How to Sustain the Nuclear Renaissance

Point of View by Colette Lewiner and Alva Qian

Contents

A brief history of the nuclear energy industry

At the beginning of the 20th century, very significant scientific discoveries happened in the nascent nuclear field. In 1939, nuclear fission and chain reaction were established. In May of that year, French Nobel prize winner Frédéric Joliot Curie secretly registered the first patents on uranium chain reaction. His first two patents defined the principle composition of the nuclear power reactors of today: moderator, cooling fluid, control rods and protection shield. During World War II, on December 2, 1942, Enrico Fermi and his team at the University of Chicago produced the world's first controlled and sustained nuclear fission reaction. After the war, Westinghouse Electric Company developed its first nuclear reactor for submarine engines. The first prototype, Submarine Thermal Reactor Mark I, was completed in 1953, installed in the Nautilus and launched the following year. The world's first nuclear electricity was generated in the Soviet Union in 1954 from the 5 MWe Obninsk reactor.

During the following industrialization phase, many western countries as well as Soviet bloc ones started to build nuclear power plants with various technologies. Some use water as cooling fluid, such as Westinghouse's Pressurized Water Reactor (PWR[1]), Soviet Union's VVER, and General Electric's Boiling Water Reactor (BWR[2]). Canada uses heavy water, in its Canada Deuterium Uranium (Candu[3]) design. There are others using CO_2 gas as cooling vector, such as Graphite-Gaz in France, Magnox and AGR[4] in the U.K. and RBMK[5] in the Soviet Union. New designs continue to be developed. A breeder technology using liquid sodium was developed, but has had limited success so far. The Pebbled Bed Modular Reactor (PBMR) design was developed in South Africa. A demonstration PBMR plant will be constructed at Koeberg, scheduled to start in 2010 and complete by 2014. These two latter technologies could lay the foundation for a new era of nuclear power plants designs, beyond the present third generation.

The first oil shock in 1973 threatened many western countries' security of energy supply. As a consequence, national nuclear energy programs became strategic priorities. Uranium prices jumped to record highs and nuclear vendors had huge stacks of orders to build new plants. Nuclear energy was booming!

What happened then?

Though a vast majority of these reactors were safely designed and operated, two major events choked the industry's growth.

In 1979, the Three Miles Island incident, though generating very little real damage, stopped new programs to build nuclear energy plants in the United States. It was the first time that a nuclear incident was put under media scrutiny, therefore arousing tremendous public and political concerns. Rightfully, the American Nuclear Safety Regulators, along with their counterparts in other western countries, decided to revisit the nuclear plant safety criteria and to reinforce them considerably. As a consequence, new US plants that were already at 90% completion would have to incur huge extra costs in order to meet the new safety standards. The industrial and financial risks became so high that many plants under construction were abandoned. Nuclear energy in the United States was stalled.

In Europe, nuclear power plant construction continued unabated. France, very conscious of its lack of domestic oil and gas resource, developed a sound nuclear energy program based on a centralized and monopolistic utility company EDF, a top league research center CEA, and a reactor vendor Framatome. The latter acquired the Westinghouse PWR technology after France decided to abandon its Graphite-Gaz design for scalability and safety reasons. France had a very intensive nuclear plant construction program from the mid 70's to mid 80's. During the year of 1981 alone, eight plants were commissioned. Also, France took a sound decision on nuclear waste treatment by choosing the closed fuel cycle.

[1] PWR: Pressurized Water Reactors. Originally developed by Westinghouse in the US, now other vendors such as Areva in France, Mitsubishi in Japan and CGNPG in China are all selling this type of reactor. Pressurized water is the coolant and nuclear reactor moderator. They use civilian grade enriched uranium.
[2] BWR: Boiling Water Reactors. This technology was developed and is still commercialized by General Electric. Boiling water is the coolant and nuclear reactor moderator. They use civilian grade enriched uranium.
[3] CANDU reactors use heavy water as the coolant and nuclear reactor moderator. They use natural (or slightly enriched) uranium. They are commercialized by AECL.
[4] Graphite Gas was the historical French design. Magnox and AGRs are U.K. designs. These reactors use CO2 gas as coolant and graphite as moderator. They are no longer commercialized by western companies. France stopped its GGRs in the 80's and U.K. has started to phase out its Magnox and will continue with its AGRs
[5] RBMK is the Chernobyl type reactor. It uses CO2 as coolant and Graphite as moderator. Unfortunately, its design has big flaws that, among other things, were responsible for the 1986 Chernobyl accident.

Other European countries continued their programs as well, including Germany and Sweden. Asian countries, notably Japan and South Korea, both natural resources poor, also started their nuclear power plant construction programs.

In May 1986, came the catastrophic news from Chernobyl. Little was known at that time on nuclear activities behind the iron curtain. The Soviet Union first attempted to hide what had happened, but was soon forced to admit that a terrible accident had occurred. It is probably the biggest civilian nuclear accident so far in history, and hopefully ever. This was a wake up call on the risks posed by certain Soviet reactors: poor designs and lack of safety and environmental concerns. As the infamous radioactive cloud spread all over Europe, this accident was no longer a Ukrainian/Soviet problem; it triggered great fear all over Europe.

After Chernobyl, nearly all European countries put their nuclear energy programs to a halt. Some, as Sweden and Italy, voted for a moratorium or even decided to phase out their operating plants. Germany also voted to phase out its plants after 40 years of operations. This said, in reality, only one Swedish plant, Baarsabeck and the Fast European Breeder, Super Phénix, located in France, were stopped. Germany did not start implementing its phasing out decision and it is not sure whether it will ever do so.

Only Asian countries continued to actively develop their nuclear energy programs: Japan, South Korea, India, and as a new comer, China.

But the wind is changing…

Having been out in the cold for many years, nuclear is now once again being embraced as an important energy source. "Nuclear Renaissance" became a much talked about phrase by media, academics, and industry alike. So how does it come about?

During the last two decades, many things happened. Four big trends are now converging in favor of nuclear energy:

Global energy demand and supply balance tightens. Primary energy supply is tight, especially oil and gas. Limited resources and insufficient investment in the past decades, compounded by increasing demands from fast growing developing economies, have driven oil prices to record highs. Just as importantly, electricity supply is also tight. Lack of investment in electricity generation infrastructures in western countries in the past few decades, combined with considerable new demands coming from developing countries, created a huge and urgent need to build new power plants. Investing in nuclear power plants is one of the solutions to provide large volumes of electricity without relying on oil and gas supplies.

Global energy security of supply is a cause of serious concern. Energy source diversification has becomes a strategic priority. Nuclear plants need uranium supplies, which are abundant and well spread geographically. Also, uranium has high energy content and thus countries and power plants can easily maintain strategic stockpiles for multi-year supply. In addition, as the price of uranium is only a small component of the total cost of producing nuclear energy, uranium price volatility barely affects the cost of nuclear electricity. This is why countries having implemented large nuclear programs have increased their energy independence.

Climate change calls for carbon free energy sources: Climate change issues, since their emergence, have quickly become a serious concern for politicians and populations across the globe. The need to build carbon-free electricity generation plants makes nuclear energy a very attractive option. At present, nuclear, together with hydropower, are the only carbon-free schedulable energy sources able to produce large volume of electricity at affordable cost.

The nuclear energy industry is maturing up: Thanks to institutions like INPO and WANO[6], plant operators now can exchange experience and best practice through various channels—for example, peer-to-peer reviews. US nuclear operators have considerably improved their plant safety and availability level. Also, mergers and acquisitions among operators have created larger players with better industry skill pools. Financially, these amortized nuclear plants with high availability and high output became attractive to investors again.

These fundamental trends will be further analyzed in the following chapters.

So what's next?

The hopes are high and the opportunities are big. The challenge now is to sustain this renaissance, and to develop it into a reliable long term energy solution. Many lessons can be drawn from the short history of the civilian nuclear energy industry in order to avoid the past errors. The construction and operation of nuclear plants, while having common features with all large industrial projects, have some very specific characteristics around safety, nuclear non-proliferation, very long construction and operations time horizon, and public opinion management. Moreover, after years of decrease or stagnation, the industry first of all has to ramp up its facilities and grow its human capabilities, and build a sound business model ensuring its long term financial viability. Certain prerequisites addressing these special features need to be in place before the industry can truly take off. In later chapters, we will examine these prerequisites in further detail.

[6] INPO: Institute of Nuclear Plant Operations. WANO: Worldwide Association of Nuclear Operators

Global Energy Outlook

We have to understand the energy dilemma the world faces nowadays—on one side is the huge pressure on energy supply, calling for massive investments on energy infrastructures, on the other side is the ever-increasing price tag on conventional hydrocarbon resources, economically, geopolitically, and environmentally. Let's analyze some fundamental facts in more detail.

Population and economic growth will put high pressure on energy supply

From 2005 to 2030, the worldwide energy demand is forecasted to have a compounded growth rate of 1.2% per annum[7], with non-OECD countries growing by 1.7% and OECD countries by 0.6%. Such forecast is made on the back of strong population and economic growth projections, especially in non-OECD countries. This trend of increased energy demand had been underestimated by many economists and business leaders until around 2005. As a consequence, the much needed investment in oil and gas exploration and production started behind the curve. While mature fields are being depleted, major oil and gas companies are unable to replace their reserves. It will take some time to ramp up infrastructures, and of course, much more time for it to impact production.

Even with increased investments, oil and gas resources are quite limited. It is rare to find very large new fields and equally difficult to exploit some that are found. At the current consumption rate, it is estimated that worldwide oil reserves (excluding heavy and non-conventional oils) will last around 44 years, and gas will last around 67 years. Coal is much more abundant, with reserves estimated to last 146 years, and is well spread worldwide. In future, coal will certainly increase its share in electricity generation. However, for environmental and climate change reasons, clean coal technologies and Carbon Sequestration and Storage (CSS) should imperatively be implemented. Today, these technologies are not yet at an industrial stage.

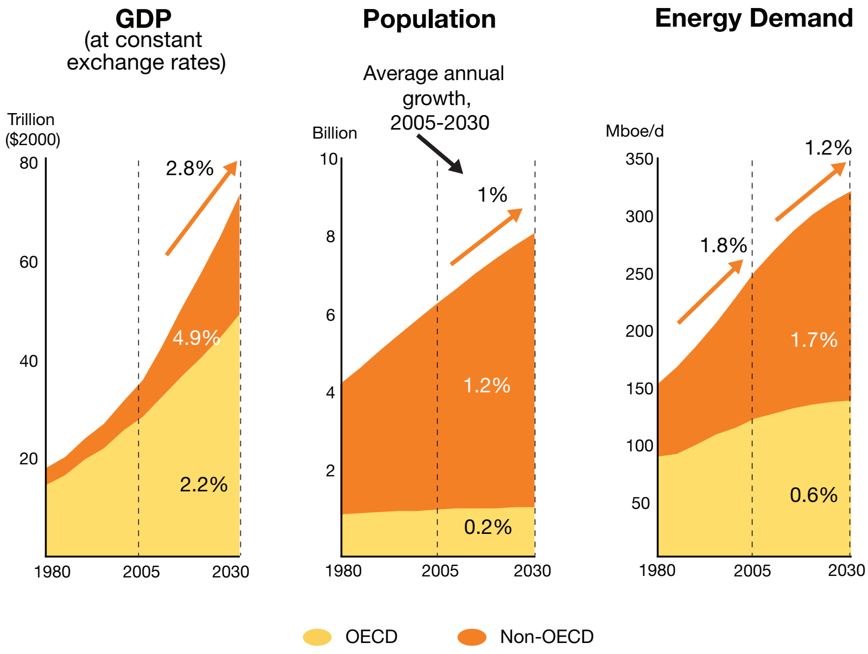
This squeeze from the increasing demand and limited supply is one of the root causes of the big price surge in oil, gas, and to a lesser extent, coal, that we have experienced since 2005. The market is betting short on energy supply going forward.

Energy security of supply is of strategic importance

The world's oil reserves are very concentrated. Around 62% of the total proven reserves are in the Middle East region. The distribution of natural gas reserves is only slightly better, with around 41% of the proved reserves in Middle East and around 27% of it in Russia.

[7] Source: studies by International Energy Agency and Total

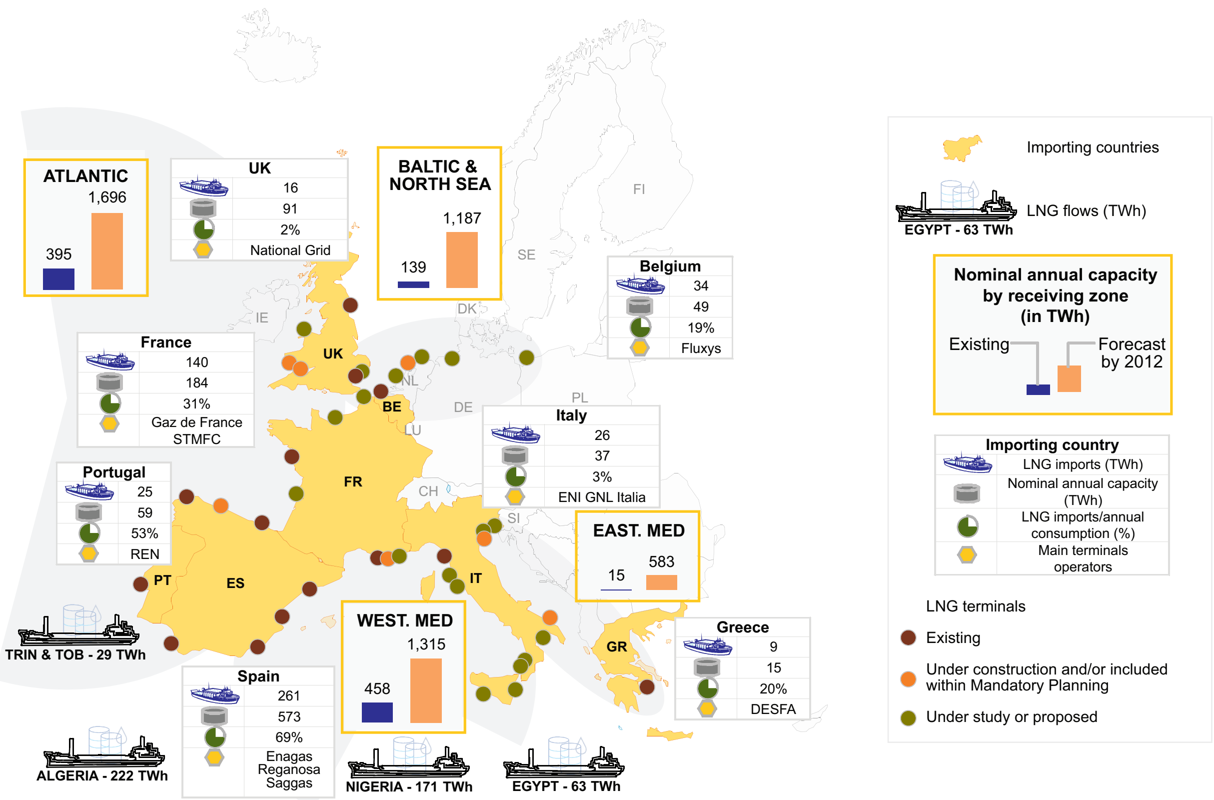
Figure 1: World population and economic growth



Source: United Nations, World Population Prospects 2006; IEA; Total.

Our world is too dependant on scarce oil and gas energy sources, thus giving a huge political and financial power to a limited number of producing countries. In tight supply periods, some of these producing countries are tempted to use energy supply as a means to achieve political objectives, adopting tactics ranging from covert threats to bluntly turning off pipelines. With North Sea oil fields depleting, OPEC will regain more power. Let's hope that OPEC will use this power in a sound way! On the gas side, the European Union (EU) is becoming more and more dependant on Russian gas supplies, which will represent 50% of total gas supplies to EU in 2030. So when Gazprom cuts gas supply to Ukraine, as it did on January 1 2006, or to other countries in this transit zone, all European countries are strongly affected, as was Italy in 2006.

Figure 2: LNG Imports and Terminals in Europe

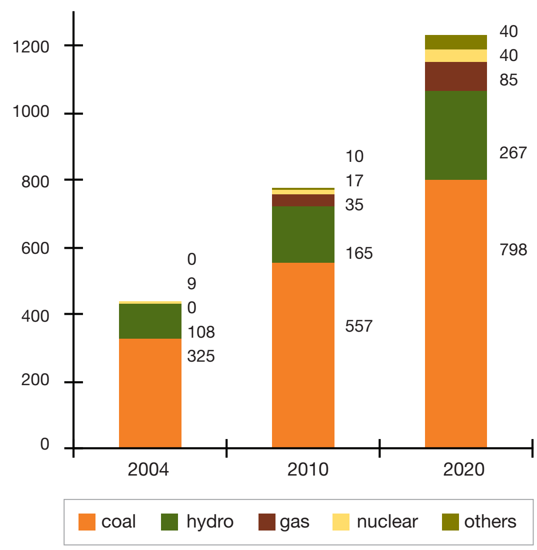


Source: GIE gle, BP statistical review of world energy 2008 - Capgemini analysis, EEMO10

Moreover, fast growing developing economies such as China and India have joined the international competition to secure energy supply, making the fight ever fiercer.

To reduce this over dependency, all major energy import countries are working hard to diversify their energy supply, both geographically and in terms of energy type. For example, in order to reduce its dependence on natural gas supplied by Russia through pipelines, Europe plans to significantly increase its capabilities of handling Liquefied Natural Gas (LNG). This move will expand Europe's geographical outreach, giving it access to 60% of the natural gas reserves worldwide. This move alone of course is not enough. Investing in developing alternative energy types is also vital. Wind, solar, biomass, geothermal, and of course, nuclear, are all needed.

Figure 3: China electricity generation energy mix (GW)



Huge investments, of the right kind, are needed

Worldwide:

According to a report from International Energy Agency (IEA) published in November 2007, at 2% global GDP[8] growth rate, the world would need cumulative investments worth about $22 trillion in energy infrastructure (oil, gas and electricity) between 2006 and 2030. The investment need is created by the conjunction of several forces. In developed countries, many components of energy infrastructure installed in the decades after the second world war, particularly power stations and electricity grids, are coming to the end of their industrial lives and will need to be replaced. It is in developing countries, however, that the need is greater. The IEA estimates that an investment of more than $11 trillion is needed in emerging economies, of which China alone accounts for $3.7 trillion.

The focus will be on electricity supply, accounting for more than half the worldwide total investment. Today, about 1.6 billion people do not have access to electricity. The global demand for electricity is expected to double in the next 20 years.

If all that's required is to meet this increased demand, then one might have some faith in the ability of the market to cope. However, the problem has become more complex due to the need to curb CO_2 emissions in order to slow down global warming. Therefore, it needs not just any investment but the right kind of investment in energy efficiency, nuclear generation, renewables and Carbon Capture and Storage technologies.

Europe

Europe's case is a good illustration of these complex problems. In Capgemini's most recent European Energy Market Observatory[9], it is estimated that investments totaling at least €1 trillion are needed in electricity and gas infrastructures in Europe. After years of insufficient investments in electricity infrastructure leading to tense supply and demand situations and even blackouts, investments have picked up since 2005.

However, the energy mix choices are questionable. The vast majority of the planned generation plants will be fossil fuelled, predominantly gas fired. Not only will these plants bear high and volatile fuel costs and contribute to European countries' increasing dependencies on imported gas, but they will also be big CO_2 emitters if built without Carbon Sequestration and Storage (CSS) facilities. So far, CSS technology is not yet at an industrial stage. Therefore, regarding the EU's objective to reduce 20% of its CO_2 emissions by year 2020, these new investments are counterproductive.

Climate Change has become a major concern

Climate change issues have emerged in the past decade or so. In recent years, due to the fear of a rapid rise of the earth's temperature, this topic quickly became a serious concern for politicians and populations across the globe. Majority of the scientists believe increased emission of CO_2 and other greenhouse effect gases are the

[8] GDP: Gross Domestic Product
[9] http://www.capgemini.com/industries/energy/eemo/

Figure 4: Main European Utilities' total investment as a % of sales

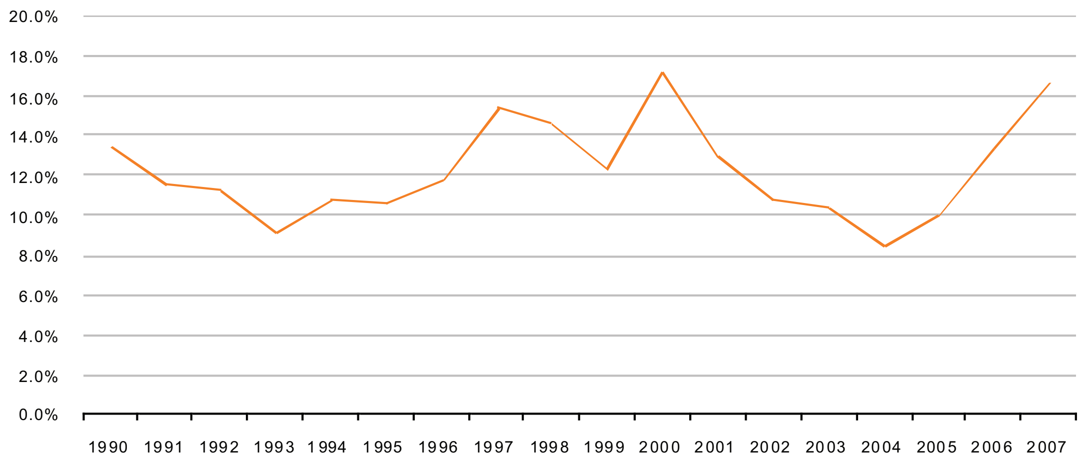
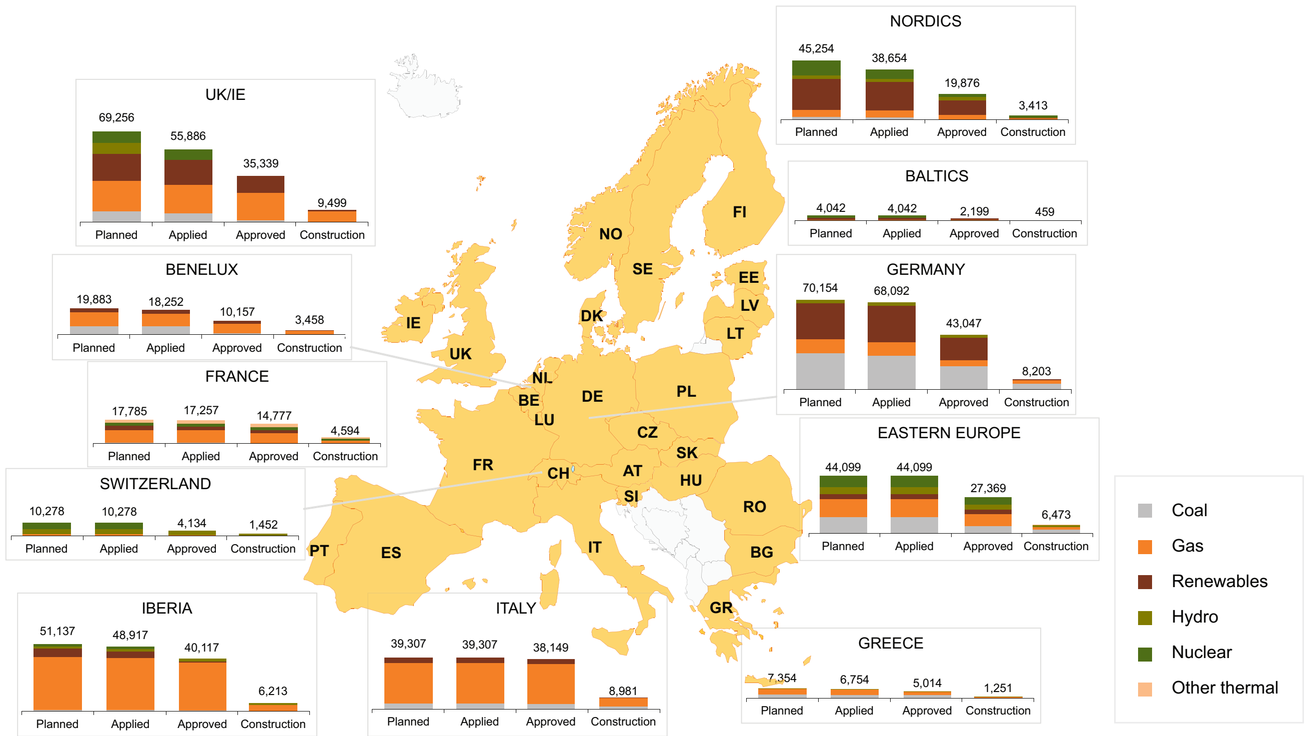


Figure 5 : Projects of new European generation capacities, in megawatts (2007)

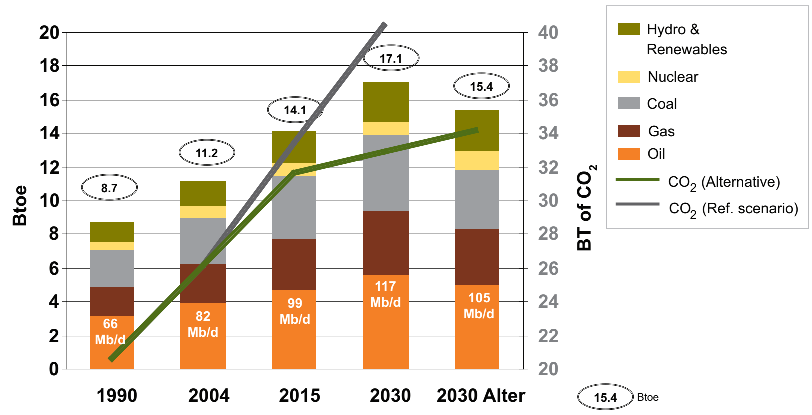


Note: All projects above 5 MW are considered. Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia and the Baltics are added from 2006 geographical perimeter
Source: Platt's PowerVision – Capgemini analysis, EEMO10

major cause for global warming. IEA forecasts that by 2030, worldwide CO_2 emissions should increase by 46% in a reference scenario.

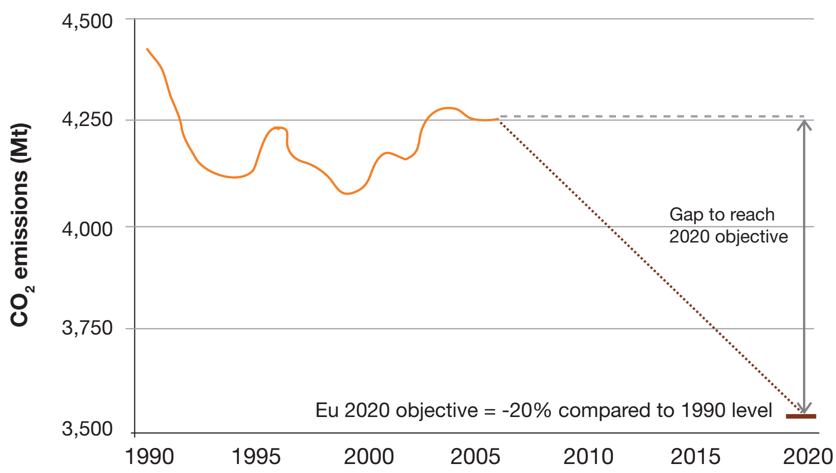
The EU is a front runner in trying to curb CO_2 emissions. Since 2006, it implemented the Emission Trading System (ETS)—a cap and trade system for CO_2 emission rights. In 2007, its member states agreed on an objective of 20% CO_2 emissions reduction by 2020. However, as seen on the following graph, these objectives will be difficult to meet.

Figure 6: World's total primary energy supply and carbon emission



Source: IEA, WEO 2006.

Figure 7: European CO_2 emissions



While fighting climate change is weighing heavy in Europe, the same questions are also keeping North American energy executives up at night, as revealed in the 2008 Platts/Capgemini study[10]. Indeed, environmental issues are looming larger than ever. When asked to name the top three challenges facing the industry, the vast majority (77 percent) of the surveyed executives identified the environment—including issues such as global warming, climate change and emissions/carbon requirements. This is indicative of the increasingly pressing nature of the impact of environmental concerns on today and tomorrow's business.

So what is the solution?

How do we respond to an increasing energy demand, with limited and unevenly distributed fossil fuel reserves, and without increasing CO_2 emissions? There is no simple answer to this complex question, but rather a combination of different actions is required, including energy savings, renewable energies development and improvement, clean coal implementation, carbon capture and storage technologies development, and nuclear energy development. The impact of these measures is shown in IEA's alternative scenario for CO_2 emission projection.

We are in a critical situation but there are some reasons for hope. High oil prices have started to reduce consumption. Individuals and businesses are becoming more environmentally sensitive and are changing behavior. New technologies and processes are continually being invented to conserve energy use. However, these positive signs are not enough. Tougher measures should be taken in developed countries in order to reduce energy consumption and CO_2 emission. Adapted measures, including energy efficiency improvement programs, need to be

[10] http://www.us.capgemini.com/PlattsStudy/

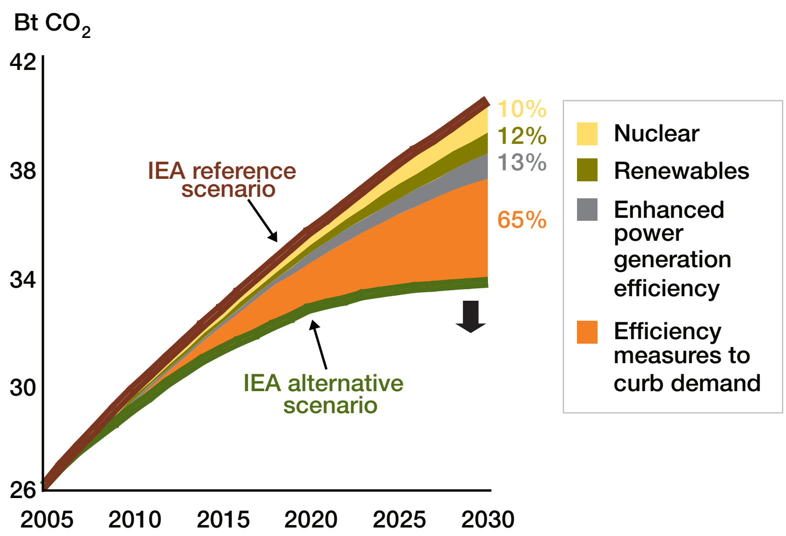
designed for developing countries. In these countries, energy consumption and CO_2 emission per capita are still very low and will surely grow because people want, rightfully, to reach better standards of living through industrial development. We should not forget that the tons of CO_2 present in the atmosphere today are linked to the activities of developed countries in the past!

Nuclear energy is an important part of the answer

Among all the alternative sources of energy, nuclear, together with hydro, are the only sources that can provide large volume of schedulable and CO_2 free electricity. It is worth noting that in IEA's "alternative scenario," nuclear alone is expected to contribute 10% of the total CO_2 emission deduction, almost the same weight as all other alternative sources of energy added together. Also, the relatively better spread of uranium resource makes nuclear energy a strategic counterbalance for many countries that are currently over-dependent on oil and gas import.

Around the world, across political spectrums, there is a wider recognition nowadays that nuclear is an important part of the solution to the energy problem the world is facing. This is why we are witnessing a worldwide Nuclear Renaissance.

Figure 8: IEA alternative scenario on CO2 emission projection by taking all saving measures (in billion tons of CO2)



How do we respond to an increasing energy demand, with limited and unevenly distributed fossil fuel reserves, and without increasing CO2 emissions?

Among all the alternative sources of energy, nuclear, together with hydro, are the only sources that can provide large volume of schedulable and CO2 free electricity.

Nuclear Renaissance

In recent years, we are witnessing two types of efforts in reviving the nuclear energy industry:

Increasing the output from existing nuclear plants

During these last years, and before new investments in nuclear plants were launched, utility companies have focused on plant uprating and lifetime extension. In many European countries, nuclear plants initially designed with a lifetime of 25 years have been extended to 40 years. Further extension to 60 years is being considered. Operators are also investing in uprating their plants in order to increase their output. These moves usually have a very good Return on Investment. Figure 9 below shows the planned and potential results of nuclear power plants' uprating and lifetime extension programs in selected European countries.

Operators have also launched programs to improve the availability of their nuclear reactors. These programs have given spectacular results in the United States where operators that were once laggards are

Figure 9: Nuclear power plant uprating and long term operations in selected countries

Country	Capacity Uprating	Long Term Operations
Belgium	Yes	Phase-out policy
Czech Republic	Planned	Planned for 40 years, potentially can be extended to 60 years (4 units)
Finland	Capacity increase of 18 megawatts completed in 2005 for Olkiluoto unit 2 and in 2006 for Olkiluoto unit 1.	Planned for 60 years for Olkiluoto units 1 and 2, as well as for unit 3 (EPR). Loviisa's 2 units have been extended to 50 years
France	No	Lifetime of 40 to 60 years (58 units)
Germany	Yes	Phase-out policy
Hungary	Under way for 4 units, capacity increase of up to 150 megawatts	Planned for 50 years (4 units)
Slovenia	Yes	Lifetime of 40 to 60 years
Slovak Republic	Under way for 4 units, capacity increase of up to 220 megawatts	Planned for 40 years, potentially extend to 60 years (4 units)
Spain	Completed for 8 units, capacity increase of up to 220 megawatts	Planned, possibly will extend to 60 years (8 units)
Sweden	Under way for 8 units, capacity increase of up to 1,296 megawatts	Planned, may extend up to 60 years or more (8 units)
Switzerland	Yes	Lifetime of 40 to 60 years
United Kingdom	No	Planned for 35 years (5 plants) or 30 years (2 plants); further extension possible

Source: Nuclear Energy Agency, Newsletter No. 24.2; 2006: P. Kovacs: "Impacts of Nuclear Power Plant Life Management and long term operation".

now “best in class” performers. These programs are often based on nationwide or international benchmarking methods, for example peer-to-peer reviews, that are supported by institutions such as INPO and WANO.

Worldwide, this industry now has more than 12,000 reactor years of experience. The global average nuclear plant availability during 2006 reached 83%. Progress has been made not only on plant electricity output measured by the Unit Capability Factor (percentage of maximum energy generation that a plant is capable of supplying to the electrical grid), but also on workers’ protection and Industrial Safety Accident Rate. Worldwide results show that the nuclear industry continues to provide one of the safest industrial work environments.[11]

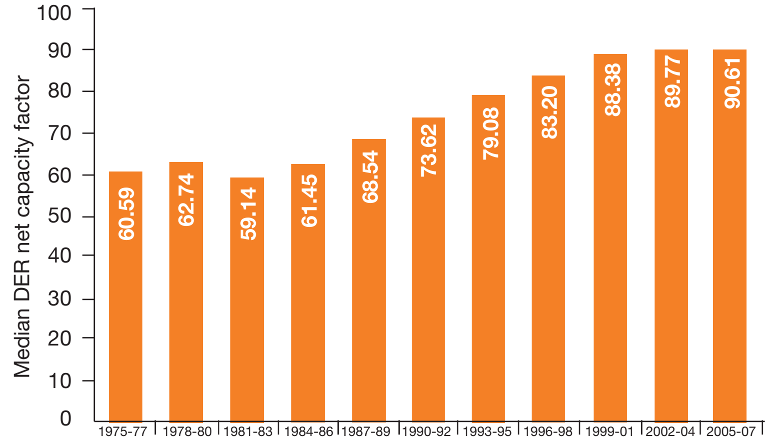
Investing in building New Nuclear Plants

Today, there are 439 reactors in operation, 34 under construction and around 320 nuclear projects planned in all the regions around the world.

Asia is the most active area:

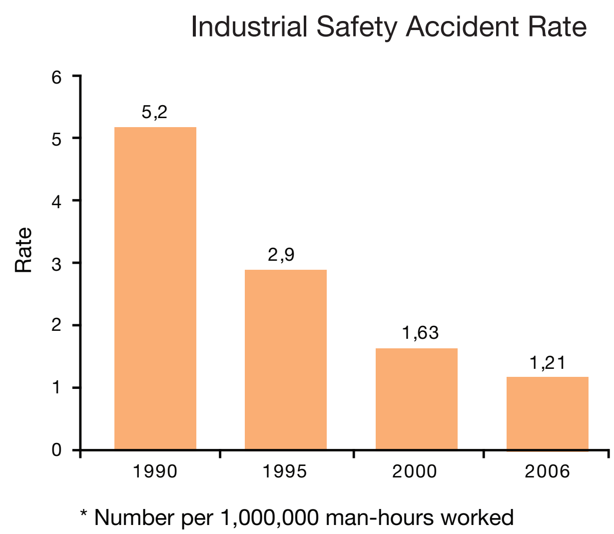
China currently has eleven operating plants, mainly in coastal areas. Eight reactors are under construction, among which some are based on Chinese technologies. Eight more reactors are planned. In October 2007, China’s National Development and Reform Commission released the country’s blueprint for nuclear energy development from 2005 to 2020. It aims to raise generation capacity to 40 gigawatts by 2020, with an additional 18 gigawatts still being built at that time. Plans include spending about $70 billion to construct scores of new 1,000 megawatts reactors during this period. By 2020, nuclear energy is expected to account for 4% of China’s total energy consumption, up from the current 2%. Since the publication of the NDRC report, there have been calls for faster speed of development.

Figure 10: US Reactors’ Capacity Factor evolution



Note: **All reactors.** For the most part, median capacity factor has leveled off, but there has still been roughly a 1-point gain in each three-year period since 1999-2001. The chart shows only reactors that are still in service now; there were 32 such reactors in 1975-1977, and in each succeeding period there were 49, 55, 65, 85, 99, 102, 103, and 104 in each of the last three. If closed reactors were included in the periods during which they operated, no median would change by as much as 1 percentage point.
Source: "Nuclear News" May 2008, American Nuclear Society.

Figure 11: Worldwide Nuclear Plants safety improvement



[11] Source: World Association of Nuclear Operators, 2007 Performance Indicators

There are suggestions that nuclear energy should account for 5% of national energy consumption by 2020.

India has seventeen nuclear power plants with a total installed capacity of 4,120 megawatts in operation. Six additional units, with a total capacity of 3,160 megawatts, are under various stages of construction. Hopes are high that following agreements with the International Atomic Energy Agency, the Nuclear Suppliers Group and the US congress, nuclear trade with global players will open up. If so, the Indian government, which was originally targeting 20,000 megawatts of nuclear power by 2020, hopes to double the nuclear capacity to achieve an installed capacity of 40,000 megawatts over the next twelve years. The US-India Business Council estimates that at least $100 billion worth of investment will be needed to develop such a program.

In **Japan**, nuclear energy is already providing 50% of the total electricity generation. In addition, eleven new units are scheduled to start commercial operation by 2014.

In **South Korea**, six reactors are under construction. There are plans for eleven new ones by 2035 that should increase the nuclear share to 60% in electricity.

Europe is becoming an active region again.

Finland is the first European country that has decided to re-launch nuclear energy. After a long debate, the Finnish government launched a tender for its fifth's nuclear plant. Areva won the bid after fierce competition. The first Areva third generation European Pressurized Water Reactor (EPR[12]) reactor is under construction at Olkiluoto, with a two year delay and 50% cost overrun. It should be online in 2011.

France has one EPR reactor presently under construction. In June 2008, the construction of a second one was announced by the French president. France derives over 75% of its electricity from nuclear energy. This is due to a longstanding policy based on energy security of supply. France is the world's largest net exporter of electricity due to its very low generation cost from nuclear, and gains over €3 billion per year from exports. France has always been very active in developing and exporting nuclear energy technology. At the very beginning of its nuclear energy program, France chose the closed fuel cycle for waste treatment. This method involves reprocessing used fuel so as to recover uranium and plutonium for reuse, and reduces the volume of high-level wastes for disposal.

U.K. has aging Magnox and AGR nuclear plants that need to be replaced. Moreover, because of the North Sea gas reserves depletion, it has become a net gas importer since 2006. After a long debate, the UK government has committed to the continued use of nuclear power and wants the first new nuclear station to come online before 2020. The current estimations are 25,000 megawatts by 2030.

Italy: After the 1987 nuclear phase out referendum, the new government is now planning new nuclear power plant construction.

Swiss operator ATEL has submitted an application to build a new third generation light water reactor.

The Netherlands: Delta, a Dutch utility company, has announced proposals to build a second reactor unit at Borssele, with generating capacity of between 1,000 and 1,600 megawatts, envisaged to be operational by 2016.

Former Eastern European Countries:
These countries often have legacy Soviet designed nuclear plants. Amid safety fears, many of these countries had to close such reactors as a condition to their European Union accession. Most of the affected companies received financial compensation for the energy output losses. They are now pursuing programs to invest in new nuclear plants, typically third generation Russian design reactors. Their projects are sometimes carried out in partnership with Western European utilities.

Romania managed to cut its electricity imports by nearly 30% in the first half of 2008 compared with the same period in 2007, thanks to a massive increase in nuclear energy output after its second nuclear reactor Cernavoda 2 started up. Romania's next two nuclear reactors, also at Cernavoda, will be built by a consortium of six European companies in a joint venture with Romania's Nuclearelectrica SA.

Bulgaria: Units 5 and 6, the most modern at Kozloduy, are the only ones still producing energy. The other four were shut down as a price for Bulgaria's EU membership. To offset the loss of production at Kozloduy and to regain its position as a major electricity exporter to the rest of the Balkans, Bulgaria has revived plans for a second nuclear power plant at Belene.

Slovakia has five nuclear reactors generating half of its electricity. Two more are under construction. In February 2007, Slovak Electric announced that it would proceed with the construction of Mochovce 3 and 4. Italian utility ENEL has agreed to invest €1.8 billion on this project, with an operation date set for 2012-13.

Lithuania: Due to strong EU concerns about the safety of its two Ignalina RBMK type reactors, when Lithuania applied to join the EU, it was required to close them both down. Since then, unit 1 was closed in December 2004 and unit 2 should be closed by the end of 2009. It will leave Russia as the only country that still operates RBMK reactors. In July 2008, Lithuanian Energy Organization together with

[12] European Pressurized Water Reactor, the Franco-German 3rd generation 1600 megawatt reactor

energy companies from Latvia, Estonia and Poland established the Visaginas project development company. This project will build a new 3,200-3,400 megawatts nuclear power plant.

Czech Republic has six nuclear reactors generating about one third of its electricity. In July 2008, the nuclear energy company CEZ announced a plan to build two more reactors at Temelin, totaling up to 3400 megawatts. Construction is to start in 2013 and the first unit will be operational in 2020.

Russia and former CIS countries

Russia has thirty one operating reactors, totaling 21,743 megawatts. Its first nuclear power plant, which is also the first in the world to produce electricity, was the 5 MW Obninsk reactor started in 1954.

The efficiency of Russian nuclear generation has increased dramatically over the last decade, with capacity factors leaping from 56% to 76% (1998-2003). Russia has seven reactors under construction. Its nuclear energy program aims at increasing the share of domestic nuclear electricity generation from 15.6% to 18.6% by 2015. This program should cost about $67 billion. By 2015, ten new reactors totaling at least 9,800 megawatts should start operating. From 2012 to 2020, two new nuclear reactors of 1,200 megawatts each should be commissioned each year.

Electricity and gas consumptions are rising strongly in Russia. Though Russia has abundant gas resources, it prefers to export more to the international market when prices are high, instead of consuming this gas locally with heavy subsidies. The more nuclear power plants Russia builds, the less gas it burns for domestic electricity generation. Exporting nuclear reactors is also a major policy and economic objective, which is why Russia is commercially active in many international bids.

Ukraine's best known nuclear power plant was Chernobyl, the only RBMK type reactor in the country. Unit 4 was destroyed in the 1986 tragic accident. Unit 2 was shut down after a turbine hall fire in 1991. Unit 1 and 3 were closed in 1997 and 2000 respectively, due to international pressure. Ukraine is still heavily dependent on nuclear energy. It has fifteen VVER type reactors generating about half of its electricity. The government plans to maintain the current nuclear share in electricity production till 2030, which may involve substantial new build.

North America:

US companies and consortia are pursuing licenses for more than thirty four nuclear power plants at 23 sites. The Nuclear Regulatory Commission has received construction/operating license applications for 7 sites and more are expected in 2008. Georgia Power has passed the first firm order to Westinghouse for two AP1000 reactors.

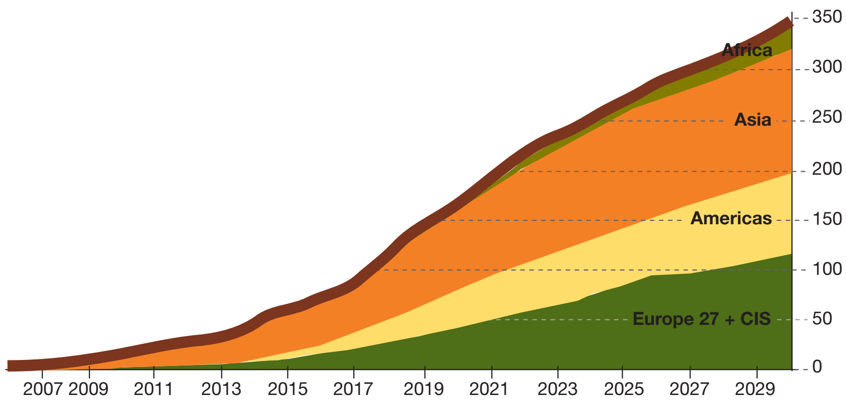
Canada: Ontario is moving forward to replace its nuclear fleet and is launching a request for proposal to select vendors. Alberta is considering building up to two twin unit plants.

South Africa's nuclear operator Eskom launched a consultation for 12 new nuclear power plants a few months ago.

Finally, **Gulf countries** that are facing high domestic electricity demand growth, wish to generate nuclear electricity in order to comply with their oil and gas exportation commitments. In 2008, United Arab Emirates has signed an agreement with several French companies to build new 3rd generation EPRs. It has signed a similar Nuclear Agreement with the US as well.

This worldwide scan demonstrates a growing demand for nuclear power in "old" nuclear countries as well as in new ones, in developed countries as well as in the developing world, in countries with experienced nuclear authorities and also in places were they don't exist yet, in nations with savvy, established nuclear operators as well as those with no or relatively less experience. According to International Atomic Energy Agency (IAEA), global nuclear energy capacity in 2008 is 372 gigawatts. By 2030, it is expected to range from a low case scenario of 473 gigawatts to a high case scenario of 748 gigawatts.

Figure 12: High case scenario projection of new nuclear energy capacity added worldwide 2007 – 2030 (in gigawatts)



Prerequisites for a sustained nuclear renaissance

Despite all the trends in favor of nuclear energy, we need to recognize that this industry is still relatively young and fragile. This emerging nuclear revival could easily derail if it is not properly nurtured. There are many prerequisites that need to be in place for this worldwide nuclear renaissance to sustain and turn into a success, and not be halted as it happened in the past.

As other large scale industrial projects, nuclear plants construction carries multidimensional risks. In addition, the nuclear industry has some unique and especially stringent requirements to comply with. Capabilities to meet these requirements are paramount prerequisites for the industry to succeed.

The most important prerequisites are:

- Effective nuclear non-proliferation control
- Stringent safety management
- Mastering the exceptionally long project lifetimes and large investments
- Long term financial viability
- Smooth industrial ramp up
- Public opinion acceptance.

The following sections elaborate each of the above prerequisites one by one:

Effective Nuclear Non-Proliferation control:

The Treaty on the Non-Proliferation of Nuclear Weapons, also known as Nuclear Non-Proliferation Treaty (NPT or NNPT) is a treaty to limit the spread of nuclear weapons. Opened for signature in 1968, the treaty entered into force in 1970. A total of 187 parties have joined the treaty, including the five nuclear-weapon States[13]. The treaty establishes a safeguards system under the responsibility of the International Atomic Energy Agency (IAEA). Safeguards are used to verify compliance with the treaty through inspections conducted by the IAEA. The treaty promotes cooperation in the field of peaceful nuclear technology and equal access to this technology for all State parties. It is worthwhile to note that, as a testament to the treaty's significance, more countries have ratified the NPT than any other weapon limitation and disarmament agreement.

Only four recognized sovereign states are not parties to the treaty: North Korea, India, Pakistan and Israel. India and Pakistan both possess and have openly tested nuclear bombs. Israel has had a policy of opacity regarding its nuclear weapons program.

- **North Korea** acceded to the treaty, violated it, and later withdrew. Presently, through the mechanism of six-party talks[14], North Korea is in discussions with other countries to close its small Yongbyong proliferating reactor and to stop the other Magnox type of reactors currently under construction.
- **India:** In December 2006, United States Congress approved the United States-India Peaceful Atomic Energy Cooperation Act. However, this

[13] They are: the United States, the United Kingdom, France, Russia, and the People's Republic of China (the permanent members of the UN Security Council).
[14] Six party talks: the People's Republic of China; the Republic of Korea (South Korea); the Democratic People's Republic of Korea (North Korea); the United States of America; the Russian Federation; and Japan.

legislation was not approved by the Indian government at that time. After some changes in the Indian parliament, it should be accepted now. This legislation allows for the transfer of civilian nuclear material to India. Despite its status outside the Nuclear Non-Proliferation Treaty, India was granted these transactions on the basis of its clean proliferation record, and its unusually high energy need fuelled by its rapid industrialization and billion-plus population. IAEA and Nuclear Suppliers Group (NSG) have given their agreements. The final step now is for it to be approved by the US Congress. If passed, this legislation will open up the $150 billion Indian nuclear market not only to US vendors, but also to vendors from other countries, notably French and Russian ones.

- Attempts by **Pakistan** to reach a similar agreement have been rebuffed by the U.S. as well as by the international community. The argument put forth is that not only does Pakistan lack the same energy requirements (as India) but that its track record as a nuclear proliferator makes impossible for it to have any sort of nuclear deal in the near future.
- **Iran** is a signatory state of the NPT and has resumed the development of uranium enrichment program in 2006. Iran claims it is part of its civilian nuclear energy program. However, the IAEA Board of Governors found Iran in noncompliance with its NPT safeguards obligations. Following IAEA's report, the United Nations Security Council passed a resolution demanding that Iran suspends its uranium enrichment. Negotiations on this critical issue are underway and sanctions have been applied to Iran.
- **South Africa** deserves a special mention as the only country that developed nuclear weapons by itself and later dismantled them.

Effective non-proliferation control and compliance with the IAEA requirements necessitate implementing a holistic control. Many countries have, in addition to the IAEA inspection systems, established national inspections in order to supply required information to the Vienna based agency. Nuclear operators have installed a comprehensive set of instrumentation and data collection systems in their facilities to enable them to respond to inspection and reporting requirements. Through this process, the operators have subsequently also gained transparency and operational reliability.

New nuclear countries and operators should not underestimate the importance of these non-proliferation systems and organization. Only transparent and trustworthy operations can succeed in the long run.

Stringent Safety Management

In the past, the nuclear energy expansion was impeded by nuclear incidents (Three Miles Island) and accident (Chernobyl). These events had mainly regional impact. Since then, global communication has developed tremendously and similar unfortunate events would have a global impact and would kill the nuclear renaissance. Therefore, it is of utmost importance to apply stringent safety management across the entire lifetime of nuclear power plants.

The first step is to put in place strong and independent safety authorities. As successful practices in some countries show, independent safety authorities are critically important in working with operators to establish rigorous operations processes and to monitor their enforcement.

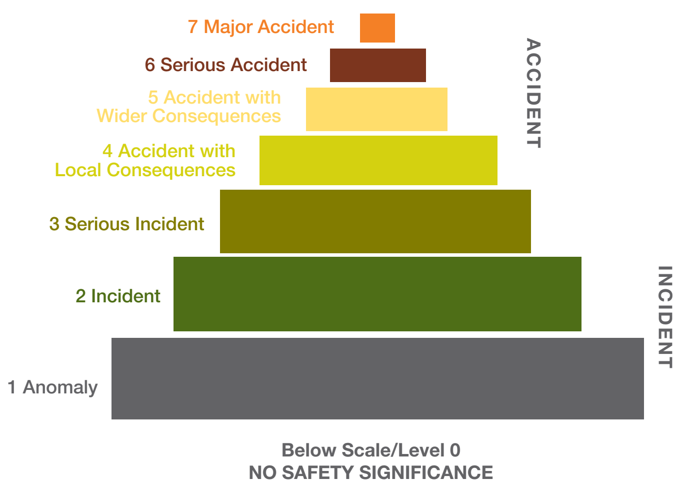
- New nuclear countries need to establish the right safety structure with the right governance and independence towards the governments. They need to start recruiting and training their staff ahead of time in order to be ready when the first operator would apply for a new plant.
- Existing nuclear countries need to reinforce their safety authorities in order to meet the new growth demands. In mid 2008, the British Business Secretary John Hutton launched an action plan on human resources. It included measures to improve recruitment and retention of staff at Nuclear Installations Inspectorate (NII), which regulates nuclear safety in UK.
- Today, seasoned nuclear safety experts are in short supply. A holistic approach should be taken, including building a strong talent pool and optimizing its usage. The latter could be achieved by streamlining review and control processes. Within one nation, this means seamless relationship with other government bodies. For example, UK's BERR[15] Ministry, in charge of new nuclear installations, created an Office of Nuclear Development in June 2008. This office will connect with environment agencies, health agencies, decommissioning bodies, and the research and education ministry, in order to coordinate among these different entities and create a one stop shop. Across borders, this means international cooperation, such as the one taking place among British, French, American and Finnish nuclear safety regulators. Also, international safety training centers should be launched to enable seasoned safety authority teams to share their experiences with new ones, and to train engineers from both "old" and "new" nuclear countries.

The importance of safe design and safe build is obvious. The Chernobyl plant didn't have an intrinsically safe functioning mode and, as many Soviet design plants, lacked a containment building. The new third generation nuclear plant design, which is the core design for most of the newly planned constructions, is much safer.

[15] the UK Department for Business, Enterprise & Regulatory Reform, in charge of the new nuclear installations development

During long years of operations, nuclear power plants need not only strictly procedures, but also a safety culture to guide their personnel. Multiple studies have proved that accidents are usually the result of a conjunction of events. Accidents could have been avoided if minor precursor incidents would have been reported and analyzed thoroughly. This is why, many savvy nuclear operators promote a safety culture based on which personnel are encouraged to report—as soon as possible—the smallest incident or non-compliance with the operations processes. Finally, implementation of the International Nuclear Event Scale (INES) introduced by IAEA considerably improved nuclear operators' transparency towards safety authorities and the public. A number of criteria are defined to assure coherent reporting of nuclear events by different official authorities. There are 8 levels on the INES scale as shown in figure 13 below.

Figure 13: International Nuclear Event Scale (INES)



Source: International Atomic Energy Agency, INES

Used fuel cycle and radioactive wastes are the most controversial topics around nuclear energy. Some high level radioactive wastes have very long lifetimes that are measured in million years. They need to be disposed in the safest way possible, and as such are awaiting scientific and industrial progress that will allow them to be converted into low level/short lifetime wastes, for example, by transmutation.

A sound treatment of these wastes is the nuclear energy industry's utmost important social responsibility. It is also critically important for the industry's long term survival.

There are two main used fuel treatment options. The open fuel cycle consists of storing the used nuclear fuel in geologically stable repositories. It is the Swedish and Finnish option. The closed fuel cycle consists of reprocessing the used fuel, recycling the extracted uranium and plutonium in MOX fuel, vitrifying the high-level radioactive wastes and storing them in geologically stable repositories. It is the French, British, and Japanese option. In France, where nuclear energy contributes more than 75% of the total electricity generation, the volume of high level radioactive wastes generated per habitant per year is that of a bead. Recycling uranium and plutonium in MOX fuel allows 30% more energy to be extracted from the original uranium and leads to a great reduction in the amount of wastes to be disposed. It preserves uranium resources which may become more scarce in the future. Overall, the cost of closed fuel cycle treatment is comparable with that of open fuel cycle.

The United States stopped nuclear fuel reprocessing under President Jimmy Carter's mandate. In 1982, it elected to directly store the used fuel in the Yucca Mountain site. According to the original plan, the site should have been opened in 1998. However, this project is still not accepted by the US congress nor by the local population. The project costs have skyrocketed. In August 2008, the US Department of Energy estimated its costs at $96 billion, a 67% increase from the 2001 estimation. This unsettled situation represents a serious obstacle for nuclear renaissance in the US.

New nuclear countries will have to choose between the open fuel cycle and closed fuel cycle. If they choose closed fuel cycle, they could either buy reprocessing services and MOX[16] fuel fabrication from a foreign supplier or they could build these facilities domestically, as China seems to have done. The former is a better solution regarding the nuclear non-proliferation control.

If all the above points on safety management are strictly adhered to, there will be much better chances that we will witness a safe nuclear renaissance this time.

[16] MOX: Mixed (Uranium/Plutonium) Oxide Fuel

Mastering exceptionally long project lifetimes and big investments

The construction of a nuclear plant costs a few billion dollars and its lifetime extends to sixty years. Moreover, seven to ten years of construction time has to be envisioned, including several years needed to get clearance on all the regulatory requirements—design, location, construction, and impact on health and environment—before building work can start. If there is strong local opposition, these lead times could be even longer. For such a long project involving a large amount of investment, risks could come from many fronts: technical complexity, contractual or environmental concerns, complex and volatile regulatory requirements, suppliers' scalability, skilled human resource scarcity, local communities' opposition, etc. All of these factors can lead to construction delays and cost overruns which have to be paid first by shareholders and at the end of the day by final customers. Some of these risks can be mitigated to a certain extent through careful planning and learning existing best practices, but others are beyond the capability of nuclear operators alone. These areas call for regulatory protections and incentives from governments.

For investors and operators to have confidence in nuclear energy projects, there is a strong need for a simple, long term and sustained regulatory framework from the governments.

Some countries are setting legislations aiming to provide such frameworks. For example, the 2005 US Energy Bill Act includes these provisions to limit risks for nuclear operators:

- Electricity produced from a qualifying advanced nuclear power plant can claim credit of 1.8 cents per kilowatt hour for the first eight years of operation. This provision applies up to 6,000 megawatts.
- The Secretary of Energy is authorized to provide a loan guarantee of up to 80% of the project cost of advanced Nuclear Power Plants.
- Standby support for delays beyond 180 days in the commencement of full operation due to litigation or the U.S. Nuclear Regulatory Commission approval (up to 6 reactors for a total of up to $2 billion).
- Funding support for construction of advanced new nuclear power plants: $1.18 billion over 2007-2009.
- Price-Anderson Act Amendments extending liability protection to 2025.

The US and U.K governments are also simplifying their complex approval processes into three steps: reactor design approval, site approval, and construction and operation license approval. The U.K. is drafting the Planning Reform Bill and the new Nuclear National Policy Statement, creating a new independent Infrastructure Planning Commission, consulting on the Strategic Sitting Assessment process and the Strategic Environmental Assessment policy. The US has established a combined Construction and Operation License agreement (COLA) once the plant design is accepted. Up to mid-2008, the NRC had received 7 COLA requests and more are expected.

There are also other regulations that have an impact on plant operation, such as the maximum river water heating authorization, or on decommissioning costs, such as the low level radioactivity limit for wastes.

All these regulations have to be sustained on the long term.

Ensuring nuclear energy's financial competitiveness

With today's high oil and gas prices, nuclear energy is cost competitive. Figure 14 below shows comparisons between the cost of generating electricity through nuclear, coal and gas energy respectively. This trend should continue into the future as oil and gas supply will continue to be tight. On top of that, CO_2 and other greenhouse effect gases costs are likely to increase. All these factors are favorable for nuclear energy.

Figure 14: Electricity generating cost (US$ c/kWh) projections for 2010 on 5% discount rate, 40 years lifetime, 85% availability, with no CO_2 price factored in for fossil fuel generation

	nuclear	coal	gas
Finland	2.76	3.64	--
France	2.54	3.33	3.92
Germany	2.86	3.52	4.90
Switzerland	2.88	--	4.36
Netherlands	3.58	--	6.04
Czech Rep	2.30	2.94	4.97
Slovakia	3.13	4.78	5.59
Romania	3.06	4.55	--
Japan	4.80	4.95	5.21
Korea	2.34	2.16	4.65
USA	3.01	2.71	4.67
Cnada	2.60	3.11	4.00

Source: OECD/IEA NEA 2005

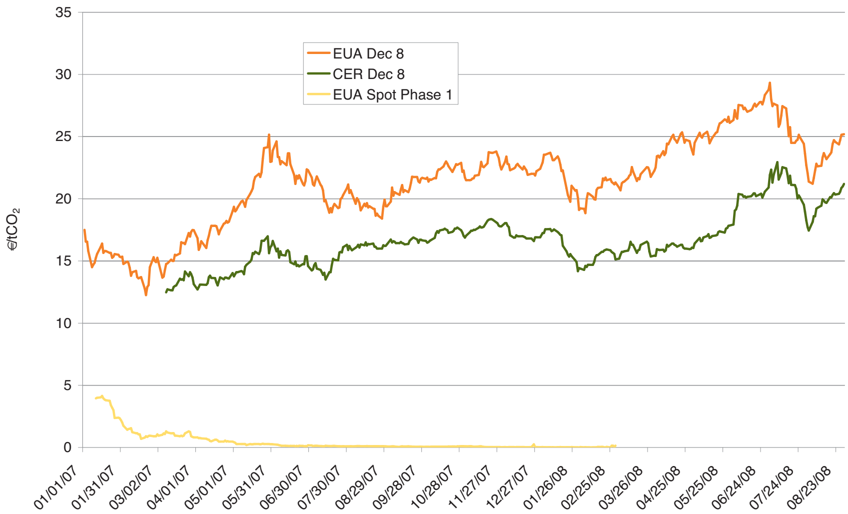
Does this mean that once a nuclear energy plant is successfully constructed and safely run, there will be no financial risks for the future? In reality, they are a few. Four risk elements have been identified below:

Need for a long term price index on greenhouse effect gases
As analyzed earlier, climate change issues and the subsequent governmental objectives to limit CO_2 emissions in many developed countries is a clear driver for nuclear renaissance. Nuclear energy competitiveness and acceptance is significantly enhanced by this factor. Though developing countries may not yet put CO_2 emissions as high priority, they have their own strong case to invest in nuclear energy.

In order to assess the long term financial viability over the very long lifetime of nuclear plants, and to compare it with that of other energy sources, a clear and long term indication on CO_2 prices is needed, and perhaps also on other greenhouse effect gases.

Since 2005, the European Union has implemented an Emission Trading Scheme (ETS), sometimes also referred to as a Cap and Trade System. This system gives CO_2 spot prices and "year ahead" prices. If the new European energy package is adopted, ETS will enable calculations on the emission prices until 2020. However, this is still a short term method, knowing that a nuclear plant decided in 2008 would not start operations before 2015 in the best case and has a lifetime of 60 years afterwards. So far, ETS is only applicable to large business entities that are heavy CO_2 emitters. Critics of the system point to problems of complexity and monitoring. A tax system could be better adapted to the dispersed residential and small business market. All these imperfections aside, ETS is still the most advanced mechanism in quantifying CO_2 costs. It is being adopted in other parts of the world, for example Australia and several US states.

Figure 15: CO_2 emission prices (2007-H1 2008)



CO_2 pricing is a fundamental component in the effort of bringing environmental costs into economic measurements. The question now is how to build on the base of ETS to come up with a long term CO_2 price index that is realistic and fair.

The long term direction of CO_2 prices will greatly impact the financial viability of nuclear energy investments. Given the seriousness of the climate change issue, we have reasons to hope some kind of long term pricing model will emerge soon. If so, it will clear a lot of uncertainty for the nuclear energy industry and surely accelerate its growth.

Coal
Among the conventional energy resources, coal is the only one that poses serious competitive threat to nuclear energy. Coal is abundant and widely spread around the world. Financial investments and technology requirements are quite low to build up infrastructures around coal mining, coal transportation, and coal fired power plants. Though coal price is often connected to the oil and gas prices, we can not exclude the possibility of a "de-bundle". If oil and gas prices go too high, triggering large investments into coal mining, then a significant coal price drop is not impossible. Currently, costs of electricity generated by nuclear power plants and by coal fired plants are comparable. A sudden coal price drop will break this balance.

However, the above analysis doesn't take into consideration the environmental factors. Pollution control and CO_2 emission costs are likely to become heavier, so there should be more requests for clean coal plants and carbon capture and storage facilities. This will push up investment costs. The first estimations are that these new clean coal fired power plants would have at least a 100% price increase compared to conventional plants.

Competition from publicly subsidized renewable energy source(s)
Renewable energies that are not economically competitive today are growing, largely thanks to public subsidies. Wind, solar, biomass are

the most prominent ones. It is estimated that $117 billion was invested on the "clean tech" area, around 10% of total investment in all forms of energy in 2007. Most of these renewable energy sources have big drawbacks. Biomass uses up land that is needed for food production. Wind and solar are not schedulable, so they require reserve energy from grid operators. Because of their relative small size, grid connections are very costly, especially for offshore wind mills. However, under public subsidy programs, utility companies have to buy a certain amount of renewable electricity at a higher price than from other sources.

So, should nuclear energy also demand for subsidy? The answer is no. Nuclear power should be built without public subsidy.

Subsidies are necessary for some nascent forms of renewable energies, especially when the Return on Investment is quick. This said, one should always bear in mind that at the end of the day, it is the end customers who pay for these additional costs. This is not a sustainable business model. Governments change and new ones may have other priorities on fund allocation. For nuclear energy, which has an exceptionally long project lifetime and very large investment needs, it is too risky to rely on such unpredictable public subsidy schemes. Actually, the majority of the present nuclear reactors in developed countries were built without public subsidies. They have successful experience in absorbing all the costs into the electricity price, including provisions for future treatment of used fuels and wastes, as well as the costs for future plant decommissioning. This model is sound and sustainable. It should be widely adopted.

Competition from deregulated market

In some parts of the world, the utilities market is being deregulated. Nuclear operators have to take a market related risk in this new environment. In the past monopolistic situation, utilities had a big and stable market share in their local area, usually near to 90%. Now they have to compete with new entrants, local and international rivals.

To achieve long term financial competitiveness, nuclear energy operators have to build sound business models, carefully assess and manage risks (especially demand risks), and optimize operations in order to succeed in the open market.

Smooth industrial ramp up

As analyzed earlier, in most parts of the world, except Asia, nuclear plant construction was nearly stopped for 20 years. The whole value chain was dormant. Only the active nuclear operators have been working on improving the security and availability of their plants. In many developed countries, vendors, suppliers, utilities, the academic world, research and development, and financial institutions have defocused from this industry. The safety shocks tainted the nuclear energy industry with a bad but undeserved reputation. Today many financial institutions are reluctant to consider investment in this field. Also, students are not interested in graduating as nuclear engineers.

To sustain this recent nuclear renaissance, different stakeholders need to ramp up capabilities both in their own territory as well as expand into new countries. The same challenge exists in the industry of oil and gas exploration. However, the particularly stringent conditions of the nuclear energy industry make it even more difficult to safely re-grow the whole value chain in a short notice.

International Collaboration

There is obviously a need for large and knowledgeable operators who are able to take the financial, construction and operational risks to implement a safety culture, and to improve operations through exchange with their peers. These operators are usually already facing a ramp up challenge in their own countries, so it is more difficult for them to respond to projects in other countries. However, EDF, the largest nuclear operator worldwide, has included nuclear investment and operations in foreign countries as part of its growth strategy. Today, EDF is obviously the preferred partner for the British government on its new nuclear plant programs. In China, many years ago, EDF helped China Guangdong Nuclear Power Group (CGNPG) in starting and operating the Daya Bay plants. The two are now joint venturing for the construction of CGNPG's two new EPR reactors. Other European nuclear operators also have ambitions to expand internationally. Such collaborations between experienced and less experienced nuclear operators are very helpful. There is a need for more of them in order to bring the new nuclear operators up to speed.

Among the relatively young nuclear operators, CGNPG in China and KHNP in South Korea also have nuclear exportation ambitions.

Supply chain capacity

The nuclear reactor vendors worldwide have to grow their production capacities. They comprise very heavy industry manufacturers with very strict quality control procedures to follow. Their products, nuclear vessel or steam generators, are gigantic steel structures measuring more than 15 meters high with walls that are more than 15 centimeters thick, but the slightest variation in the steel formula or a lack of quality control in welding can generate safety issues. It is clear that it will take time for these vendors to ramp up their production capacity again. Though vendors usually have a few years of lead time from order to delivery, they need to start preparations now because there could soon be a busy growth period in the industry.

Most vendors are already taking positive steps:

- In July 2008, Areva and Arcelor Mittal signed a Memorandum of Understanding to increase Le Creusot's forging capacity. According to Areva, Creusot Forge can make 80% of a nuclear power plant's components with its current capabilities, and with the new investment, this figure would reach 100%.
- In August 2008, Westinghouse Electric has decided to form a joint venture with Shaw Group to make and assemble structural and equipment modules for Westinghouse's AP1000 nuclear plants.
- Britain's Sheffield Forgemasters is extending its capacity to be able to provide some key components for the AP1000 reactor.
- These vendors have also started to reengineer their logistics in order to deliver these big pieces of equipment all over the world.

Certain countries, for example China, request these vendors to set up local joint ventures to manufacture specific pieces of equipment, or to provide engineering capacities as well as transferring their technological knowledge. These partnerships can bring together the deep know-hows from the "old" nuclear countries and the abundant industrial and human resources from the "new" nuclear countries. If well managed, it should help pull together enough resources for a successful worldwide vendor capability ramp up. It needs to be pointed out that the extent of knowledge transfer, acceptable for both parties, remains an unanswered question.

Aside from these big vendors, there is a need to reinvigorate or to create an industrial network of nuclear components and services providers. It applies to new nuclear countries as well as existing ones that are launching new programs. Each of these countries need to:

- Establish a map of critical competencies
- Decide what should be provided at national or local level and what could be imported
- Identify the gaps
- Create the right incentives to bridge those gaps.

This should be a very rewarding exercise. The UK government has declared: "A new fleet of reactors would potentially create up to 100,000 jobs and represent about £20 billion worth of business for UK companies."

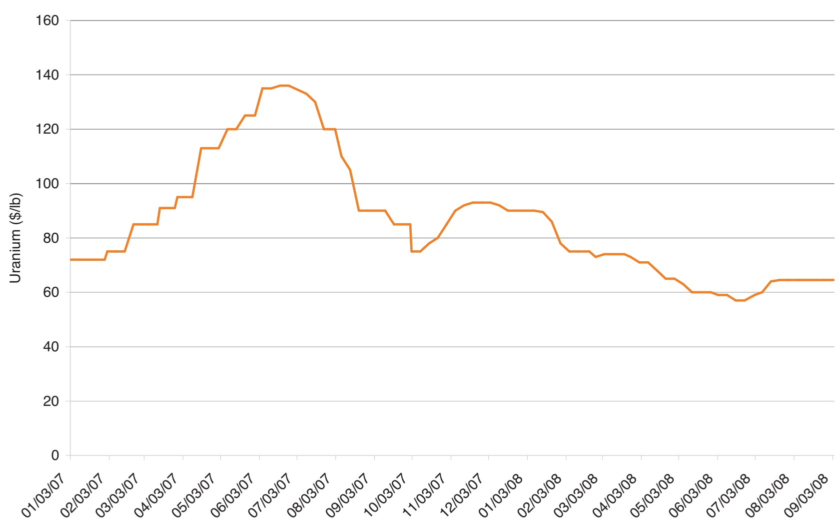
Uranium Supply

There is a widespread view that uranium supply is a threat to nuclear revival. This fear pushed uranium price up in early 2007, but it has since dropped again.

We believe that uranium supply is not a real issue. After the cold war and in the context of the disarmament treaties framework, the US and Russia have agreed to transform military stockpiles into civilian use—the so called "Weapons to Plough" program. This agreement was implemented both by diluting highly enriched uranium and by recycling plutonium through MOX fuels, thus recovering uranium and reducing fresh needs.

This program, combined with the low period of nuclear plants construction, created excessive stocks at various stages of the fuel cycle, thus pushing uranium price down. Many mines were mothballed and few new ones were opened. Now, as these military converted stockpiles are coming to an end, together with announcements of new nuclear builds, they have pushed the price of uranium up again.

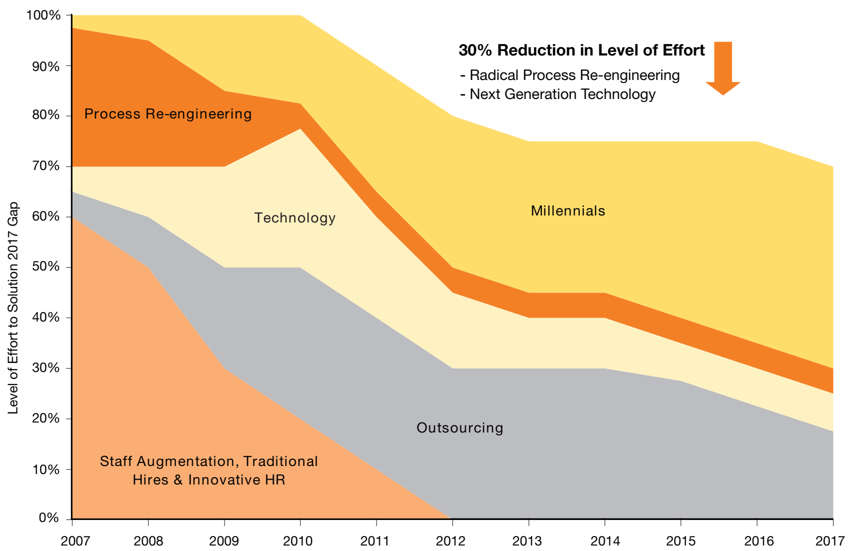
Figure 16: Uranium Price Evolution



There is no real threat linked to uranium supply. According to the latest edition of the world reference on uranium, the so-called "Red Book[17]," the known to exist uranium is enough to fuel the world's fleet of nuclear reactors at current consumption rates for at least a century. Moreover, plutonium and used uranium recycling enables a 30% decrease in needs. Finally, new fourth generation reactors should use less uranium for the same electricity output.

This said, we could witness some uranium supply bottlenecks linked to delays in opening new mines or increasing mine productions. This risk would be mitigated by the long lead time involved in the construction of reactors. It gives enough time for mining companies to get organized and for the operators to buffer the ups and downs with their reserve stockpiles.

Figure 17: How to bridge the talent gap in the nuclear industry by 2017?



Competent human resources

Aging workforce is a major issue. Safety Authorities, vendors and operators all need to massively recruit personnel to replace the retiring baby boomers and meet growing demand. This squeeze is exacerbated by a few factors:

- Staff layoffs done in the past 10 years to control cost
- Students' lack of interest in engineering
- Decline of nuclear engineering courses in higher education.

In a report published in May 2008, US Nuclear Regulatory Commission estimated that about 35 percent of those working at U.S. nuclear utilities will be eligible for retirement in the next 5 to 10 years and that 90,000 new workers will be needed by 2011. In the UK, the government is also taking measures to meet the expected high levels of demand for trained staff in the industry, by working together with the National Skills Academy for Nuclear and the Nuclear Decommissioning Authority. The UK National Skills Academy for Nuclear is a good example of national coordination to solve human resource shortages. It was established in early 2008 at the request of nuclear employers to address the key skills shortage and training challenges. It works on coordinating and qualifying industry needs with academic institutions and communicating towards future students. Other countries could benefit from this experience.

To overcome the human resources gap, nuclear energy operators need to take a holistic view. As shown in figure 17, they need not only to launch specific training and recruitment programs and retain senior "grey hair" specialists, but also:

- Use new Knowledge Management tools,
- Streamline their internal processes,
- Outsource non-core activities and
- Modify the working environment to retain the new generations of employees.

These topics are discussed in detail in the Capgemini Point of View "Preparing for the nuclear power renaissance"[18].

Re-launch nuclear related research and development programs

In the past few decades, nuclear knowledge, technologies and safety tools have been improved by academic and research work. There are of course still issues pending, notably those related to safe and long term disposal of nuclear radioactive wastes that need to be tackled.

The French Atomic Energy Commission has never discontinued its excellent research work. Great achievements have been made around nuclear waste transmutation and 4th generation reactors that would use less uranium and generate less waste. In many existing nuclear countries, research and development funding needs to be increased. Some measures have been announced:

- In July 2008, the UK confirmed that it will establish a National Nuclear

[17] The Red Book, officially titled, "Uranium 2007: Resources, Production and Demand." It is jointly prepared by the OECD's Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA)

[18] http://www.capgemini.com/resources/thought_leadership/preparing_for_the_nuclear_power_renaissance

Laboratory that would play a vital role in cleaning up the country's nuclear waste legacy, and also contributing to the new nuclear build.

- In North America, there are also some actions taken; for example, the FY 2009 energy research and development budget requested by the US president includes $1.4 billion to promote the expansion of safe, emissions-free nuclear power.

Nuclear research institutions also need to be created in new nuclear countries in order to support the industry and attract young talent.

Public opinion acceptance

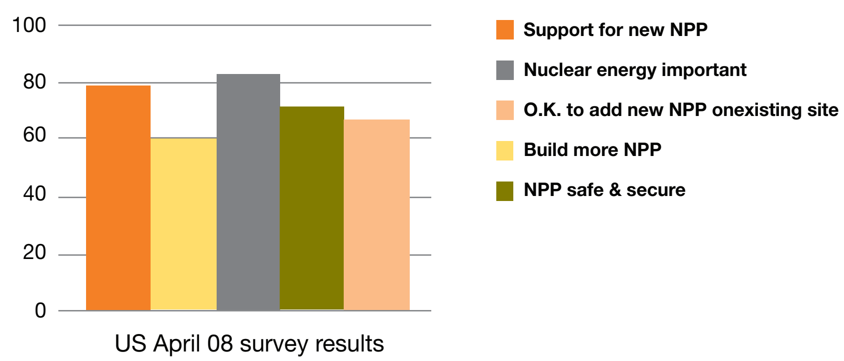
All projects to construct big industrial facilities need to convince the general public and overcome the usual "not in my backyard" type of local opposition. However, this issue is particularly sensitive in the case of nuclear plants. There are a few reasons for it.

In the public's mind, civilian nuclear activities are still linked with military nuclear activities. Memories of the Hiroshima and Nagasaki bombings are still vivid. In this context, it is remarkable that Japan has developed a successful civilian nuclear program.

Radioactivity can have long term effects on human health. The fact that it is invisible further enhances people's sense of danger. The Chernobyl disaster very negatively affected the public opinions in Europe. The infamous radioactive cloud demonstrated that nuclear damage can spread far and wide through the atmosphere and water. Though, at the end of the day, the actual damage from the Chernobyl accident is much less than media and some national authorities initially announced, the psychological impact is huge and long lasting.

Nuclear energy is a young industry. Due to lack of knowledge, mistakes were made in the past on handling radioactive wastes. Many countries, including Russia, the US, the UK and France, have undertaken large clean up programs on their old nuclear sites. For example, the US Department of Energy has a large multi-billion dollar program to clean up the Hanford site and other former military sites.

Figure 18: April 08 US Opinion survey



Finally, the nuclear industry is very technical, so it is difficult for the wide public to understand its activities in details. In the past, nuclear stakeholders, instead of addressing the people's real concerns related to health, security and environment protection, tended to give out very technical type of information. In 1993, to improve communication messages and channels, the European Nuclear Society created an association called Woman In Nuclear (WIN). This organization has the mission to encourage women, who usually have better sensibility on human related issues, to communicate with the public and politicians. Today, it is a worldwide organization gathering 2,500 members from 68 countries.

Due to the lack of effective communication and mutual understanding with the nuclear energy industry, non-governmental organizations such as Greenpeace started a media war against nuclear activities. Slightest incidents were amplified. Distorted information caused undue fears on nuclear industry's threat to public health and environment. These media campaigns had a real impact on public opinions. Truth and facts were often lost in the flood of distorted attacks. It is interesting to note that one of Greenpeace' founders, Patrick Moore, changed his opinion. He declared: "Nuclear energy is the only large-scale, cost-effective energy source that can reduce these emissions while continuing to satisfy a growing demand for power. And these days it can do so safely."

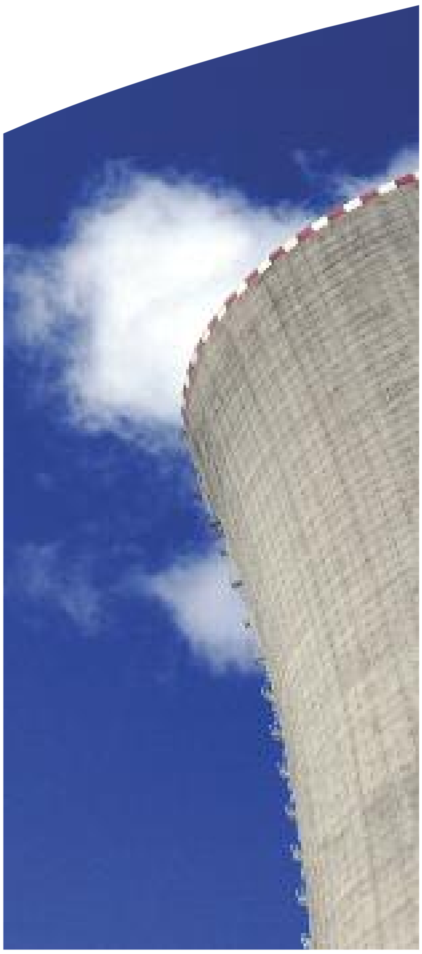
It is telling that public opinions are usually much more acceptant towards nuclear energy in countries that are resource poor, such as France, Japan, South Korea, China and India. In many other countries, it is the combined force of climate change issues and energy supply-demand gap that tipped support in favor of nuclear energy. Equally, if not more importantly, it is also the safe operations record of nuclear facilities and better communication efforts, in the past two decades or so, that have favorably influenced general public opinion on nuclear energy.

Even in countries with nuclear moratorium, such as Sweden, or with reactor phase out decisions, such as Germany, public opinions are evolving positively. An opinion poll conducted in July 2008 indicates that 40 percent of Swedes favor continued use of the country's existing reactor units and new nuclear build if necessary. That compares to 33 percent in November 2007 and 31 percent in May 2007. In Germany, things are also changing. In January 2006, a Deutsche Bank study argues that extending the lifetime of all German nuclear power plants to 60 years would mean adding 19,000 megawatts capacity that would otherwise have to be replaced. According to a recent survey conducted by the German Atomic Forum and published in August 2008, more than half of the German population and 80% of its businesses are in favor of extending plants' operating lifetimes beyond their current phase-out dates. The outcome of the 2009 general elections will be crucial for the future of nuclear power in Germany.

Local public opinion: The NIMBY (not in my back yard) syndrome exists mostly for new nuclear plants. Local population demonstrations resulted in construction delays and sometimes even cause projects to be dropped completely, as the Plogoff project in France. However, the population living in areas near existing well-operated plants is generally in favor of nuclear. They have positive experiences, enjoying the creation of jobs, small businesses and tax related financial benefits. This is why decisions adopted by many politicians, including French and British, are to build new plants on existing sites. For this reason, local nuclear operators with available spaces on their existing sites became attractive acquisition targets. The most recent case is EDF's take-over of British Energy at £12.4 billion. It will give EDF almost all the UK's nuclear power stations and control over most of the best sites for building more, giving it a dominant position for the planned revival of the UK's nuclear industry.

Even if public opinion is getting more favorable to nuclear energy, there is still a long way to go before the public can be truly assured about nuclear energy. There should be no more nuclear accidents. Governments and nuclear operators should continue to clean up old nuclear sites. Communication skills still need improvement. There is an obligation to provide the public with all possible relevant information, in an easy to understand way, and in a timely manner.

The stakes are very high here. Only with public opinion acceptance will the nuclear energy industry have occasions to materialize and demonstrate its enormous potential. If the public is not convinced, national and local opposition could deteriorate the economics of nuclear energy by creating big project overruns. At the extreme, it could kill the nuclear energy programs all together, therefore depriving some countries of a schedulable, financially competitive and CO_2 free energy source.



Conclusions

This overview shows that there is a real revival of the nuclear energy industry. It is triggered by the following trends:

- Population and economic growth is creating high pressure on energy supply
- Energy security of supply is becoming of strategic importance
- Huge investments, of the right kind, are needed to solve the energy crisis
- Climate change has become a major concern.

In order to sustain this wave of nuclear renaissance, each country's governments, local authorities, financial institutions and mainly the whole value chain of the nuclear energy industry have to get organized quickly. This is true in countries with existing nuclear programs as well as in new nuclear countries. At the same time, an international collaboration is needed. All nuclear energy development efforts need to be planned and coordinated with a global perspective. Fragility in one or two countries, for example safety accidents or breach of nuclear non-proliferation, could bring devastating chain reactions to the entire industry across the world. This means even if competition exists in the nuclear energy sector, there is a need for solidarity.

The industry should draw on the lessons of the past. Nuclear energy is a complex industry with lots of inherited risks. There are clear prerequisites that need to be in place before this worldwide nuclear renaissance can sustain and can turn into a success. We need:

- Effective Nuclear Non-Proliferation control
- Stringent Safety Management
- Mastering exceptionally long project lifetimes and big investments
- Ensuring nuclear energy's financial competitiveness
- Smooth industrial ramp up
- Public opinion acceptance.

With these prerequisites in mind, operators, vendors and financial parties can better apprehend the multidimensional challenges they face and make necessary preparations at very early stages. With objective assessments and proactive actions from all the stakeholders, we have reason to believe that this time, nuclear energy will be able to deliver its huge potential.

Our planet *needs* nuclear energy. Success is therefore an obligation.

About Capgemini

Capgemini, one of the world's foremost providers of consulting, technology and outsourcing services, enables its clients to transform and perform through technologies. Capgemini provides its clients with insights and capabilities that boost their freedom to achieve superior results through a unique way of working—the Collaborative Business Experience—and through a global delivery model called Rightshore®, which aims to offer the right resources in the right location at competitive cost. Present in 36 countries, Capgemini reported 2007 global revenues of EUR 8.7 billion and employs over 86,000 people worldwide.

With 1.15 billion euros revenue in 2007 and 10,000+ dedicated consultants engaged in Energy, Utilities and Chemicals projects across Europe, North America and Asia Pacific, Capgemini's Energy, Utilities & Chemicals Global Sector serves the business consulting and information technology needs of many of the world's largest players of this industry.

More information about our services, offices and research is available at **www.capgemini.com/energy**

This point of view has benefited greatly from suggestions and comments from Hervé Griffon, Capgemini Energy, Utilities and Chemicals Global Sector Deputy Leader, and Philippe Coquet, Capgemini Global Sector Utilities Strategy Lab Research Lead.

Contacts
Colette Lewiner
colette.lewiner@capgemini.com

Alva Qian
alva.qian@capgemini.com

www.capgemini.com/energy