Nuclear power at a crossroads
Conditions for a revival of the industry

The future of nuclear power will be determined by the effectiveness of the industry and the institutions that govern it, since these will ultimately determine public trust, without which a nuclear renaissance cannot occur.

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NUCLEAR FUEL

CHINA

SCRUTINY

ACCIDENTS

FUKUSHIMA

Nuclear power will continue to provide electricity throughout this century, but it is uncertain if it will make a significant contribution to the world's energy supply. Will it persist as an essential part of the global energy mix, or will it gradually decline and become negligible as plants are shut down without replacement? The answer to this question relies on a number of important factors, any one of which may limit the advancement of the nuclear industry, at least until breakthrough technologies are developed and deployed.

The current role of nuclear power generation must be viewed within the wider global energy context, since this is the bedrock on which the future of this technology will unfold. The impact of a small number of critical accidents over the last 60 years is significant. It is fair to say that a nuclear renaissance was under way during the first decade of this century, but it was interrupted by the earthquake and tsunami on the east coast of Japan in March 2011 and the crisis those events precipitated at the Fukushima Dai-ichi plant. These incidents reopened the debate on the future of nuclear power in many countries, and the industry remains under scrutiny today. Of the 31 countries that currently generate nuclear power, five have decided to phase out this technology, and Japan may one day follow suit.

A number of countries remain undeterred, and will continue to build new plants; the UK is expected to replace its ageing nuclear fleet, and China is forging ahead with ambitious plans that (if realised) will make it a dominant force in the nuclear industry (see Figure 1). But for a global renaissance, the

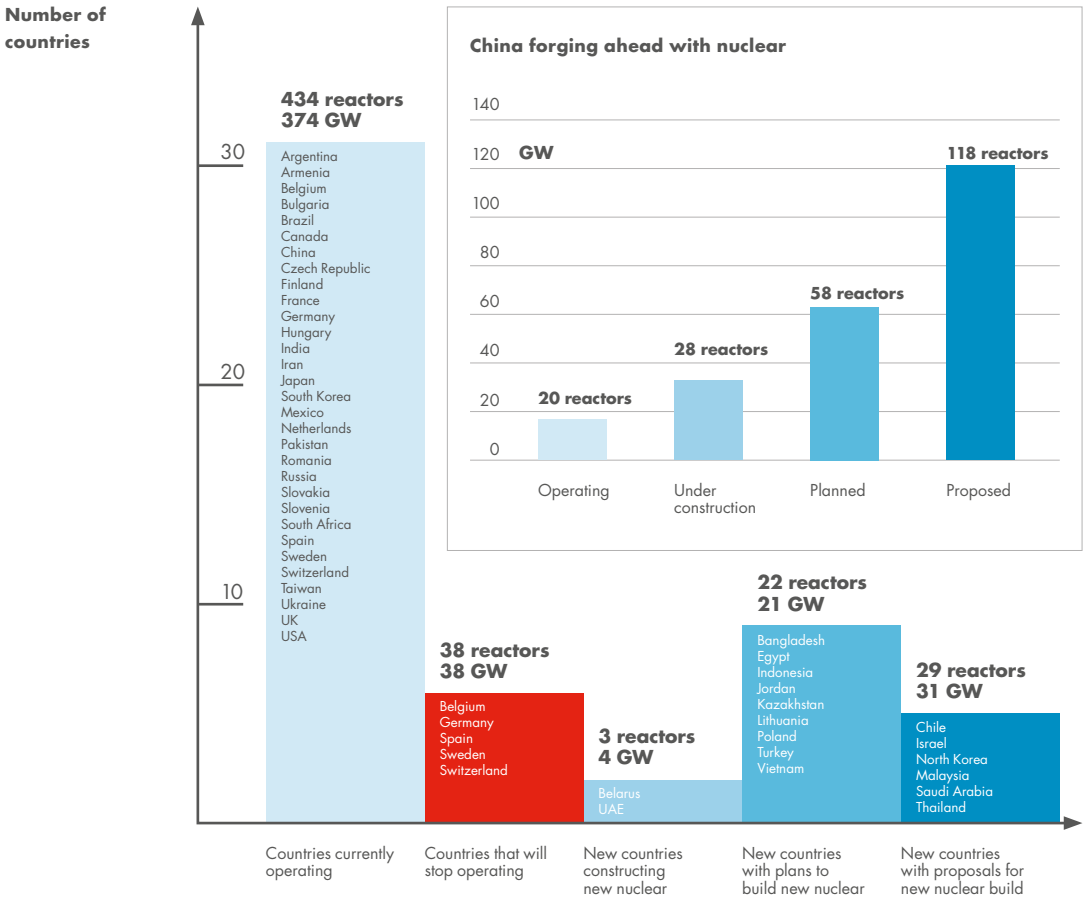


Figure 1: Nuclear power today and in the future.

industry needs to gain public confidence and show that nuclear power satisfies the basic tenets of sustainable development.

Nuclear power generation is a mature industry which has delivered large quantities of baseload electricity since the first civil nuclear reactor began operating in 1956 at Calder Hall in the UK. Today, almost 60 years later, there are 434 reactors operating in 31 countries around the world, with a combined generating capacity of 374 gigawatts electrical. Seventeen other countries from Eastern Europe, the Middle East and Asia are either constructing new nuclear plants, or have plans or proposals for new plants. The existing global fleet of plants generated about 2,500 terawatt-hours or about 11% of the world's electricity needs in 2012. Nuclear power currently constitutes only about 5% of the world's total energy supply, and this percentage has remained virtually static for about 20 years. Despite the fact that its contribution is relatively small on a global scale, in some countries nuclear power constitutes a major electricity source.

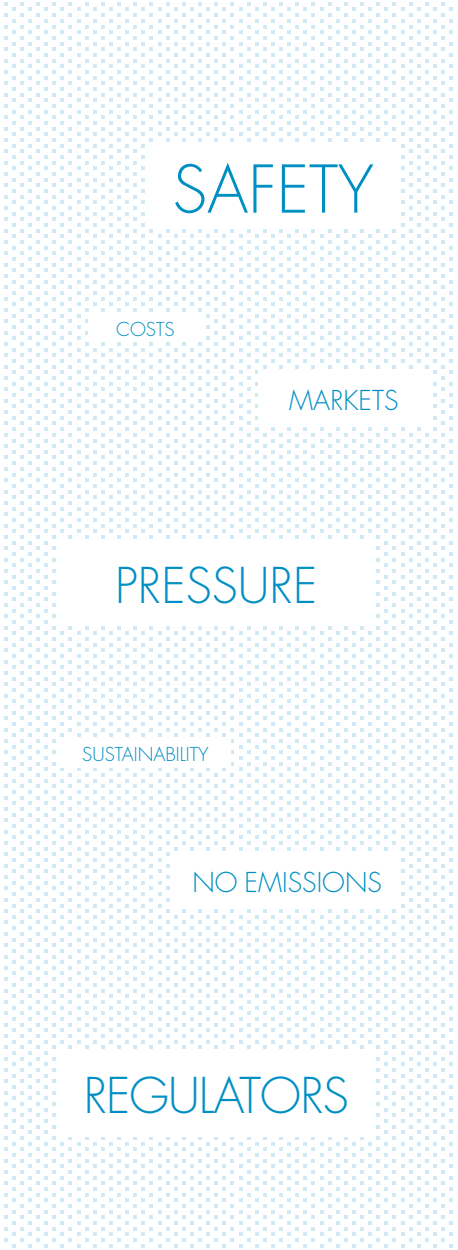
There are a range of factors that will determine the future of the nuclear industry, including technical issues, political agendas and public opinion. For nuclear power to remain a significant factor, the industry must craft a credible argument that clearly portrays nuclear power as a viable, sustainable energy resource for the future, and not just an option of last resort. In order for any type of development to be considered sustainable, it must meet the needs of society today without sacrificing the needs of future generations. This principle provides a solid basis for the three 'pillars of sustainability': the economic rationale, environmental footprint, and social impact.

There are many who believe that nuclear power technology can never meet the criteria for sustainable development. Others believe that the sustainable development debate actually provides an opportunity to take a more holistic view of this technology, to highlight both its advantages and its disadvantages. There is no analytical formula based on a detailed description of each 'pillar' that can be used to evaluate whether a technology or industry is sustainable. There are both objective and subjective factors to be considered: quantitative measurements and data, as well as the more qualitative political, philosophical and emotional issues. The constituent elements of each pillar must be assessed as positive or negative, and their perceived importance will vary across different groups. The current cultural climate and state of social development will also have a key influence on these evaluations. Thus, the industry must gain the public trust that is crucial to the nuclear debate by providing better information about the nuclear process to all stakeholders, in an open and transparent approach.

Place in the energy mix

Is there a sound economic rationale for the further development of nuclear power generation? There is little doubt that large quantities of affordable, reliable electricity are fundamental to supporting society's economic growth and the quality of life of its citizens. It powers industry and commercial activities, heating and lighting for homes, and mass transportation, water and sanitation, all essential in modern society. Nuclear generation contributes a significant share of the electricity supplied in the countries where it operates. For example, France generates 75% of its electricity from nuclear plants, while China's nuclear capacity, at just 2% of total electricity, is projected to grow rapidly. On average, in the 31 countries that host nuclear plants, almost 24% of their total electricity is derived from nuclear power. Germany relies on nuclear sources for 16% of its electricity and must look to other technologies once it decommissions its nuclear plants. Other countries find themselves in a similarly serious situation: Spain and Switzerland depend on nuclear power for 36% of their electricity while Belgium's nuclear-generated share is just over 50%. It will be no easy task for any of these countries to find viable alternatives to nuclear power generation, and meeting the demand for electricity using other resources may result in increased carbon emissions over the short term.

Some have suggested that nuclear power is not sustainable because it is too expensive. The construction of a new nuclear plant must make economic sense, and the same holds true for any type of power plant. Building a new nuclear power station represents a capital-intensive infrastructure project, and three parameters play key roles in determining its economic viability: the interest rate for securing capital, the cost of fuel for the market's benchmark technology (usually gas), and the cost of handling carbon emissions. Financing these projects can be difficult in liberalised markets and so it falls to governments to support the deployment of nuclear technology with a variety of financial instruments to effectively reduce the cost of the required capital.



At low gas prices and carbon costs, gas remains the preferred energy source; at high gas prices and carbon costs, nuclear is favoured. The greatest influencers in making this choice are the availability and cost of gas resources, and the importance of the decarbonisation agenda. Despite a continuing healthy reserves-to-production ratio, competition for gas supplies is expected to increase as global demand grows in future decades. The shale gas revolution in the USA has signalled the potential of gas derived from unconventional sources and this will contribute to the world gas supply. Gas prices are currently low, but they are expected to show a net upward trend driven by increasing demand over the operational lifetime of a new nuclear build.

Despite the lack of an international agreement on climate change for the post-2020 period, the pressure to reduce worldwide carbon dioxide emissions remains. As the impact of climate change becomes more tangible, politicians will eventually reach consensus on a plan that is likely to increase the cost of carbon and place additional economic pressure on the use of fossil fuels. There remains the potential for the emergence of a truly disruptive technology that will reduce the importance of the carbon-free benefits of nuclear power generation. Carbon capture and storage (CCS) technologies are currently being developed to address the issue of increased carbon dioxide emissions produced by the use of fossil-fuel sources, but the complexity and cost of these projects has resulted in slow development. Pilot projects at a meaningful scale are on the horizon, and these will provide the information required to go forward with this technology.

In this light, it is plausible to expect that nuclear energy generation can compete economically with leading alternative technologies in the medium to long term. A further benefit – security of supply – is not formally valued today, but will serve to broaden the economic appeal of nuclear when it is recognised in the market.

Emissions and waste

What about the environmental impact of nuclear power generation? Most discussions about the sustainable development of energy sources are primarily focused on climate change. The carbon produced by conventional energy generation methods will persist in the earth's atmosphere for centuries. Although the nuclear industry was developed primarily to deliver large quantities of baseload electricity to aid economic development, and not as a way to address climate change concerns, this is a technology that can do both. Nuclear generation does not emit the large quantities of carbon dioxide that result from energy generation using fossil fuels. Assuming a conservative value of 500 grams per kilowatt-hour of carbon dioxide for electricity derived from fossil sources, the global supply of 2,500 terawatt-hours of electricity produced annually using nuclear power avoids the production of 1.3 gigatonnes of carbon dioxide each year. To put this number into context, this is equivalent to removing about a quarter of all carbon emissions produced in the USA. The nuclear power sector has arguably been the single greatest contributor in efforts to curtail carbon emissions over the past 60 years. Without it, the detrimental impact of atmospheric carbon would be much greater today and in the future.

There is little doubt that governments, and the people they represent, are likely to view the nuclear option as more favourable when the threat of climate change is imminent. But they do so reluctantly, primarily because progress in resolving the long-term nuclear waste issue has been slow. With the possible excep- tion of one or two countries, government and industry have done a poor job of explaining these issues and their potential solutions to the public, despite the fact that opinion polls confirm this key concern.

The issue of inter-generational environmental equity is a key principle of sustainable development. It is reasonable to expect that the generation that receives the benefit of the electricity generated should also be responsible for dealing with the by-products of its production. While the actual management of some nuclear wastes may be delayed until the future, producers have a current obligation to develop, fund and implement a practical solution for this task. The industry wants to do this; the question remains one of how to advance this debate. Discussion must occur on three levels: technical, social and political. In the past, the industry's focus has been mainly technical, showing that its solutions are safe and feasible, but this has been demonstrated only to a relatively narrow group of stakeholders composed of regulators, academics and peers.

Positions on the long-term safety of storing nuclear waste are polarised. At one end, some NGOs maintain there is no safe way to dispose of highly radioactive waste and therefore its production should stop, while at the other end, the industry contends that the technical aspects of this problem

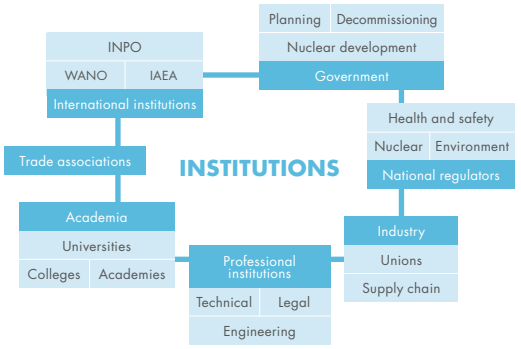


Figure 2: Strong institutions are essential for new nuclear build. Note: WANO, World Association of Nuclear Operations; INPO, Institute of Nuclear Power Operators; IAEA, International Atomic Energy Agency.

are well understood, and that solutions for safe disposal already exist. The public is not educated on these issues, and so its opinion has vacillated as people try to decide whether the NGOs are more trustworthy than the industry. A long-term, concerted education programme is needed to put the nuclear waste problem and its implications in perspective, and convince the public that nuclear waste can be handled safely and responsibly. At the outset, the industry could explain that the volume of waste is relatively small, that it is not uniquely hazardous, and that most of the waste has a relatively short half-life. People need to know that the industry stores and monitors its wastes safely, that it oversees their long-term management, and that these activities are routinely scrutinised by an independent and a highly competent regulator.

The development of waste-disposal facilities in Finland and Sweden has shown that public involvement and consensus are crucial, with government acting as a key facilitator. In Finland's case, many lessons have been learned from the operation of two waste repositories for low- and intermediate-level waste over the course of 25 years, and this knowledge has been instrumental in gaining public confidence in a proposed long-term solution. This experience is encouraging for the industry, but it can be difficult to leverage this type of success across countries and cultures. Nevertheless, the practical knowledge gained can be adopted across national boundaries. Timely resolution of the waste-disposal problem will not only make the safe storage and management of existing wastes practical, but will foster the development of future disposal strategies. If left unresolved, this issue could present an ongoing, significant barrier to the construction of new nuclear plants.

Acceptance

How does the development of nuclear power affect society? This question is perhaps the most difficult to answer because it involves contentious issues including concerns over dangers from radioactive emissions and accidents, plant security, and the proliferation of nuclear weapons. The role of institutions that provide operational guidelines on both a national and international level is critical in this area (see Figure 2). The industry's track record for avoiding radioactive releases to the environment from normal operations is very good. A strict regulatory framework, rigorously enforced by an independent regulator, ensures that the radioactive dosage to employees and the public is kept well within safe limits – as people go about their normal daily lives, they are likely to receive more radiation exposure from natural sources than from nuclear power stations.

Communities that host nuclear plants tend to have a better understanding of nuclear safety and more confidence in the way the industry conducts its operations. This has been achieved through regular meetings where industry can inform and discuss issues with its local stakeholders. But these efforts should be extended by the numerous institutions that play a role in the industry to increase awareness in the broader population.

Some significant accidents during the past 60 years have damaged the nuclear industry's reputation for safety and delayed its advancement. Like most accidents, these did not result from a single issue, but from a confluence of issues that contributed to a severe outcome. And these causes were not purely technical in nature – they included poor management decisions and operational hubris. To its credit, the industry has responded to these problems by acknowledging that nuclear technology is unique, requiring its own global institutions (see Figure 3). The Institute of Nuclear Power Opera- tions (INPO) was created after the Three Mile Island accident, and the World Association of Nuclear Operators (WANO) was created after the Chernobyl accident. These institutions have improved the industry's performance considerably by promoting a 'safety-first' approach, establishing questioning attitudes, and encouraging constant examination as part of ongoing organisational learning. A strong

SOCIETY

INPO

VIABILITY

SECURITY

FINLAND

CHERNOBYL

WANO

FRANCE

OPERATORS

REGULATORS

WASTE

GOVERNMENTS

COMMUNITY

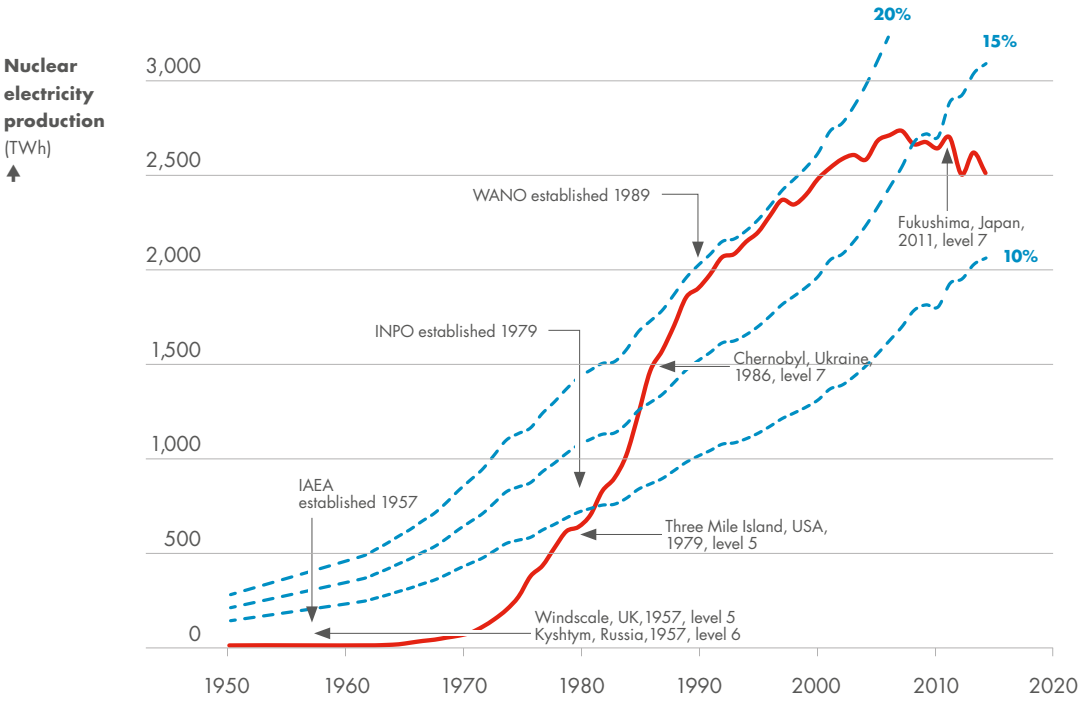


Figure 3: The journey of nuclear. Institutions enabled its growth while incidents hampered it. The red line shows the growth of nuclear electricity production compared to percentages of the world total electricity production (blue dashed lines).

commitment by their leaders to furthering these aims, independent of economic, political or other consequences is crucial.

Former US Vice President Al Gore, a long-time environmentalist, visited post-accident Chernobyl in the summer of 1998. In a speech during that visit he proposed that nuclear energy could remain a viable energy option in the future if the industry could meet its challenges: "Nuclear power, designed well, regulated properly, cared for meticulously, has a place in the world's energy supply."

The industry currently operates under a regulatory regime in which security and safety share top priority. Public opinion will improve with the industry's continued effort to maintain this culture of high security at the operator and state levels, and with the ongoing development of international co-operation programmes where scrutiny of practice is encouraged. Peer reviews by international experts provide independent scrutiny of nuclear operational practices and a powerful method for sharing operating information, and this practice is accepted worldwide. This aspect of nuclear culture is an essential prerequisite for countries developing new nuclear projects, as well as an important practice for the countries who now provide it.

A number of developing countries around the world are turning to government-operated civil nuclear power both to meet the growing domestic demand for electricity and to limit reliance on foreign conventional fossil fuels. A fundamental challenge for these countries is their capacity for sufficient technical and institutional support of the industry. This is important throughout the nuclear cycle, including plant construction, operation and decommissioning, and the management of waste. Developing strong institutions to oversee these activities takes time, as does establishing a culture in which nuclear operators engender trust in the public at local, national and international levels. The possibility that civil nuclear power facilities could be used to develop military programmes raises another key concern about nuclear development – nuclear weapons proliferation. For this reason, strong international co-operation is vitally important; all countries who operate nuclear

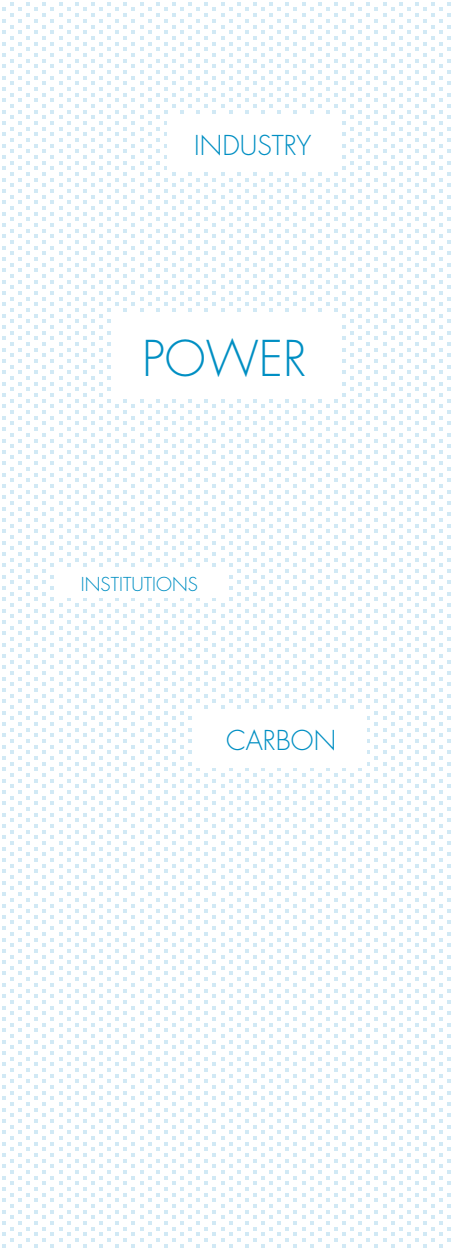
facilities must become members of a community that accepts the need for transparency and peer group scrutiny. Public confidence relies on the implementation of these safeguards.

Today, nuclear power generation is at a crossroads with the scale of its contribution to the future energy mix uncertain. The long operational lives of nuclear plants suggest that this technology will be contributing to the world electricity mix throughout this century. It is possible that some countries (notably the major developing countries such as China and India, and established nuclear countries such as the UK and France) will continue to construct nuclear power stations in an effort to diversify their electricity mix or to replace ageing plants. There may also be a handful of additional countries that will develop nuclear power facilities for the first time. These countries must first establish strong and enduring institutions for their new nuclear industry, and it is incumbent on the existing nuclear community to share its knowledge and provide support for these new members.

There are a number of studies describing possible future scenarios for nuclear power. Shell's two New Lens scenarios, Mountains and Oceans, describe the energy landscape over a period from 1960 to 2060. These scenarios present similar predictions of overall energy consumption rates, with fossil fuels continuing to play a dominant role, but there are differences including the relative contri-butions of the three main fossil fuels (coal, oil and gas), and the contribution of low-carbon technologies. The Mountains scenario suggests that nuclear generation will increase threefold, while Oceans suggests a doubling over the same period. But in both of these scenarios, the future contribution of nuclear power to the world's energy is expected to remain low, at around 10% in Mountains and 5% in Oceans. The high-level message of this analysis is that nuclear may well play an important role in some countries, but it will constitute only a small portion of total global energy.

Climate concerns which, in the past, convinced many that nuclear should be part of the future energy mix, appear insufficient to encourage a full-blown nuclear renaissance today. Instead, the industry is undergoing a far less dramatic period of recovery and rehabilitation as it seeks to prove itself once again in the public eye and secure a position as an important player in the future energy landscape.

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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