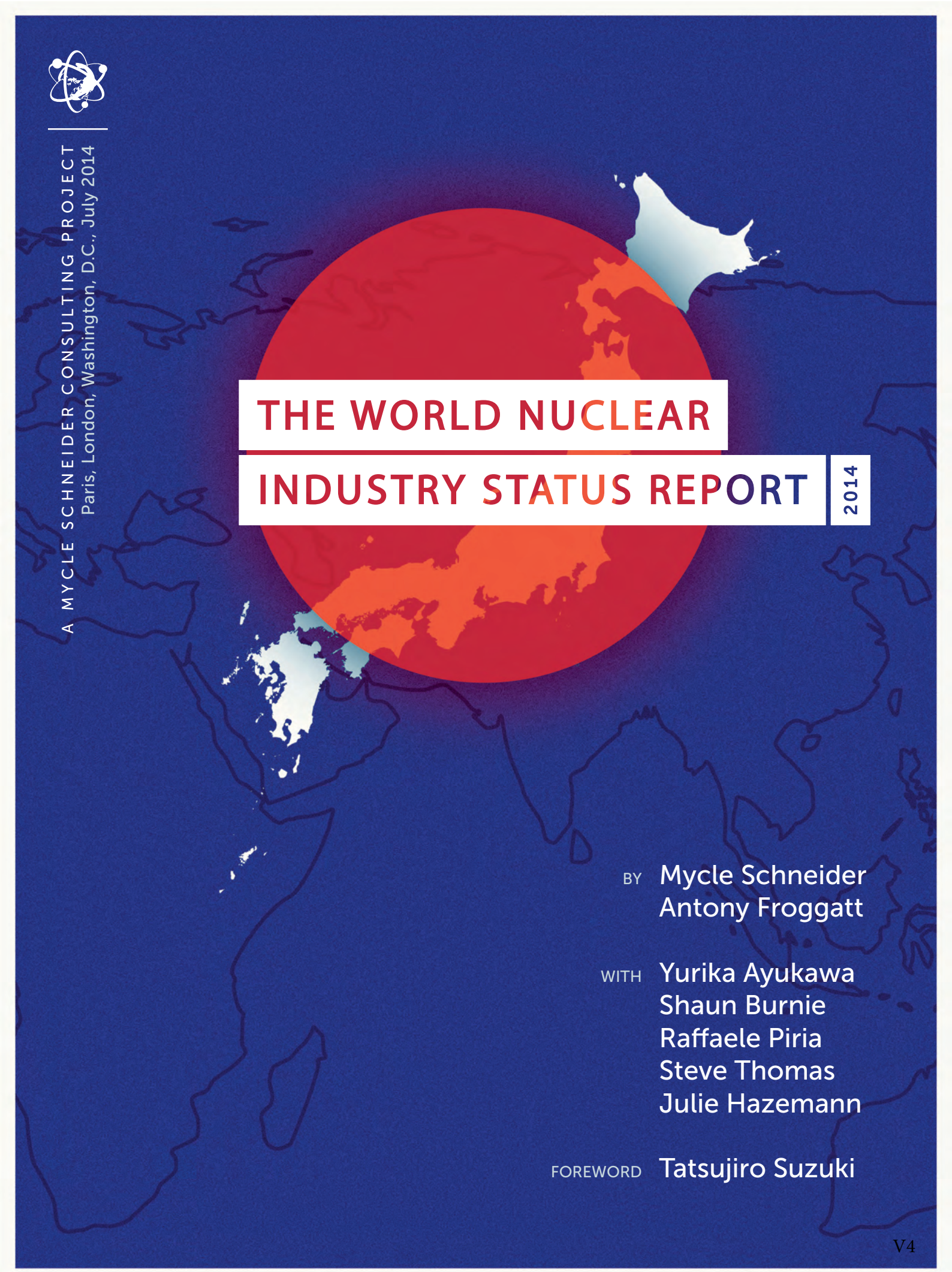
A MYCLE SCHNEIDER CONSULTING PROJECT
Paris, London, Washington, D.C., July 2014



THE WORLD NUCLEAR INDUSTRY STATUS REPORT 2014

BY Mycle Schneider
Antony Froggatt

WITH Yurika Ayukawa
Shaun Burnie
Raffaele Piria
Steve Thomas
Julie Hazemann

FOREWORD Tatsujiro Suzuki

V4

HEINRICH BÖLL STIFTUNG
The Green Political Foundation

SCHWEIZERISCHE ENERGIE-STIFTUNG
FONDATION SUISSE DE L'ENERGIE
SES

Fred & Alice Stanback

The World Nuclear Industry Status Report 2014

By

Mycle Schneider
Independent Consultant, Paris, France
Project Coordinator and Lead Author

Antony Froggatt
Independent Consultant, London, U.K.
Lead Author

With

Yurika Ayukawa
Professor for Environment & Energy Policy, Chiba University of Commerce, Japan
Contributing Author

Shaun Burnie
Independent Consultant, Hamburg, Germany
Contributing Author

Raffaele Piria
Independent Consultant, Berlin, Germany
Contributing Author

Steve Thomas
Professor for Energy Policy, Greenwich University, U.K.
Contributing Author

Julie Hazemann
Director of EnerWebWatch, Paris, France
Documentary Research, Modeling and Graphic Design

Foreword by Tatsujiro Suzuki
Former Vice-Chairman of the Japan Atomic Energy Commission

Paris, London, Washington, D.C., July 2014

A Mycle Schneider Consulting Project

Cover page created by Noëlle Papay

Acknowledgments

The project coordinator wishes to thank his colleague and main co-author Antony Froggatt for his continuous solid contribution to this project. A big thanks to contributing authors Steve Thomas, Yurika Ayukawa, Raffaele Piria and Shaun Burnie for their creative special contributions to this report and their patience with me. The project would not be possible without Julie Hazemann's countless hours of work on the core database and the graphic illustrations. Thank you.

A special thank you to Tatsujiro Suzuki for his thoughtful foreword.

Many other people have contributed pieces of work to make this project possible and bring it to the current standard. These include in particular Fraunhofer's ISE that has contributed a number of enlightening graphic illustrations on the German electricity system and Nuclear Engineering International that provided the nuclear load factor statistics.

The report has greatly benefitted from partial or full proof-reading, editing suggestions and comments by Amory B. Lovins, Walt Patterson, M.V. Ramana, Doug Koplow, Paul Jobin, Sabine von Stockar. I'm grateful to my daughter Nina Schneider who served as an effective all-round verifier.

Thank you all.

The authors wish to thank in particular Fred & Alice Stanback, Amory B. Lovins, Rocky Mountain Institute, Rebecca Harms, the Greens-EFA Group in the European Parliament, Rebecca Bertram, Heinrich Böll Foundation U.S., Sabine von Stockar, the Swiss Renewable Energy Foundation, Hermann Hatzfeldt, Hatzfeldt Foundation, for their generous continued support for this project.

A big thank you to Philippe Rivière for his reliable work on the website and his generous assistance at any time of the day as well as to Noëlle Papay who has created the well-thought special cover page for this report.

Note
This report contains a very large amount of factual and numerical data. While we do our utmost to verify and double-check, nobody is perfect. The authors are always grateful for corrections and suggested improvements.

Lead Authors' Contacts

Mycle Schneider
45, allée des deux cèdres
91210 Draveil (Paris)
France
Phone: +33-1-69 83 23 79
Email: mycle@orange.fr

Antony Froggatt
53a Nevill Road
London N16 8SW
United Kingdom
Ph: +44-79 68 80 52 99
E: a.froggatt@btinternet.com

Table of Contents

Foreword **4**
Executive Summary and Conclusions **6**
Introduction **12**
General Overview Worldwide **13**
Potential Newcomer Countries **25**
Construction Times **32**
Construction Times of Past and Currently *Operating* Reactors 32
Construction Times and Costs of Reactors Currently *Under Construction* 34
The Economics of Nuclear Power—Rapidly Changing **34**
Nuclear Power Plant Lifetimes 34
Reactor Vendor Strategies 40
Chinese Vendors and Markets 46
Competitiveness of Vendors 47
The Hinkley Point C Deal 48
Financial Markets, Nuclear Power and Changing Power Markets **54**
Fukushima – A Status Report **59**
Off-site Challenges: Evacuation, Decontamination 59
Lawsuits 64
Cause of the Accident: Wave or Shake?—Questions and Findings 65
TEPCO's Roadmap Towards Restoration and Decommissioning 67
On-site Challenges: Water, Waste, Radiation 68
Summary and Prospects 72
Nuclear Power vs. Renewable Energy **73**
Investment 73
Installed Capacity 76
Electricity Generation 76
Paying to Produce 81

Annexes **93**
Annex 1. Overview by Region and Country **94**
Africa 94
The Americas 95
United States Focus 98
Asia 105
China Focus 105
Japan Focus 111
European Union (EU28) and Switzerland 119
France Focus 124
Former Soviet Union 136
Annex 2: Japanese Nuclear Reactor Status 1 July 2014 ..... **140**
Annex 3: Status of Lifetime Extension in the U.S. **142**
Annex 4: Definition of Credit Rating by the Main Agencies **145**
Annex 5: About the Authors **146**
Annex 6: Abbreviations **148**
Annex 7: Status of Nuclear Power in the World (1 July 2014) **155**
Annex 8. Nuclear Reactors in the World Listed as "Under Construction" (1 July 2014) **156**

Foreword

By **Tatsujiro Suzuki***

"What will be the impact of the Fukushima nuclear accident on the global nuclear industry?" This is the question that I have been asked many times since March 11, 2011. The answer is, of course, "no one really knows." But, it is an unavoidable question that needs to be explored, even though we cannot predict the future. More than three years later, we hear both positive and negative views on the future of nuclear industry. But, I believe those voices are mostly based on their "wishful thinking" and not necessarily the result of detailed analysis of the current situation. Without deeper understanding of what happened in the past and of what is happening now, a wise decision for the future action cannot be made.

The World Nuclear Industry Status Report (WNISR) 2014 is a perfect reference for that purpose. There are other authoritative references on the global nuclear energy situation, such as the ones by the International Atomic Energy Agency (IAEA) and the World Nuclear Association (WNA) etc., or some dark projections are made by citizen organizations against nuclear energy. All reports are useful, of course, but it is critically important to understand the past and current situations *without bias* for a healthy public policy debate. Unfortunately, not only policy makers but also the general public are confused by arguments and ideologies imposed by both pro-and anti-nuclear organizations. This is not healthy. Now we have *The World Nuclear Industry Status Report 2014*, which is, I believe, at least one of such "reliable, unbiased, and trusted" information sources.

One important innovation that *The World Nuclear Industry Status Report* made this year is to establish a new category, called "Long Term Outage (LTO)." Its definition is very clear and empirical: "A nuclear power reactor is considered in LTO if it has not generated any power in the entire previous calendar year and in the first semester of the current calendar year." I believe this simple new category can bring new insights into the nuclear energy policy debate as it can reflect the actual situation more accurately than previously discussed. Thanks to the new category of LTO, now we realize that the impact of the Fukushima Daiichi nuclear accident has been already significant. This is also important as it excludes any "biased" observation on the status of the global nuclear industry. I congratulate the authors of *The World Nuclear Industry Status Report 2014* for creating such a simple, but very significant, innovative category of reactor status.

Another important contribution that *The World Nuclear Industry Status Report 2014* makes is to illustrate the clear trend of the declining share of nuclear energy in the world's power production. It says: "*The nuclear share in the world's power generation declined steadily from a historic peak of 17.6 percent in 1996 to 10.8 percent in 2013.*" In fact, the WNISR in previous years already highlighted this trend, and I learned a lot from the impressive, detailed assessment of "new construction vs shutdown" statistics. Although experts familiar with the nuclear industry are aware that such trends could be confirmed—as the average age of existing nuclear plants get older in the last decade—the expectation of and media reporting about a "Nuclear Renaissance" obscured such concerns. In fact, this may be the biggest difference between the impacts of the Fukushima accident and the impacts of previous most serious nuclear accidents, i.e. Three Mile Island (TMI) and Chernobyl. In case of the latter two accidents, which happened in 1979 and 1986 respectively, the average age of nuclear reactors in the world was relatively low, and thus nuclear power generation continued to increase due to improved capacity factors even without many new construction projects. But, now as the average age of nuclear reactors are getting higher (now 28.5 years), more than 200 reactors may face shutdown in the coming two decades. Thus, if new construction pace does not match the pace of shutdown, it is clear that the nuclear share will decline rapidly. Even some IAEA and OECD/IEA projections suggest similar trends (a declining nuclear share), but *The World Nuclear Industry Status Report 2014* demonstrates this tendency most clearly and all energy/environmental experts should be aware of this fact, regardless of their position on nuclear energy.

Finally, let me conclude this Foreword by sending out my personal message. Even over three years after the accident, people who were forced to evacuate from their homeland have not recovered their life back. Their anger, frustration, anxiety and fear of radiation risk have not disappeared. I myself, as a nuclear energy expert and as one of the government officials then, would like to express sincere apologies and sympathy with those people. By talking with evacuated citizens face-to-face, I learned that logical explanation of radiological risk is not enough. The most important factor in human relationship is "trust", which is lost completely after the Fukushima nuclear accident. In order to recover trust, policy must be designed not only based on "logic" but also on "humanity", i.e. sharing

the feeling with the victims of the accident and other citizens who are concerned about future accident risks of nuclear power plants. Without the attitude of sharing the hard feelings of the victims of the accident, it is difficult to recover public trust. The future fate of the nuclear industry can depend on how much we will learn from this accident and how much we recover public trust. In this sense, it is important to share accurate information with complete transparency.

I sincerely believe that *The World Nuclear Industry Status Report 2014* can be a good reference for anyone who is interested in nuclear energy and understand the reality of the global nuclear industry more accurately without bias. The report will definitely contribute to improve transparency of the policy debate over nuclear energy.

---

*Tatsujiro Suzuki is Vice Director and a Professor of the Research Center for Nuclear Weapons Abolition (RECNA), Nagasaki University, Japan. Until the end of March 2014, he was Vice Chairman of the Japan Atomic Energy Commission (JAEC).

Executive Summary and Conclusions

The *World Nuclear Industry Status Report 2014* provides a comprehensive overview of nuclear power plant data, including information on operation, production and construction. The WNISR assesses the status of new-build programs in current nuclear countries as well as in potential newcomer countries. A 20-page chapter on nuclear economics looks at the rapidly changing market conditions for nuclear power plants, whether operating, under construction, or in the planning stage. Reactor vendor strategies and the "Hinkley Point C Deal" are analyzed in particular. The performance on financial markets of major utilities is documented.

The WNISR2013 featured for the first time a Fukushima Status Report that triggered widespread media and analyst attention. The 2014 edition entirely updates that Fukushima chapter.

The Nuclear Power vs. Renewable Energy chapter that provides comparative data on investment, capacity, and generation has been greatly extended by a section on system issues. How does nuclear power perform in systems with high renewable energy share? Is this the end of traditional base-load/peak-load concepts?

Finally, the 45-page Annex 1 provides a country-by-country overview of all 31 countries operating nuclear power plants, with extended Focus sections on China, Japan, and the United States.

Operation and Construction Data (1 July 2014)[1]

Operation. There are 31 countries operating nuclear power plants in the world.[2] A total of 388 reactors have a combined installed capacity of 333 GW[3]. Only two Japanese units (Ohi-3 and -4) have generated power in 2013 and WNISR classifies 43 reactors[4] as being in Long-Term Outage (LTO).[5] Besides the Japanese reactors, one Indian and one South Korean reactor meet the LTO criteria. Ten reactors at Fukushima Daiichi and Daini are considered closed permanently, and are therefore not included in the count of operating nuclear power plants. As of the middle of July 2014, it appears likely that at the most two reactors (Sendai-1 and -2 in Kyushu Prefecture) will restart before the end of the year.

The nuclear industry is in decline: The 388 operating reactors are 50 fewer than the peak in 2002, while the total installed capacity peaked in 2010 at 367 GW before declining to the current level, which is comparable to levels last seen two decades ago. Annual nuclear electricity generation reached a maximum of 2,660 TWh in 2006 and dropped to 2,359 TWh in 2013, which represents however a stabilization (+0.6 percent) after two consecutive years of significant decline (-4 percent in 2011, -7 percent in 2012), corresponding to a level previously seen in 1999.

The nuclear share of the world's power generation declined steadily from a historic peak of 17.6 percent in 1996[6] to 10.8 percent in 2013[7]. Nuclear power's share of global commercial primary energy production declined from the 2012 low of 4.5 percent, a level last seen in 1984[8], to a new low of 4.4 percent.[9]

---

[1] See Annex 7 for a country-by-country overview of reactors in operation and under construction as well as the nuclear share in electricity generation and primary energy.

[2] Unless otherwise noted, the figures indicated are as of 1 July 2014.

[3] All figures are given for nominal net electricity generating capacity. GW stands for gigawatt or thousand megawatt.

[4] Including the Monju reactor, shut down since 1995, listed under "Long Term Shutdown" in the IAEA-PRIS database.

[5] WNISR considers that a unit enters the LTO period—once it is meeting the criteria of zero power production in the previous calendar year and in the first half of the current calendar year—from the day it is disconnected from the grid. WNISR counts the startup of a reactor from the day of grid connection and the shutdown from grid disconnection. This is the first year that WNISR has adopted the LTO category trying to provide an alternative for an increasingly misleading representation of the industrial reality in world nuclear statistics provided by other sources. Besides the Japanese reactors, one Indian and one South Korean reactor meet the LTO criteria.

[6] Readjustment from the figure of 17 percent in 1993 in previous editions of the WNISR. See Figure 1 and related footnote.

[7] WNISR2013 indicated a 10.4 percent share for year 2012. However, the adjusted figure for that year is 10.9 percent. In other words, the nuclear share remained stable (-0.1 percentage points).

[8] According to BP, "Statistical Review of World Energy", June 2014.

[9] Ibidem.

As in 2012, the "big five" nuclear generating countries—by rank, the United States, France, Russia, South Korea and China—generated 68 percent of the world's nuclear electricity in 2013. And, as in 2012, only one country, the Czech Republic, reached its record nuclear contribution to the national electricity mix in 2013.

Age. In the absence of major new-build programs apart from China, the unit-weighted average age of the world operating nuclear reactor fleet continues to increase and by mid-2014 stood at 28.5 years. Over 170 units (44 percent of the total) have operated for 30 years or more; of those units, including 39 that have run for over 40 years.

Construction. As one year earlier, fourteen countries are currently building nuclear power plants. With Belarus, a new country was added to the countries engaged in nuclear projects, while Taiwan has halted construction work at two units. As of July 2014, 67 reactors were under construction (one more than in July 2013) with a total capacity of 64 GW. The average building time of the units under construction stands at 7 years. However:

- Eight reactors have been listed as "under construction" for more than 20 years, another for 12 years.
- At least 49 have encountered construction delays, most of them significant (several months to several years). For the first time, major delays—several months to over two years—have been admitted on three quarters (21/28) of the construction projects in China.
- For the remaining 18 reactor units, either construction began within the past five years or the reactors have not yet reached projected start-up dates, making it difficult or impossible to assess whether they are on schedule or not.
- Two-thirds (43) of the units under construction are located in three countries: China, India and Russia.

The average construction time of the last 37 units that started up in nine countries since 2004 was 10 years with a large range from 3.8 to 36.3 years.

Twenty-eight years after the Chernobyl disaster, none of the next generation or so-called Generation III or III+ has entered service with construction projects in Finland and France many years behind schedule.

Reactor Status and Nuclear Programs

- **Startups and Shutdowns.** In 2013, four reactors started up (3 in China, 1 in India), while one was shut down (in the U.S.).[10] In the first half of 2014, two started up (1 each in China and Argentina) and none were closed.
- **Newcomer Program Delays.** Delays have occurred in the development of the nuclear programs for most of the more advanced potential newcomer countries, including Bangladesh, Jordan, Lithuania, Poland, Saudi Arabia, Turkey, and Vietnam.

Construction & New Build Issues

- **Construction Starts.** In 2013, construction began on 10 reactors, including 4 units on two sites in the US, a first in 35 years. In the first half of 2014, a second unit got underway in Belarus and work started on a small 25-MW pilot plant in Argentina.
- **Construction Halt.** In Taiwan, construction on two units (Lungmen-1 and -2), which had been under construction for the past 15 years has been halted.
- **Certification Delays.** The certification of new reactor designs encounters continuous obstacles. In the U.S., the Nuclear Regulatory Commission (NRC) first delayed to 2015 the certification of the Franco-German-designed EP[11]and now no longer projects any completion date for the review. The NRC rejected the license application for the South Korean APR1400 due to lack of information in key areas. Only the Westinghouse AP1000 has received full generic design approval in the U.S. There is no projected completion date for the renewal of the certification for the two versions of the ABWR (GE-Hitachi and Toshiba).
- **Construction Start Delays.** Various countries' construction starts were delayed, including in Vietnam, previously considered to feature one of the most advanced potential newcomer projects.

[10] Shutdown is defined as definitively taken off the grid. The shutdown date is the last day when the reactor generated electricity.

[11] European Pressurized Water Reactor (in Europe) or Evolutionary Pressurized Water Reactor (in the U.S. and elsewhere).

• **Project Delays and Cancellations.** Over the past few years, numerous nuclear projects have been indefinitely delayed or cancelled. The most recent is the call for tender for two new units at the Czech Temelin site that was simply withdrawn in April 2014, officially due to low electricity prices and a lack of government guarantees.

Economics and Finances

• **Capital Cost Increases.** Construction costs are a key determinant of the final nuclear electricity generating costs and many projects are significantly over budget. Investment cost estimates have increased in the past decade or so from US$1,000 to around US$8,000 per installed kilowatt. The latter, record figure is for the two EPRs at Hinkley Point in the U.K. Construction cost estimates increased in virtually all countries, including China, Finland, France, and the United Arab Emirates. In the U.S., the builder of two units at the VC Summer site in South Carolina has asked for the seventh price increase since 2009 to meet rising costs. The analogous Vogtle project in Georgia has reported modest cost increases but the project's independent construction monitor has expressed concern these may be understated.

• **State Aid.** The U.K. model of Contract for Difference (CFD), a kind of feed-in tariff agreement for nuclear electricity that is aimed at providing a subsidy scheme for new-build, is likely to violate current EU competition rules. In February 2014, the EU Commission opened a formal enquiry considering "at this stage that the notified measures involves State Aid", the result of which, as of July 2014, had not been announced but it is likely that significant modifications will need to be made to the financial model of the project for it to proceed.

• **Operating Cost Increases.** In some countries (including France, Germany, the U.S. and Sweden), historically low inflation-adjusted operating costs—especially for major repairs—have escalated so rapidly that the average reactor's operating cost is barely below, or even exceeds, the normal band of wholesale power prices. The largest nuclear operator in the world, the French state-controlled utility EDF experienced an income deficit of about €1.5 billion (US$2 billion) in 2012, because tariffs did not cover the running costs. According to the French Court of Accounts, the cost of generating nuclear power increased by 21 percent between 2010 and 2013, from 49.6 €/MWh to 59.8 €/MWh (US$67.8–81.7/MWh) , an increase of 16 percent in real terms). In Germany, operator E.ON decided to close one of its reactors seven months earlier than required by law because of projected income does not cover the costs. In Sweden, income from electricity sales for at least three reactors was below production costs in two of the past four years. In the U.S., utilities decided to retire at least five reactors that no longer cover operating costs, including two with operating licenses valid beyond 2030. One study identifies up to 38 U.S. units threatened by the same fate. In Belgium, operator Electrabel (GDF-Suez) lost its legal case against a nuclear fuel tax and wonders whether future operation of its seven plants is still worthwhile.

• **Life Extension.** The extension of operating periods beyond original design basis is handled differently from country to country. While in the U.S. about three quarters of the reactors have already received licenses extensions for up to a total lifetime of 60 years, in France, only 10-year extensions are granted and the safety authorities made it clear that there is no guarantee that all units will pass the 40-year in-depth examinations. According to one assessment, the costs for upgrading the plants for operating beyond 40 years could vary between €1 billion and €4 billion (US$1.4–5.5 billion) *per reactor*. Furthermore, the proposals for lifetime extensions appear in conflict with the French government's target to reduce the nuclear share from the current three quarters to half by 2025.

• **Post-Fukushima Costs.** Additional costs arising from upgrading and backfitting measures following the lessons of the Fukushima crisis remain uncertain and vary widely according to the requirements of the safety authorities in various countries. At least in some countries, including Japan and France, they will significantly affect the economic competitiveness of nuclear power.

• **Income and Debt.** In 2013, for the first time in its 60-year history, German utility RWE filed a loss of €2.8 billion (US$3.8 billion) after writing down the value of its conventional power plants by close to €5 billion (US$6.8 billion). Debt level remains very high amongst the European nuclear utilities. The two largest French groups (EDF and GDF-Suez) and the two largest German utilities (E.ON and RWE) share about equally a total of more than €127 billion (US$173 billion) in debt.

• **Credit Rating.** Over the past year, few changes were observed in the credit ratings of 11 assessed nuclear utilities: GDF-Suez was downgraded by credit-rating agency Standard

and Poor's from A to BBB+, while for Finish utility and EPR builder TVO, the outlook changed to negative. Moody's perceived Czech utility CEZ's decision to abandon a new-build project as "credit positive" and considers nuclear construction projects generally as "credit negative".

- **Share Value.** Since 2008, Europe's top ten utilities lost half of their €1 trillion (US$1.4 trillion) share value. A regional comparison shows Asian utilities have recovered little with their average share value still almost half of the 2008 value, European utilities still 30 percent down, while U.S. utilities are almost 30 percent *above* the level of five years ago even though total U.S. electricity use has been drifting down since 2007.

Fukushima Status Report

This assessment includes analyses of on-site and off-site challenges that have arisen from the 3/11 disaster and remain significant three years after the beginning of the disaster.

• On-site Challenges. In a highly positive development, since November 2013 and as of the middle of July 2014, over three quarters of the spent fuel had been transferred from the pool in the badly damaged unit 4 to a common pool. The operation is to be completed by the end of 2014. This significantly reduces the radioactive inventory exposed to possible further degradation (draining of the pool, spent fuel fire), especially in the event of additional severe earthquakes or weather events.

The main parameters, however, remain largely unchanged from the previous year. Radiation readings inside the reactor buildings of units 1–3 continue to make direct human intervention almost impossible. Massive amounts of water, about 360 tons per day, are still pumped into the destroyed reactors to cool the molten fuel. This water, as well as a similar quantity of groundwater, seeps into the basements of the reactor buildings, some of it is decontaminated to some degree and then re-injected. The amount of radioactive water that cannot be re-used is constantly increasing and, as of 15 July 2014, exceeds 500,000 tons in precarious storage including about 90,000 tons sitting in the power plant basements. Tank storage capacity is to be increased to 800,000 tons by the end of March 2015. Numerous leaks have been reported, including the discovery in August 2013 of a 300-ton leak from a tank of highly radioactive water[12], rated Level 3 on the International Nuclear Event Scale (INES), and a 100-ton leak from another tank with even higher activity levels.[13] It turned out that hundreds of 1,000-m^3 storage tanks had not even been equipped with volume gauges. Several hundred tanks that were simply bolted together will be replaced by welded containers. Sophisticated water decontamination systems remain plagued with technical failures and have yet to operate continuously for any significant length of time. A much advertised US$0.5 billion underground ice-wall, designed to avoid water influx into the reactor basements and to be completed by March 2015, has an uncertain future. A short test section failed to freeze as anticipated. In the meantime, TEPCO has reached an agreement with local fishermens' unions, allowing for a groundwater bypass to be activated in April 2014, to allow discharge into the sea. It is expected that the measure could reduce the water intrusion into the basements by a one quarter or some 100 m^3 per day.

Around 32,000 workers, 28,000 of whom are subcontractors, have worked at the Fukushima site since 3/11 (not including firemen, policemen, military). By May 2014, the daily average of on-site workers was 4,200, up 40 percent from a year earlier. Recruitment is becoming increasingly difficult.

In December 2013, TEPCO formally announced the shutdown of Fukushima Daiichi (I) Units 5 and 6. The four reactors at Fukushima Daini (II), 15 km from the Daiichi site inside the exclusion zone remain officially "operational", but operating them appears entirely unrealistic.

• Off-site Challenges. Officially, as of March 2014, more than 130,000 people in Fukushima Prefecture are still evacuated. About 100,000 people are from designated evacuation zones. Many more people have voluntarily left. Another 137,000 people is still living in temporary housing spread out over seven or more prefectures. About 1,700 deaths have been officially recognized as linked to mental causes or lack of medical care triggered by the nuclear disaster and ensuing evacuation. Suicide rates are on the rise.

In April 2014, a few hundred residents were allowed for the first time to return to a previously evacuated region. However, it is estimated that only about one-fourth of the residents returned. Others commute from evacuation residences outside the area. A government-commissioned study, hidden from the public for six months, concluded that radiation exposure, while remaining below the

[12] 80 million Bq per liter of Beta radiation emitting radionuclides (strontium, tritium…) and 100,000 Bq/l of Cesium-137.

[13] 230 million Bq/l of Beta emitters and 9,300 Bq/l of Cesium-137.

post-emergency level of 20 mSv per year, could exceed the pre-disaster limit of 1 mSv per year in the areas cleared for resident to return.

A total of 101 municipalities in eight prefectures were designated as a "Scheduled Contamination Survey Zone", where annual doses between 1 mSv and 20 mSv are predicted and local authorities are responsible for decontamination work. In addition, the central government is in charge of decontamination efforts in 11 municipalities in Fukushima Prefecture covering 235 km^2, where annual doses exceed 20 mSv. Decontamination efforts are far behind schedule, mainly because of technical difficulties, lack of waste storage facilities and shortage of manpower. Disputes over cost coverage between the Ministry of Environment, which is officially responsible, and TEPCO, the Fukushima operator, lead to additional delays. The three-year decontamination budget for 2011-2013 totaled ¥1.3 trillion (US$13 billion), but just a third has been spent and of that TEPCO reimbursed less than 20 percent. A complex variety of companies and subcontractors is at work, often under obscure circumstances. Press agency *Reuters* has identified 733 companies working under Ministry of Environment contract with 56 subcontractors, some of which are reported to specifically recruit homeless people for work in contaminated areas. The Yakuza, the Japanese mafia, also has reportedly entered the system.

As of 11 July 2014, more than 2.2 million compensation claims had been filed by individuals, corporations, trade unions, and local governments, of which TEPCO has paid ¥4 trillion (US$40 billion) in total settling around 2 million claims. Numerous law suits against TEPCO are underway, including one filed by a group of U.S. sailors, exposed to radiation in emergency U.S. Navy operations right after 3/11. In March 2014, over 4,000 citizens from 39 countries filed a collective (class action) lawsuit against nuclear manufacturers, including Hitachi, Toshiba and General Electric to pay compensation to the victims of the Fukushima nuclear disaster.

Nuclear Power vs. Renewable Energy Deployment

The year 2013 brought a number of new developments that widened the gap between nuclear power and renewable energy costs and market trends.

- **Investment.** Global investment in renewable energy totaled US$214 billion in 2013, decreasing for the second year in a row, down from a record US$300 billion in 2011, but still four times the 2004 amount. The decrease, however, was four-fifth due to lower costs and only one-fifth due to lower sales As in 2012, with US$54.2 billion spent, China has been the largest investor. Some of the past large investors showed sharp declines in expenditures over the previous year, like Italy (-76 percent), Germany (-57 percent) and the U.S. (-23 percent). On the other side, some countries increased investments significantly with Japan (+75 percent) advancing to the third position, the U.K. (+46 percent) taking rank four, and newcomer Australia entering the Top Ten for the first time. Also, decreasing amounts pay for more installed capacity as system costs continue to decrease. Regional analysis reveals that over the past decade Europe spent 40 percent of the US$1.6 trillion total investment, while China alone holds a 20 percent share. According to a new assessment by the OECD's International Energy Agency, during 2000-13 global investment in power plants was split between renewables (57 percent), fossil fuels (40 percent) and nuclear power (3 percent).
- **Installed Capacity.** Globally, since 2000, the annual growth rates for wind power have averaged 25 percent and for solar photovoltaics 43 percent. This has resulted in 2013 alone in 32 GW of wind and 37 GW of solar being added. Nuclear generating capacity declined by 19 GW compared to the 2000 level.[14] In the European Union, in the same time frame, wind increased by 105 GW outpacing natural gas plants with 103 GW and solar with 80 GW, while nuclear decreased by 13 GW. In 2013, wind and solar added 11 GW each to the European grids, while all fossil fuels decreased and nuclear remained stable. By the end of 2013, China had a total of 91 GW of operating wind power capacity. China's 18 GW of installed solar capacity for the first time exceeded operating nuclear capacity. China added a new world record of at least 12 GW of solar in just one year (vs. 3 GW of nuclear), overtaking Germany's previous 7.6 GW record and exceeding cumulative U.S. additions since it invented photovoltaics in the 1950s. China now aims at 40 GW solar and will probably exceed the 100 GW wind power target for 2015.
- **Electricity Generation.** In 2013, Spain generated more power from wind than from any other source, outpacing nuclear for the first time. It is also the first time that wind has become the largest electricity generating source over an entire year in any country. Spain has thus joined the list of nuclear countries that produce more electricity from new renewables—excluding large hydro-power—than from nuclear power that includes Brazil, China, Germany, India and Japan.

[14] Even considering the LTO reactors as "operational", nuclear would only have increased capacity by 17.5 GW.

In Italy, solar photovoltaics provided 8 percent of the national electricity production—ten times its contribution in 2010 and two and half times higher than the maximum annual contribution ever made by nuclear power, before the country abandoned its use.

Compared to 1997, when the Kyoto Protocol on climate change was signed, in 2013, there has been an additional of 616 TWh per year of wind power produced in 2013, 124 TWh of solar photovoltaics outpacing nuclear with just 114 TWh. In 2013, growth rates for generation from wind power above 20 percent were seen in North America, Europe and Eurasia and Asia Pacific, with the two largest markets, the U.S. (19 percent) and China (38 percent). In the world of photovoltaics, North America saw a more than doubling of power generation, Asia Pacific a 75 percent increase.

- **Increasing System Incompatibilities.** The traditional concept of baseload electricity generation might become obsolete with increasing renewable energy penetration in national grid systems. Several countries now experience periods of very low or even negative electricity prices on the spot market. Electricity generators literally pay to produce because shutdown and restart would cost them even more. As illustrated with empirical examples from Germany, nuclear plants turn out the least flexible to react to unfavorable economic conditions and keep operating for hundreds of hours at spot prices below their average marginal operating costs.
- **Increased Renewables Generation Entailing Lower Power Prices**

  In 2013, the German system generated 152 TWh from renewables, 56 percent more than from nuclear plants. In just the two past years, the number of hours with negative prices more than quadrupled, from 15 to 64. The hours with prices below €15/MWh (US$20.5/MWh) increased from 161 to 727 (8 percent of the time). From 2011 to the first quarter of 2014, average baseload prices decreased by an astonishing 40 percent. Consequently, in 2013, Germany exported a record 34 TWh *net* to neighboring countries, while nuclear France—otherwise also a net power exporter—remains a net power *importer* from Germany. This is quite the opposite of what had been forecasted following the German nuclear phase-out decision, but accurately reflects Germany's more competitive wholesale power prices.