Revisiting the future

Reflections on Shell's 1995 scenarios

Shell long-term energy scenarios describe how technological and social developments play out and determine the evolving supply and demand of energy. Chris Anastasi, who worked in Shell's scenario team in the 1990s, looks back on the scenarios he helped to create, its successes and failures, and what we can learn for the future.

Chris Anastasi

DEMATERIALISATION

SCENARIOS

SOLAR

LOW-CARBON

21ST CENTURY

Scenarios are a useful tool for imagining the future through the use of creative and analytical thinking. While imminent events cannot be predicted with anything approaching certainty, scenarios explore what is possible, if not probable, and help in the decision-making process. Since the 1970s Shell, a pioneer in scenario analysis, has produced hundreds of scenarios. Most of these are used internally, but it has made public some of the details of its world energy scenarios.

In 1995, Shell's first two long-term energy scenarios covering the first half of the 21st century were developed. These were based on the observation that, over time, competitive forces stimulate productivity improvements in both supply and demand. In the first scenario – Sustained Growth – increasing demand is met by an abundant energy supply at competitive prices, while in the second – Dematerialisation – energy demands are met by more efficient technologies (see Figure 1).

The two scenarios present sharply contrasting views of the future energy landscape in terms of total energy requirements and the spectrum of technologies deployed. The Sustained Growth scenario describes a world in which renewables could play a key role in the world's energy mix with biomass, wind and solar prominent in the transition to a low-carbon future. The most attractive feature of this scenario is the promise of a world where energy consumption is no longer seen to be a bad thing.

The Dematerialisation scenario, on the other hand, describes a world in which a combination of energy efficiency and changes in economic structure result in lower energy consumption. Paradoxically, this world mitigates against the widespread adoption of renewable technologies such as wind and solar because they are unable to compete against the

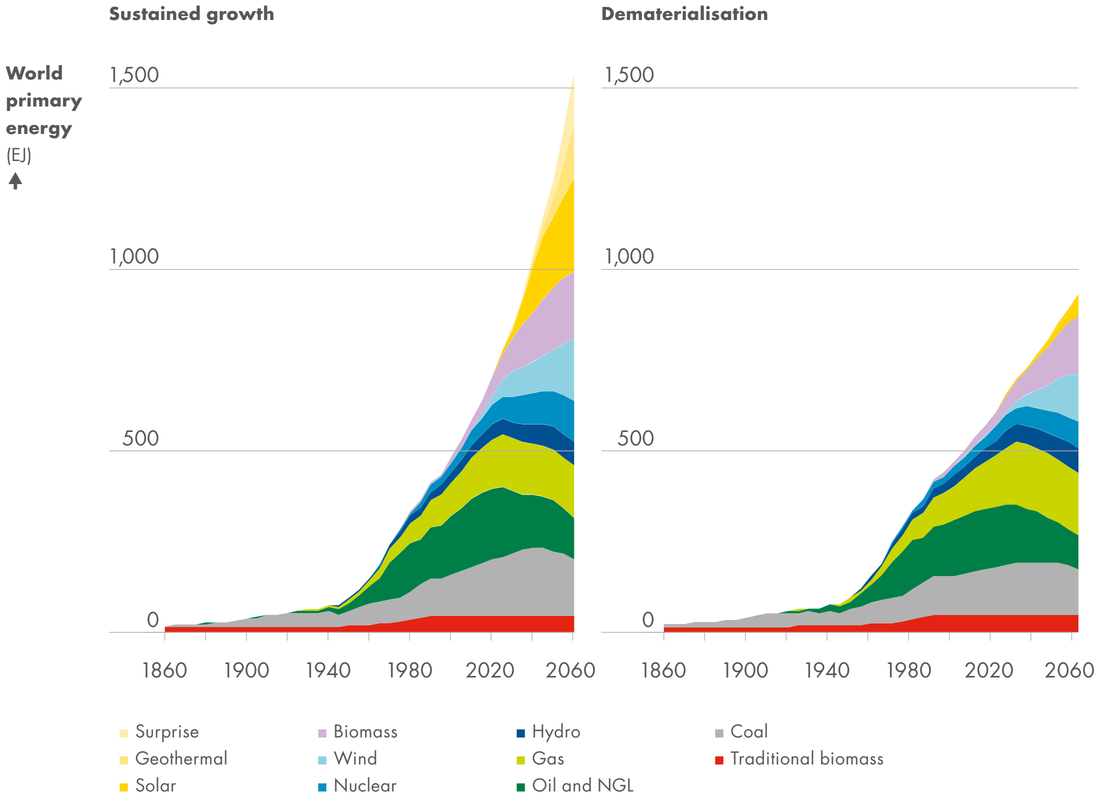

Figure 1: Total primary energy production for the Sustained Growth and Dematerialisation scenarios, showing the energy share projected for each type of production. Note that in Sustained Growth, total energy consumption is greater, and the share from renewables is larger.

efficient use of the mainstream fossil-fuel technologies.

Although their outcomes are quite different, there are some important similarities in these two scenarios. Both recognise that there is considerable inertia in the energy system with continued fossil-fuel consumption, and the carbon emissions associated with it. Atmospheric carbon dioxide levels were projected to rise steadily until 2060, breaking the 400 ppm threshold early in the 21st century, and then reaching 500 ppm in 2060. Despite considerable political rhetoric on the dangers posed by climate change, the first milestone has already been met – in mid 2013.

Lessons from the scenarios

Looking at these scenarios now, almost 20 years after they were developed, what can be learned? Are the driving forces identified still the same, or have new forces emerged that will better define the future? And what surprising developments have occurred that may signal a fundamental shift in the energy system in the future?

Three distinct insights came from these studies: recognition of the host of scientific discoveries and technological innovations achieved in the generation before the 20th century; an understanding of the fundamental drivers of energy consumption and the practical application of this knowledge; and new concepts that help explain why some emerging activities thrived while others suffered delayed development or failed entirely.

These same three insights are equally valid today with the caveat that the prominent role of technology in determining the make-up of the future energy supply may be surpassed by the influence of human behaviour.

The discoveries that served to shape the world at the beginning of the 20th century were delivered by a global population of 1.7 billion people, an incredible effort in a world where education was limited and opportunities to excel were rare. Between 1871 and 1911, major discoveries and inventions led to the creation of new technology sectors: electricity, telecommunications and transport (see Figure 2).

Some discoveries made during this time were actively pursued, while others fell victim to competing developments. There were also complete ‘surprises’ such as the detection of natural radioactivity, which would not begin making a contribution to the energy system for another 50 years.

At the outset of the 21st century the global population was 6 billion and it is increasing by about a billion people every 15 years. Education has become a basic right, and there are few boundaries to accessing knowledge. The intellectual

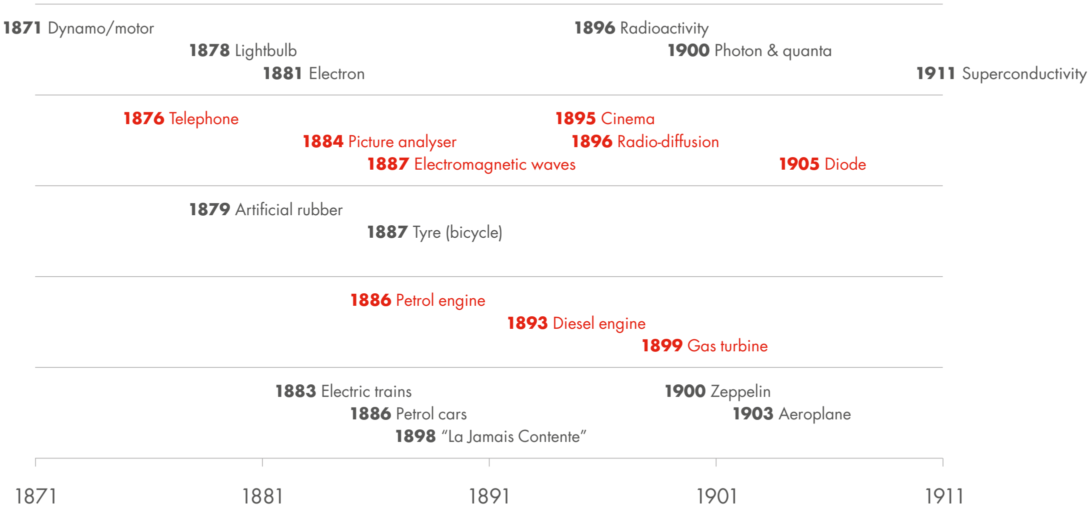

Figure 2: Timeline of significant inventions and technological discoveries for the period 1871–1911 in electrical energy, communication, synthetic materials, fuel and transportation. These breakthroughs have had a significant influence on shaping today’s world.

capacity of the world today has grown substantially since the beginning of the last century, and history suggests that this will enable the rapid pace of technological innovation to continue throughout this century. The challenge to emerging technologies remains the same: how to advance new innovations, and how to define the roles of the market and the government in that process.

Converging developments

It can be difficult to identify a single driver for the evolution process. Advancements in a number of apparently unrelated fields can suddenly converge and give rise to entirely new developments. Converging development features a coming together of societal needs, technological innovation, resource exploitation and manufacturing improvements. For example, by 1870 coal was emerging as a leading energy source, steel cost was decreasing while its quality improved, and mechanical and civil engineering were the flagships of technology. In parallel, industrialisation had accelerated the urbanisation process, which increased the need to transport goods and people between cities and within suburban areas. These factors led to the development of railways and mass transport systems such as the London Underground, which opened in 1863 and is still one of the largest systems of its kind in the world.

In the history of economic development, there are times when converging needs and resources can result in a radical change in lifestyles. In the 1920s, the capacity for individual mobility was realised with the advent of the mass-produced, affordable car. Its development arose from the convergence of a new fuel with high energy density (oil), new and improved materials, new manufacturing techniques and a social desire for freedom and consumption. The 'supercar' is the outcome of converging social and technological developments in the 1990s. Social issues involved increasing competition among car manufacturers and public concerns about pollution from car exhausts, primarily in urban areas. On the technology side, advances were being made in internal combustion engine control and efficiency, in fuel cell development, and in the formulation of more diverse, higher-quality fuels. There were also advancements in energy storage systems, from improving conventional batteries to exploring the potential of revolutionary high-speed composite flywheels which could deliver extremely high energy output and unmatched power storage density. Today an increasing number of pure electric or hybrid cars are commercially available, and they are putting pressure on manufacturers of conventional vehicles to improve their performance.

Electric car technology is not an entirely new concept, only one that failed to gain a foothold in the past. A battery-driven electric car with a light aluminium body, La Jamais Contente, was usurped by the internal combustion engine despite the fact that it held the land speed record at 105 kilometres per hour in 1898. Today, as the number of electric vehicles increases, it is evident that this technology faded in importance but did not vanish; it only required favourable converging developments to return and become viable.

What can this tell us about potential future developments? Consider Distributed Energy, a local method of delivering electricity to consumers. The societal motivations advancing these systems are environmental concerns (and the provision of subsidies for the technologies that address them), the appeal of community ownership, and the desire of individuals to take greater control of their energy needs (see Figure 3).

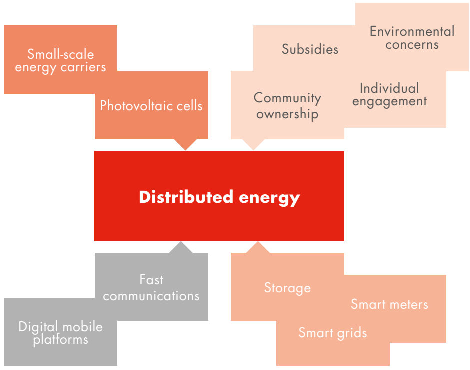

Figure 3: Converging developments today could signal a change in the way electricity is provided to consumers.

These same drivers have worked to promote the deployment of a number of small-scale, mostly renewable technologies. Although biomass and more recently wind power have been the main focus of activity, attention has turned increasingly to photovoltaic cells as a potentially disruptive technology. These systems require smart meters allied with smart grids, and new storage systems that are able to smooth electricity flows. The communications revolution of the last 20 years that has empowered individuals is also a necessary prerequisite for these systems, since it will allow individuals and companies to better respond to changing daily and seasonal needs.

Co-evolution of technology

While converging development describes the coming together of technological development and societal needs, the concept of co-evolution of technology recognises that development can be complex, requiring a more holistic approach. This concept addresses the need for co-ordinated innovation in different areas to develop new, potentially disruptive technologies, and explains the challenges faced in delivering new products to the market in a timely fashion, from plastic bottles to computers to mobile phones.

In the Sustained Growth scenario, it was recognised that the commercialisation of photovoltaic cells would require developments to bring about cost reduction to make this technology competitive with more established technologies. This technology also required innovations in materials to improve the efficiency of cells, new manufacturing techniques to facilitate volume production, advancements in energy conversion and storage, and the development of decentralised grid management methods to allow interaction between consumers and local distribution systems. Failure or development delays in any of these areas would hamper progress for this technology.

Carbon capture and storage is a recent technology that many believe is essential to meet the challenge of decarbonising the electricity and manufacturing sectors because it can make the continued use of fossil fuels benign. Applying the co-evolution concept, technological developments for three distinct capabilities must coalesce to advance this technology: carbon capture, transport and storage (see Figure 4). It is true that some established technology exists in each of these fields, but further innovation is required for its optimum configuration. A climate of co-operation between the disparate companies that will work together to build this new and highly complex process must also be developed.

And finally, deployment of this technology hinges on the creation of a robust framework to regulate storage operations, and on assurances from government that confirm the environmental integrity of the storage medium since it ultimately assumes the carbon liability on behalf of its citizens. The success or failure of this technology could ultimately determine the future of fossil fuels as part of the world energy supply.

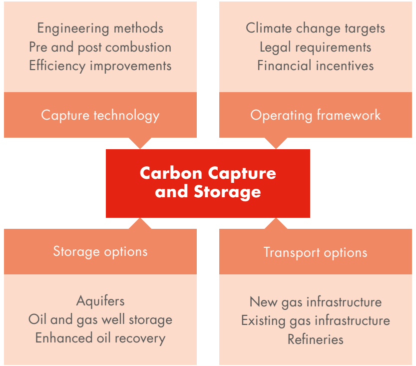

Figure 4: Co-evolution of technology in the development of carbon capture and storage.

Cost decline and the learning curve

Cost decline is critical to the development of technologies. The concept of learning curves (where costs decline as knowledge increases and methods improve) has been clearly demonstrated in the manufacturing sector where a rapid reduction of unit costs resulted from the use of new materials and processes, the development of innovative practices, and an increase in the scale of production. Ultimately, the continuing cost decline of any product is constrained by the technical limitations of the technology used to produce it.

In the 1995 scenarios, the learning curve concept was used to explore potential cost reductions for new energy providers, and especially for the newcomers to the electricity sector: wind, biomass and solar. As development of these renewable energy technologies progressed, they were expected to follow steeper learning curves than mature players, initially capturing niche markets, and then later competing in the core market. In the Sustained Growth scenario this core market competition was projected to begin between 2010 and 2020, depending on locations and markets.

Just as projected, solar photovoltaic cells have experienced a dramatic cost decline brought about

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COSTS

NUCLEAR RENAISSANCE

by generous subsidies that have encouraged deployment at scale, advanced efficiency gains, and fostered the development of new manufacturing techniques. The resulting collapse in price has led to an exponential increase in deployment and there are more developments on the horizon. When this technology is integrated into new applications its customer base will grow, leading to innovations in a number of new areas that will further reduce costs. Of all the renewable energy technologies, solar photovoltaics has the best chance to become a fabled 'disruptive' technology.

What about the learning curve for other renewable technologies highlighted in the Sustained Growth and Dematerialisation scenarios? Onshore wind has become a mature industry with costs gradually converging with other mainstream technologies in the energy market. There has also been significant progress with offshore wind, particularly over the last decade, with the major factor in reducing the cost of this technology being increasing scale. Offshore costs could potentially continue to fall, particularly because it is possible to deploy larger turbines in this environment without protest. Subsidies have helped the development of this technology in the short term, but it is uncertain how long these will continue.

The use of biomass as an alternative fuel, particularly for electricity generation, has proved even more problematic, with concerns about sustainability and competition for resources likely to limit deployment. These issues will probably not be resolved in the short term and further advancements in technology and public acceptance may be required to make biomass a significant contributor in the global energy scene.

The progress of the marine technologies – wave and tidal – has also been disappointing over the last 20 years. Learning has just begun, and they will require more development and extended demonstration to fully assess their potential over the long term.

In short, in spite of impressive advances, there are still major challenges ahead which may limit future deployment of these renewable technologies in the future, the most important of which is the need for flexible generation in the mix and the lack of new scalable storage options. For wind, there is growing resistance to onshore deployment by local communities who obtain relatively little benefit by contributing to national renewable aspirations, while offshore wind costs may remain stubbornly high and the public may ultimately not be willing to continue with subsidies for an extended period. Biomass development has suffered from sustainability issues, and marine technologies have simply not advanced. The 1995 scenarios assumed that the required technical solutions would be forthcoming and did not take into account the societal backlash against the more intrusive renewable technologies.

Could nuclear power present a solution? The 1995 scenarios and the latest long-term scenarios have noted that nuclear power can produce large volumes of low-carbon electricity, and for this reason it seemed poised to make a significant ongoing contribution to the world's energy mix. Unfortunately, the latest accident at Fukushima Dai-ichi has stalled what may have been a nuclear renaissance. It is unlikely that this technology will be major contributor to the world's future energy scene, unless a new generation of nuclear technologies can be developed. Nuclear fusion continues to excite with the potential for limitless production of clean energy, but this technology seems perpetually destined to elude successful exploitation, with commercialisation at best many decades away.

And what role might fossil fuels play in the future? There is undoubtedly significant inertia in the energy system that works against the rapid removal of fossil fuels from the energy mix. Both the Sustained Growth and Dematerialisation scenarios projected a continued rise in the use of fossil fuels, with peak consumption at around 2020, followed by a gentle decline over the remaining decades of the 21st century. The latest Shell long-term scenarios, Mountains and Oceans, have the peak pushed back further to about 2050, followed, once again, by a gentle decline over many decades. It appears that peak oil consumption, like nuclear fusion, is an event that lies on a continually retreating horizon.

Part of the reason for the ongoing consumption of fossil fuels is their continued availability at affordable prices. As in the past, with high oil (and gas) prices and technological developments, more resources become economical to exploit. Today, the reserves-to-production (R/P) ratios for oil and gas are higher than 30 years ago – the R/P ratio for oil has risen from 35 years in 1982 to 52 years in 2012, and the R/P ratio for gas has risen from 52 years in 1982 to 56 years in 2012.

A surprising development is that the R/P ratio for coal has fallen markedly, from 228 years in 1992 to 108 years in 2012. The biggest decline is in the coal R/P for the Asia Pacific region, which has dropped from around 180 years to just over 50 years, reflecting the past 20 years of high economic growth and heavy reliance on this fuel. Although the 1995 scenarios recognised the difference between resources and economic reserves, and limited expected coal exploitation accordingly, they did not anticipate such a rapid decline in R/P ratio.

Today, there are concerns that political events in producer countries could lead to a fall in production, but history shows that these declines would be temporary and short-lived because those economies rely heavily on oil and gas revenues. In reality, fossil-fuel suppliers and consumers are clearly dependent on each other, and as indicated in the scenarios, fossil fuels will continue to play a significant role in the energy mix throughout this century.

Events on the horizon

The 1995 scenarios introduced the idea that there are always surprising discoveries and developments on the horizon, and like those seen at the beginning of the last century, breakthroughs will ultimately have a major impact on the energy system. The emergence of carbon capture and storage could be such a disruptive technology, but even with some minor successes in this area, a full demonstration project has yet to be commissioned. It will take at least another decade until this technology becomes mainstream. Or perhaps the long-awaited nuclear fusion reactor will be the surprising development in the second half of the 21st century.

When the scenarios were created, they made note of some of the potential technological developments that were on the horizon at that time. Molecular design was rather new, but had the potential to contribute in many areas; molecules could be made by conventional chemistry, but their atoms could also be manipulated directly, and this new realm was called ‘nanotechnology’. Although not specifically foreseen, graphene, a two-dimensional carbon-based material, was successfully created in the laboratory around the turn of the century using molecular design technology. Experts believe this novel material will revolutionise a number of industries, most notably electronics and manufacturing, but its most important use may be in photovoltaic devices and energy storage systems which could ultimately help these technologies become major contributors to the world’s energy supply. Technologies that use graphene are still at a very early stage, and it can typically take years, possibly even decades for such innovations to deliver useful and commercial products. Nevertheless, considerable technical and business knowledge exists that can maximise our chances of fully exploiting the potential associated with this material.

It remains very difficult to anticipate the long-term effect on the energy sector of the use of molecular design in both biotechnologies and solid state technologies. Some developments will result in improved energy systems with cheaper and abundant energy supply (for example, improved biomass yields, solar photovoltaics, superconductivity) or they may extend opportunities for using energy (for example, increased mobility, more widespread longevity). Other developments will lead to energy savings from the use of lighter and novel materials (such as bio-polymers) to new methods of food preservation.

Information technology (IT) today has a major positive impact on our work and home environments, but the 1995 studies projected that IT use would go on to revolutionise energy use in other ways, for example, through the application of ‘virtual reality’ and the evolution of ‘intelligent’ houses. These expectations have not yet been realised – in some cases, the technologies have not been forthcoming, but their adoption has also been limited by an inability to engage the individual in meaningful ways.

Transforming the energy system

Over the last 20 years, the world’s energy system has been shaped in part by societal concerns over climate change and the resulting efforts to slow its progress. Carbon reductions have been sought in many sectors of the economy, and there have been some encouraging new developments in this area that were successfully projected in the 1995 scenarios: hybrid cars, photovoltaic cells and new methods of communication will continue to play an influential role in the future energy system.

These concerns and efforts have not proved sufficient to transform the system completely, although other societal drivers, such as the need for individual mobility, have succeeded in doing so in the past. There are suggestions that a climate change ‘signal’ would mobilise the necessary action across the world; however, the effects of climate change are slow and gradual, and regardless of repeated attempts by scientists to gather and present the

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FUSION

GROWTH

DECARBONISING

CAPACITY

ADAPTATION

MITIGATION

evidence of these effects, there has thus far been relatively little change in human behaviour.

The financial crisis in 2008 shifted priorities with climate change dropping lower on the political agenda, and investment in green technologies becoming more difficult. There has been some concerted action in creating and implementing carbon mitigation policy, most notably in the European Union where firm targets for carbon emission reductions and the deployment of renewable technologies have been adopted; elsewhere in the world, action has been patchy. A global agreement for addressing this problem is needed, but a lack of political will is apparent, and so carbon concentrations in the atmosphere continue to rise.

Another more worrying factor, which was not anticipated in the 1995 scenarios, is the emergence of climate change 'fatigue', particularly at the policy level, and this may further reduce the drive to decarbonise the energy system.

Looking ahead, the need to adapt to climate change will become increasingly important, especially because the earth's capacity to sustain life in a climate-changed world may be limited. Many of the strategies for mitigation are also helpful for adaptation, for example, developments that reduce energy use in the home and workplace can help us to adapt to a world where energy is scarce. Adaptation will certainly require innovations to address, for example, water and agricultural shortages and threats to public health. All of these will have implications for energy use in both the natural and developed environment.

One school of thought is that the enormous innovative capacity of humankind will provide the solutions to transform the energy system, not only to meet the challenge of climate change but to ensure sufficient resources for future generations. An alternative view is that there is insufficient collective will at the political or individual level to affect the changes needed, and that humankind will sleepwalk into a very uncomfortable future world.

The author wishes to recognise Georges Dupont-Roc, who made a major contribution to the Shell 1995 long-term scenarios.

Chris Anastasi worked in Shell's scenarios team in the 1990s and has been a member of a number of Government Committees and Advisory Boards, in the UK and elsewhere.

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