the World Energy Council are referenced below. The key recommendation of the energy technologies report was that “energy RD&D spending and technology transfer needed to be increased in order to meet the requirements of those without energy services more quickly, and to provide the efficient, reliable and clean energy-related technologies which are required everywhere” (page 53).

The other World Energy Council (WEC) report referred to was: “Living in One World”, published in 2001, where the Chairman of the study was Sir John Baker, former Chairman and then Honorary Chairman of the WEC and I was the “Director of Study and Principal Author” (page 194). We had an effective set of Advisory Board and Study Group members. The book contained two scenarios: the threat of “An Unliveable World” and the hope of “A Liveable World”, the latter counting heavily upon renewable energy. The book also mentioned risk of future pandemics. In his Preface the then Chairman of the WEC, Jim Adam, stated that we had marshalled for attention a body of opinion “which represents the strongly held views of many members of the World Energy Council, but not all of them” (page 10). Jim Adam also stressed: “The challenge of renewable energy is that it tends to involve what we call low ‘energy density.’” Certainly “Living in One World” gave it insufficient attention. As a reviewer (Jefferson Tester) of Vaclav Smil’s book: “Power Density: A Key to Understanding Energy Sources and Uses”, 2015, remarked: power density is “often forgotten or neglected in making sound energy choices.” Others would highlight the importance of energy return on energy invested (EROI), given the relatively poor returns for most renewable forms of energy by comparison with the fossil fuels – though the latter have tended to decline in recent years.

Shortly before “Living in One World” had been published there appeared from the WEC: “Energy for Tomorrow’s World – Acting Now!”, 2000, a study intended to update the 1993 one. There was less optimism about technological advances to 2020 than there had been in 1993, and despite scenarios going out to 2050 and beyond the book did not reveal much about longer term aspirations or fears. The longer-term scenarios referred to were those which had been published in “Global Energy Perspectives”, 1998. The author had been closely involved with this project throughout 1998–1999.

The starting point for the WEC’s connection with IIASA had been the publication of the Commission’s Report: “Energy for Tomorrow’s World” in 1993. As Nebojsa Nakicenovic (hereafter Naki) pointed out in his Foreword to the 1995 WEC/IIASA Report: “Global Energy Perspectives to 2050 and Beyond”, IIASA and the WEC both then had a 20-year history in analysing potential energy futures. For IIASA this had begun with a paper by Wolf Hafele in November 1974: “Future Energy Resources”, which had been presented to the World Power Conference two months earlier. Hafele looked to nuclear, eventually nuclear fusion, and solar energy for the future. Then in 1981 Hafele as Programme Leader, led the publication of a two-volume work: “Energy in a Finite World: Path to a Sustainable Future”, of which Naki was one of the co-authors. These volumes were the product of IIASA’s Energy Systems Programme.

The WEC/IIASA Report: “Global Energy Perspectives to 2050 and Beyond” was directed by Naki and I was a member of the Steering Group and a co-author [13]. Six scenarios were presented, formal energy models were used to help analyse the implications of the scenarios, and the assumptions and findings of the 1993 WEC Commission Report were reviewed. Three scenarios covered High Growth cases; Case B was a single Middle Course scenario; and the Ecologically Driven Case C consisted of two scenarios. By 2050 renewables were projected to contribute 36% to 39% of global primary energy supply under the two Ecologically Driven scenarios; the contribution of renewables under the three high growth scenarios ranged from 16% to 30% by 2050; and in Case B renewables were projected to contribute 22%. Nuclear’s contribution under the various scenarios ranged from 4% to 12%, these boundaries reflecting the high and low in the two environmentally

driven scenarios. The logic behind the high growth scenarios was that all were technologically driven, with the largest expansion under scenario A3 reflecting the biggest switch to renewables aided by recourse to natural gas in the interim.

An expanded, but largely unchanged, version of this report was published by Cambridge University Press in 1998, edited by Naki, Arnulf Grubler, and Alan McDonald [14]. I was described as a Lead Author and member of the study’s Steering Group, but due to the onset of terminal illness of the WEC’s Secretary-General, Ian Lindsay, was probably generously so described as I had to take on broader WEC duties. Naki was the Project Leader. No significant additional information for the purposes of this chapter was provided by this 1998 report compared with the 1995 one, but the book is 280 pages in length compared with 113 pages for the 1995 report.

There followed in 2000 the report: “Energy and the Challenge of Sustainability”, produced for the United Nations Development Programme, the WEC, and the UN Department of Economic Affairs [15]. Chaired by Jose Goldemberg, there was an Editorial Board of 21 people of which I was one (brief biographies were listed on pages 471–474) and a vast number of other people formed an Advisory Panel and Peer Reviewers (also listed). Naki wrote the Energy Scenarios chapter; Hans-Holger Rogner the one on Energy Resources; Wim Turkenburg the one on Renewable Energy Technologies; Dennis Anderson on Energy and Economic Prosperity (where he discussed “the transition from traditional to modern energy sources”); and I wrote Chapter 12: “Energy Policies for Sustainable Development”. Authors of other chapters included Amulya Reddy on Energy and Social Issues; John Holdren with Kirk Smith on Energy, the Environment and Health; Hisham Khatib on Energy Security; and Jose Goldemberg on Rural Energy in Developing Countries. The challenges covered mainly focussed upon the need for modern energy services to be universally accessible, provided reliably, and used in a manner which does not threaten the health and well-being of current and future generations. The Energy Scenarios chapter largely mirrored the IIASA/WEC scenarios as published in 1995 and 1998. The chapter on energy policies mainly focussed upon the need to place greater emphasis on end-use efficiency, renewable energies, and low-emission technologies.

The Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) was a natural follow-on from the three preceding reports mentioned above, although on this occasion 40 SRES scenarios were examined. Carbon dioxide, methane, Nitrous Oxide, Sulphur hexafluoride, and Halocarbons were among the gases covered. The SRES writing team, led by Naki, broadly concluded that there could be no “best guess” scenarios and that any future analysis would draw on scenarios from each of the three which had been developed ([16], page 315).

My own involvement with the IPCC had begun in 1991 with an invitation from Sir John Houghton, then Co-Chairman of IPCC Working Group I. It was followed by an invitation from Bert Bolin, then the IPCC’s Chairman. My first role had been as a so-called “expert” reviewer of “An Evaluation of the IPCC IS92 Emissions Scenarios”, which formed part of the IPCC Report: “Climate Change 1994: Radiative Forcing of Climate Change and An Evaluation of the IPCC IS92 Emission Scenarios”, 1995. Then with the IPCC’s Second Assessment in 1995 I found myself a Lead Author in the chapter on “Energy Supply Mitigation Options” with several friends and colleagues, some of whose names have already appeared in this paper.

Simultaneously with contributing to the 1995 IPCC Second Assessment from Working Group II, I also contributed to Chapter 7: “A Generic Assessment of Response Options” of Working Group III. Mitigation and Adaptation options were the main focus of this chapter, and in the Mitigation part renewable energy technologies, fossil fuel switching, nuclear energy, and carbon dioxide capture and storage were covered [17]. Interestingly, Table 7.4 provided the contribution of ‘new’ renewables to total renewable energy production. Modern biomass led the way at 7.8% of the total; followed a long way behind by small hydro at

1.2%; then solar and geothermal at 0.8% each; and then wind at only 0.1%. Traditional biomass was calculated as making 59.6% of the total renewables contribution followed by large hydro at 29.8%, both figures once again from the 1993 WEC Report. The chapter mentioned that some renewable technologies could become viable in the near future, solar PV was specifically mentioned (though, as so often, largely derived from California), but the share of renewables in the global energy mix was not expected to exceed 25% by 2020 ([18], page 242).

The IPCC's Third Assessment in 2001 saw me as a co-author of the Synthesis Report and in the role of an Editorial Reviewer. The latter required checking responses to review comments received by the authors of Chapter 5: "Barriers, Opportunities, and Market Potential of Technologies and Practices" in the Working Group III Mitigation Report. By then I had moved on from the WEC to a consultancy. For the IPCC's Fourth Assessment in 2007 I was an internal expert reviewer of the Working Group III "Mitigation of Climate Change" report, listed as Chairman of the Policies Committee of the World Renewable Energy Network & Congresses - a role I had held since 1991 but was due to end. This departure was the result of my insistence on continuing to make public reference to the actual performance of UK onshore wind energy developments despite opposition from the WREN/WREC Wind Energy Committee. These references were to load factors achieved, as provided by developers and operators to the UK official body, Ofgem, so the objections of key wind energy people seemed out of order - not least because they threw some doubt on an important criterion for scenarios intended to assess the contribution of wind energy both in volume and over time. My role as an external "expert reviewer" in Working Groups II and III continued up to the Fifth Assessment in 2014. It was my own fault that I was tardy in responding to invitations to participate in the Sixth Assessment.

4. Into the 21st century

Among the Lead Authors of the IPCC's Special Report on Emissions Scenarios was Shell's Gerald (Ged) Davis, and it is to the numerous Shell Group scenario books 2001–2021 that I now turn. This reliance reflects the fact that, although I have had papers and book chapters published in the field of scenarios and energy transitions over the past twenty years (most of them since I became an academic in 2007, and so have also lectured on the topics), it is Shell's work which has captured my main attention on scenarios.

Shell's 1995 scenarios - 'Dematerialisation' and 'Sustained Growth' - reflected the expectation of major expansion of renewables. The 'Sustained Growth' scenario suggested that renewable energy sources could provide 50% of world primary energy supply by 2050. The 1998 scenario 'The New Game' was based upon the proposition that the Kyoto Protocol worked, with the trading of carbon emissions permits playing a significant role. The scene was set for the 21st century. But whether Shell could have an impact on constraining economic growth and energy demand was not uppermost in that scene-setting. The scenarios then and since have been focussed on seeking to portray alternative views on how the global economy and its energy system might evolve. In that search the challenges of addressing climatic change have been a recurring theme, though running concurrently with that have been difficulties in assessing which non-fossil fuel technologies and locations offered sufficiently attractive financial terms consistent with shareholders' interests and societal concerns.

Ged Davis kicked it off in timeline terms with a paper to an Oil & Money conference in London on October 29, 2001: "First, there is an overarching question about the ability of a dynamic energy system to respond to the threat of climate change." He referred to two scenarios: 'Dynamics as Usual' and 'The Spirit of the Coming Age'. The two scenarios had some different features - in energy resources, the timing and nature of technology developments, and social priorities. There were also some common features: natural gas would play a vital role as a bridging fuel over the following two decades (as it still does); pressures

on the oil market as new vehicle technologies come in; and the potential for renewables to be the eventual primary source of energy if robust storage solutions are found. However, as the next publication pointed out, renewables might not follow a steady growth trajectory.

The Shell Global Energy Scenarios set out in the public book: "Energy Needs, Choices and Possibilities: Scenarios to 2050", 2001, anticipated that the energy industry will be different - and in ways difficult to comprehend. Again there were the two scenarios: 'Dynamics as Usual' and 'The Spirit of the Coming Age'. The oil age would be ending, partly reflecting scarcity as the "Peak" of "The Oil Mountain" had long passed by 2040 and a transition to a "renewables renaissance" was projected for 'Dynamics as Usual'. Renewables in this scenario had burgeoned in the first two decades of the 21st century as, with government support and declining costs of wind and solar PV power, electricity grids are transformed. The government support was underpinned by public concerns about climate, supply security, and public health. Renewables achieved 10% per annum compound growth over this period, wind and solar PV achieving about 20% per annum. But then the pace of expansion was expected to stall as rural communities become increasingly opposed to nearby wind energy developments, environmental concerns prevented large-scale development of biomass, solar PV gains only in niche markets, little progress was made with energy storage, and electricity demand in OECD countries stagnates. The situation in developing countries was expected to be somewhat different, with renewable energy sources expanding after 2010, and wind power being drawn upon - especially in China and India, which also expanded hydro and nuclear developments. 'Dynamics as Usual' was described as where: "Looking back from 2050 the energy transition looks to be a continuation of past dynamics" (page 40). But its logic largely hung on the development of a new generation of renewables around 2025 and advances in energy storage. If that occurred then: "By 2050 renewables could account for a third of world primary energy and be supplying all incremental energy."

'The Spirit of the Coming Age' was heavily dependent on increasing reliance on hydrogen fuel cells after 2025 as both a heat and power source, widely produced from coal, oil and gas fields but with carbon dioxide extracted and sequestered at source. Large-scale renewable energy schemes would take over the role as main source of hydrogen, beginning around 2030 and passing other sources by 2050. I recall that in 2001 there was a peak of interest in hydrogen fuel cells, highlighted by a conference organised by BP-Sohio (as it was then) at Silver City near Toronto in which the company Ballard figured prominently. Interest quickly fell away thereafter but has kept popping up in the Shell scenario books in recent years as well as in some other quarters where descriptions varying from green to blue, and grey to black, have gained traction.

In 2002 appeared "People and Connections: Global Scenarios" (Public Summary), followed in 2003 by "Scenarios: An Explorer's Guide", which highlighted the scenarios 'Business Class' and 'Prism', but revealed little that explicitly related to energy transitions or energy more generally. They were more socio-political in nature, but the latter clearly aimed at assisting those who wished to engage in scenario work (and was re-issued over the next several years). In 2005 the weighty 217-page book: "Shell Global Scenarios to 2025: The future business environment: trends, trade-offs and choices" was published. There were three scenarios: 'Low Trust Globalisation', 'Open Doors', and 'Flags'. Issued in the wake of 9/11 it was partly focussed on "the dual crisis of security and trust" in the face of terrorism, but also considered what might happen following the Kyoto Protocol. "Low Trust Globalisation" was intended to reflect modest positive actions in its wake; "Open Doors" was based upon the assumption that there would be a "Beyond Kyoto" agreement with a global mechanism created to supervise implementation; and "Flags" depicted Kyoto as unravelling as countries, companies and societies opted out. On page 212 of this scenario book estimates of maximum renewable energy resources were given by area and globally based on a 10 billion world population, with the conclusion: "Renewables have the potential to meet all energy needs, at least in

theory.”

In the 2008 scenario book: “Energy: Shell energy scenarios to 2050” China and India were seen as entering their most energy-intensive phase of economic growth, and there would be no “silver bullet” that would completely resolve supply-demand tensions and environmental tensions were seen to be increasing. Reflecting the various challenges were the scenarios: “Scramble” where there was uncoordinated action at national and bilateral levels, with second-generation biofuels proving to be one of the more successful stories and co-ordinated action on climate change one of the least. The other scenario, “Blueprints”, was more optimistic, with renewable energy sources growing rapidly for power generation and electric vehicles. Pressure from the grassroots, not least in cities, facilitates climate change mitigation and adaptation.

The year 2013 saw Shell's scenarios put on “new lenses” to view familiar landscapes from fresh angles to help focus on and clarify possible futures. The main purpose was to explore how rapid the adoption of effective policies to tackle anthropogenic climate change and deploy decarbonised technologies at the required scale might become. The two new scenarios were “Mountains” and “Oceans”. “Mountains” assumed a growing concentration of socio-political power and gave emphasis to renewable energy expansion and carbon capture and storage (CCS), though all this failed to avoid global average temperature rising above the 2 °C goal. “Oceans”, which was founded upon continued heavy reliance on the fossil fuels until mid-century, after which solar overtakes these beyond 2050, in a world of distributed socio-political power. Other issues covered in this scenario book were extreme weather events, population migration, and food and potable water shortages. With three-quarters of the world's population projected to be living in cities by 2050 would come additional pressures of infrastructural development needs, social and political pressures, environmental degradation, and global resource efficiency and sustainability. These were issues covered in the 2014 publication: “New Lenses on Future Cities: A New Lens Scenarios Supplement”.

Looking back and comparing the Scramble/Blueprints and Mountains/Oceans scenarios as well as the subsequent reports and “sketches” of countries and cities, key developments have progressed within scenario ranges and ongoing challenges remain clear. Whereas new technology deployment has so far progressed at the more rapid end of scenario ranges, policy deployment has been closer to the sluggish end. Progress in addressing the needed changes in the face of anthropogenic change remains particularly slow, and has not been helped by Russia's incursion into Ukraine and the responses that has not surprisingly entailed.

Although Shell had engaged with other organisations in their building of scenarios from the 1990s, it was from 2014 that scenario books focused on specific countries and markets began to appear. These are listed in the supplementary Annex.

Then in 2016 came a further New Lens Scenarios Supplement: “A Better Life With A Healthy Planet: Pathways to Net-Zero Emissions”. The “Oceans” and “Mountains” scenarios again featured, and alongside them appeared in a chart of World Cumulative Emissions from 1751 to 2100 MIT's 2 °C Pathway. All three scenarios showed carbon dioxide emissions by 2100 less than 60% of an “Unconstrained” projection. The book also had a diagram headed: “Plausible Balance in an Emerging Net-Zero Emissions World” where remaining carbon dioxide equivalent emissions from fossil fuel use are offset by net biomass absorption and CCS (page 69). Solar and wind are anticipated to provide about 40% of global energy, nuclear and hydroelectricity about 12%, and about 15% “from the ‘bio’ domain”. This would leave about 20% to 25% hydrocarbons in the global energy mix, primarily gas and oil (reflecting the needs of long-distance transport and petrochemicals), hence the need for net biomass absorption and CCS. The share of electricity in final energy use is expected to grow from 20% today to “well over 50%”.

Importantly, the book emphasised the need to handle the intermittency of wind and solar power, and for technical breakthroughs in storage (specifically battery storage capacity), smart-grid technology,

and the integration of solar with building materials. The authors also made clear that they believed “the 30-year ‘rule’ is still a useful predictor of the pace of change” (page 41). The aspirations behind “A Better Life with a Healthy Planet”, and the belief that under certain conditions a net-zero emissions world is feasible, led Jeremy Bentham to describe it as “my love-letter to the world” (personal communication, March 29th 2021). Jeremy added: “And indeed, the sectoral attention and rehabilitation of the net-zero emissions perspective highlighted in that report have now become core aspects of the strategy of Shell and others.” Jeremy has been Vice-President, Global Business Environment and Head of Shell Scenarios since 2006. His chapter: “Energy: A Better Life with a Healthy Planet” in “Realistic Hope” set out the challenges and what he regards as “a realistic hope” very clearly [19].

The focus of Shell's scenario team continued to be on climate change issues with the publication in 2018 of: “Sky: Meeting the Goals of the Paris Agreement”. “Sky” was an extension of the “Mountains” and “Oceans” scenarios, setting out how energy services could be provided to the world by 2070 while meeting the Paris Agreement's climate objectives. The book highlighted the challenge that systems transformations are unpredictable and take time – even a century typically showing just a handful of major transformations. It highlighted that there is “no margin for interruption, stalled technologies, delayed deployment, policy indecision, or national back-tracking” (page 17). The “Sky” scenario is based on the assumptions that coal consumption falls from the early 2030s; significant advances in technology deployment occur from the 2020s; governments introduce effective policies – particularly funding new renewable energy technologies and constraining carbon emissions; and by 2040 hydrogen emerges as a significant energy carrier. The book recognised that the big challenge was political will and, underlying this, the social will to address the multiple challenges.

Shell's scenario work on seeking net-zero emissions led among other things to Shell becoming a founding member of the Energy Transitions Commission, formed of some 48 company Presidents, CEOs, etc. from around the world who are committed to that goal. Jeremy Bentham is Shell's representative on the Commission. Their recent reports include “Assessing the commitments from COP-26” (November 2021), and “Making the Hydrogen Economy Possible: Accelerating Clean Hydrogen in an Electrified Economy” (April 2021).

The year 2018 also saw Shell publish its “Energy Transition Report” which reviewed the risks and opportunities facing Shell, and provided reasons why its “strategy, portfolio and strong financial framework give us the sources of resilience to potential changes in the energy system to 2030” (page 25). By 2050, the Report concluded, Shell anticipates bringing down its Net Carbon Footprint by 50%, “in step with society's progress towards meeting the goals of the Paris Agreement” (page 76).

The most recently issued Shell scenarios book is: “The Energy Transformation Scenarios”, (2021). There are two “traditional” scenarios – “Waves” and “Islands” – which seek to “explore future possible worlds without any specific focus on creating a desired outcome.” Then there is “Sky 1.5” which reflects the spirit of the “Sky” scenario of 2018. “Sky 1.5” starts off by considering the SARS-2 pandemic and responses to it, but the main emphasis is on the socio-political challenges of supporting the availability of energy services to everyone, achieving the transition of the global energy system to one which uses sustainable sources of energy, and the need to gain widespread support. There is recognition that: “The required pace of change is extremely challenging, but technically and economically feasible if action accelerates decisively from now. And, as history has shown, sometimes shocks galvanise people into action” (page 91). Regrettably, as the SARS-CoV-2 (COVID-19) pandemic has illustrated, even the more obvious shocks and needed rapid responses may not be forthcoming [10]. One feature of the SARS-CoV-2 pandemic has been what seems a strange lack of interest in the major books and journal papers which have appeared on the history of pandemics and the debate over the likely origin of the SARS-CoV-2 pandemic. Shell's 2021 scenario book warned that: “Global societies may need to be prepared for any of the scenarios with a focus on their

own resilience, but no one can be a passive spectator.” That view needs some qualification: “no one *should* be a passive spectator.” Shell has not been. A more active involvement is shown, *inter alia*, in its series “Rethinking the 2020s” where updated views on climate change and the energy transition were joined by those on health and COVID-19 on September 9, 2020 (<https://shell.com/rethinkingthe2020s>).

Shell's scenario work has been supported by its World Energy Model, applied in the 2008 scenarios onwards. The model has sought to handle numerous key issues such as the power densities of the various forms of energy inputs; intermittency of wind and solar resulting in the need for higher back-up requirements affecting production efficiencies and therefore costs; and EROIs (energy return on energy invested). Load factors achieved or likely to be achievable, specifically for wind and solar power, have not been raised much (personal communication, March 15th 2021). In much of this work there is reliance on external research. The 2017 contribution provided an outline of the history of Shell's world modelling activities, including an effort in 1974 which had over 3000 equations and took 19 h 40 min to run on a mainframe (Shell's report mentioned 20 h). The Report admits: “The ‘black box’ nature, with unclear linkages, means that it gains little support.” I recall my opposition as there were far more important and immediate priorities at the time, as referred to in Section 3 above, but times have changed since.

One well publicised example of how things have changed, though mirroring a steady evolution which has been taking place for over thirty years, came in February 2021 with the Shell Strategy Day. Shell's CEO, Ben van Beurden, set out Shell's planned role in “Powering Progress” to accelerate its transition to a net-zero emissions business [20]. It was accompanied by the report: “Shell Energy Transition Strategy” which was put to shareholders for an advisory vote. The “Shell Energy Transition Strategy” report will be updated every three years until 2050, and every year from 2022 an advisory vote from shareholders will be held on progress towards Shell's plans and targets [21].

5. Concluding comments

For more than fifty years Shell has considered the prospect and possible natures of future energy transitions, especially in its scenario work. There have been periods when coal and nuclear have been given emphasis, and the former has crept back from time to time in recent years with the prospects for CCS being considered as offering some sort of future for coal also. More generally, ‘new’ renewables have been promoted, particularly solar, biomass, and wind. Hydroelectricity has long been seen to have a modest role, and wave and geothermal have been among others briefly mentioned. There are huge challenges in seeking to find sound schemes – financially and technically. This search for non-fossil fuel opportunities has run parallel with examining the value of existing assets and likely prospects for further investments in oil and gas - Shell have cut back on the former and scrutinised the latter, with considerable care for the best part of forty years. It is unfortunate that more attractive and larger investment opportunities in non-fossil fuel developments have not been forthcoming.

Messages from various quarters have from time to time seemed confusing. For example, a headline in *The Guardian* of 17 March 2009: “Shell dumps wind, solar and hydro power in favour of biofuels” [22]. Or *The Financial Times* of 8 December 2020: “Shell executives quit amid discord over green push” [23]. Or “For nine years, multinationals like Shell and Bayer funded a prominent climate denier” [24–26]. Reports that Shell has supported “a prominent climate denier” would not have gone down well then or now with the people I have known well in Shell (I came across six mentioned in [27] but they never discussed climate change related issues with me). Shell's latest decision of close relevance here was the announcement of the sale of their Permian Basin interest on 20 September 2021 to ConocoPhillips for US\$ 9.5 billion. They still rank around 4th in world rankings of oil and gas companies. Where they will rank fifty years from now in an energy transitioning world falls outside the remit of this paper. But this sale is claimed to have two main

purposes: to fund the energy transition to non-fossil fuel sources, and to accelerate cash delivery to shareholders [27].

Anthropogenic climate change, like natural climate change, has its uncertainties. Sound precautionary measures are required where the future, as always, is uncertain and the approach of developing and applying alternative scenarios lies at the heart of being able to cope better with uncertainty and change. A transition to forms of energy which are less polluting lies at the heart of scenarios for a more sustainable future. There are some who consider “the vast majority of the academic and practitioner literature treated the conduct of scenario planning as a ‘black box’.” This would be strongly rejected by anyone familiar with Shell's contacts with international and national organisations, academia, and its scenario work and publications [28]. Shell's scenario work has also come under fire from those who dispute Shell's work in the context of energy transitions, solar PV, and climatic change. This again has been strongly countered in previously published work [28] as well as here. The evidence for openness has long been available for everyone willing to see.

This is not to deny that, however good one's scenario work, making sound investments towards facilitating ‘net zero’ emissions in an uncertain future is a serious challenge. It is also the case that although Shell's past scenario work is deservedly highly regarded its history is, probably inevitably, somewhat chequered. The ‘New Belle Epoque’ scenario in the 1970s was probably not useful, there was also a failure in the mid-1970s to pick up on ‘Hard Times’ coming, or to focus in good time on the oil price collapse and recovery in the mid-1980s. Despite some weaknesses there have, as indicated in this paper, been both specific sectoral benefits and overall strategic gains, for half a century. For the past two decades, at least, the strategic direction has flagged an energy transformation [29]. How much of a setback to the needed energy transition that will result from Russia's incursion into Ukraine remains to be seen.

Declaration of competing interest

No conflict of interest involved with this paper.

Appendix A. Annex I: Shell Scenario and Related Publications 1971–2022. Annex II: Scenario Teams - their role and desirable qualities

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