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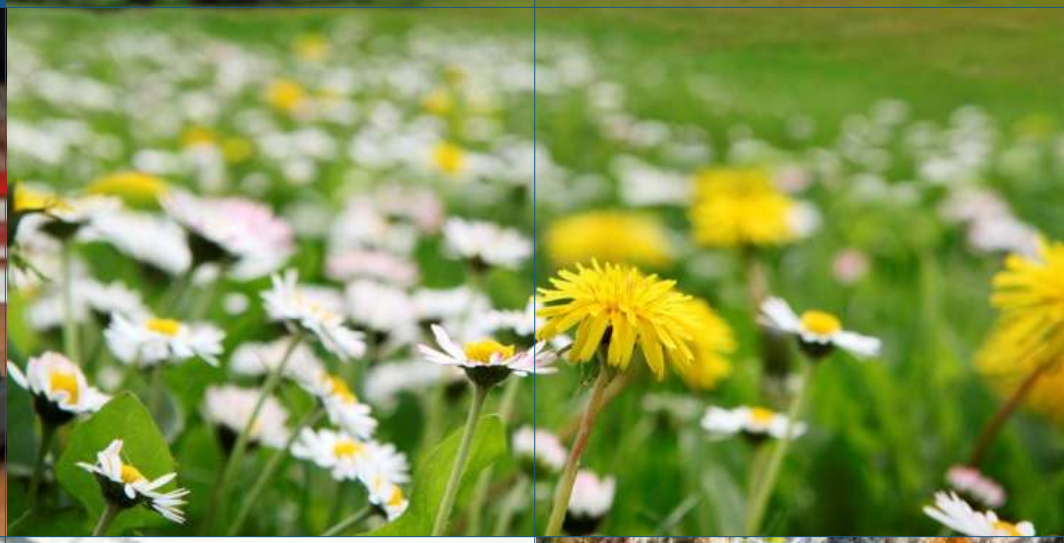
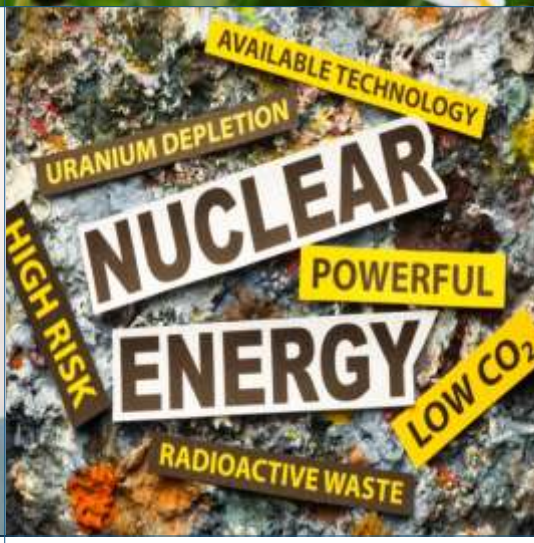
World Energy Perspective:
Nuclear Energy One Year After Fukushima

World Energy Council





World Energy Perspective: Nuclear Energy One Year After Fukushima

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Foreword

A year after the accident at the Fukushima Daiichi nuclear power plant in Japan, I am honoured to unveil the reflections of WEC's nuclear taskforce on the future of global nuclear energy.

As a truly international organisation comprising 93 countries, and genuinely dedicated to the promotion of all types of energy solution for the greatest benefit of all and for the environment, it is WEC's duty to share, with the community of energy leaders and governments, its views on nuclear power.

It was WEC's mission to take time, stand back, and consult experts from all over the world in order to assess the multiple impacts of the Fukushima accident in the international economic, geopolitical and environmental contexts and to develop a list of issues to be debated for the long-term future of nuclear energy.

Our long-term energy future must address three key challenges. First, security of supply, and the need to secure economic growth in the context of a rising energy demand; second, environmental protection, including the struggle against climate change and mitigation of CO_2 emissions; and third, ensuring energy access for the poorest people. To meet these challenges, the world will require all sources of energy, energy efficiency and moderation, and accessible and CO_2 free technologies, including renewable energies, cleaner fossil fuels, and CCS. Clearly, in this perspective, safe nuclear power is one of our energy solutions—as the energy policies of many countries already show.

As I draft this foreword, **there are almost 50 countries that are operating, building, or simply considering nuclear generation as a viable solution for electricity generation. Half of them are "newcomers"**, aiming to develop nuclear power production in order to cope better with the challenges of an affordable, CO_2 free energy production. More than 60 nuclear power plants are now under construction, in China, India, Russia, Korea, France, Finland, and the UAE.

These numbers suffice to indicate that **nuclear power will continue**, even if some countries like Germany, Italy, and Switzerland, have decided to abandon nuclear power.

Nuclear energy will play a full part in the future energy mix provided nuclear safety and at the same time transparency are continuously being reinforced. This will strengthen public acceptance, in particular through the **setting up and maintenance of efficient governance of nuclear safety that is internationally credible**.

This new WEC report, "World Energy Perspective: Nuclear Energy One Year After Fukushima", shows that after the accident, the public, political leaders as well as nuclear industry leaders could seize an opportunity to reinforce once more the necessary international coordination on matters of nuclear safety. Even though the accident of Fukushima was fundamentally different from the two earlier accidents at Three Mile Island and Chernobyl, it demonstrates that there is a rationale, a demand and a room to improve, on a continuous basis, our ambitions in the matter of nuclear safety.

International governance on nuclear safety has already improved a lot since the 1980's thanks to the efforts of all parties, but I am confident it can go one step further, on all aspects of nuclear safety, be it on the conception and design of the plants; or on operation, crisis management and dismantling; or on communication, transparency and control by independent authorities.

WEC's report suggests that reinforcing international coordination on nuclear safety is an ambitious goal, considering all the hard work that has already been done and the need to respect legitimate concerns as regards national sovereignty. There is reason to believe this is achievable as long as:

- We build on current initiatives and existing institutions and structures such as the IAEA, the International Nuclear Agency, in coordination with the initiatives of operators' bodies like WANO, national regulator's coordinator like WENRA, INRA, the international group of experts at INSAG, and provide them with the needed support to advise and increase coordination and cooperation on all aspects.
- A strong political statement, expressed by a representative political body at an international level such as G20, legitimates this move towards more coordination and cooperation in the current system, thus confirming all agreed efforts to deliver a further improved form of international governance.

These measures should result in rebuilding and regaining public trust in nuclear power, which is key for its acceptance. They should also increase the capacity of nation states to participate in international governance.

International accord is hard to achieve on any topic, and international governance in nuclear power is being challenged. Nevertheless, the safety of **global nuclear power is one of the rare issues on which an international accord could be achieved with a reasonable level of efforts—the need to act is urgent, and the time is right, since:**

- **New power plants are being programmed or will start being constructed. Some are being rejuvenated following post-Fukushima stress tests**; others will receive new investments to enhance safety that could mean they will run for a further 10 or more years.
- Nuclear safety is, by definition, a global challenge. Global improvement of nuclear safety necessitates defining nuclear safety standards to which all countries that exploit, develop, or consider developing nuclear power, fully subscribe.

Alongside these activities focused on nuclear energy, there should be parallel attempts to increase global governance of safe and environmentally friendly energy sources. All energy sources must be exploited with consideration for the environment and safety, in a global framework.

Therefore, I believe there is a real opportunity for our world leaders to promote a consensual solution to this issue and thus demonstrate that **real international governance, where emerging countries can also fully participate, can be successful**.

What I mean by "**real international governance" begins here**, with all WEC members. The challenges we face are tremendous: be they the safety of nuclear energy or other forms of energy, the security of supply to ensure economic growth, the protection of our environment, or the struggle to promote universal access to modern energy sources. To tackle to all these challenges, the sector will need clear leadership.

WEC can be a catalyst in the world's attempt to build dialogue, share vision, and develop global governance. **WEC's network of experts is ready to contribute and help in shaping renewed international governance to ensure nuclear safety.**

I wish you an insightful reading of these reflections by the **WEC's nuclear taskforce on the future of global nuclear energy.**

Pierre Gadonneix
Chair World Energy Council

Executive Summary

The incident at the Fukushima Daiichi nuclear power plant—the result of a devastating earthquake and subsequent tsunami on March 11, 2011—has re-invigorated the debate about how to meet the world's growing demands for energy and the contribution of nuclear power to the global energy mix.

This report demonstrates that the Fukushima accident has not so far led to a significant retraction in nuclear power programmes in countries outside Europe, except Japan itself. In Europe, changes in nuclear policies have only taken place in Germany, Switzerland, and Italy. Progress in many national programmes, especially in non-OECD countries, has been delayed, but there is no indication that their pursuit of nuclear power has declined in response to Fukushima.

The report suggests that, across all countries, greater attention is likely to be paid to aspects of safety and regulation, including both infrastructure and education, and that ambitious timelines for planning, construction, and implementation of plants may become more realistic. The incident is likely to encourage operational and technological improvements, and result in a wide range of actions and measures to improve the safety of the technology by various governments, vendors and utilities worldwide in response to public concerns.

In terms of implementing safety and regulation, most WEC member countries showed strong political support for the adoption and convergence of international safety regulations, but this was not matched by support for the international enforcement of safety standards. However, most member countries strongly agreed that there is a need to improve public understanding and acceptance of nuclear technology, and its costs and risks.

The report suggests a process to ensure the development of minimum and harmonised international safety standards for the construction, operation, and maintenance of nuclear power: first, the establishment of an international organisation that would draw-up these standards, working with national safety agencies; second, the empowerment of this organisation to verify national adherence to these standards.

Introduction

The incident at the Fukushima Daiichi nuclear power plant—a result of a devastating earthquake and subsequent tsunami on 11 March 2011—has re-invigorated the debate on how to meet the world's growing demands for energy and the contribution of nuclear power to the global energy mix.

As part of the World Energy Council (WEC) energy scenarios flagship study, a nuclear taskforce was set up to investigate the impact of this incident on national nuclear energy plans across the world. It also looked into nuclear safety systems, looking for opportunities to improve global nuclear governance.

In collaboration with WEC member committees, the taskforce conducted a survey across countries where nuclear power is already part of the energy mix, discussing the responses in a series of conference calls. This brief report summarises the responses to the survey, and subsequent discussions. . It concludes with recommendations to improve the international governance of nuclear power, following the Fukushima incident.

1. History of Nuclear Power Generation

Although electricity was generated for the first time by a nuclear reactor in 1951 at the EBR-I experimental station near Arco-Idaho (USA), the commissioning of the former USSR's Obninsk Nuclear Power Plant in 1954 marks the beginning of the development of nuclear power. Since then, the global nuclear industry has evolved through three main stages (Figure 1).

The first period, between 1954 and 1974, is one of growth. Until 1965, about seven reactors were started being constructed each year, but by 1970, this had accelerated, and the following year construction on as many as 37 reactors started. The first oil shock of 1973/74 gave the growth rate additional momentum.

The second period extends from the late 1970s to the mid-2000s, and is marked by a slowdown. Globally, an average building of only two to three reactors per year had started by the end of this period. This downturn was initially triggered by the high construction costs of nuclear plants, and then exacerbated by the collapse of oil prices. Delays and/or cancellations in nuclear projects were aggravated by the availability of inexpensive, modular and highly efficient combined-cycle turbines, along with market deregulations in many countries. Further suspensions and cancellations were prompted by the accident at Three Mile Island (USA, 1979), which caused enormous public concern about nuclear safety and further complicated the regulatory process.

Figure 1
Nuclear Reactor Construction Starts and Total Capacity, 1951-2011
Source: IEA, World Energy Outlook, 2011

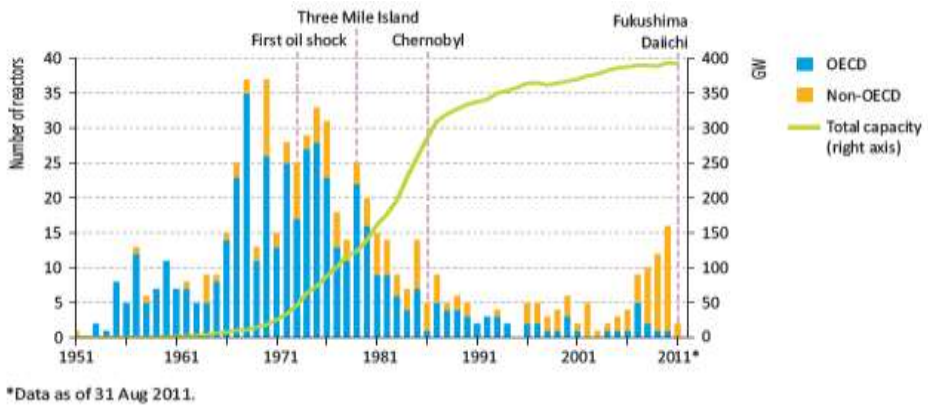
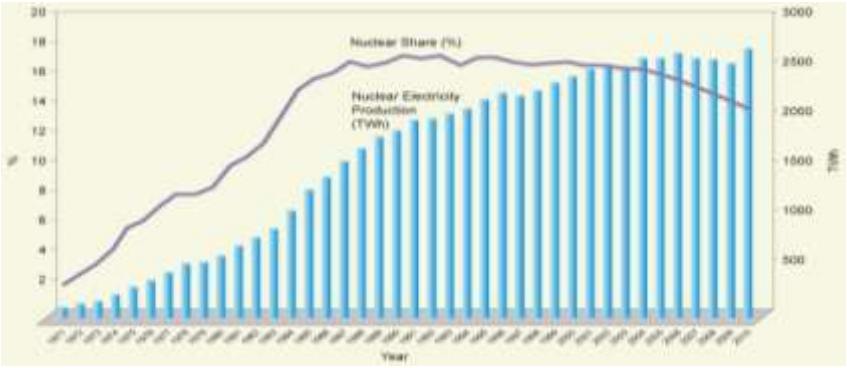


Figure 2
Nuclear Electricity Production and Total Share Electricity Production
Source: WNA



Activities were further depressed by a second disastrous nuclear accident at the Chernobyl nuclear power plant (Ukraine, 1986). And the resulting slowdown was further amplified by low energy prices throughout much of the 1980s and 1990s. These made the risks of the higher capital investment needed to build nuclear power plants even less attractive.

The third period extends from the mid-2000s until the beginning of 2011, and is commonly called the "nuclear renaissance". The global nuclear sector enjoyed an upward trend, largely because of rapid development in non-OECD countries (mainly China). Most of the recent interest in nuclear power is justified by its cost-effectiveness compared to fossil fuels, its environmental advantages, and national concerns about security of energy supply.

Despite the downturn of the second period, overall, these three periods saw a constant increase in nuclear production. By the mid-2000s (over the first two periods), nuclear production increased to about 2,600 TWh, and has been almost constant over the last 10 years (Figure 2). Nuclear power's total share of total electricity production increased to a level of about 17% by the late 1980s, but has since been falling behind overall growth in electricity generation. Consequently its market share slipped to 13.5% in 2010.

There has been continuous improvement and technological development in nuclear power, based on lessons learned in the construction and operation of nuclear plants. The tragic accidents at Three Mile Island and Chernobyl, both caused by operational and management failures, triggered in-depth examinations of equipment, training procedures, and safety culture. This led to a profound increase in safety, with improvements in the processes of both the vendors, who designed plants and reactors, and the owners, who operated them, under the supervision of national regulators. However, market pressures, especially, in deregulated markets, resulted in the streamlining of nuclear power operations, which translated into much higher availability factors for nuclear towards the end of the second period. High availability factors are essential to create favourable economic conditions for any capital intensive technology. As a result of these changes, , average availability of nuclear worldwide increased from 60% to 80%, with some countries at 90% (e.g., the USA, Finland, Switzerland, Sweden.). Plant lives have been extended through better understanding of the aging of materials and the need to replace components. Power levels have been increased through improved performance analysis, tools, and risk assessments. Enhanced instrumentation and operator-assistance systems have been introduced, and these also contribute to better, safer performance.

Most importantly, the sharing of knowledge, largely driven by the International Atomic Energy Agency (IAEA), World Association of Nuclear Operators (WANO), and the Institute of Nuclear Power Operations (INPO), has greatly contributed to the dissemination of good practices. Collective efforts in routine inspections, peer reviews, decennial inspections, and license renewals can keep an operating reactor fleet in the best safety condition. In addition, most nuclear power operators learn about the requirements of their reactors from the

operating experience collected in the Utility Requirement Document (USA) and the European Utility Requirements (Europe).

These have been the inspiration to vendors for the so-called Generation III reactors, which are currently being built in many countries. Typically, these new reactors have a design life of 60 years, more than 90% availability, a 12-24 month fuel-cycle, reduced probability of off-site radiation releases, and very low occupational radiation. Some of the new designs incorporate passive safety systems that do not depend on active electric pumps to maintain core cooling, requiring no operator action for 72 hours after an accident occurs. Should a core melt accident occur, most of these designs include a core retention system.

Despite all these operational and technological improvements, the recent accident at Fukushima, caused by a natural disaster, is expected to heighten safety concerns. Governments and utilities worldwide are likely to respond to public concerns about the safety of the technology—but how they will act and what measures they will take remains a question. This report sets out the evidence for the different possible future directions for global nuclear power.

2. The Global Nuclear Situation Before the Fukushima Accident

On March 10, 2011, a total of 30 countries had 442 commercial nuclear power reactors with a total installed capacity of 379,001 MWe (Table 1). In addition, 65 nuclear power reactors were under construction (62,862 MWe, equivalent to 17% of existing capacity), while over 159 were planned (total capacity of 178,123 MWe, equivalent to 47% of present capacity).

Table 1 shows that countries in the Organisation for Economic Cooperation and Development (OECD) dominated the world's nuclear electricity production in 2010. The largest nuclear power producer was the USA (807.08 TWh) followed by France (410.09 TWh), Japan (280.25 TWh), Russia (159.41 TWh), South Korea (141.89 TWh) and Germany (133.01 TWh). Nuclear energy accounted for 74% of France's total electricity generation, and 33% or more in Armenia, Belgium, Bulgaria, Czech Republic, Hungary, Slovakia, Slovenia, Sweden, Switzerland, and Ukraine. Finland, Germany, Japan, and South Korea each generated more than 25% of their electricity from nuclear energy, while nuclear supplied about 20% of the electricity in Romania, Spain, Taiwan, and the USA.

Looking at the number of operable reactors in early March 2011, the OECD countries dominated the market. The capacity was the largest in the USA (104 reactors), followed by France (58 reactors), Japan (54 reactors), Russia (32 reactors), South Korea (21 reactors), India (20 reactors), the UK (19 reactors), Canada (18 reactors), and Germany (17 reactors). In contrast, most of the nuclear plants under construction were in non-OECD countries. China alone accounted for 42% of the construction (27 reactors), followed by Russia with 17% (11 reactors), and India with 8% (five reactors).

Similarly, most of the planned and proposed reactors were also in non-OECD regions. Of the total 159 planned reactors, China accounted for 31% (50 reactors), followed by India 11% (18 reactors), Russia 9% (14 reactors), and Japan 8% (12 reactors). Of the 323 proposed reactors, China accounted for 34% (110), India 12% (40), Russia 9% (30), the USA 7% (23), and Ukraine 6% (20).

Table 1

World Nuclear Power Reactors (as of March 10, 2011)

Source: IAEA for "Nuclear Electricity Generation", "Reactors Operable", "Reactors under Construction"; WNA: for "Reactors Planned" and "Reactors Proposed"

Country	Nuclear Electricity Generation 2010		Reactors Operable March 10, 2011		Reactors under Construction March 10, 2011		Reactors Planned March 2011		Reactors Proposed March 2011	
	TWh	% Tot.	No.	MWe	No.	MWe	No.	MWe	No.	MWe
Argentina	6.69	5.91	2	935	1	692	2	773	1	740
Armenia	2.29	39.42	1	375			1	1,060		
Bangladesh							2	2,000		
Belarus							2	2,000	2	2,000
Belgium	45.73	51.16	7	5,926						
Brazil	13.90	3.06	2	1,884	1	1,245			4	4,000
Bulgaria	14.24	33.13	2	1,906	2	1,906	2	1,900		
Canada	85.50	15.17	18	12,569			3	3,300	3	3,800
Chile									4	4,400
China	70.96	1.82	13	10,058	27	27,230	50	57,830	110	108,000
Czech Republic	26.44	33.27	6	3,678			2	2,400	1	1,200
Egypt							1	1000	1	1,000
Finland	21.89	28.43	4	2,716	1	1,600			2	3,000
France	410.09	74.12	58	63,130	1	1,600	1	1,720	1	1,100
Germany	133.01	27.26	17	20,490						
Hungary	14.66	42.10	4	1,889					2	2,200
India	20.48	2.85	20	4,391	5	3,564	18	15,700	40	49,000
Indonesia							2	2,000	4	4,000
Iran					1	915	2	2,000	1	300
Israel									1	1,200
Italy									10	17,000
Japan	280.25	29.21	54	46,821	2	2,650	12	16,538	1	1,300
Jordan							1	1,000		
Kazakhstan							2	600	2	600
Korea-North							0	0	1	950
Korea-South	141.89	32.18	21	18,698	5	5,560	6	8,400		
Lithuania									1	1,700
Malaysia									1	1,200
Mexico	5.59	3.59	2	1,300					2	2,000
Netherlands	3.75	3.38	1	487					1	1,000
Pakistan	2.56	2.60	2	425	1	300	2	600	2	2,000
Poland							6	6,000		
Romania	10.70	19.48	2	1,300			2	1,310	1	655
Russia	159.41	17.09	32	22,693	11	9,153	14	1,6000	30	28,000
Saudi Arabia										
Slovakia	13.54	51.80	4	1,816	2	7,82			1	1,200
Slovenia	5.38	37.30	1	666					1	1,000
South Africa	12.90	5.18	2	1,800					6	9,600
Spain	59.26	20.09	8	7,514						
Sweden	55.73	38.13	10	9,298						
Switzerland	25.34	38.01	5	3,263					3	4,000
Taiwan	39.89	19.30	6	4,982	2	2,600	1	1,350		
Thailand									5	5,000
Turkey							4	4,800	4	5,600
Ukraine	83.95	48.11	15	13,107	2	1,900	2	1,900	20	27,000
UAE							4	5,600	10	14,400
UK	62.9	15.66	19	10,137			4	6,680	9	12,000
USA	807.08	19.59	104	100,747	1	1,165	9	11,662	23	34,000
Vietnam							2	2,000	12	13,000
WORLD	2,630		442	373,001	65	62,862	159	178,123	323	369,145

Notes:
Operating = Connected to the grid
Building/Construction = first concrete for reactor poured, or major refurbishment under way
Planned = Approvals, funding, or major commitment in place, mostly expected in operation within 8–10 years
Proposed = Specific programme or site proposals, expected operation mostly within 15 years

3. The Fukushima Daiichi Power Plant Incident

On Friday March 11, 2011, an earthquake measuring 9.0 on the Richter scale hit northeast Japan, with an epicentre near the island of Honshu. It triggered a tsunami 43-49 feet high which struck the Fukushima Daiichi nuclear power plant. The plant comprises six reactor units, producing a total of 4,696 MW). In response to the tsunami, Units 1, 2, and 3 (which were operating at that time) underwent an automatic emergency shutdown while Units 4, 5, and 6 were already offline for the usual periodic inspections. After the reactors in Units 1, 2 and 3 were safely shut down the emergency core-cooling system was activated. The tsunami meant that the emergency cooling system was flooded, which caused the loss of all functions, making it impossible to control the reactors.

As a result of insufficient cooling, reactor water vaporised, exposing the upper part of the fuel rods. The steam reacted with the high temperature zirconium alloy casing of the fuel rods and generated hydrogen, which leaked into the containment vessel and the reactor building, where it gradually accumulated. When the hydrogen reached a concentration at the explosive limit, reacting with the oxygen in the atmosphere, it caused an explosion at Units 1 and 2. As a result, the roofs and other parts of the reactor buildings were blown off. Continued lack of cooling caused fuel meltdown and radioactive materials were released into the atmosphere (estimated at about 10% of the total radiation dose when compared to Chernobyl). The speedy evacuation of up to 200,000 people living in the 20 km zone and the establishment of a “no-entry zone” around the Fukushima-Daiichi site within the first three days after the accident has been instrumental in limiting the radiation exposure of the local population.

The IAEA assessed the severity of the Fukushima accident as Level 7, based on the International Nuclear and Radiological Event Scale (INES). The reactors were later cooled by water poured into the buildings. One month after the earthquake, the government re-designated evacuation zones. In addition to the “no-entry zone” they set up a “voluntary evacuation zone”, which was the area that lay between 20 km and 30 km from the power station. By late May, a total of 62,000 people had been evacuated from the no-entry zone which covers an area of approximately 600 km2.

4. Changes After the Fukushima Accident

The Fukushima accident prompted an immediate review of the safety of nuclear energy in most countries with nuclear programmes. Many of these countries announced comprehensive safety reviews, which could lead to regulatory changes that would slow or even eliminate plans for expansions of and investments in nuclear power. Even before completing these safety reviews, some countries have decided to close plants that seem particularly risky because of their age or location. More extreme responses include the decision to abandon the use of nuclear energy completely—this includes countries with explicit plans to explore and/or develop nuclear power; others have put their plans on hold. In contrast, several countries (mostly developing countries) have re-affirmed their intentions to develop nuclear power as an important part of their energy mix, or substantially increase nuclear capacity. They are motivated by the need to meet rising power demands efficiently, and/or the desire to reduce dependence on fossil fuels (and quell associated concerns about security of supply and emissions). A summary of these changes can be seen in Table 2.

Of the 31 countries with nuclear energy programmes, those that experienced the most profound public reactions and public policy changes included: Japan, Germany, Italy, and Switzerland.

1. Japan: Before Fukushima, Japan was the world's third-largest producer of electricity from nuclear power. Nuclear energy accounted for about 30% of the country's total electricity production (54 reactors providing 47 GW). The Japanese government had ambitious plans to expand the nuclear component of the country's energy mix to reach 41% of the country's total power supply by 2017, and 53% by 2030 (up from about 29% in 2010). Plans were in place to construct nine new reactors by 2020 and another five by 2030.

The Fukushima accident threw these ambitious long-term plans into doubt, partly because of severe public resistance. Immediately after the accident, the Prime Minister was forced to request that some nuclear reactors in the rest of the country be shut down. In addition, the ongoing construction of reactors has been entirely halted and a new rule has been introduced, requiring that the reactors that were shut down are stress-tested before they are restarted and that they undergo periodic inspections. In addition, Fukushima Daiichi Units 1 to 4 were to be decommissioned; the government also announced immediate measures to boost nuclear safety, as well as plans to undertake a stringent safety assessment at each reactor to check its capacity to withstand extreme natural events.

By mid-February 2012, only two of Japan's nuclear power reactors were in operation, while the remaining 48 reactors were shut for periodic inspections, unplanned inspection, or even anticipated decommissioning. Since Fukushima, all Japan's nuclear reactors have been undergoing two-phase stress tests at the direction of the Japanese government. The first phase (to determine whether the plants can withstand large earthquakes and tsunamis) is carried out while reactors are offline for periodic inspections. This effectively means that all plants that have entered scheduled maintenance outages since the accident

Table 2

Nuclear Energy Policy Changes After Fukushima (as of January 2012)

Source: IAEA for "Nuclear Electricity Generation", "Reactors Operable", "Reactors under Construction"; WNA: for "Reactors Planned" and "Reactors Proposed"

1 Countries with "**existing"** nuclear installations:	
Use of nuclear power in principle **not being contested**[1]	Argentina, Armenia, Belgium[2], Brazil, Bulgaria, Canada, China, Czech Republic, Finland, France, Hungary, India[3], Iran, Mexico, Netherlands, Pakistan, Romania, Russia, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Taiwan, Ukraine, United Kingdom, United States
Use of existing nuclear power **being contested**	**Japan**[4]
Use of existing nuclear power **being phased-out**	**Germany**[5]**, Switzerland**[6]
2 Countries "**currently constructing"** new nuclear installations:	
Construction projects **not being contested**[7]	Argentina, Brazil, Bulgaria, China, Finland, France, India, South Korea, Pakistan, Russia, Slovakia, Taiwan, Ukraine, United States
Construction projects **cancelled, scaled-back or delayed**	**Japan**
3-Countries with "**plans and/or proposals to construct"** new nuclear installations:	
Plans/proposals for new constructions **not being contested**	All 31 countries mentioned in Table-3 (see below) except Germany, Switzerland, Italy
Plans/proposals for new constructions **prohibited**	**Germany, Switzerland, Italy**[8]

Notes:
1) Assessing safety installations and incorporating lessons learned
2) Government is expressing concern about the feasibility of implementing a phase-out.
3) The public response and protests taking place at Kudankulam-1 (still under construction), suggest there may be further protests, and potentially a government response, especially given the democratic regime.
4) Clarifications to come in an update to the Japan's Strategic Energy Plan (expected 2012)
5) Immediate suspension of eight nuclear installations following Fukushima, and phased-out closure of remaining power plants as fast as possible
6) Expected closure of five nuclear power plant units between 2019 and 2034
7) Partial modification of safety standards or licensing procedures
8) Effective construction bans existed in Germany before Fukushima. These bans were being revisited as part of the "nuclear renaissance", but Fukushima halted or reversed these developments reversed this direction. In Italy, a referendum in June 2011 imposed a permanent ban on the reintroduction of a nuclear power programme.

cannot resume operations, until they get government approval. Tests have now been completed at a number of plants, and Japan's nuclear safety regulator, the Nuclear and Industrial Safety Agency, recently endorsed the findings from the first units to complete the tests (Kansai's Ohi 3 and 4), although the plants are still awaiting permission to restart.

In October 2011, the government published a white paper confirming that Japan's dependency on nuclear energy will be reduced as much as possible in the medium and long term. In fact, these long-term plans may include deploying more renewable energy, as well as stepping-up measures to improve energy efficiency and to encourage cleaner use of fossil fuels. The new energy policy will be developed by mid-2012. In addition in mid-2011, a decision was made to set up a new independent nuclear regulation agency under the Environmental Ministry. The new agency will be launched in April 2012, combining the role of Nuclear and Industrial Safety Agency (NISA) and Nuclear Safety Commission (NSC). This reorganisation will create an entity responsible for regulating nuclear power generation, which is separate from the entity that is promoting it.

The government will also establish a nuclear safety investigation committee responsible for overseeing the new nuclear regulatory agency, and give it legal power to conduct hearings and onsite inspections—essential for investigating the cause and damage of nuclear accidents. By the end of 2012, the Federation of Electric Power Companies of Japan will establish an independent organisation to study nuclear safety measures. As cooperation with relevant foreign organisations is essential in order to enhance the effectiveness of the new organisation, on February 2012, the federation agreed to coordinate with the US Institute of Nuclear Power Operations.

2. Germany: Outside Japan, the most significant impact of the Fukushima accident has been in Germany. In 2010, the country had 17 reactors operating, with a total gross capacity of 20 GW, providing about 23% of the country's electricity. Within days of the accident, and in an unexpected response, the German government ordered the suspension of operations at seven of its older nuclear plants (operational before 1980), and decided that another, older plant, which was temporarily offline due to technical reasons, should not be restarted.

In May 2011, the government followed with a decision to abandon completely the use of nuclear power by 2022. Eight facilities will be closed permanently, while the country will be phasing out its remaining nine nuclear power plants gradually: one plant each in 2015, 2017, and 2019, respectively; three plants in 2021, and three plants in 2022. This phase-out plan ensures shutting down the remaining nuclear power capacities without running into critical system instabilities. It will also lead to an average plant lifetime of approximately 30 years under such a phase-out plan. The German decision to phase-out nuclear by 2022 will constitute a challenge to its energy mix. It will also affect the energy system in Europe, since it will mean that more intermittent power output will have to be delivered to Germany, and more electricity will be traded across borders; gas-powered plants are expected to be brought online to balance the system. This will have price implications for both the European electricity and gas markets, but the nature of this is currently unknown.

3. Italy: Responses in other countries have varied. In Italy, the government has decided to scrap its previous plans to reintroduce nuclear-generated electricity. A referendum in June 2011 imposed a permanent ban on the reintroduction of a nuclear power programme.

4. Switzerland: In Switzerland, the government announced its intention to decommission its five nuclear power plants gradually between 2019 and 2034. The Swiss phase-out will be organised according to the safety of the operating plants, and is expected to lead to a total lifetime of about 50 years for each plant. In addition, Switzerland has suspended the licensing under discussion for three new nuclear power plants.

In other countries, many governments seem to be standing by their use of nuclear energy, at least in principle. Some of these countries already have nuclear power, while others are about to acquire it. These countries' decisions to uphold their nuclear

Table 3
Summary of Recent Developments on Nuclear Power in Different Countries
Source: WNA, IEA, WEC

	Operable Nuclear Capacity January 2012 (MWe)	Policy Announcements and Actions Relating to Nuclear Power (March 2011 and-February 22, 2012)
European Union	122,411	Announced plans to stress test all plants in its 27 countries. Each country is responsible for its specific programme.
United States	101,240	Continues to support nuclear power while stressing safety as paramount concern.
France	63,130	Continues to support nuclear power while carrying out European Union stress test and looking to increase the role of renewables.
Japan	44,102	Wrote-off Fukushima Daiichi Units 1-4, which are to be decommissioned. All remaining nuclear reactors have been undergoing two-phase stress tests. Announced a review of the existing plan for nuclear power. The new energy policy will be developed by mid-2012.
Russia	23,643	Affirmed plan to double nuclear capacity by 2020 while undertaking comprehensive safety review.
South Korea	19,675	Affirmed plan to continue expansion of the nuclear industry and to conduct safety checks.
Ukraine	13,107	Plans to maintain nuclear share in electricity production to 2030, which involves substantial new builds.
Canada	12,569	Plans to expand its nuclear capacity over the next decade by building more new reactors.
Germany	12,068	Immediately shut reactors operational before 1980 and announced that all other reactors would be closed by 2022.
China	11,688	Temporarily suspended approval of new nuclear reactors, but affirmed 12th Five-Year Plan target to start construction of an additional 40 GW of nuclear capacity in the period 2011–2015.
United Kingdom	9,920	Affirmed commitment to nuclear power by announcing plans to build eight new reactors by 2025.
Sweden	9,304	The government is working with the utilities to expand nuclear capacity to replace the 1200 MWe lost in closure of Barsebäck 1 and 2.
Spain	7,567	Government commitment to the future of nuclear energy in Spain has been uncertain, but is firming up.
Belgium	5,927	Little government support for nuclear energy. The government is expressing concern about the feasibility of implementing the phase out.
Taiwan	5081	Plans to expand its nuclear capacity, with two new reactors under construction.
India	4,391	Affirmed plans to boost nuclear capacity to 63 GW by 2032 and to review safety.
Czech Republic	3,678	Affirmed plans to build two new units at its Temelin nuclear power station.
Switzerland	3,263	Announced plans to close its five nuclear reactors by 2034.
Finland	2,736	Affirmed plans to build nuclear power station at Pyäjoki.
Bulgaria	1,906	Affirmed plans to build two nuclear power station (2 x 1000 MW reactors) at Belene.
Brazil	1,884	Plans to build two new nuclear plants in the northeast and two more near Angra in the southeast are underway.
Hungary	1,889	Parliament has expressed overwhelming support for building two new power reactors.
Slovakia	1,816	Government commitment to the future of nuclear energy is strong.

	Operable Nuclear Capacity January 2012 (MWe)	Policy Announcements and Actions Relating to Nuclear Power (March 2011 and-February 22, 2012)
South Africa	1,800	Affirmed commitment to nuclear power by confirming 9.6 GW by 2030.
Mexico	1,300	Some government support for expanding nuclear energy to reduce reliance on natural gas, but recent low gas prices may undermine this.
Romania	1,300	Affirmed no change to constructing Cernovada 3 and 4 (2 x 720 MW).
Argentina	935	Government commitment to the future of nuclear energy is strong.
Iran	915	Affirmed commitment to nuclear power by starting up Bushehr on 8 May 2011.
Pakistan	725	Government commitment to the future of nuclear energy is strong.
Slovenia	688	Nuclear power plant at Krsko (operated 1983) operational life was designed to be 40 years, but a 20-year extension is being sought.
Netherlands	482	Public and political support is increasing for expanding nuclear energy.
Armenia	375	Has one reactor in operation and the government has approved a joint venture to build another by 2018.
Saudi Arabia	Planning 20,000	Affirmed that using nuclear power is under consideration.
Poland	Planning 6,000	Affirmed plans to commission its first reactor by 2025.
UAE	Planning 5,600 Proposing 14,400	Affirmed no change to plans to build their first nuclear power plants.
Turkey	Planning 4,800 Proposing 5,600	Affirmed no change to plans to commission the first of four planned reactors of 1.2 GW by 2018.
Vietnam	Planning 4,000 Proposing 6,700	Affirmed no change to plans to build their first nuclear power plants.
Belarus	Planning 2,000 Proposing 2,000	Government commitment to the future of nuclear energy is strong.
Bangladesh	Planning 2,000	Government commitment to the future of nuclear energy is strong.
Indonesia	Planning 2,000 Proposing 4,000	Delayed, its first nuclear power plant project until after 2020: the government has not yet taken the decision to build a nuclear power plant..
Lithuania	Planning 1,350	Government commitment to the future of nuclear energy is strong.
Egypt	Planning 1,000 Proposing 1,000	The new government has not made any statements about its plans for the El Dabaa plant.
Jordan	Planning 1,000	Government commitment to the future of nuclear energy is strong.
Kazakhstan	Planning 600 Proposing 600	The government is considering future options for nuclear power.
Italy	Proposing 17,000	A referendum in June 2011 imposed a permanent ban on the reintroduction of a nuclear power programme.
Thailand	Proposing 5,000	Delayed its first nuclear power plant projects until after 2020.
Chile	Proposing 4,400	On March 21, 2011, signed a nuclear power cooperation agreement with the USA.
Malaysia	Proposing 2000	The government is considering future options for nuclear power.
Israel	Proposing 1,200	Plans to develop nuclear plant with Jordan most likely will not proceed.
North Korea	Proposing 950)	Is not currently considered to have serious intentions to deploy nuclear power for electricity.

Table 4

World Nuclear Power Reactors as of 22 February 2012

Source: IAEA: for "Nuclear Electricity Generation", "Reactors Operable", and "Reactors under Construction" ; WNA: for "Reactor Planned" and "Reactors Proposed"

Country	Reactors Operable February 22, 2012		Under Construction February, 22 2012		Reactors Planned February 2012		Reactors Proposed February 2012	
	No.	MWe	No.	MWe	No.	MWe	No.	MWe
Argentina	2	935	1	692	2	773	1	740
Armenia	1	375			1	1,060		
Bangladesh					2	2,000		
Belarus					2	2,000	2	2,000
Belgium	7	5,927						
Brazil	2	1,884	1	1,245			4	4,000
Bulgaria	2	1,906	2	1,906	2	1,900		
Canada	18	12,624			3	3,300	3	3,800
Chile							4	4,400
China	16	11,688	26	26,620	51	57,480	120	123,000
Czech Republic	6	3,766			2	2,400	1	1,200
Egypt					1	1,000	1	1,000
Finland	4	2,736	1	1,600			2	3,000
France	58	63,130	1	1,600	1	1,720	1	1,100
Germany	9	12,068						
Hungary	4	1,889					2	2,200
India	20	4,391	7	4,824	17	15,000	40	49,000
Indonesia					2	2,000	4	4,000
Iran	1	915			2	2,000	1	300
Israel							1	1,200
Italy							10	17,000
Japan	50	44,215	2	2,650	10	13,772	5	6,760
Jordan					1	1,000		
Kazakhstan					2	600	2	600
Korea North							1	950
Korea-South	23	20,671	3	3,640	6	8,400		
Lithuania					1	1,350		
Malaysia							2	2,000
Mexico	2	1,300					2	2,000
Netherlands	1	482					1	1,000
Pakistan	3	725	2	630	1	340	2	2,000
Poland					6	6,000		
Romania	2	1,300			2	1,310	1	655
Russia	33	23,643	10	8,203	14	16,000	30	28,000
Saudi Arabia							16	20,000
Slovakia	4	1,816	2	782			1	1,200
Slovenia	1	688					1	1,000
South Africa	2	1,830					6	9,600
Spain	8	7,567						
Sweden	10	9,320						
Switzerland	5	3,263					3	4,000
Taiwan (China)	6	5,081	2	2,600	1	1,350		
Thailand							5	5,000
Turkey					4	4,800	4	5,600
Ukraine	15	13,107	2	1,900	2	1,900	11	12,000
UAE					4	5,600	10	14,400
UK	18	9,920			4	6,680	9	12,000
USA	104	101,240	1	1,165	11	13,260	19	25,500
Vietnam					4	4,000	6	6,700
WORLD	437	370,402	63	60,057	161	178,995	334	378 ,905

Note:
Operating = Connected to the grid
Building/Construction = First concrete for reactor poured, or major refurbishment under way;
Planned = Approvals, funding or major commitment in place, mostly expected in operation within 8–10 years;
Proposed = Specific programme or site proposals, expected operation mostly within 15 years.

plans are motivated by the economics of nuclear power compared to other forms of electricity generation, rising demand for electricity, and the need to reduce dependency on fossil fuels, while addressing concerns surrounding security of supply and climate change.

Table 3 gives an overview of policy announcements and actions relating to nuclear power between the Fukushima accident and February 22, 2012. More details are included in the Appendix to this report.

These policy and investment changes and announcements indicate that there are few major changes in the status of global nuclear power (see Table 4). The WEC's canvass of Member Countries revealed figures different from those included in Table-4 and they came from Bulgaria, Canada, Finland, Japan, Hungary, Italy, Romania, Russia, Saudi Arabia, South Korea, Switzerland, Ukraine, and USA.

In a survey conducted by WEC, the above statistics included in Table-4 were confirmed except for the following:

- Bulgaria reported no reactors under construction. The construction of two reactors was suspended in the 1990s. The government and parliament still need to take the final decision whether to resume, change the site (Kozloduy instead of Belene) or stop construction.
- Canada reported 17 operable reactors, three reactors under construction, two planned and one proposed.
- Finland reported two planned and none proposed. Two new units are in the "planning phase" and are expected to be operational within 8–10 years. These reactors have also been approved by the parliament, which is the most significant hurdle for new units.
- Japan reported 54 operable reactors and seven planned.
- Hungary reported none proposed.
- Italy reported none proposed.
- Romania reported two proposed.
- Russia reported 10 planned and 20 proposed.
- Saudi Arabia reported that using nuclear is still under consideration and that the WNA figures given above are speculative.
- South Korea reported 21 operable reactors and seven reactors under construction.
- Switzerland reported that the licensing procedure for three proposed reactors has been suspended since Fukushima.
- Ukraine reported no reactors under construction and six proposed.
- The USA reported seven planned and 27 proposed.

The net changes in the number of nuclear reactors worldwide, summarised below in Table 5, show that the major changes included 13 reactors exiting service (eight in Germany, four in Japan, and one in the UK), while eight reactors entered service (three in China, one in Iran, two in South Korea, one in Pakistan, and one in Russia). As for

Table 5
Net Changes in the Number of Reactors (March 10, 2011 and February 22, 2012)

	Operating	Under Construction	Planned	Proposed
China	3	-1	1	10
Germany	-8			
India		2	-1	
Iran	1	-1		
Japan	-4		-2	4
Korea-South	2	-2		
Lithuania			1	-1
Malaysia				1
Pakistan	1	1	-1	
Russia	1	-1		
Saudi Arabia				16
Ukraine				-9
United Kingdom*	-1			
USA			2	-4
Vietnam			2	-6

*On October 24, 2011, Magnox Ltd. announced that Unit 1 at Oldbury nuclear power plant would be permanently shut down in February 2012 (10 months earlier than expected) after 44 years of operation.

construction, five reactors were completed (one in China, one in Iran, two in South Korea, and one in Russia), while construction started on three reactors (two in India, and one in Pakistan). As for reactors in the planning stages, four reactors were dropped (one in India, two in Japan, and one in Pakistan), while six more were added (one in China, one in Lithuania, two in the USA, and two in Vietnam).

5. Long-Term Implications

The long-term implications of the Fukushima accident remain quite uncertain, as many governments continue to reassess their plans for the use of nuclear power. In trying to get an idea of the long-term implications of Fukushima Daiichi, previous nuclear accidents (i.e., Three Mile Island and Chernobyl) may offer points of reference: they affected, to a certain extent, the trajectory of nuclear power for many decades.

Among the long-term outcomes, may be a general sense that ambivalent or negative views of nuclear energy and, in particular, questions about its safety, were justified This may involve an increase in the so-called “not in my backyard” mentality, with people not wanting facilities/plants in their immediate vicinity or neighbourhood. In contrast, in the hope that the global community can learn from Fukushima, those in favour of nuclear energy may call for improvements in safety procedures and plans, including the reconsideration of future sites of new nuclear power plants. However, since risk profiles are reactor- and site-dependent, it is likely that response capabilities will have to vary by location—meaning that identifying minimum safety standards could be problematic. However, it is still possible to share examples of best practice between countries and operators.

The emerging non-OECD countries (mainly China and India) are expected to dominate future growth. Since these countries need to utilise all options to meet their rapidly growing electricity demand and secure certain levels of economic growth, it would be potentially very costly for them to rule out the option to increase their use of nuclear power. This is exacerbated by the increasing price of energy from other sources, political stability in certain energy-producing markets, as well as concerns about carbon emissions and climate change. As Table 5 shows, only Germany, Japan, Switzerland, and Italy have retracted their nuclear power programmes. The developing nations (especially China, Russia, and India) are continuing their planned projects.

The IAEA also argues that Fukushima has not led to a significant retraction in nuclear power programmes outside Europe, except for Japan. Progress in several national programmes, especially in countries new to nuclear power, has been delayed, especially with regard to near-term decisions to start such programmes. Generally, however, these countries have not shown any indication that their pursuit of nuclear power has declined after Fukushima. It seems likely that greater attention will be paid to issues of safety and regulation, including education, and that ambitious construction timelines may give way to more realistic schedules.

6. WEC Survey Results

Soon after the Fukushima accident, the WEC conducted a response survey covering member countries with nuclear power facilities. The survey showed that most countries that have nuclear power installations understand that their own national nuclear authority is independent, resourced, transparent, and able to enforce standards. However, they all showed a high degree of uncertainty about the state of nuclear governance in other countries.

The survey also showed that there is both greater willingness to strengthen national nuclear authority in light of Fukushima, and strong agreement that there is the need to improve public understanding and acceptance of nuclear technology, and its costs, benefits, and risks. While there seems to be relatively high support for the adoption and convergence of international safety regulations, there also seems to be comparatively lower support for the international enforcement of safety standards. The response has been unanimous that the media affects the public discourse of nuclear energy the most. Therefore the most pressing barrier for the future acceptance and development of nuclear power is understood to be public perception, closely followed by a lack of policy.

When asked about the potential for substitution fuels, natural gas has emerged as the clear winner globally, with biomass being a strong contender. Renewables were only mentioned in countries with high potential, e.g., solar in Spain. Higher electricity prices are thought to be the most direct implication of nuclear substitution, with energy security concerns and higher greenhouse gas emissions (GHGs) emissions also highlighted by many countries. Regional analysis further showed that the perception of nuclear safety in developing countries has not changed significantly when compared to that in developed countries. Lack of skilled technicians and engineers is an important barrier for the future of nuclear in developing countries. Coal and fuel imports will continue to play a more important role in ensuring energy security in those areas than they do in developed countries.

7. International Governance: Potential for Improvement

Undoubtedly, nuclear power production provides unique governance challenges. Above all, there is the fact that national boundaries are meaningless in the context of nuclear accidents. However, currently, nuclear governance rests with nation states, with a limited level of oversight by the International Atomic Energy Agency (IAEA), and peer review organised by the World Association of Nuclear Operators (WANO) and the Institute of Nuclear Power Operations (INPO).

The fundamental objective of the IAEA is to ensure that atomic energy is not put to any military use. Apart from its NPT mandate, the IAEA has no power to intervene in the nuclear affairs of a state, unless it is specifically requested to do so by the state itself. In all cases, the sovereignty of the state supersedes that of the IAEA.

All other organisations, including WANO and INPO, are focused on helping and advising members to achieve the highest levels of operational safety and reliability. They also promote the highest levels of safety and reliability in the operation of commercial nuclear power plants. Such objectives are made possible via peer reviews, technical support and access to global libraries of operating experiences.

There is clear and critical need to strengthen the global governance of nuclear energy. Examples of successful global governance can be found in many industries, and may provide models for the nuclear power industry. The aviation industry, for example, has many similarities with the nuclear industry, since both have competing designers, manufacturers, and operators, all of which work under national authorities. Yet, the aviation industry uses international certification standards to ensure airworthiness, as well as protocols for navigation systems, etc. In line with this train of thought, the following points have been highlighted by the nuclear task force members as a contribution for further debate in the future:

1. **Public Acceptability:** As a major stakeholder that can radically affect local policies and plans, the public should be well informed of issues surrounding nuclear generation, including its role in an energy mix, available technologies, costs, and benefits as well as, risk and safety concerns.

2. **Standards:** Independent and competent national nuclear safety agencies should adopt minimum safety and reliability operation and maintenance standards, including site location parameters, and skills training and certification maintenance. There should also be minimum transparency standards—to allow verification of these standards.

3. **Verification**: An international organisation should be empowered to work with each national nuclear safety agency to draw up these standards and verify adherence to them. The process and results of verification should be publicly available.

4. **Design:** The same organisation should produce an international accreditation standard for reactor design.

5. **Liability and Risk:** The organisation should also promote the communication of good

practices on liability assessment, long-term stewardship as well as risk sharing and management.

6. **Human Resources Management:** The organisation should share good practices in human resources management (relating to, for example, nuclear operators, contractors, subcontractors, etc.), including social protection, education, and training, with national nuclear safety agencies.

7. **Global Cooperation:** The organisation should work with national nuclear safety agencies to prepare for nuclear incidents (e.g., the creation of emergency response plans, formation of expert teams, etc.) and exchange scientific information and expertise (subject to due diligence).

8. **Finance:** Funding mechanisms should be revised to ensure strict compliance to national and international standards.

9. **Structure:** At national and international levels, there should be an unbundling of responsibilities for the promotion and safety of nuclear power, so as to reduce the potential for conflicts of interest.

The above 9 points are not intended as the definitive word on the subject; indeed it is clear that even WEC members may differ in opinion on some of these points. They are intended to inform the agenda of the vigorous discussion that must still be held; nationally and internationally, within WEC and outside of WEC. As the discussion and debate develops we hope that governance issues will receive the serious consideration they deserve.

Appendix A. Recent Developments in Global Nuclear Power

Table 6

Recent Developments in Global Nuclear Power as of mid-February 2012 (Countries are listed in order of their operable nuclear capacity).

Source: WNA, IEA, WEC

Country	Operable Nuclear Capacity January 2012 (MWe)	Key Developments (Up to February 22, 2012)
European Union	**122,411**	**Announced plans to stress test all 143 plants in its 27 countries.** In March 2011, the European Union (EU) decided to conduct stress tests on all 143 reactors in its 27 countries. These tests are intended to test against all extraordinary events including earthquakes, flooding, and all other initiating events potentially leading to multiple losses of safety functions. The results of the tests are expected during 2012. In addition, the EU has asked neighbouring countries to commit to implementing the same stress tests on their own nuclear plants.
United States	**101,240**	**Continues to support nuclear power while stressing safety as paramount concern.** The USA is the world's biggest nuclear power producer: its Nuclear Regulatory Commission (NRC) has launched a comprehensive review of the country's nuclear facilities and operations in order to identify and apply lessons learned from Fukushima. The review comprises two parts: i) identifying immediate changes needed to maintain safety during emergencies such as natural disasters (hurricanes and earthquakes) and power outages (completed in June 2011); and ii) examining other changes that may be needed (ongoing). Three months after Fukushima the NRC announced no safety problems in the operation of the country's 104 reactors and that there are no risks in extending the lives of the existing reactors. By September 2011, 71 reactors had already received license extensions of up to 60 years; by October 2011, 13 additional licenses were under scrutiny/definition. As for constructing new reactors, very low domestic gas prices present problems for the justification of merchant nuclear plants in the short to medium term. Only four new units in energy-regulated states are going to be in service before 2020. Nevertheless, on February 9, 2012, the NRC granted; (1) combined operating licenses for two AP1000 units at Plant Vogtle in Georgia (the first time since 1978) and (2) two additional units of the same type to be built in South Carolina, are expected to get their COL in March 2012.

Country	Operable Nuclear Capacity January 2012 (MWe)	Key Developments (Up to February 22, 2012)
France	**63,130**	**Continues to support nuclear power while carrying out European Union stress tests and looking to increase the role of renewables.** France is the world's second-largest nuclear power-producing country, and the country most dependent on nuclear power (75% to 80% of its power generation. A recent government report (*Energies 2050*, Feb. 2012) states that extending the life of the country's existing nuclear fleet is the best way to meet energy challenges in the future, along with increasing energy efficiency, development of renewables, and some EPR units. The French Nuclear Safety Authority (NSA) has been charged with carrying out safety assessments of all nuclear facilities in the country. The NSA stated that France's 58 nuclear reactors have a sufficient level of safety and therefore, none of them should be closed. The NSA also stated that these reactors' continued generation requires increasing their robustness in the face of situations beyond the safety margins they already have. Developments confirm this concern with safety: in July 2011, Électricité De France (EdF) revised the completion date of the Flamanville reactor (Generation III European Pressurised Reactor, EPR), to 2016, with an additional cost of €6 billion; the delay stems in part from the need to carry out new safety tests. In September 2011, EdF awarded contracts for the replacement of steam generators for the 1300 MW-class fleet (20 reactors, 8 sites), and three months later, a contract was put in place to upgrade monitoring and control systems for the same plants. The French government has also confirmed its intention to increase the share of renewables in the electricity generation mix.
Japan*	**44,102**	**Announced a review of the existing plan for nuclear power to account for 53% of electricity output by 2030.**
Russia	**23,643**	**Affirmed plan to double nuclear capacity by 2020 while undertaking comprehensive safety reviews.** With a more aggressive approach and 10 reactors currently under construction, Russia affirmed its plan to double the current nuclear capacity (22,000 MW) by 2020. This is in addition to instructing Rosatom, the state-owned nuclear corporation, to undertake a comprehensive safety review of its nuclear fleet. In June 2011, and following the checks made on Russia nuclear plants, the programme "Safety Upgrade" was announced: this would ensure that there are back-up power and water supplies. A second programme, to upgrade the power and extend the life (by 15 years) of the country's existing reactors is proceeding fast. Moreover, the Kaliningrad plant (2 x 1200 MW units) on the Baltic coast received its construction license in November 2011. The first unit is planned to come online in 2017, and is scheduled for grid-connection in 2018. Two-thirds of the energy that will be produced is targeted for export to Germany, Poland, and the Baltic States. Other nuclear advances include: advances in fast neutron reactor technology, in which Russia is a world leader, and the construction of seven or eight floating nuclear power plants by 2015. The government has also increased its support for building nuclear plants abroad: approaches by the Russian Buy-Operate-Own (BOO) include offering to supply all fuel and repatriate used fuel for the life of the plant. Russia is involved in this capacity in at least seven countries including Ukraine, Belarus, India, China, Turkey, Vietnam, and Bangladesh.

Country	Operable Nuclear Capacity January 2012 (MWe)	Key Developments (Up to February 22, 2012)
South Korea	**18,682**	**Affirmed plan to continue expansion of the nuclear industry and to conduct safety checks.** In 2011, South Korea had 21 reactors in operation, with a capacity of 19 GW providing 31% of the country's electricity. In mid-2011, the government reaffirmed the plan to raise this to 27 GW by 2020 and to 43 GW by 2030, supplying 59% of the national electricity demand. In November 2011, the government stressed again its commitment to complete six new reactors by 2016. The South Korean technology-export programmes and efforts are impressive, especially in light of its success in supplying four reactors to the UAE. South Korea wants to be the third-largest exporter of nuclear power plants by 2030, supplying more than 20% of the world market (its so-called "Nu-Tech 2030 programme").
Ukraine	**13,107**	**Plans to raise nuclear share in electricity production by 2030, which involves substantial new builds.** In mid-2011, the Ukraine energy strategy out to 2030 was updated, and in the electricity sector, nuclear power's role was emphasised, with greater attention to improved safety and increased domestic-fuel fabrication. The mid-2011 energy-policy revision proposes 2300 MWe of new capacity, with a decision on technology design to come after 2015.
Canada	**12,569**	**Plans to expand its nuclear capacity over the next decade by building more new reactors.** To meet current and future electricity needs in Canada, provincial governments and power companies have made the decision to extend the operating life of a number of reactors by refurbishing them. In November 2011, unit 1 at Bruce-A was given regulatory approval for fuel loading, and unit 2 is expected back online in mid-2012. An independent review panel appointed in 2009 by the Environment Department and CNSC concluded in August 2011 that the construction of up to four new reactors in the Darlington site was unlikely to cause adverse environmental effects. In December 2011, Bruce Power shelved Alberta's nuclear project, ending a positive four-year engagement process with the local people. In 2011, its operating licence was extended to 2016.
Germany*	**12,068**	**Immediately shut-down reactors that were operational before 1980 and announced that all other reactors would be closed by 2022, effectively reversing a decision taken in 2010 to delay a previous phase-out plan agreed in 2001.**
China	**11,688**	**Temporarily suspended approval of new nuclear reactors, but affirmed the 12th Five-Year Plan target to start construction of an additional 40 GW of nuclear capacity between 2011 and 2015.** China has the world's most ambitious nuclear expansion plans (70-80 GW in operation by 2020 and 200-300 GW by 2030) and had 28 reactors under construction in 2010. Following the Fukushima accident, in March 2011, the Chinese State Council announced the suspension of approvals of new plants and ordered safety checks on existing plants and those under construction. In June 2011, all of China's operating nuclear reactors were reported to have passed their safety inspections.

Country	Operable Nuclear Capacity January 2012 (MWe)	Key Developments (Up to February 22, 2012)
China (continued)		In December 2011, the National Energy Administration (NEA) stated that China will make nuclear energy the foundation of its power generation system in the next 10 to 20 years with up to 300 GW of nuclear capacity added over that period. China's new national plan for nuclear safety is being approved, and construction of nuclear plants will resume in March 2012. China has also affirmed its 12th Five-Year Plan target to start construction of an additional 40 GW of nuclear capacity between 2011 and 2015. Of the plan's 34 approved reactors, the construction of four units, due to start in 2011, was suspended; but the construction of three other units was begun after March 2011 and two reactors were connected to the network in 2011. As of January 9, 2012, China has 26 reactors under construction.
United Kingdom	**9,920**	**Affirmed commitment to nuclear power by announcing plans to build eight new reactors by 2025.** An interim report by the country's Chief Inspector of Nuclear Installations concluded that there is no need to alter the operation of its nuclear plants or change plans for adding new capacity. In June 2011, the government announced a list of eight sites deemed suitable for new nuclear plants to be built by 2025. In July 2011, the new government issued a new Electricity Market Reform (EMR) white paper, including a carbon price floor fundamental to the economics of new UK nuclear reactors (£16 per tonne of CO_2 in 2013, rising to £30 per ton in 2020 and to £70 per ton in 2030). The EMR package also includes a long term-contracts framework (feed-in tariffs) for all low-carbon technologies. The office of Nuclear Regulation has granted authorisation for the EPR and AP1000 technologies to be deployed in the UK's nuclear programme.
Sweden	**9,304**	**The government is working with the country's utilities to expand nuclear capacity so as to replace the 1200 MWe lost through closure of Barsebäck 1 and 2.** Sweden's 1997 energy policy allowed 10 reactors to operate for longer than was originally envisaged by its 1980 phase-out policy. It also resulted in the premature closure of a two-unit plant. The phase-out policy was abandoned completely in 2010. Current legislation is paving the way to replace and renew the current nuclear generating capacity.
Spain	**7,567**	**Government commitment to the future of nuclear energy has been uncertain, but is firming up.** In February 2011, Consejo de Seguridad Nuclear (CSN) of Spain recommended a 10-year extension for the nuclear power station at Cofrentes in Spain, and in July 2011 it recommended the same for the nuclear power stations Asco 1 and 2; these were agreed in March 2011 and September 2011, respectively. Another licence renewal is due in 2014. Meanwhile, there has been a change of government (elected November 2011): during his election campaign, the new Prime Minister Mariano Rajoy stated that he would revisit the decision to close the nuclear power station at Santa María de Garoña. He is likely to keep it open until 2019, the end of its current license recommended by CSN.

Country	Operable Nuclear Capacity January 2012 (MWe)	Key Developments (Up to February 22, 2012)
Belgium	**5,927**	**Little government support for nuclear energy and nuclear power generation incurs a EUR 0.5 cent/kWh tax. The government is expressing concern about the feasibility of implementing the phase-out.** In October 2011, several political parties were negotiating to form a new government: they agreed that the 2003 nuclear phase-out law (closing three reactors by 2015 and the others by 2025) should be implemented if adequate power could be secured from other sources and prices would not rise unduly. The new government is now expressing concern about the feasibility of implementing this phase-out.
Taiwan	**5,081**	**Plans to expand its nuclear capacity; two new reactors are under construction.** Following Fukushima, the Atomic Energy Council (AEC) initiated a comprehensive nuclear safety review, and the first phase of this was completed in September. The AEC also strengthened its radiation protection capacity and contingency mechanisms, since Taiwan is very prone to seismic activity. In January 2012, the AEC said that its post-Fukushima inspections found no safety concerns with the six operating nuclear units.
India	**4,391**	**Affirmed plans to boost nuclear capacity to 63 GW by 2032, and to review safety.** India, which is actively promoting the role of nuclear power in meeting its growing electricity demand, has ordered emergency safety checks to be carried out on all nuclear plants. In addition, it has affirmed plans to boost nuclear capacity and signalled that there will be no change to its announced targets. Starting from the present 4.385 GW, produced by 20 reactors in service, India has a very ambitious programme to double the capacity in service by 2015, and to have more than 63 GW in operation by 2032. The construction of Kakrapar 4 (630 MWe) started in March 2011, while the construction of Rajasthan Unit 7 (630 MWe) started in July 2011. With these two new constructions, the total number of reactors under construction increases to seven. The construction progress seems to be on schedule, except for Kudankulam-1 and Kudankulam-2 which have both been under construction since 2002. Kudankulam-1 was due to start supplying power in March 2008 and to go into commercial operation late in 2008, but this schedule has slipped by more than three years. Towards the end of 2011 and at the beginning of 2012, completion and fuel loading was being delayed by public protests. The construction of Kudankulam-2 is about eight months behind Kudankulam-1. **Signpost:** in light of the public response and protest taking place at Kudankulam-1 (still under construction), further protests, and potentially a government response, is something to watch for, especially given the democratic governance of India.

Country	Operable Nuclear Capacity January 2012 (MWe)	Key Developments (Up to February 22, 2012)
Czech Republic	**3,678**	**Affirmed plans to build two new units at its Temelin nuclear power station.** In October 2011, three selected candidates (AREVA, Toshiba-W, and Rosatom) were formally invited by the Czech state-owned power company (CEZ) to present their offers for two complete power plant units at Temelin on a full turnkey basis. Contract would include an option to order three more reactors for other locations.
Switzerland*	**3,263**	**Announced plans to close its five nuclear reactors by 2034.**
Finland	**2,736**	**Affirmed plans to build nuclear power station at Pyhäjoki.** In July 2011, the Fennovoima project company (70% of which is owned by electricity-intensive industries and resellers, of which EoN owns 33%) invited Areva and Toshiba to bid for the delivery and construction of a reactor and turbine island for a new nuclear plant. A decision is expected in 2012-2013, to be followed by preparation of the selected and approved site at Pyhäjoki. TVO has authorisation to build an additional (fourth) unit at Olkiluoto.
Bulgaria	**1,906**	**Affirmed plans to build nuclear power station (2 x 1000 MW reactors) at Belene, but construction deadline extended.** In September 2011, Atomstroyexport (a leading Russian engineering company of Rosatom) and National Electricity Company (NEK) of Bulgaria signed a supplement to their agreement to construct two reactors (2 x 1000 MW) for the Belene plant.
Brazil	**1,884**	**Plans to build two new nuclear plants in the northeast and two more in the southeast are underway.** At the end of 2009, the Brazilian nuclear utility Eletronuclear commenced initial siting-studies at four potential locations in the northeast of the country. It is aiming to present a list of 40 possible sites to the Mines and Energy Ministry by mid-2011, with a view to sites and technology being selected by the end of 2011. Eletronuclear is looking at the Westinghouse AP1000, the Areva-Mitsubishi Atmea-1, and Atomstroyexport's VVER-1000.
Hungary	**1,889**	**The Hungarian parliament has expressed overwhelming support for building two new power reactors.**
Slovakia	**1,816**	**Government commitment to the future of nuclear energy is strong.** In August 2010, the newly-elected Slovakian government said it was keen for the Bohunice project to proceed, but would not provide any financial support for it. The plant is not expected to be operational before 2025.
South Africa	**1,800**	**Affirmed commitment to nuclear power by confirming 9.6 GW by 2030.** South Africa confirmed in mid-2011 that it is planning 9,600 MW of new nuclear capacity by 2030. Bids are expected to be called in 2012. On February 27, 2012, the South African Minister of Energy stressed that the government would not stipulate the source of the nuclear energy technology to be used.
Mexico	**1,300**	**Some government support for expanding nuclear energy to reduce reliance on natural gas.** In the longer term, Mexico may look to employ small reactors such as IRIS to provide power and desalinate seawater for agricultural use.

Country	Operable Nuclear Capacity January 2012 (MWe)	Key Developments (Up to February 22, 2012)
Romania	**1,300**	**Affirmed no change to constructing Cernovada 3 and 4 (2 x 720 MW).** In August 2011, the China Nuclear Power Engineering Company (CNPEC) expressed interest in investing in two of Romania's units, Cernovada 3 and 4 (2 x 720 MW). A South Korean consortium has also expressed interest in this project.
Argentina	**935**	**Government commitment to the future of nuclear energy is strong.** The completion of the country's third reactor is expected by early 2012. The license of the Embalse CANDU-6 type plant will be extended by 25-30 years in partnership with CANDU Energy Inc. and its power will be increased by about 35 MWe. Contracts for $440 million were signed in August 2011 and the main work is due to commence in November 2013. The reactor will be offline for about 20 months while work takes place. Altogether, the project will take five years. In May 2011, Rosatom and the Argentine Planning and Investments Minister said they were discussing the possibility of joint development and construction of a 640 MWe reactor of unspecified type.
Iran	**915**	**Affirmed commitment to nuclear power by starting up Bushehr on May, 8 2011.** Has not suspended its enrichment-related activities or its work on heavy water-related projects, as required by the UN Security Council. The Iranian reactor in Bushehr started up on May 8, 2011, was connected to the grid in early September 2011, and is expected to enter commercial operation in February 2012.
Pakistan	**725**	**Government commitment to the future of nuclear energy is strong.** In August 2011, it was reported that Pakistan was aiming to build 8,000 MWe nuclear power plants at 10 sites by 2030. Construction of two of these has begun: Chasnup Unit 3 at the end of May 2011, and Chasnup Unit 4 on December 18, 2011
Slovenia	**688**	**The operational life of the nuclear power plant at Krsko (est. 1983) was designed to be 40 years, but a 20-year extension is being sought.** The government is considering an additional unit of 1,000- 1,600 MWe at the Krsko site, which will extend its operational life by 40 years. GEN Energija submitted an application to the country's Ministry of Economy in January 2010; a decision by the Slovenian parliament is expected shortly.
Netherlands	**481**	**A previous decision to phase out nuclear power has been reversed. Public and political support is increasing for expanding nuclear energy.** In 1994, the Dutch parliament voted to phase out the Borssele nuclear power plant by 2003, but legal difficulties obstructed that process. In 2003, the ruling conservative government coalition moved the closure date back to 2013, but in 2005 the phase-out decision was abandoned altogether.

Country	Operable Nuclear Capacity January 2012 (MWe)	Key Developments (Up to February 22, 2012)
Armenia	**375**	**Has one reactor in operation and the government has approved a joint venture to build another by 2018.** Armenia's Metsamor plant is a concern to the European Union (EU) and to neighbouring Turkey, 16 km away. There have been various calls to shut it down before 2016, but Armenia is dependent on it. It has agreed with the EU that it will close the plant before the end of its design lifetime, provided that alternative replacement capacity will be available.
Saudi Arabia	**Planning 20,000**	**Affirmed that using nuclear power is still under consideration.** In June 2011, the government stated its intention to develop essential atomic energy to meet the Kingdom's growing requirements. According to the WNA, King Abdullah City for Atomic and Renewable Energy (KACARE) said that it plans "to construct 16 nuclear reactors over the next 20 years at a cost of $80 billion; the first two are planned to come online in 10 years and then two more per year up to 2030, to generate about 20% of Saudi Arabia's electricity."
Poland	**Planning 6,000**	**Affirmed plans to commission its first reactor by 2025.** Legislation was passed by parliament (407 votes to 2) in May and June 2011; tenders for the first 3000 MW plant have been issued with site qualification and the selection of the final supplier expected to happen in 2013. The first reactor is expected to be commissioned in 2025.
UAE	**Planning 5,600 Proposing 14,400**	**Affirmed no change to plans to build their first nuclear power plants.**
Turkey	**Planning 4,800 Proposing 5,600**	**Affirmed no change to plans to commission the first of four planned reactors of 1.2 GW by 2018.** In May 2010, Russian and Turkish heads of state signed an intergovernmental agreement for Rosatom to build, own, and operate the Akkuyu plant (4 x 1200 MW units) in Turkey. In December 2010, the parliaments of both countries ratified the agreement and the project company was registered. In December 2011, the project company filed applications for construction permits and an operating license. An environmental-impact assessment has begun, in order to start construction of the first unit in 2013 with the intention of bringing the first reactor into service in 2018, and the other units by 2019–2021. In addition, Turkey has had plans since 2008 to build a second nuclear plant in Sinop with four reactors. In November 2011, the Turkish Prime Minister requested the South Korean President to renew a previous KEPCO offer to build four reactors (4 x 1400 MW) on a BOO scheme. Discussions are underway with Mitsubishi/Kansay (Japan), Areva/GdF, and EdF.
Vietnam	**Planning 4,000 Proposing 6,700**	**Affirmed no change to plans to build their first nuclear power plants.** In November 2011, Vietnam signed a credit agreement with Russia for two reactors (2 x 1200 MW) to be constructed as a turnkey project, coming into operation in 2020. It also signed an intergovernmental agreement with Japan for construction of a second nuclear plant with two reactors to come online in 2021-2022. At the end of 2011, the Vietnamese and South Korean Presidents signed a cooperation agreement that included the development of a third nuclear plant.

Country	Operable Nuclear Capacity January 2012 (MWe)	Key Developments (Up to February 22, 2012)
Belarus	**Planning 2,000 Proposing 2,000**	**Government commitment to the future of nuclear energy is strong.** In October 2011, Belarus signed a construction agreement with Atomyexport to provide two reactors (2 x 1200 MW) in Ostorvets, with reactors expected to come online in 2017-2018.
Bangladesh	**Planning 2,000**	**Government commitment to the future of nuclear energy is strong.** In November 2011, Bangladesh signed an intergovernmental agreement with Russia for two reactors (2 x 1000 MW) to be built in Rooppur; Russia would provide the fuel, and take back used fuel. Construction of the first unit is expected to start in 2012, leading to operation in 2018.
Indonesia	**Planning 2,000 Proposing 4,000**	**Delayed their first nuclear power-plant projects until after 2020.** Russia is hoping to export floating nuclear plants on a fully serviced basis to provide power to Indonesia's smaller islands.
Lithuania	**Planning 1,350**	**Government commitment to the future of nuclear energy is strong.** In July 2011, the Lithuanian government selected GE-Hitachi for the EPC contract of the Visiginas plant. GE-Hitachi expects to build a 1350 MW advanced boiling water reactor (ABWR) to be in operation in 2020.
Egypt	**Planning 1,000 Proposing 1,000**	**The new government has not made any statements about its plans for the El Dabaa plant.** In 2006, Egypt announced it would revive its civilian nuclear power programme, and within the next 10 years would build a 1,000 MW nuclear power station at El Dabaa. During 2011, the site was targeted by protesters claiming that their land was wrongly taken by the government to make way for the nuclear plant. As of 2012, as a result of those protests, the site has been shut down.
Jordan	**Planning 1,000**	**Government commitment to the future of nuclear energy is strong.** After short-listing possible strategic partners in February 2011, Jordan expects to sign an EPC contract in 2012 with one of the three qualified suppliers (Areva, Atomstroyexport and AECL) to start construction in 2013 of a 750-1100 MW plant for operation in 2020.
Kazakhstan	**Planning 600 Proposing 600**	**The government is considering future options for nuclear power.** The government is also committed to increased uranium exports. In 2009, it became the world's leading uranium producer, with almost 28% of world production, rising to 33% in 2010 and about 35% in 2011.
Italy*	**Proposing 17,000**	**A referendum in June 2011 imposed a permanent ban on the reintroduction of a nuclear power programme.**
Thailand	**Proposing 5,000**	**Delayed their first nuclear power-plant projects until after 2020.** Following the Fukushima accident, Thailand's plans for its first reactor were put on hold until after 2020.
Chile	**Proposing 4,400**	**In March 21, 2011, the USA and Chile signed a nuclear power cooperation agreement.**

Country	Operable Nuclear Capacity January 2012 (MWe)	Key Developments (Up to February 22, 2012)
Malaysia	**Proposing 2000**	**The government is considering future options for nuclear power.** In January 2011, the Malaysia Nuclear Power Corporation was commissioned under the new Economic Transformation Programme (ETP) to spearhead the eventual deployment of nuclear power plants in a 12-year time frame, subject to the scheduled 2013 decision on the matter.
Israel	**Proposing 1,200**	**Plans to develop nuclear plant with Jordan most likely will not proceed.** Early in 2010, Israel said that it would prefer to develop its nuclear plant in collaboration with Jordan, but the overture was not reciprocated. In mid-2011, the Israeli Prime Minister was quoted as saying that its development plans would not proceed.
North Korea	**Proposing 950**	**Not currently considered to have serious intentions to deploy nuclear power for electricity; other nuclear projects suspended.**

*More details on these countries are included in the main body of the report.

Appendix B. Task Force Members

Task Force Leader

Alessandro Clerici, Senior Advisor to the President, ABB Italy, Italy

Members

Alexander Zafiriou, Political Affairs & Corporate Communications, E.ON AG, Germany

Anne Revol, Analyst, Strategy Division, EDF, France

Ashutosh Shastri, Director, Enerstrat Consulting, India

Boris Bokarev, Economic Controlling Deputy Director, Rosatom, Russia

Christophe Bonnery, Vice President, Energy Policy, AREVA, France

Fernando Naredo, Vice President, Government Affairs, Europe, Westinghouse, Belgium

Hans-Wilhelm Schiffer, Senior Manager, General Economic Policy/Science, RWE, Germany

Helen El-Mallakh, Associate Director, ICEED Centre, United States

Ionut Purica, Senior Researcher, Romanian Academy, Romania

Laurent Joudon, Director, Strategy Division, EdF, France

Luiz Augusto Figuera, Coordinator, Internal Affairs, Eletrobras, Brazil

Mstislav Voskresenskiy, Executive Director, Russian WEC, Russia

Paulo Cesar Fernandez, Senior Electrical Engineer, Eletrobras, Brazil

Yury Samoshin, International Business Deputy Director, Rosatom, Russia

Contributors

Alexander Bychkov, Deputy Director General, IAEA

Holger Rogner, Head, Planning and Economics Studies Section, IAEA

WEC London Office

Christoph Frei, Secretary General

Karl Rose, Director of Global Studies

Ayed Al-Qahtani, Senior Project Manager

Philip Thomas, Project Manager

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Tunisia
Turkey
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United Arab Emirates
United Kingdom
United States
Uruguay
Zimbabwe

World Energy Council
Regency House 1-4 Warwick Street
London W1B 5LT United Kingdom
T (+44) 20 7734 5996
F (+44) 20 7734 5926
E info@worldenergy.org
www.worldenergy.org

For sustainable energy.

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