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Impacts of the Fukushima Daiichi Accident on Nuclear Development Policies

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Impacts of the Fukushima Daiichi Accident on Nuclear Development Policies

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Cover photos: Tsunami at Fukushima Daini (TEPCO); Industrial wind installation (Carlos Castilla, Shutterstock); Placement of first AP1000 steam generator at Virgil C. Summer unit 2, United States (SCE&G).

Foreword

In October 2012, the NEA Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle (NDC) endorsed a proposal to include the "Impacts of Fukushima on Nuclear Development Policies" project in the 2013-2014 Programme of Work for the NEA Division of Nuclear Development (DEV) in an effort to review changes in nuclear energy policies following the accident at the Fukushima Daiichi nuclear power plant (NPP). Such an assessment would provide insight not only into the current trajectory of nuclear power development but also into the likelihood of meeting rising energy demand to 2025 and beyond, while achieving greenhouse gas reduction goals and the important policy goal of decarbonising electricity generation.

Keeping abreast of policy changes is important for NEA member countries, in particular those with nuclear power programmes, reactor vendors and associated businesses. Since most must also make decisions on commitments to meet greenhouse gas emission reduction targets, on the need to replace ageing electricity generating facilities and on energy security of supply concerns, it is important for them to be up-to-date on developments in nuclear power in other countries so as to inform their own decision making.

It became clear as time progressed after the March 2011 accident that a few key countries would not be able to finalise policy responses to the accident for some time, and thus the NDC agreed to extend the study to cover approximately a six-year period following the accident. Today, policies in the majority of countries with nuclear power remain unchanged. In some countries, the changes in nuclear energy policies are evident, whereas in others they are much less so. Clearly, policy changes driven by the Fukushima Daiichi accident have slowed the development of nuclear energy, but countries' policy re-evaluations of nuclear power linked to the accident generally appear to have subsided.

Other factors, in particular abundant, low-cost natural gas (mainly in the United States), ambitious targets for developing variable renewable energy generation, the risk averse investment climate persisting since the global financial crisis in 2008, the low demand for and price of electricity in many developed countries and the challenges of investing in thermal electricity generating facilities of any kind in liberalised markets (particularly in Europe and in some areas of the United States), appear to be the main factors affecting investment decisions for nuclear power projects in many parts of the world today. This uncertainty and inherent risk context offers a more likely explanation to why projections for nuclear development have tended to decrease, for instance, the 2035 projections of the NEA/International Atomic Energy Agency (IAEA) *Uranium: Resources, Production and Demand* (the "Red Book") or the two-degree scenario (2DS) projections of the International Energy Agency (IEA) *Energy Technology Perspectives*.

Acknowledgements

This report was produced under the auspices of the NEA Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle (NDC). It was drafted by Mr Robert Vance and Mr David Henderson, former and current staff of the NEA Division of Nuclear Development, from a review of news articles, press releases and from member country contributions to two series of publications: *Uranium: Resources, Production and Demand* and *Nuclear Energy Data*, the former of which also includes data contributed by IAEA member states. Information on installed capacity was taken primarily from the IAEA Power Reactor Information System (PRIS). The contribution of Mr Laurie Moore, who provided editorial assistance throughout the preparation of the report, is also gratefully acknowledged.

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List of abbreviations and acronyms

BOO	Build, own and operate
CNNC	China National Nuclear Corporation
CNSC	Canadian Nuclear Safety Commission
EDF	Électricité de France
ENSI	Federal Nuclear Safety Inspectorate (Switzerland)
ENSREG	European Nuclear Safety Regulators Group
EU	European Union
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
KHNP	Korea Hydro & Nuclear Power
NEA	Nuclear Energy Agency
NPA	Nuclear Power Act
NPP	Nuclear power plant
NRA	Nuclear Regulation Authority (United States)
NRC	Nuclear Regulatory Commission (United States)
PHWR	Pressurised heavy water reactors
PNRA	Pakistan Nuclear Regulatory Authority
PRIS	Power Reactor Information System (IAEA)
PWR	Pressurised water reactor
RBMK	Reaktor Bolshoy Moshchnosti Kanalnyi
SSM	Swedish Radiation Safety Authority
VVER	Water-water energetic reactor

Units

GWe	Gigawatt electric
MWe	Megawatt electric
TWh	Terawatt-hour

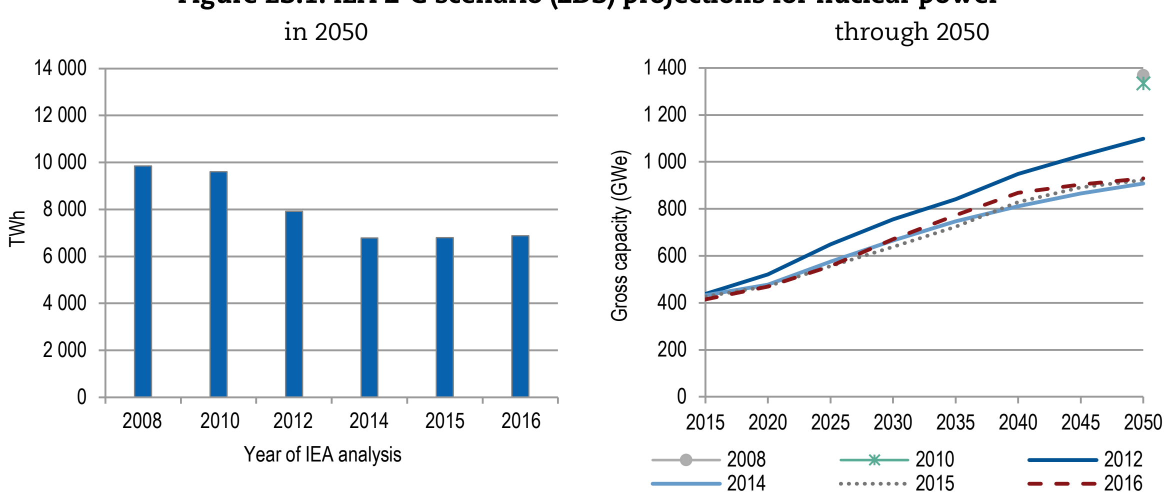
Executive summary

Six years have passed since the Fukushima Daiichi accident, and nuclear power development efforts have made significant progress globally, with 33 units starting construction (32 GWe) and 38 grid connections (34 GWe). However, some uncertainties remain in terms of policy responses to the event, most notably in the East Asia region. Overall, it is clear that projections have decreased from those of the 2007-2011 time frame, but a number of events taking place before and after the Fukushima Daiichi accident have made it quite difficult to attribute such an impact to a single cause.

More and more references were being made to a "nuclear renaissance" beginning around 2001, and a number of countries developed ambitious plans for new nuclear capacity. The high-case scenario in *Uranium 2009: Resources, Production and Demand* projected a 50% increase in worldwide capacity by 2025 (from 372 to 616 GWe) and a doubling by 2035 (to 781 GWe). The International Energy Agency's 2°C scenario (2DS) projections included a similar expansion as recently as 2012 (from 393 to 841 GWe by 2035). A global financial crisis between 2007 and 2009 affected specific countries differently but nonetheless drove a global recession that extended beyond 2011 and affected a number of investment decisions.

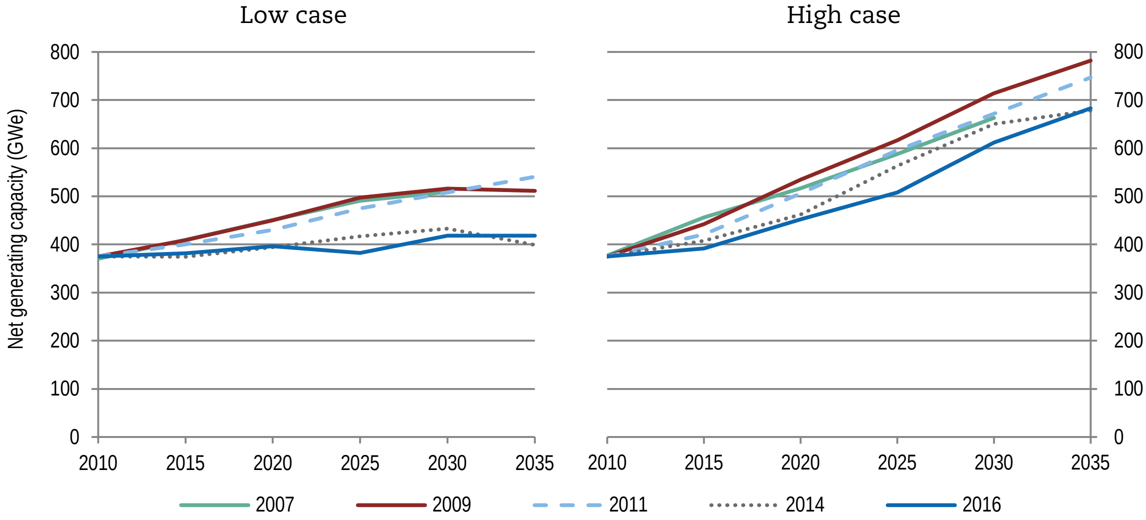
A number of governments, particularly in Western Europe, have made clear policy changes as a direct result of the accident. However, it is also clear from a country-by-country review that, despite changes in some countries, most countries with nuclear power or with plans to add nuclear power to their energy mix have maintained an interest in developing the technology. In several cases, visible delays in programme implementation have resulted from safety reviews and resultant required actions. Safety reviews, regulatory changes and nuclear power plant (NPP) modifications considered necessary to bolster defences against rare but severe natural events have also added costs both to existing NPPs and to those under development in these countries. The figures below show the global changes and are followed by brief summaries of the policy effects in various world regions.

Figure ES.1. IEA 2°C scenario (2DS) projections for nuclear power



Source: IEA data.

Figure ES.2. NEA/IAEA low and high case projections



Source: The 2007, 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Table ES.1. Difference between NEA/IAEA 2035 low and high case projections

(GWe)

	2007*	2009	2011	2014	2016
High	663.1	782.0	746.4	678.5	682.7
Low	509.1	511.0	540.3	399.1	418.1
Difference	154.0	270.9	206.1	279.3	264.6

* 2007 projections are for 2030, the latest year available in that report.

Source: The 2007, 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

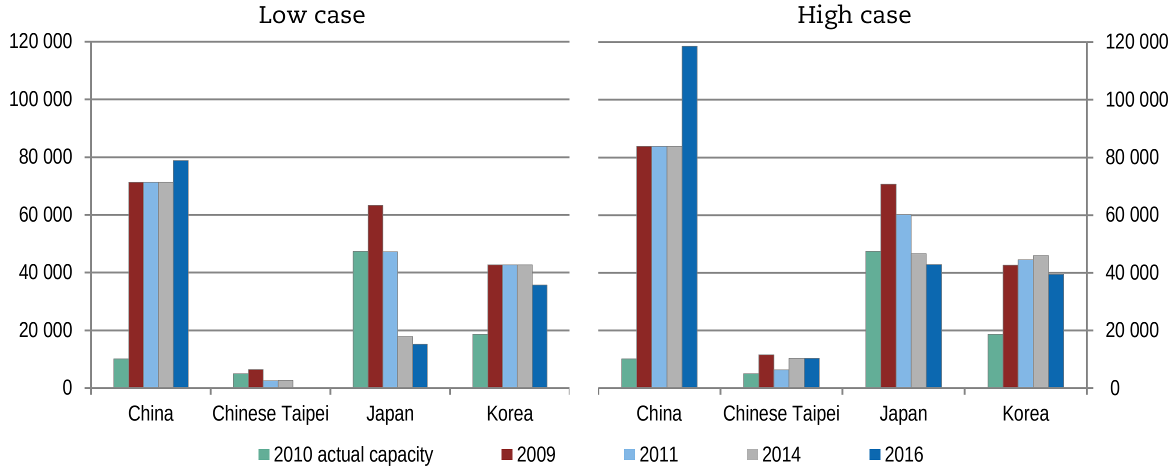
East and Southeast Asia

Policy responses to the Fukushima Daiichi accident in East and Southeast Asia were initially less clear than those in Western Europe and in some cases are still pending, but nonetheless have the potential to be more significant. This is to be expected as the countries in this region are geographically the closest neighbours to the scene of the Fukushima Daiichi accident. Since the accident, public distrust of nuclear power in this region has clearly increased.

In China and Korea, there appears to be limited impact on long-term plans, as the governments still have very ambitious deployment plans. In Chinese Taipei, strong public opposition to nuclear power has led to a planned phase-out of nuclear, including two new reactors almost ready for operation, pending a national referendum which has not yet taken place. Should the referendum result go against nuclear power, it is possible that as much as 11.5 GWe of nuclear generating capacity could be out of service by 2025, if the older operational reactors are limited to a maximum 40 years of lifetime service.

In Japan, the direct policy result of the accident has been a significant reduction in nuclear generating targets from those announced in 2010 that would have increased nuclear generation to 30-50% of national electricity generation. In its 2015 Intended Nationally Determined Contribution (INDC), the government announced a target of nuclear generation accounting for 20-22% of national generating capacity (roughly 35-40 GWe of installed nuclear generating capacity). This is down from 2010 operating levels, but not as much as had been rumoured. The policy change is evident in the changes to nuclear generating capacity projections from 2009 to 2016. Despite the passage of six years, there is still considerable uncertainty on the ultimate level of nuclear in overall generation. As of December 2016, only five reactors have been restarted in Japan.

Figure ES.3. Evolution of NEA/IAEA 2030 capacity projections – East Asia



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

In Southeast Asia, there were no operational power reactors as of mid-2016, but several countries are considering adding nuclear power generation to their energy mix, suggesting growth in nuclear generating capacity in the longer term as the region is experiencing strong economic growth and rising energy demand. Concerns about climate change, air pollution, security of energy supply and energy mix diversification, along with volatile fossil fuel prices, are the main drivers of nuclear development policies. However, political support was generally weak in the years immediately following the Fukushima Daiichi accident, owing to public safety and cost concerns. Even so, a number of countries continue to evaluate and plan for the deployment of nuclear power.

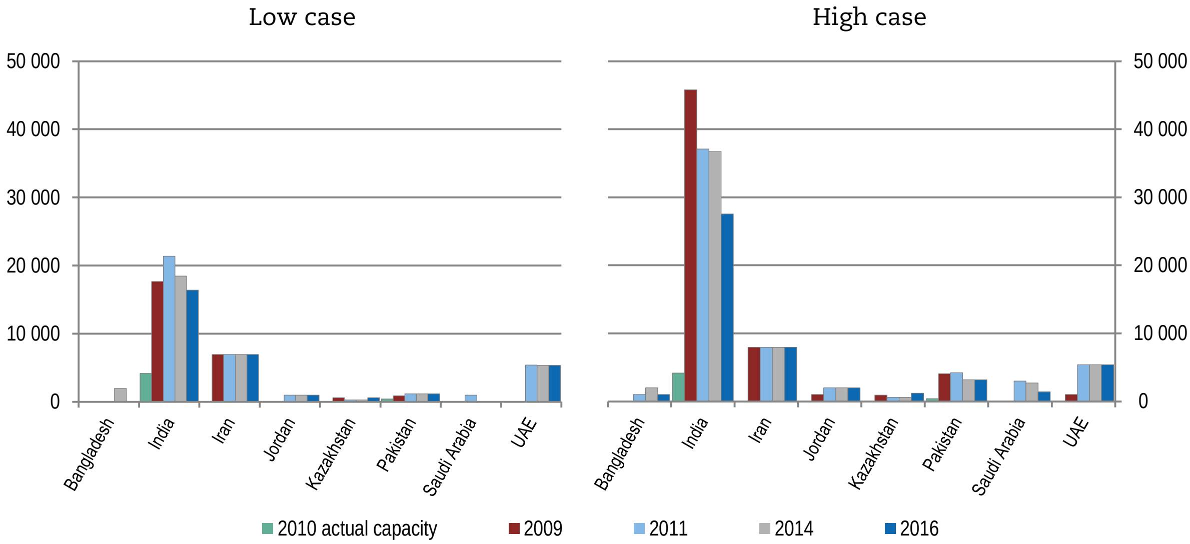
Middle East, Central and South Asia

Nuclear development policies and plans in these regions do not seem to have been negatively impacted by the Fukushima Daiichi accident whatsoever. In fact, plans have expanded in several countries, and lower projected deployment or delays in these countries are almost categorically unrelated to the effects from Fukushima Daiichi.

Next to China, India is projected to achieve the greatest growth in nuclear generating capacity in the coming years. Although public distrust in nuclear power had reportedly increased following the Fukushima Daiichi accident, and was responsible for a delay in the opening of the Kudankulam reactor, the majority of the delay is more likely related to other issues, in particular concerns about nuclear liability that is reportedly holding back expected investments in the construction of imported light water reactor technology (Chellaney, 2015).

Iran's projections have not changed over the past five years, and Kazakhstan's and Pakistan's projections decreased only slightly because of delays in the early steps of the decision and siting processes in these countries. Other countries in this region have increased deployment plans since 2009. Kuwait cancelled its near-term plans to build four reactors, but it appears that there may still be interest in eventual deployment. The United Arab Emirates is building four APR1400 units (5.6 GWe gross) that appear to be on schedule with the first unit starting operation in 2017.

Figure ES.4. Evolution of NEA/IAEA 2030 capacity projections – Middle East, Central and South Asia



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Europe

Countries that made the most immediate clear-cut decisions regarding their nuclear power programmes, as a direct result of the Fukushima Daiichi accident, are almost all in Western Europe. In Belgium, the government abandoned a ten-year extension for the operating lives of the three oldest reactors. In Germany, the government decided to immediately and permanently shut down eight older reactors (a total of 8.4 GWe) and to limit the lifetime of the remaining reactors such that by the end of 2022 all nine remaining operable reactors in the country would be shut down. In Italy, a potential return to the use of nuclear power to generate electricity was quashed by a referendum vote that overwhelmingly favoured eliminating the programme. In Switzerland, the Cabinet cancelled plans to build new units and ordered a plan to phase out existing nuclear power generation. However, such plans have not yet received approval, and it is unclear whether extended operation may still be an option.

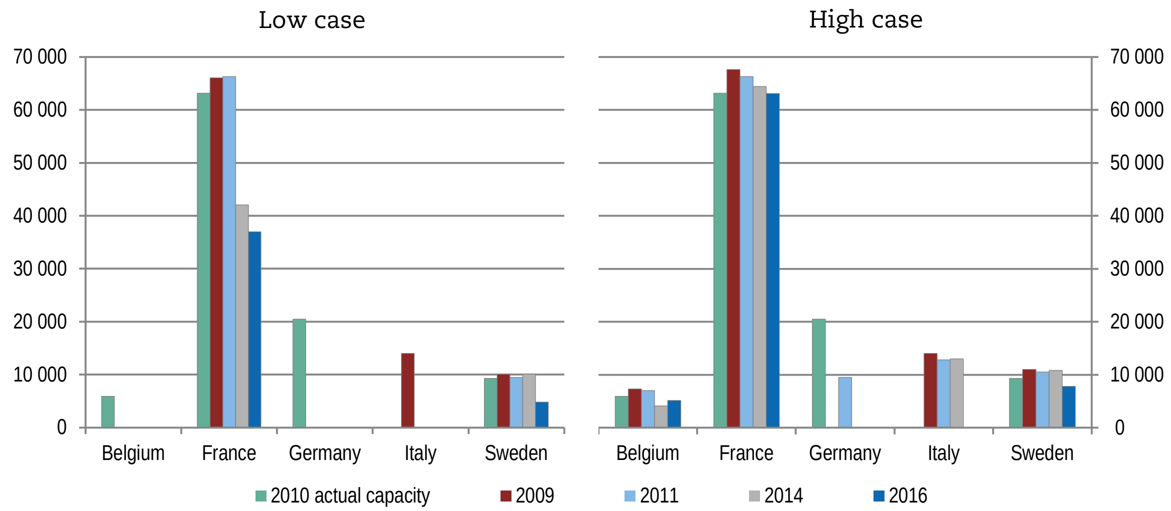
With the exception of Italy's potential return to nuclear power, the prior projections in most cases outlined only very modest growth, if at all, in any of these countries by 2035. No growth was projected by 2030 in Belgium and Germany because nuclear phase-out policies were already in existence prior to the Fukushima Daiichi accident; policy reaction following the accident in essence accelerated the timing of the phase-out.

In France and Sweden, actions by government some years after the Fukushima Daiichi accident could have a potentially larger impact on installed nuclear generating capacity by 2035 than the immediate policy actions that were taken. Although not necessarily a direct result of the Fukushima Daiichi accident, the timing of the policy debate in France and the new law capping nuclear generation at current levels was influenced by a growing concern about the safety of nuclear power in a country that produces 75% of its electricity from nuclear power. Sweden's nuclear policy has swayed over the past three decades between nuclear phase-out to allowing the construction of replacement reactors on existing sites. A recent agreement announced by the parliament could allow Sweden to avoid the near or total elimination of the nuclear fleet (9.7 GWe) by 2035 which, until recently, seemed probable.

Other (eastern) European countries seem to have adopted a completely different rationale. Overall, they have maintained support for existing nuclear power and continued plans to build additional capacity. In Russia, new capacity projections have decreased from 2009 owing to reduced needs and the financial requirements for such a steep build rate. The other countries in this region have either maintained or increased deployment plans.

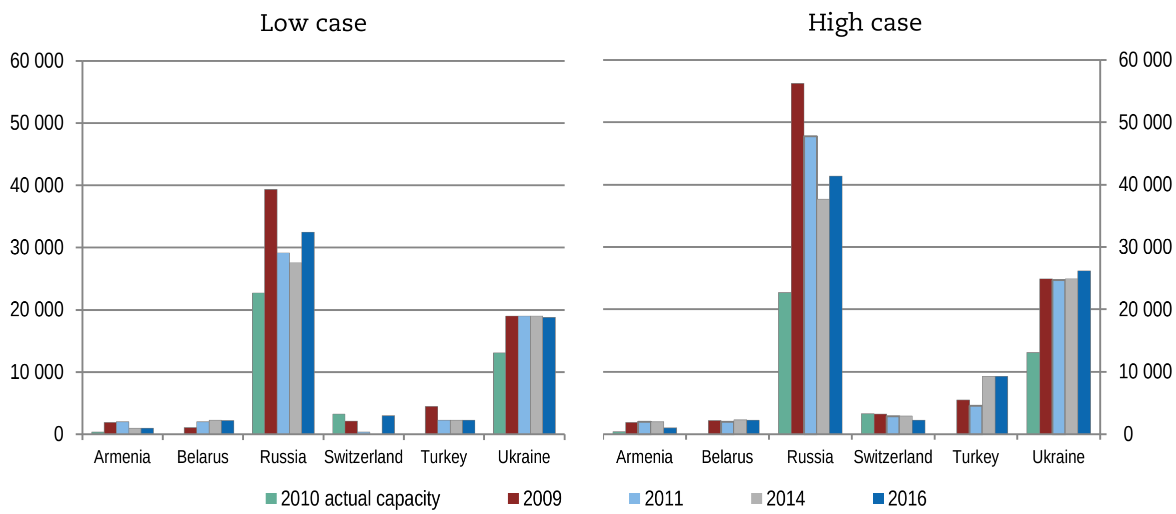
In summary, aside from accelerating the implementation of existing phase-out plans and abandoning the pursuit of a potential return to nuclear power in Italy, direct policy changes in Europe have not substantially changed the overall outlook for nuclear generating capacity.

Figure ES.5. Evolution of NEA/IAEA 2030 capacity projections – Europe (EU)



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Figure ES.6. Evolution of NEA/IAEA 2030 capacity projections – Europe (non-EU)

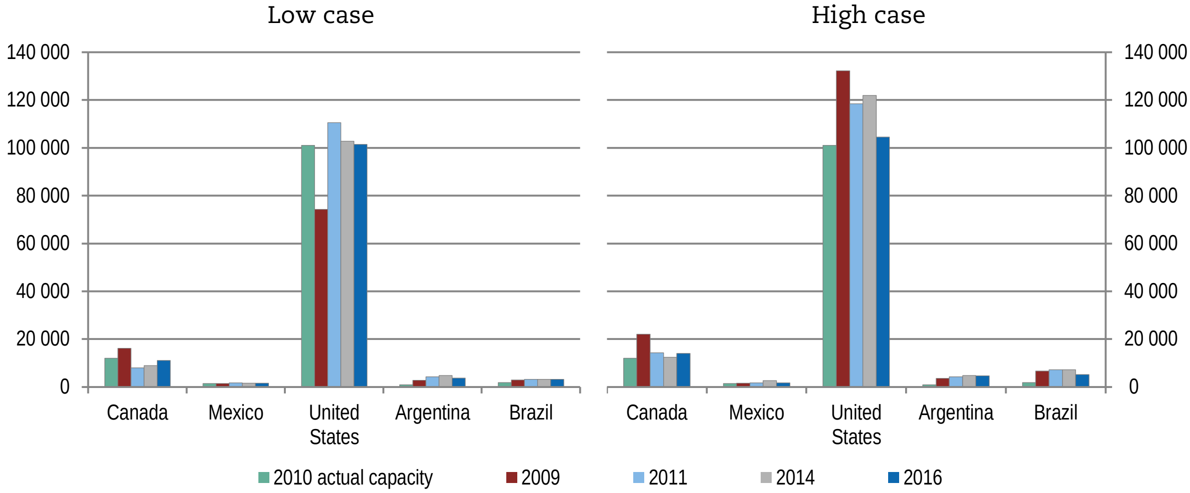


Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Americas

In North, Central and South America there have been no changes to policies or even projections attributable to Fukushima Daiichi. In North America, the reduced projections are a result of financial and economic issues – market pricing and natural gas specifically. In South America, commitment continues, and projections have increased since 2009. Of the countries currently without nuclear power, some have decided to delay decisions or reconsider their plans to pursue it, while others have continued to move forward with plans and to sign co-operation agreements.

Figure ES.7. Evolution of NEA/IAEA 2030 capacity projections – Americas

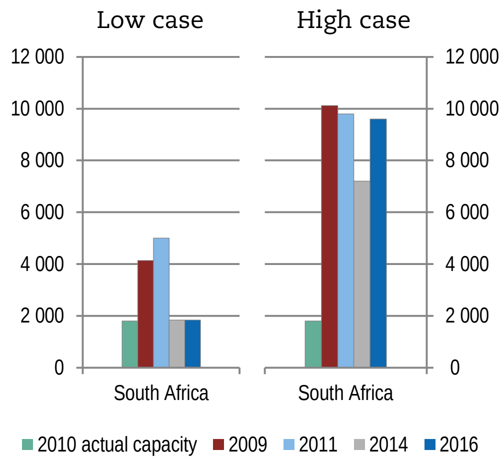


Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Africa

The outlook in Africa post-Fukushima seems only to be positive. As the only existing nuclear power producer, South Africa has continued its support and has approved plans to add capacity in the near term. A number of other nations, including Egypt, Ghana, Kenya and Nigeria, have taken steps towards deploying nuclear generation.

Figure ES.8. Evolution of NEA/IAEA 2030 capacity projections – Africa

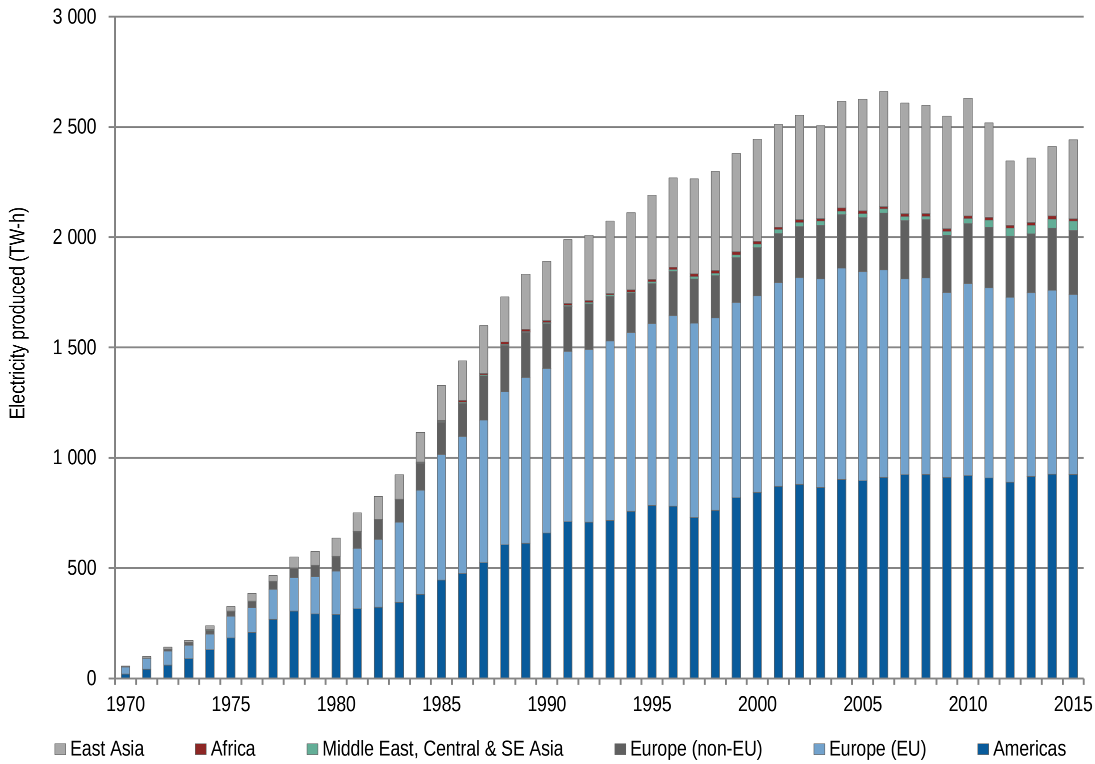


Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Conclusion

Overall, apart from Japan, Chinese Taipei and some countries in Western Europe, there seems to be little ultimate change, particularly quantitative, that is directly attributable to the Fukushima Daiichi accident. In general, countries with previous commitment to nuclear power remained committed, and those that had plans to phase out nuclear energy accelerated those plans. A few countries that seemed to be actively considering the adoption of nuclear power have delayed or deferred such decisions. In general, re-evaluations resulting from the Fukushima Daiichi accident seem to have largely been settled. Economic and market factors, environmental or climate change goals, and natural resource constraints would appear to be much larger drivers of deployment decisions and projections in the six years since March 2011.

Figure ES.9. Global nuclear electricity production



Source: IAEA Power Reactor Information System (PRIS).

Introduction

The Great East Japan Earthquake (the largest ever recorded in Japan at a magnitude of 9 on the Richter scale; and powerful enough to move Japan's main island Honshu 2.4 m eastward) and massive tsunami waves on 11 March 2011 caused widespread devastation and significant loss of life in north-central Japan. The natural disaster also triggered a serious accident at the Fukushima Daiichi nuclear power plant (NPP) that led to significant off-site radiation releases from fuel meltdowns in the three reactors in operation at the time in the six-unit facility. Although the three operating reactors shut down safely as designed, immediately following the earthquake, the backup generators supplying emergency power to the NPP failed less than one hour later when the ensuing large tsunami waves overwhelmed the facility's defences. With all power sources cut and cooling capabilities lost, the water level dropped, exposing the core, producing significant amounts of hydrogen from the exothermic reaction of the cladding with steam, and eventually causing the fuel to melt and drop to the bottom of the vessels. The hydrogen later collected in the containment buildings outside the reactor vessels and caused dramatic explosions in the tops of the buildings at three units.

Over 18 000 lives were lost, according to the Japan National Police Agency, as a direct result of the earthquake and tsunami. However, no loss of life occurred or is expected to occur as a result of the radiation releases from the nuclear accident, although there remains some scientific debate more generally about the health impacts of long-term exposure to low levels of radiation. The evacuation of over 150 000 inhabitants from the affected area disrupted the lives of evacuees and caused additional stress (Parungao, 2014; Flores, 2016).

Unlike the Chernobyl accident in 1986, early notification, evacuation, and sheltering of inhabitants is estimated to have broadly prevented much public radiation exposure (NEA, 2015). The United Nations Scientific Committee on the Effects of Atomic Radiation report on the radiological consequences of the accident (UNSCEAR, 2014) concluded that radioactive releases from the Fukushima Daiichi NPP were between 10% and 20% of the releases from the Chernobyl accident. No fatalities are considered to have occurred from exposure to radiation, although some injuries and fatalities occurred during the evacuation, and some injuries and fatalities occurred at the NPP as a result of accidents related to the earthquake and tsunami. Nonetheless, sizeable areas of the Fukushima prefecture have been contaminated by radioactive fallout from the accident. Although a few areas within the governmentally designated evacuation zones have been reopened for evacuees to return, many areas have not yet been reopened. The complex psychological and social nature of this long-term removal has caused considerable stress among evacuees.

Even without direct casualties from radiological consequences, the event initiated worldwide concern about the safety of nuclear power. The accident impacted public perception of nuclear power safety since the events, including the hydrogen explosions, were broadcast worldwide on television as they occurred over the course of several days.

The accident at the Fukushima Daiichi NPP has been a serious setback for the nuclear industry in Japan and around the world. Countries with operational NPPs immediately launched reviews of the safety of existing reactors (referred to as "stress tests" in the European Union). Within months of the accident, two countries (Belgium and Germany) strengthened their pre-existing phase-out plans, one (Switzerland) turned away from plans to build new reactors to replace existing reactors once the planned operational lifetimes have been reached and another (Italy) overwhelmingly voted in June 2011 against proceeding with plans to re-establish a nuclear programme. Other countries displayed varied policy reactions ranging from continuing with existing nuclear power development plans after conducting reviews of their nuclear energy systems and concluding that the reactors were safe to continue operating (e.g. Mexico), or requiring upgrades to safety systems and associated facilities to improve the ability to respond to a similar situation involving loss of power and cooling abilities (e.g. United States) to abandonment (e.g. Kuwait) or postponement (e.g. Thailand) of existing plans to develop NPPs.

This report aims to outline the consequences of the accident in two main areas:

- policy responses of governments with operational NPPs or those considering the addition of NPPs to the energy mix, focusing on governments that reacted to the Fukushima Daiichi accident with policy or other changes;
- effects on the pace of global nuclear power development, compared to the rate of growth considered necessary to avoid the most damaging impacts of global climate change caused by human-produced greenhouse gas emissions.

Regional policy responses

A number of countries took immediate policy action in response to the events at Fukushima Daiichi, either withdrawing or reaffirming support, while others took more time to make such decisions, such as engaging in formal public dialogue and debate. The most significant of such policy responses are presented below, grouped by region.

In addition to policy statements, multiple projections from *Uranium: Resources, Production and Demand* (the NEA/IAEA co-published "Red Book") through to 2035 are included for each country as a visual representation of the changing landscape over the period from 2009 to 2015. In some cases, these projections represent official government policy, while others represent only estimates by the NEA/IAEA at the time. Regardless, these projections are one way to quantify the changes that have taken place over that period. Some decreases appear to be directly attributable to reactions to the Fukushima Daiichi accident, while others do not. In yet other cases, the projections have not changed at all or have even increased.

East Asia

China

In China, 31 operational reactors (26.7 GWe net) provided about 3% of national electricity production in 2015, and a total of 24 reactors were under construction (in total amounting to 24.1 GWe net) as of 31 December 2015. The government plans to add significant nuclear generating capacity in order to meet rising energy demand and limit emissions of greenhouse gases and other air pollutants (e.g. nitrogen oxides and sulphur oxides). Poor air quality, largely due to emissions from coal-fired plants, is a significant public health issue in China.

Immediately after the Fukushima Daiichi accident, the Chinese government froze the nuclear power programme in order to conduct safety checks on all operating plants and those under construction. Prior approvals for as many as 25 planned reactors were suspended, and approvals for the construction of new reactors were brought to a halt. By June 2011, safety checks had been completed. No serious issues were identified, and no reactors were taken out of service. The government reaffirmed a commitment to safety by stating its intention to incorporate all the IAEA safety standards and formally requesting public input on the draft safety plan. By late 2011, it was not yet clear what implications these potential new regulatory requirements would have on the country's nuclear development plans, notably those stemming from an assessment of several planned and approved projects involving the generation II CPR-1000 design.

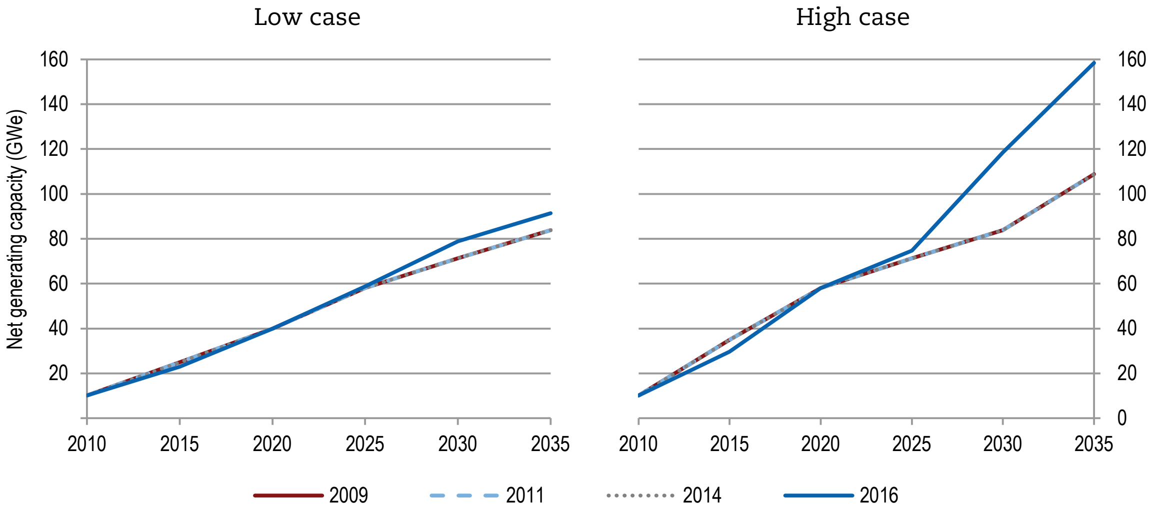
In late 2012, after the safety plan was finalised and safety requirements were enhanced, approvals for planned units were resumed, although at a slower pace than prior to the Fukushima Daiichi accident. As outlined in the "Mid- to Long-term Nuclear Development Plan (2011-2020)" issued in October 2012, China aims to have 58 GW (net) of nuclear power in operation and 30 GW under construction by 2020, down from the pre-Fukushima target of 80 GWe in operation by 2020 (Zhang and Zhoa, 2013). Only reactor designs that comply with the new safety standards (essentially generation III designs) would be approved, and no approvals would be granted for inland sites in seismically active areas prone to water shortages until 2015. To meet the new safety requirements, capital costs for each unit could increase by 10-20%. Updated plans in 2014 call for the Hualong 1 reactor design to be deployed in the majority of these new projects, including eventually at inland sites. Hualong 1 is a combination of the China National Nuclear Corporation (CNNC) and China General Nuclear Power Corporation (CGN) reactor designs that are largely built upon, and modernised from, a French design imported in the 1990s. It is a three-loop pressurised water reactor with a combination of active and passive safety systems, a single stack layout, 177 nuclear fuel assemblies, a double containment structure, and comprehensive defence-in-depth design. It also incorporates aspects of the ACPR-1000, a design developed from the Westinghouse AP-1000 reactor, such as a double containment. In addition to local construction, China is also planning to market and export the Hualong 1 design as HPR-1000.

In early 2015, approvals began to be granted for new NPP construction projects, albeit at a slower pace than expected prior to the Fukushima Daiichi accident. Although construction projects initiated prior to the Fukushima Daiichi accident continued during the time taken to review safety and development plans, some delays occurred as a result of the required safety inspections. Construction of the imported AP-1000 reactors had also fallen behind schedule, reportedly due to difficulties in sourcing equipment in a timely manner (Henry, 2015) and tough new safety checks (Stanway, 2014). As a result of these and other factors, the 2020 target of 58 GWe will not be met, as current construction will bring the total only to 53 GWe. However, this represents incredible progress, with capacity more than doubling from 12.8 GWe in 2012 to 26.7 GWe in 2015.

Public concerns about nuclear power safety in China have increased since the Fukushima Daiichi accident. Protests in mid-2013 led to the cancellation of a project to construct and operate a uranium processing and nuclear fuel manufacturing facility in southern Guangdong Province. It has also been reported that public resistance to the construction of NPPs at inland sites over safety concerns (cooling water availability) and potential impacts on water resources may make progress in these areas challenging.

NEA/IAEA projections to 2035 did not change over the period 2009 to 2014 and only increased in the 2016 Red Book.

Figure 1. Capacity in China: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Chinese Taipei

In Chinese Taipei, six operating reactors (a combined total of 5.05 GWe) generated about 16% of national electricity production in 2015. All six units are operated by state-run Taiwan Power Co., or Taipower. Two advanced boiling water reactors (ABWRs) under construction at the Lungmen NPP (a total of 2.6 GWe) were originally scheduled for completion in 2004, but the multiple contractors involved in this project, political interventions and other factors led to significant delays. In January 2014, it was announced that the first ABWR would be in operation in 2015 and the second by 2017 (WNA, 2015a). However, in April 2014, the government decided in the face of significant political and public opposition at least in part stemming from the Fukushima Daiichi accident that Lungmen unit 1 would be mothballed after construction and safety checks were completed and unit 2 construction activities would be suspended (WNN, 2014a).

Chinese Taipei imports over 97% of its energy requirements (mainly coal, oil and liquefied natural gas) while nuclear power and hydro (including pumped storage) comprise the majority of domestically produced energy sources, along with minor amounts of biofuels and waste, solar and wind energy. The Renewable Energy Development Act of 2009 set a goal of 9.95 GWe installed capacity by 2030 and 3.76 GWe of renewable energy sources had been installed by the end of 2013. In 2009, Taipower had also been considering the construction of an additional six reactors with the first pair to be in operation by 2020 (WNA, 2015).

In November 2011, after the Fukushima Daiichi accident, the government of Chinese Taipei released a new energy plan that calls for the country to "decrease nuclear dependence," ceasing operation of all 6 operating reactors as they reach 40 years of operation between 2018 and 2025. Even prior to the Fukushima Daiichi accident, construction of the Lungmen NPP was vocally opposed, and the accident has since galvanised opposition to nuclear power. The determination by the nuclear regulator (the Atomic Energy Council, or AEC), following a comprehensive safety review, that no safety concerns had been identified in the six operating units did not appear to appease those opposed. In 2013, a peer review by the European Commission and the European Nuclear Safety Regulators Group (ENSREG) confirmed the safety of the units and recommended that the assessment of all natural hazards be updated, with particular reference to earthquakes and tsunamis since Chinese Taipei is located in a seismically active area (ENSREG, 2013). Also in 2013, the Cabinet changed the mandate of the AEC to safety inspection and repositioned the agency directly under the Cabinet.

The debate about the future of nuclear energy in Chinese Taipei has continued, punctuated by several large public demonstrations against nuclear power. In March 2013, the government proposed a referendum on the fate of the Lungmen NPP as a way of resolving the long-standing dispute (Hsu, 2013). The proposed referendum question asks whether construction of the Lungmen plant should be suspended. However, the validity of a referendum has been questioned. National law requires 50% participation by eligible voters and all past six referenda on other subjects have failed to achieve this level of participation (Crane, 2014). After construction was completed in July 2014, the Lungmen 1 reactor passed a rigorous review of 126 systems before being sealed and work on Lungmen 2 was suspended pending the referendum result. Unit 1 was "sealed" on 1 July 2015 for three years "until the future of the facility can be determined in a national referendum" (Taiwan Today, 2015). As of this writing, the referendum had not been held owing to continuing debate on the legitimacy of the 50% participation requirement and the wording of the referendum question. However, the Democratic Progressive Party, elected in January 2016, favours the planned phase-out, including the abandonment of the Lungmen reactors.

The Red Book projections for Chinese Taipei dropped after the Fukushima Daiichi accident. The high case projections have returned to pre-Fukushima levels for 2035, resembling a two or three-year delay after 2025. The low case, which represents current government policy, has decreased significantly, showing further delay on the units under construction and the planned retirements.

Figure 2. Capacity in Chinese Taipei: Changes in long-term projections

Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Japan

In 2010, electricity generated at 54 operational NPPs (47.4 GWe net) amounted to just under 30% of total national electricity generation. Three reactors were under construction (2.9 GWe net), and an additional twelve reactors (15.9 GWe net) were considered firmly committed to construction. Prior to the Fukushima Daiichi accident, the Third Strategic Energy Plan of 2010 outlined a roadmap to 2030 that would see zero-emission power sources (mainly nuclear energy and renewable energy sources, including hydro) accounting for approximately 70% of electricity generation. It included the construction of 9 new reactors and increasing the capacity factor of the reactor fleet to 85% by 2020, with an additional 14 new reactors and a further improvement in fleet capacity factor to 90% by 2030, pushing the contribution of electricity generation at NPPs to about 50% of total 2030 electricity supply in Japan.

As a result of the Fukushima Daiichi accident and investigations into its causes, all remaining operational reactors in Japan were gradually taken offline during regularly scheduled maintenance outages, with the exception of two reactors (Ohi 3 and 4) that were allowed to continue operating (although not continuously) until September 2013. The initial response of the government in power at the time of and immediately after the accident included a complete exit from nuclear power. However, following a general election in December 2013 and the formation of a new government, the new Basic Energy Plan was announced in April 2014. It aims to pursue energy security, economic efficiency and environmental objectives by continuing to use nuclear power as an important baseload power source, provided that safety can be assured (METI, 2014). In June 2015, a consultative committee supported a government plan for nuclear power to generate 20-22% of national electricity generation by 2030 (Tsukimori, 2015), and a policy with a 22% nuclear share was subsequently adopted by the government (Watanabe, 2015). It is estimated that about 35 reactors would need to be online to achieve this target (Miyazawa, 2015).

The new, independent Nuclear Regulation Authority (NRA) established in 2012 developed new, stringent regulations that were enacted in 2013. The government stated that it will follow NRA judgement (using its new conformity assessment process) and proceed with authorised reactor restarts, at the same time working to lower dependency on nuclear power to the extent possible, mainly through the implementation of strengthened energy conservation measures and the installation of renewable energy sources. Reactor restarts and rejuvenation of the nuclear industry is, however, proving to be a challenge given the stringent new regulatory requirements, costs associated with retrofitting reactors to meet these requirements and heightened public distrust and resistance. As a result, there remains uncertainty concerning the number of reactors that will eventually be returned to service.

As of December 2015, utilities and operators had applied to the NRA for a review of the safety systems of 26 reactors for conformance with the new, stringent regulatory requirements (Table 1). Although compliance was determined for four reactors (Sendai 1 and 2, and Takahama 3 and 4) before the end of 2014, only two (Sendai 1 and 2) had been brought back into service by the end of 2015 due to the time-intensive regulatory process that follows substantial safety system upgrades. Each reactor is also obtaining local government consent prior to restart. The other two reactors (Takahama 3 and 4) received approval to restart in February 2016 but were subsequently shut down due to a district court injunction over claims of inadequate emergency evacuation planning. A fifth reactor, Ikata 3, restarted on 12 August 2016.

Table 1. Applications to the NRA (Japan) for power reactor conformity assessment to new regulations

Reactor	Licensee	Type	Application date
Tomari 1 and 2	Hokkaido	PWR	8 July 2013
Tomari 3	Hokkaido	PWR	8 July 2013
Takahama 3 and 4	Kansai	PWR	8 July 2013
Ohi 3 and 4	Kansai	PWR	8 July 2013
Ikata 3	Shikoku	PWR	8 July 2013
Sendai 1 and 2	Kyushu	PWR	8 July 2013
Genkai 3 and 4	Kyushu	PWR	12 July 2013
Kashiwazaki-Kariwa 6 and 7	Tokyo	ABWR	27 September 2013
Shimane 2	Chugoku	BWR	25 December 2013
Onagawa 2	Tohoku	BWR	27 December 2013
Hamaoka 4	Chubu	BWR	14 February 2014
Tokai Daini	Japan Atomic Power Company	BWR	20 May 2014
Higashidoro 1	Tohoku	BWR	10 June 2014
Shika 2	Hokuriku	ABWR	12 August 2014
Ohma 1*	J-Power	ABWR	18 December 2014
Mihama 3	Kansai	PWR	17 March 2015
Takahama 1 and 2**	Kansai	PWR	15 May 2015
Hamaoka 3	Chubu	BWR	17 June 2015
Tsuruga 2	Japan Atomic Power Company	PWR	5 November 2015

* Under construction; the world's first reactor powered exclusively by mixed oxide fuel. ** Applications filed for both restart and 20-year life extensions. BWR: Boiling water reactor; PWR: Pressurised water reactor; ABWR: Advanced boiling water reactor.

Source: Modified from an NRA presentation to the IEA In-Depth Review of Energy Policies, 16 December 2014.

With all but three operable power reactors offline, the strategic goals of Japanese energy policy are being undermined (see Figure 3). In order to make up for the loss of nuclear generation (30% of electricity generation prior to the accident), large quantities of fossil fuels are being imported at significant cost, contributing to successive trade deficits, increased reliance on imported fuels and increased electricity prices by 20% for households and 30% for industry compared to before the Fukushima Daiichi accident (Cunningham, 2015). By the end of 2012, greenhouse gas emissions had increased by 9% above 2010 levels. However, anti-nuclear sentiment remains strong, and reactor restarts are being opposed.

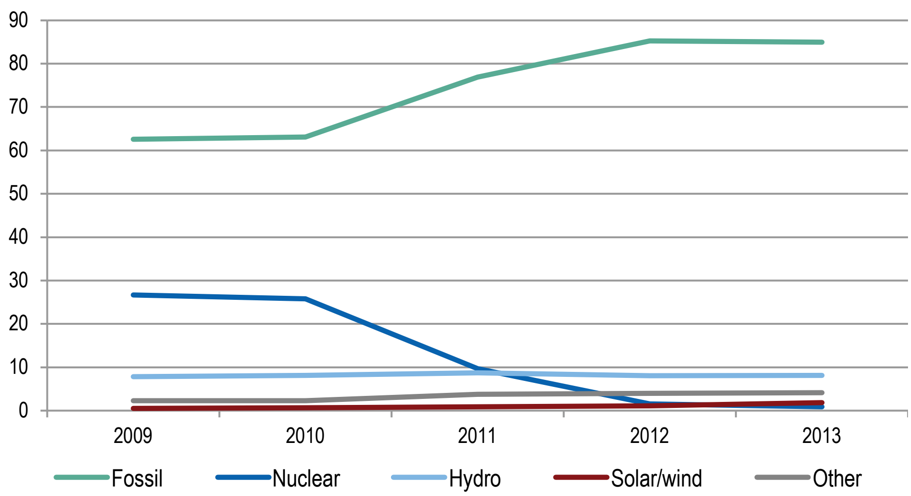
In March 2015, utilities announced that five reactors (Genkai 1, Mihama 1 and 2, Shimane 1 and Tsuruga 1) would be permanently shut down and decommissioned (WNN, 2015b), since the costs of the upgrades required to meet the new regulatory standards could not be justified economically, owing to the age of the units (from 39 to 46 years) and their relatively small capacity (less than 560 MWe [megawatt electric] each). In addition to the permanent closure of all 6 Fukushima Daiichi reactors, these announcements reduce the total capacity of the 43 remaining operable reactors in Japan to 40 290 MWe.

However, there has been progress on the restart of Japanese units. In addition to the five units allowed to restart so far, the Institute of Energy Economics, Japan (IEEJ) estimated that 18 reactors could be restarted by the end of 2017 (WNN, 2016a). There appears to be opportunity for extended operation of plants as well. In June 2016, NRA granted a 20-year licence extension for Takahama 1 and 2, allowing the units to operate for 60 years in total until 2034 and 2035 (WNN, 2016b).

The contrast in NEA/IAEA projections is fairly stark, with very strong increase in nuclear capacity in both the high and low cases pre-Fukushima and a much wider gap between high and low cases post-Fukushima. In fact, the high case is only a slight reduction from pre-Fukushima levels to 2035, while the low case represents an 80% reduction.

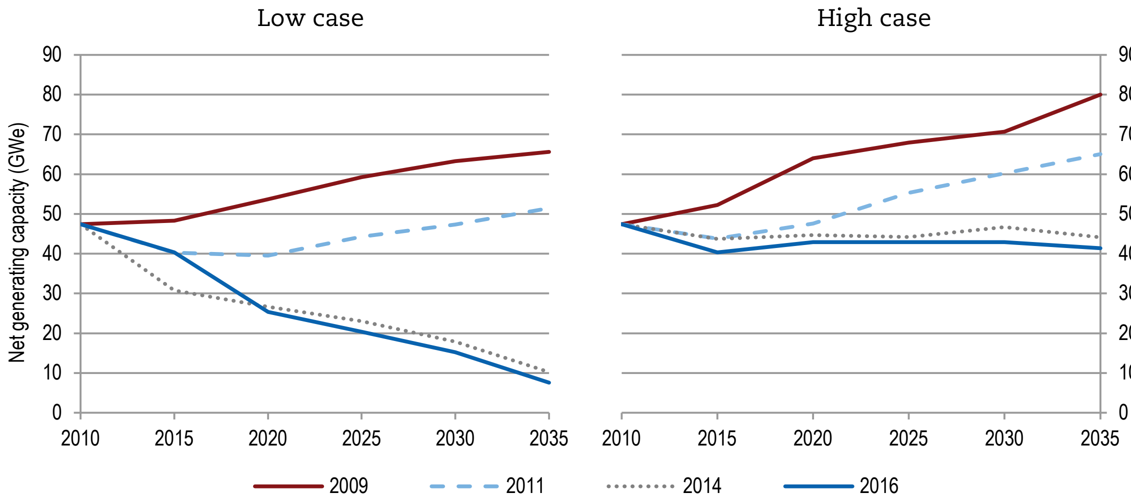
Figure 3. Electricity mix in Japan (2009-2013)

11% low C in 2013 vs. 35% in 2009



Source: IEA data.

Figure 4. Capacity in Japan: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Korea

About 32% of the total electricity generated in 2015 was produced by 24 operational reactors in Korea. Four units have been completed since 2011, increasing total net nuclear generating capacity to 23 GWe. Construction of an additional three reactors is underway, including work on two 1.34 GWe reactors (Shin-Hanul 1 and 2) initiated in 2012 and 2013, respectively. Shin-Hanul is the new name for the second phase of this NPP, formerly known as Shin-Ulchin. Yonggwang and Ulchin were also renamed to Hanbit and Hanul respectively, following pressure from local fishermen who felt that issues at these NPPs led to reduced sales of their catch marketed under these regional names.

In late 2008, the Korean government announced a new "National Energy Basic Plan" that called for an increase in nuclear generating capacity to amount to about 40% of the country's generating facilities by 2030, with 39 units in operation. According to this plan, nuclear capacity was expected to reach 32.9 GWe, about 33% of total generation capacity by the end of 2022.

Following the Fukushima Daiichi accident, the government ordered safety inspections of all operational NPPs. Although no problems were identified in the review, planned safety upgrades amounting to about USD 1 billion are being implemented over a five-year period, principally to strengthen defences against natural hazards such as earthquakes and tsunamis (Young-won, 2014). In October 2011, the Nuclear Safety and Security Commission (NSSC) was established under the Office of the President to enhance the independence of the nuclear regulator following an IAEA Integrated Regulatory Review Service mission. In April 2012, a resident inspection team (consisting of 6 to 8 inspectors) was established at each NPP to conduct field inspections in a more in-depth way and strengthen safety verification on a real time basis.

After these actions, the government stated that there would be no changes to its national energy plan, reaffirming the strategy of increasing nuclear generating capacity to provide 40-50% of electricity supply by 2030 and arguing that there is no viable alternative to nuclear power for Korea.

However, a station blackout at the Kori 1 reactor that was not reported to the NSSC, as required, combined with revelations of forged safety reports forced the temporary closure of several reactors, a delay in the construction of two units (Shin-Kori 3 and 4) and weakened public trust in nuclear power. The unexpected closure of reactors for subsequent safety checks in turn led to concerns of an inadequate supply of electricity (Park and Lee, 2013).

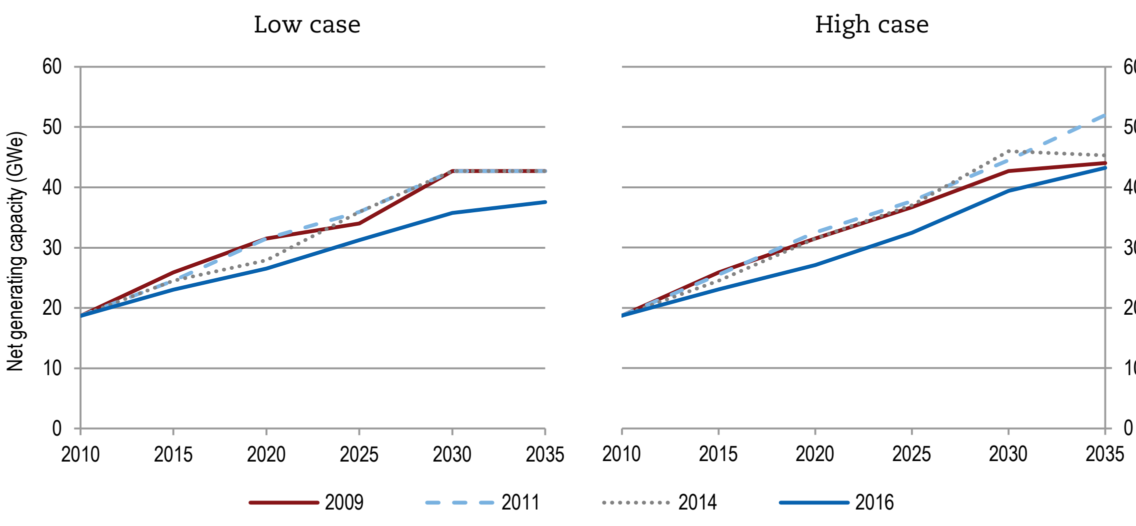
In 2013, the Korean government released the second National Energy Basic Plan (2013-2035) that sets out the main goals for demand management, distributed power generation, energy sustainability, energy security and public acceptance. After inter-agency co-ordination, the plan was passed at a Cabinet meeting on 14 January 2014 presided over by the Prime Minister. The plan was based on the expectation that until 2035 total energy and electricity consumption will continue to increase annually at an average of 0.9% and 2.5% respectively and that the government will maintain the share of nuclear power at around 29% of total generating capacity. Renewable energy is set at 11%, as laid out in the first National Energy Basic Plan, and the share of electricity produced by natural gas is projected to increase.

The 29% target for the nuclear generating capacity share by 2035 is reduced from 40% by 2030 as outlined in the 2008 plan. Despite this decrease, however, all reactors under construction, along with all planned reactors, will proceed and are scheduled to be completed by 2022. Low-cost electricity generated by NPPs has been a key element of the rapid development of the Korean economy and is expected to continue to be an important part of the energy mix.

In June 2015, it was announced that the Kori 1 reactor would be retired from service in 2017 after 40 years of operation. At the time of this announcement, it was reported that the CEO of the Korea Hydro & Nuclear Power (KHNP) wrote to employees that "Some may regret the decision to shut Kori 1, although its safety was guaranteed, but the nuclear industry is now faced with a paradigm shift" (WNN, 2015d). Despite the importance of nuclear power in the country's development, declining public confidence, initiated by the Fukushima Daiichi accident and spurred on by a number of incidents in the domestic industry, has created uncertainties about the future development of the technology in Korea. In June 2015, the Korean government abandoned plans to build four coal-fired plants and instead will add two NPPs to meet power demand and reduce greenhouse gas emissions, subject to public hearings (Cho, 2015).

As seen below, the Red Book projections changed insignificantly between 2009 and 2014. The 2016 Red Book data still has considerable growth, even in the low case, but shows a slower increase to 2020.

Figure 5. Capacity in Korea: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Southeast Asia

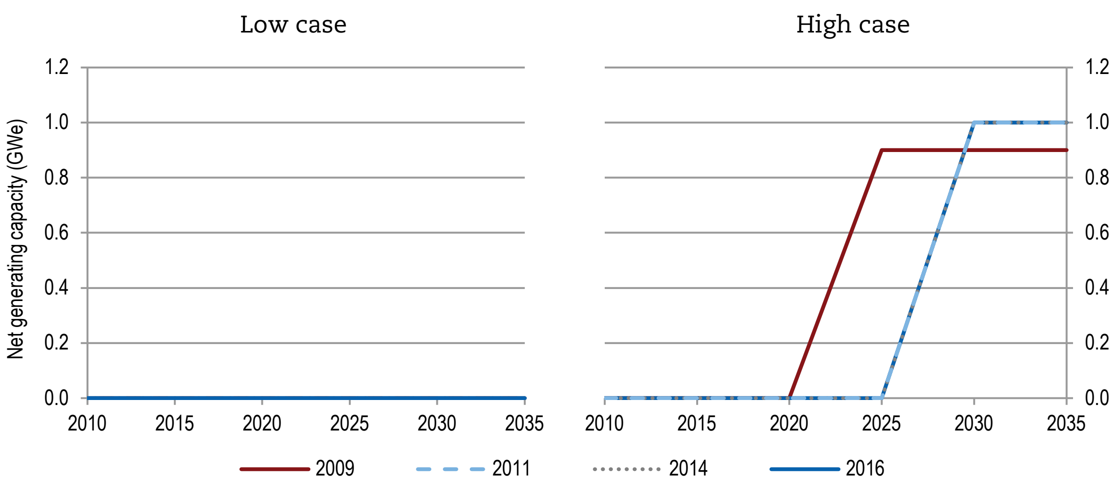
There are no operational power reactors in this region as of 2016, but several countries are considering adding nuclear power generation to their energy mix, suggesting growth in nuclear generating capacity in the longer term as the region is experiencing strong economic growth and rising energy demand. Concerns about climate change, air pollution, security of energy supply and energy mix diversification along with volatile fossil fuel prices are the main drivers of nuclear development policies. However, political support was generally weak in the years immediately following the 2011 accident (except in Viet Nam), owing to public safety and cost concerns. The Fukushima Daiichi accident weakened public confidence in nuclear power in many countries and political support in turn softened. Even so, a number of countries continue to evaluate and plan for the deployment of nuclear power.

Malaysia

Following the decision to develop a national nuclear policy in 2008, the government established the Malaysian Nuclear Power Corporation in late 2011 to plan, spearhead and co-ordinate the implementation of a nuclear energy development programme by taking the necessary action to realise the first NPP in the country. Driven by an emerging gap in electricity production and demand and the need to diversify the energy mix, a target of 2 GWe of nuclear generating capacity was adopted, with the first unit to be operational by 2021 (Kamaldin, 2010). Although work continues towards realising this goal through efforts to promote public acceptance, adopt the necessary regulations, sign the required international treaties and obtain low-cost financing, it was reported that the programme had been delayed as a result of public distrust following the Fukushima Daiichi accident (Zaragoza, 2013a).

The Red Book projections effectively show a four- to five-year delay in the addition of any capacity in the high cases and no addition of nuclear capacity in the low cases.

Figure 6. Capacity in Malaysia: Changes in long-term projections



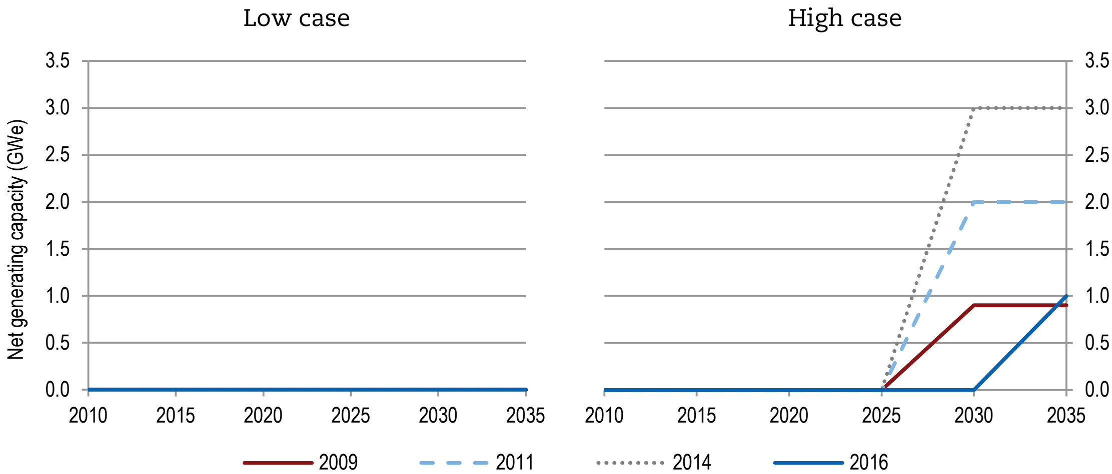
Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Thailand

Currently, Thailand relies on natural gas to generate over 70% of its electricity. Domestic fossil fuel energy reserves are in decline and electricity demand is expected to double by 2024. A third revision of the National Energy Policy Council in 2012 scaled back the planned contribution of nuclear energy in Thailand from 10% to 5% and set back the schedule for the installation of the first unit to 2026 (Anon, 2012a), the second three-year postponement since the Fukushima Daiichi accident. The postponements were reportedly implemented in order to ensure safety and improve public understanding of nuclear energy (Wiriyapong, 2016). The Thailand Power Development Plan of 2010 called for the installation of a total of 5 GWe of nuclear generating capacity by 2030, but its most recent Power Development Plan projects two units by 2036.

In this case, the post-Fukushima Red Book high case projections are likely overly optimistic, at least in terms of timing, especially as they do not reflect the postponement(s) described above.

Figure 7. Capacity in Thailand: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Viet Nam

Viet Nam has no operating nuclear power reactors, although it has operated a research reactor off and on starting in 1963 and has considered nuclear power since the 1970s or 1980s. The electricity system in Viet Nam already requires rationing, and further shortages are forecast by 2020. With annual economic growth of over 5%, the government established a master plan in 2010 with a goal of nuclear power supplying as much as 25% of domestic electricity production by 2050. The country relies on hydro to produce over one-third of supply, but there is little prospect for expanding hydro capacity and fossil fuels are already in short supply. The Fukushima Daiichi accident did not directly change Viet Nam's plans to build NPPs, but it reportedly contributed to delays in the implementation of plans to construct NPPs.

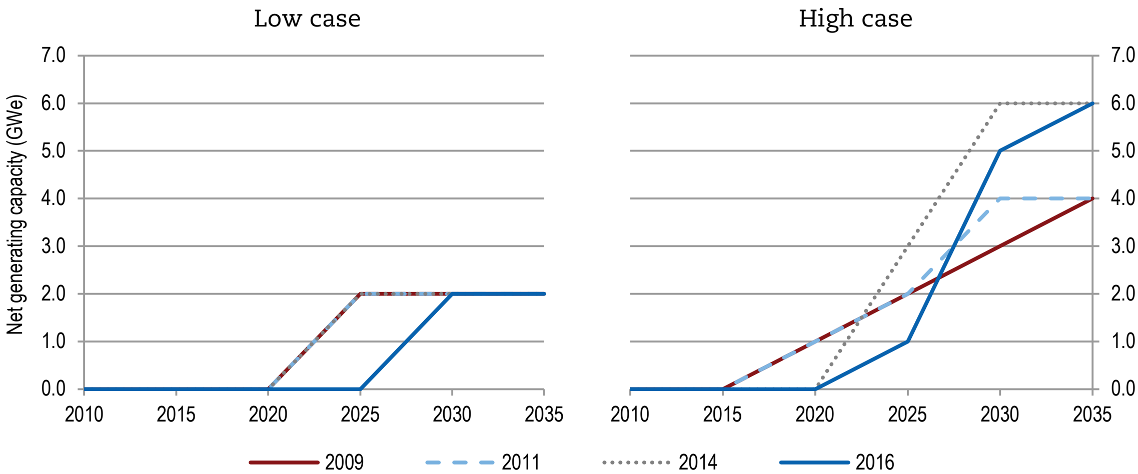
In 2010, the Ministry of Industry and Trade signed an agreement with Atomstroyexport of Russia to construct the country's first NPP on a turnkey basis. This agreement covers two AES-2006 water-water energetic reactors (VVERs) (1.2 GWe each) to be built at Phuoc Dinh (Ninh Thuan province) and reportedly includes a low interest loan of USD 10 billion, the provision of nuclear fuel and the return of used fuel for reprocessing for the life of the plant (Daly, 2013). It was considered to be the first of as many as ten NPPs (15 GWe total) that would be operational by 2030.

In August 2013, it was announced that construction of a centre for nuclear science technology would be undertaken, funded by loans of up to USD 500 million from Russia to further accelerate training. The government has also launched an information campaign to better inform the public on nuclear power (Daly, 2013).

Construction of the first reactor was initially expected to begin by the end of 2014 with commissioning by 2020, but this schedule has reportedly been delayed by at least five years owing to continuing negotiations on technology and financing and an underestimation of the length of time required to develop the legal framework for nuclear power. The need for the additional generating capacity has become less urgent since electricity demand is not rising as rapidly as projected in 2011. Following the Fukushima Daiichi accident, the government has made statements that safety is the first priority for nuclear power and that more time needs to be spent on safety and informing the public about nuclear power (Trong Khanh, 2015). In November 2016, the government cancelled its plans to build the nuclear units, citing significantly reduced cost of coal and lower forecasted electricity consumption of 11% per year from 2016 to 2020, down from 17-20% (Trong Khanh, 2016).

Based only on NEA/IAEA estimates from the Red Book, not official government plans, the long-term nuclear capacity projections for Viet Nam have increased for the high case, and the low case remained at 2 GWe pre- and post-Fukushima. These projections are now clearly invalid but, combined with the rationale provided in the November 2016 announcement, suggest that the Fukushima Daiichi accident did not have a significant impact on policies.

Figure 8. Capacity in Viet Nam: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Other countries in the region

The governments of Indonesia, the Philippines and Singapore have considered the use of nuclear power to help meet rising electricity demand, despite recurring large-scale natural hazards. The Indonesian government has made definite moves towards establishing nuclear capacity, but has not yet established a Nuclear Energy Programme Implementing Organisation. They also signed an agreement with China in August 2016 to jointly develop a high-temperature gas-cooled reactor in Indonesia. In 2012, the Prime Minister of Cambodia reportedly cancelled a feasibility study on establishing an NPP in the Koh Kong province in response to the Chernobyl and Fukushima Daiichi accidents (Anon, 2012c), and Singapore concluded in 2012 that no available nuclear technology is suitable for deployment in the city-state, noting that the decision was not influenced by the Fukushima Daiichi accident (Kamaldin, 2012).

Middle East, Central and South Asia

Bangladesh

There is currently no nuclear power in Bangladesh. Over 30% of the population in Bangladesh is without electricity, and of those that have access to electricity, power cuts are frequent. In order to overcome these significant issues that hinder development, the government launched the Vision 21 programme (WNA, 2015b) that includes the addition of 20 GWe of new generating capacity by 2021, with a target energy mix of domestic coal (30%), imported coal (20%), natural gas (25%), liquid fuel (5%), nuclear, renewable energy and power import (20%).

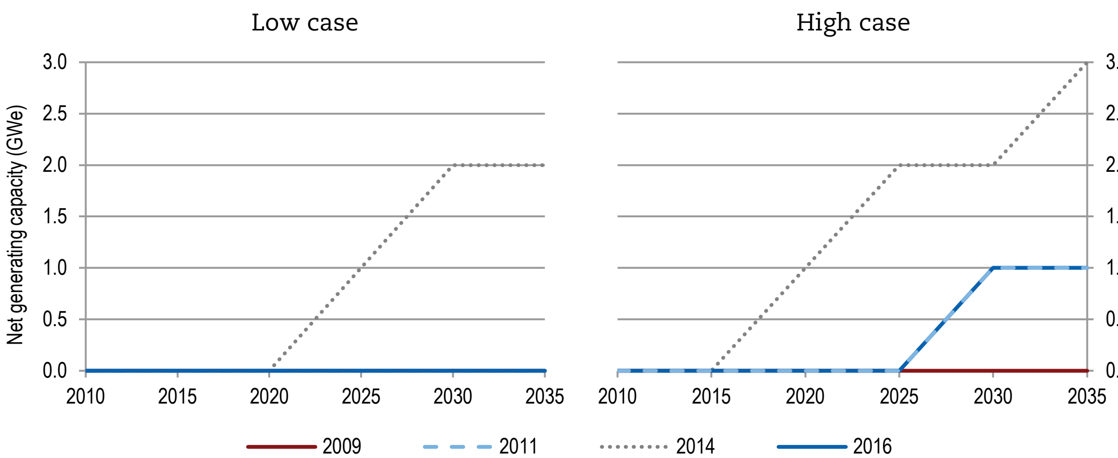
Vision 21 is considered a vital step in the development of economic prosperity in the country. In 2012, for example, total generation capacity amounted to 5 GWe with daily demand reaching 6.5 GWe. The installation of 5 GWe of nuclear generating capacity by 2030 is part of a longer-term plan to meet rapidly growing electricity demand as domestic natural gas supply, on which the country relies heavily for electricity generation, is fast depleting and could run out in a decade.

An intergovernmental agreement signed with Russia in 2010 for nuclear co-operation in areas such as siting, design, construction and operation of power and research reactors, water desalination plants and elementary particle accelerators set the stage for the development of nuclear generating capacity. A nuclear energy bill was later introduced in parliament in May 2012 that led to the establishment of the Bangladesh Atomic Energy Regulatory Authority. The Fukushima Daiichi accident does not appear to have had any impact of the country's nuclear development programme.

In March 2012, the Cabinet ratified an agreement with Rosatom to build two VVER reactors (2 GWe in total) at the Rooppur site, about 200 km north of Dhaka. Under the terms of the agreement, Russia will reportedly build, own and operate (BOO) the plant, as well as assist in the development of the required infrastructure, supply fuel, take back spent fuel for the entire lifetime operation of both reactors and provide assistance in decommissioning the facilities (Anon, 2011). Loans from Russia are to finance 90% of the costs.

The government signed an agreement with Russia in late 2015 to construct the two VVER units with a target date of 2022 set for the first electricity generated from the first unit. In June 2016, the regulatory authority issued the site licence, and the government signed the credit agreement with Russia a month later. From these developments and Red Book projections, there is clearly no negative impact on policies.

Figure 9. Capacity in Bangladesh: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

India

At the end of 2015, 21 reactors (5.3 GWe net) were operational, supplying 3.5% of domestic electricity generation. Kundankulam 1 (0.917 GWe net) was connected to the grid in 2013. A total of six reactors were under construction with a combined capacity of 3.9 GWe net (four pressurised heavy water reactors (PHWRs), one PWR and a prototype fast reactor). The second Kundankulam PWR (0.917 GWe net) began commercial operation in 2016, with Rosatom supplying both VVER units and fuel for the reactors (a project originally agreed to in 1988).

Like China and some other fast growing economies in the developing world, nuclear power generation is being increased owing to its characteristics of low emissions of carbon dioxide and other gases that contribute to poor air quality, its competitive generation costs and the low and relatively stable cost of fuel. Because of the significant amount of energy in uranium, transport of large amounts of fuel is not required, and fuel for several years of generation can be stored readily at NPPs, easing security of supply concerns.

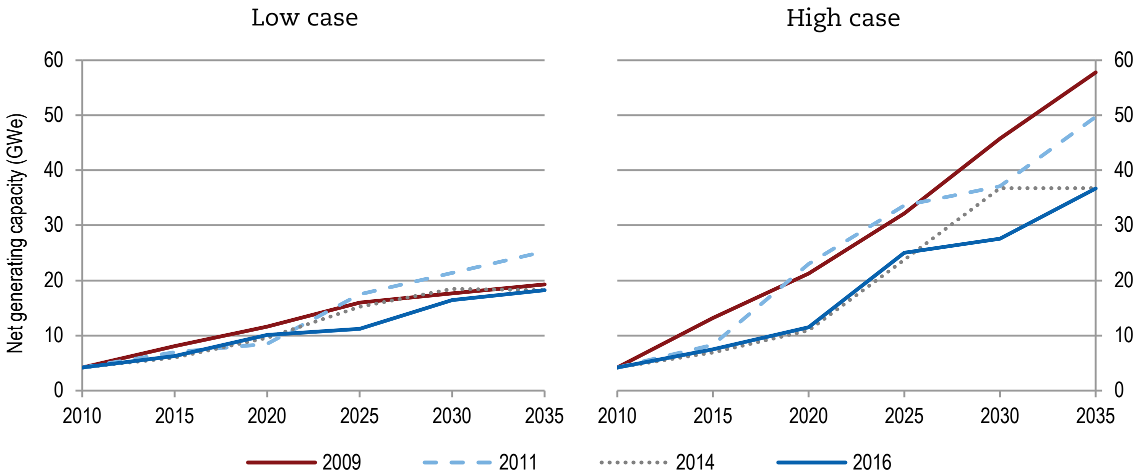
Nuclear power is seen by the government of India as a viable replacement of coal-fired plants that will not only reduce air pollution but provide large amounts of baseload electricity to help meet increasing demand and avoid current power shortages. Despite being the world's third largest coal producer, about 60% of electricity supply is produced by burning coal, and domestic production cannot keep pace with national demand (EIA, 2014). India imported some 165 million tonnes of coal in fiscal year 2013-2014, contributing to its current account deficit (Mazumdaru, 2014). Some 40% of India's population do not have access to electricity, and, of those that do, 40% experience power shortages on a daily basis, in part due to an ageing and overburdened electricity grid.

Following the Fukushima Daiichi accident, the Prime Minister ordered the operator of India's NPPs, the Nuclear Power Corporation of India Limited (NPCIL), to conduct a review of safety and security at all operating plants. Although the review concluded that "adequate provisions exist" at the sites, the need to strengthen defences against extreme events at some sites was noted (Verma, 2011). The government is therefore continuing with ambitious plans to increase nuclear generation capacity to as much as 23 GWe by 2022 and 65 GWe by 2032, close the existing uranium fuel cycle and develop a thorium fuel cycle. In late 2014 it was reported that India had signed an agreement with Russia for the supply of 12 reactors over the next 20 years, 6 more to be built at the Kundankulam site and another 6 to be built at a second, unnamed site (Basu, 2014).

Although the government of India remains committed to the development of nuclear power, public concerns about the safety of nuclear power increased after the Fukushima Daiichi accident. Lengthy (18-month) public demonstrations at the Kudankulam NPP, just as the first of two VVER reactors was ready for fuel loading and commissioning, as well as other indications of public and local political resistance, could reshape at least some of these development plans. In March 2015, after a 12-day peer review of the Atomic Energy Regulatory Board (AERB), the IAEA recommended that India should tighten its nuclear safety by assuring the legal independence of the AERB (IAEA, 2015). It also recommended that the AERB should conduct more frequent on-site inspections and allow for independent verification and more effective regulatory oversight.

India's 2010 Civil Liability for Nuclear Damage Act, which allows the operator recourse against suppliers under certain circumstances, still seems to be discouraging foreign investment to some degree. In 2015, a nuclear insurance pool was established, and commercial negotiations are ongoing with a number of reactor vendors. However, as of August 2016, no firm contract had been signed. Aside from a visible delay, there do not appear to be significant of policy changes in Red Book projections.

Figure 10. Capacity in India: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

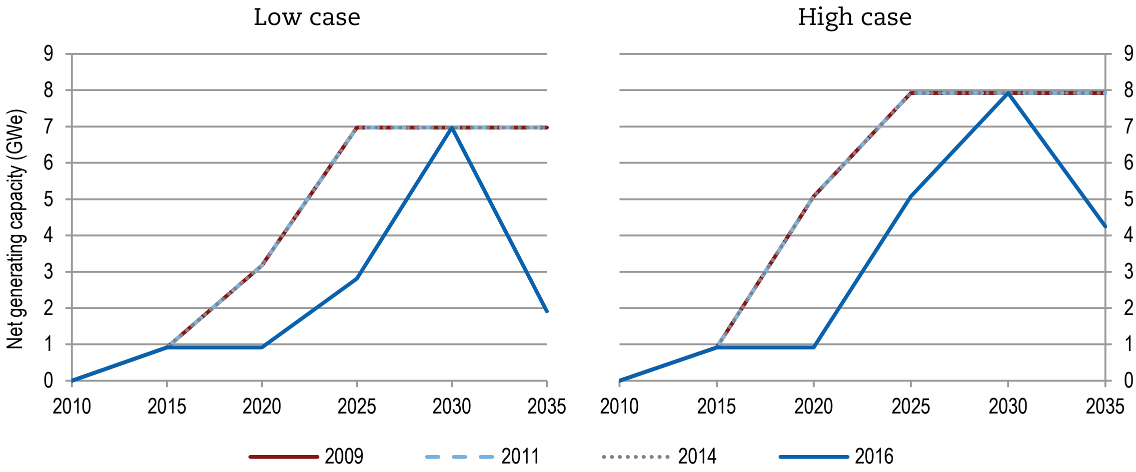
Islamic Republic of Iran

Russia completed construction and brought Iran's first NPP into operation in 2011. Work on this reactor (Bushehr) started in 1975 based on the German Biblis design, stopped in 1979 and was restarted in the late 1990s as a VVER-1000 design. In 2013, the single 915 MWe Bushehr reactor, operating under IAEA safeguards, supplied 1.5% of the electricity generated in the country. There is no indication that the Fukushima Daiichi accident has had any impact on Iran's plans to further develop nuclear power generation.

Rosatom signed a contract in 2014 to build two more reactors at Bushehr, which started construction in 2016, possibly followed by another two units and an additional four reactors at another, unnamed site (WNN, 2014b). The agreement includes lifetime fuel supply and spent fuel take-back for reprocessing, as in the existing arrangement for the operating unit (Bushehr 1). Two desalination plants are also reported to be included in the agreement, and work on the first phase of the initial desalination plant has reportedly underway at Bushehr in mid-2014. In 2013, the Atomic Energy Organisation of Iran (AEOI) identified 16 new sites suitable for the construction of NPPs (Anon, 2013).

After the 2015 adoption of a comprehensive agreement between the government of Iran and the P5+1 on Iran's nuclear power programme, the development of nuclear power may be able to increase more rapidly as the door could be opened for Iran to engage with global suppliers of nuclear power reactors. In September 2016, Iran and Russia signed agreements and held a ceremony to lay the foundation stone for Bushehr units 2 and 3, which they said will be VVER-1000 generation III+ technology. The 2016 Red Book projections show a delay from previous government estimates. The sharp drop in 2035 represents a differing estimate by the NEA/IAEA from Iran's official projections up to 2030, as opposed to an actual reduction of capacity. Therefore, there does not appear to be any policy impact from Fukushima Daiichi.

Figure 11. Capacity in Iran: Changes in long-term projections

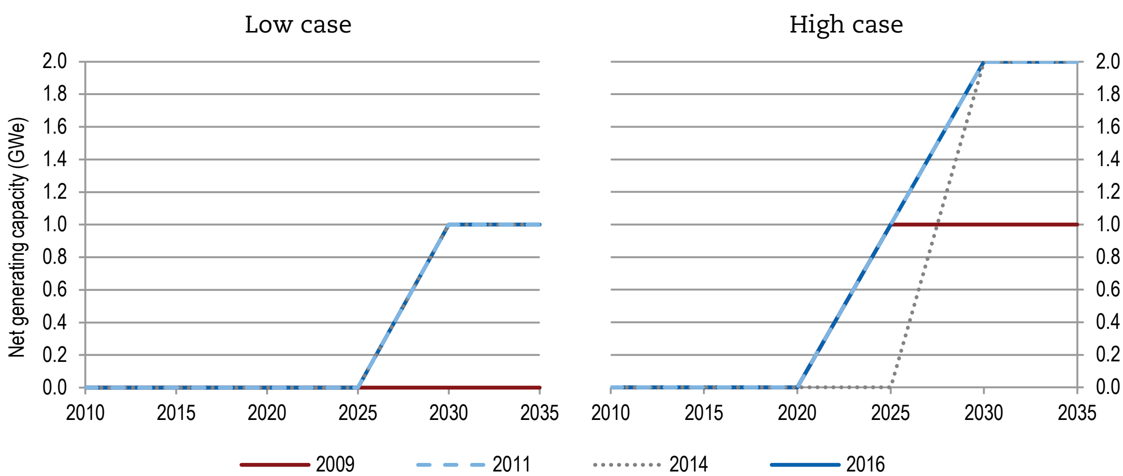


Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Jordan

Plans to develop nuclear power in Jordan, a country that imports over 97% of its energy needs and is prone to disruptions in Egyptian gas supply and experiences periodic blackouts, have moved ahead, seemingly unaffected by the Fukushima Daiichi accident. In October 2014, detailed studies of the selected site were underway prior to making a final investment decision on installing nuclear generating capacity. In early 2015, Jordan signed an agreement with Rosatom to begin feasibility and environmental assessments towards two reactors (1 GWe each), with desalination capabilities included (McNeil, 2015; Al-Khalidi, 2015). Aside from a delay in completing the first unit, the longer-term projections have only increased.

Figure 12. Capacity in Jordan: Changes in long-term projections



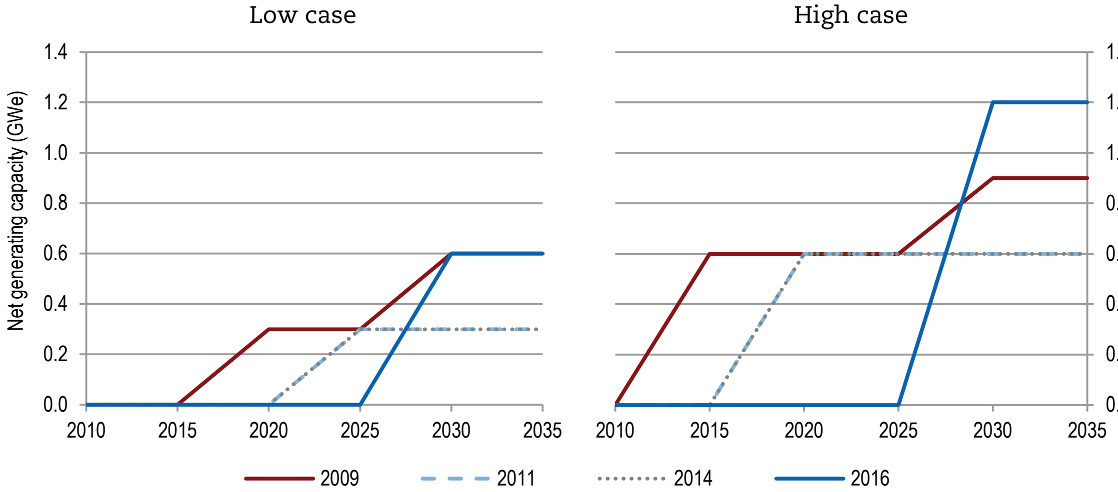
Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Kazakhstan

Kazakhstan, the world's largest uranium producer, has long expressed its intention to develop nuclear power and is moving ahead with plans to construct an NPP with as many as two reactors for electricity generation. A sodium-cooled fast reactor, BN-350, operated at the Aktau NPP from 1973 to 1999. The Fukushima Daiichi accident has not had an impact on this plan. In October 2014, Kazakhstan signed a nuclear co-operation agreement with Russia to develop an NPP in the Kurchatov region of eastern Kazakhstan, with Rosatom providing the reactor technology and Kazakhstan supplying components of nuclear fuel for the reactor (Rosatom, 2014). In late 2015, the Vice Minister of Energy explained that decisions on reactor siting and vendor would be made within two to three years, with 2025 being the time frame for commissioning to meet projected electricity demand.

In this context, the Red Book estimates represent continued delay in deploying nuclear power, but there does not appear to be any departure from plans to pursue it.

Figure 13. Capacity in Kazakhstan: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Pakistan

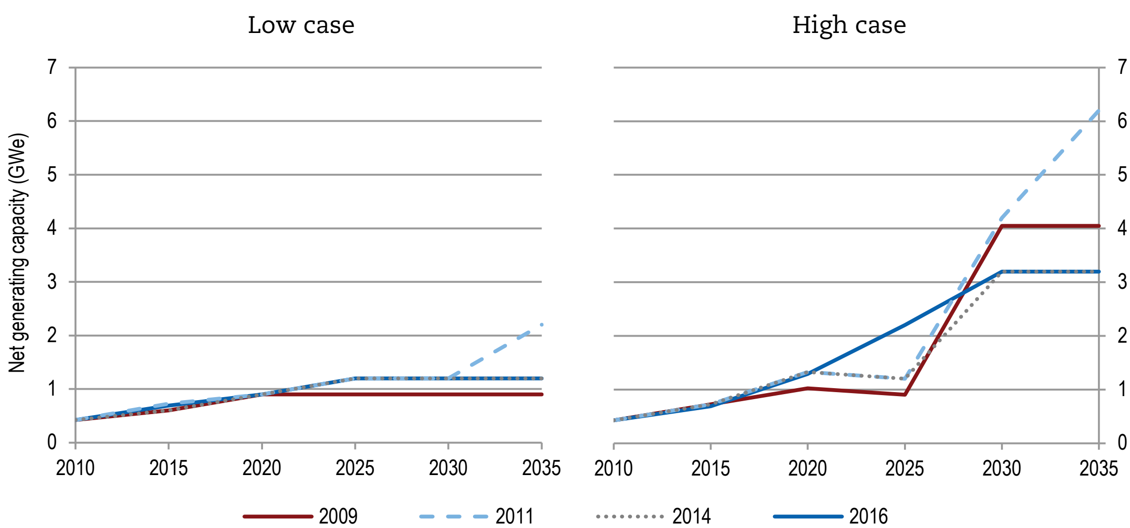
Prior to 2016, three reactors operating in Pakistan (0.69 GWe net) provided about 4% of domestic electricity production. Three units are currently under construction (a combined total of 2.3 GWe net), and one unit was completed in late 2016. All but one of the units in operation, and all under construction and planned, are being supplied with financing by China, and fuel for the two units being built near Karachi is reportedly to be provided as part of the contract (Masood and Buckley, 2013).

Following the Fukushima Daiichi accident, the Pakistan Nuclear Regulatory Authority (PNRA) launched a review of the regulatory framework and regulations governing the safety of NPPs (PNRA and PAEC, 2012). Areas of further improvement were identified and modifications to reactors and safety regulations are being undertaken in order to strengthen controls on the release of radioactive materials during an accident, reinforce emergency operating procedures and off-site emergency preparedness plans and responses to severe accidents, re-evaluate potential initiating events, strengthen backup power supply by requiring operators to ensure that the safety systems can function on a longer-term basis than currently required. Efforts to introduce passive design features in the emergency core cooling systems, hydrogen re-combiners and spent fuel cooling systems are being encouraged. The PNRA required operators to submit details of specific actions to be taken to address these issues. The submitted improvements, after approval by PNRA (collectively referred to as the Fukushima Response Action Plan), are being implemented to introduce more stringent safety controls. The review and subsequent actions did not, however, bring about any change to Pakistan's policies towards nuclear power.

It was reported in 2013 that the government had restated long-standing plans to have a total of 8 GWe of nuclear power in operation at ten sites by 2030 and as many as 40 GWe operational by 2050 (Wang, 2013). However, a court order delaying site preparation activities at the Karachi NPP was the result of actions by local citizens prompted by concerns of the potential impacts of earthquakes, cyclones and tsunamis on the facility and was most likely a reaction to the Fukushima Daiichi accident (Craig, 2013). The Karachi NPP construction was relaunched in August 2015 based on the Chinese Hualong One design, rather than the initial ACP-1000 design (WNN, 2015c).

Pakistan suffers from acute energy shortfalls. Blackouts reportedly peak at 16 hours a day in urban areas and as much as 22 hours a day in rural areas. Chronic underinvestment in infrastructure has been cited as one of the main causes for the shortfalls. The central bank has reportedly warned that energy shortages have effectively capped economic growth. The combined effect of the government setting low electricity prices and customers failing to pay bills regularly means that the utilities cannot afford to make the required investments (AFP, 2012). The push to develop nuclear power with financing from China is an attempt to wean the country off expensive imports of fossil fuels while meeting increased electricity demand. The continued commitment to nuclear power at levels near those projected pre-Fukushima is evident in the Red Book projections below.

Figure 14. Capacity in Pakistan: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

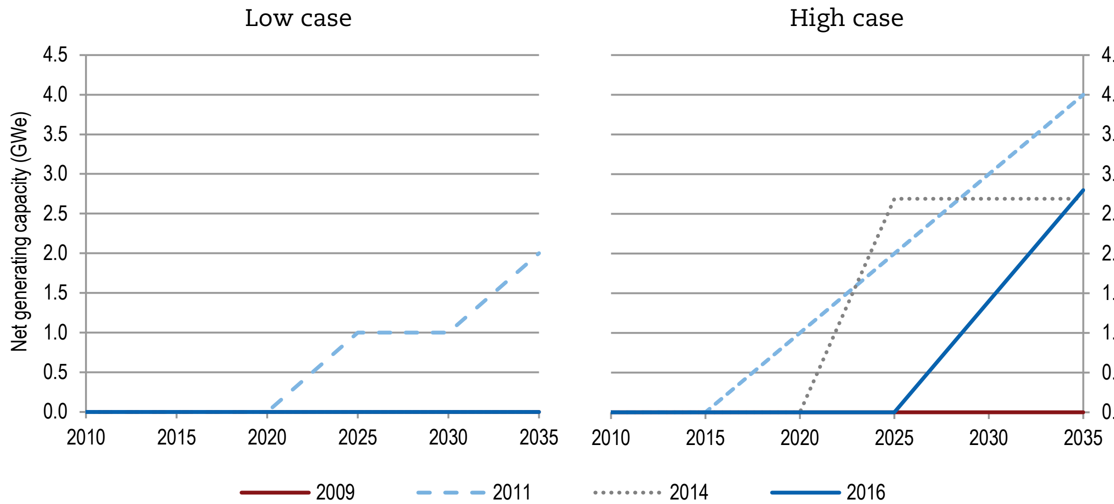
Saudi Arabia

The King Abdullah City for Atomic and Renewable Energy (Ka-Care) was established by royal decree 2010 with the aim of building a sustainable energy future by developing substantial alternative energy capacity for its rapidly growing population. The initiative was launched to meet growing energy and water needs in a sustainable fashion by producing electricity with a combination of nuclear power and renewable energy sources. Currently, Saudi Arabia consumes about 25% of total domestic oil and gas production, the majority of which (the equivalent of about 1 billion barrels per year) is used in electricity generation (Conca, 2014). Using non-fossil fuel sources of energy would not only help reduce reliance on domestic non-renewable hydrocarbon resources, but would extend the lifetime of oil exports. Saudi Arabia is currently ranked among the world's largest per capita energy consumers, just behind the United States.

In 2012, Ka-Care established plans to build some 41 GWe of solar, 20 GWe of geothermal and wind and 17 GWe of nuclear generating capacity in the next 20 years. This initiative seemed unaffected by the Fukushima Daiichi accident. In fact, in mid-2014, it was announced that nuclear capacity would be installed as quickly as possible, with the first units to be online by 2022 (WNA, 2015c). The potential of nuclear energy for co-generation and desalination was also cited as a reason for the desired increased pace of development (Saudi Arabia is currently the world's largest producer of desalinated water, using primarily oil and natural gas powered processes). General Electric Hitachi Nuclear Energy and Toshiba/Westinghouse signed agreements with Exelon Nuclear Partners to secure construction contracts for the nuclear units. Areva and Électricité de France (EDF) had previously signed agreements with Saudi companies and universities for the development of industrial and technical skills and human resources required for the successful development of nuclear power. Nuclear co-operation agreements have also been signed with Argentina, China (CNNC), the Czech Republic, Korea and the United Kingdom.

However, Ka-Care announced on 19 January 2015 that the timeline for the installation of this significant amount of renewable and nuclear capacity had been pushed back to 2040 (Shamseddine, 2015). Although no reason for the delay was provided, it has been reported that lower oil prices had removed some of the incentive to urgently pursue the installation of significant new electricity generating capacity (Zeller, 2015). Saudi Arabia has continued to sign co-operation agreements on nuclear technologies, including small modular reactors (e.g. SMART with Korea in 2015) and high-temperature gas reactors (e.g. China in 2016), so there is no perceived departure from deployment of nuclear power.

Figure 15. Capacity in Saudi Arabia: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

United Arab Emirates

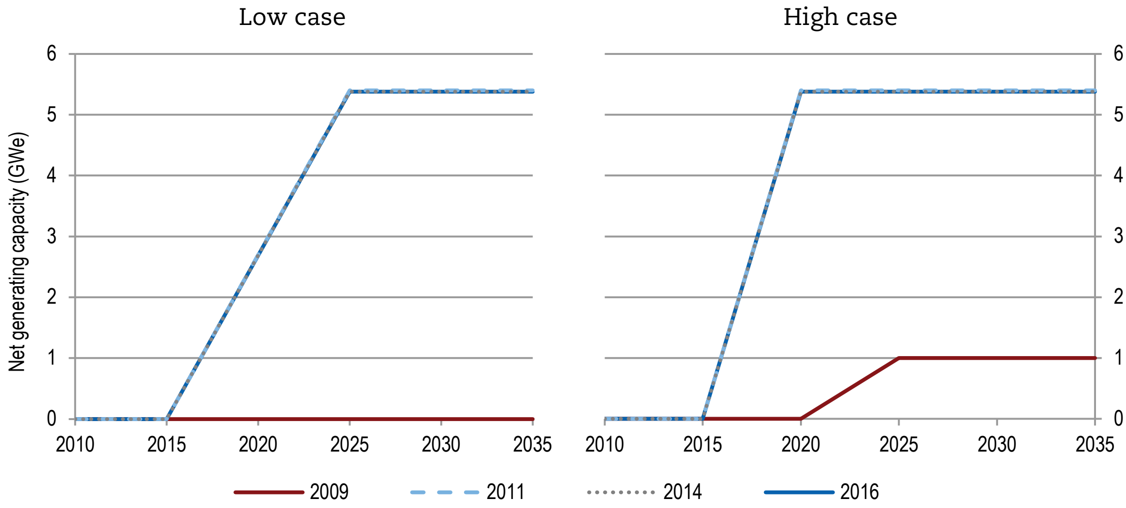
A consortium from Korea led by the Korea Electric Power Corporation (KEPCO) won a contract in 2009 to build four APR-1400 reactors (a total of 5.4 GWe net) for USD 20 billion (Bakr and Mee-Young, 2009). The contract includes provisions that will require the KEPCO consortium to hold an equity interest in the facility, assist in the design, operation and maintenance of the reactors, provide training and education for plant technicians and supply the initial fuel loads for all four units (ENEC, 2010). The Fukushima Daiichi accident shaped the construction licence review to some extent in terms of placing added emphasis on the ability of the proposed reactor designs to respond to natural disasters and how serious accidents would be managed, among other issues (UAE, 2012). After a two-year review, a licence to begin construction of the first unit was granted in 2012. The Bakarah site is not tectonically active and is not known as an area subject to tsunamis.

Construction of the first unit (Barakah 1) officially began in July 2012, with the subsequent units (Barakah 2, 3 and 4) starting construction in 2013, 2014 and 2015. Work is reportedly on track for the completion of the first Barakah unit in 2017, with the other three reactors scheduled for completion in successive years thereafter. When all four units are in operation, the Barakah NPP is expected to produce about 25% of national electricity requirements and reduce annual CO_2 emissions by 12 million tonnes (Forum on Energy, 2013). The government also plans to continue diversifying its energy mix by installing 2.5 GWe of generating capacity from renewable energy sources by 2020 in order to reduce reliance on natural gas for electricity generation.

Increasing energy demand, combined with policies to reduce greenhouse gas emissions and domestic consumption of natural gas in order to maintain the inflow of foreign capital through exports were central considerations in the government's decision to develop the Barakah NPP. After signing agreements with the IAEA for the use of nuclear power for peaceful purposes and nuclear co-operation agreements with a number of countries, during which the country agreed not to pursue domestic enrichment and reprocessing initiatives, the United Arab Emirates is continuing to implement its nuclear development plans with full international co-operation. The government has also indicated that it will continue to evaluate additional safety measures that could be incorporated into the reactor design as post-Fukushima analysis and developments emerge.

Red Book projections show considerable acceleration of deployment plans since the Fukushima Daiichi accident.

Figure 16. Capacity in the United Arab Emirates: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Other countries in the region

Other countries in the region have been considering the development of nuclear power generating facilities. In 2012, it was announced that Bahrain had postponed its nuclear development plans and Kuwait had abandoned plans to build four reactors by 2020, both in response to the Fukushima Daiichi accident. However, in 2014, it was reported that Kuwait had discussed with Russia the possibility of improving co-operation in the development of nuclear energy for peaceful purposes. Other countries have not yet made any concrete moves to establish capacity.

European Union

Following the Fukushima Daiichi accident, pre-existing nuclear phase-out policies were accelerated to some extent in Belgium and Germany, just after the phase-out policies had been relaxed in both countries. All reactors in Germany are now planned to be permanently shut down by the end of 2022 and in Belgium by 2025.

In response to the Fukushima Daiichi accident, stress tests were carried out on the entire European Union (EU) reactor fleet as well as in some adjacent countries with nuclear power (Switzerland and Ukraine) in order to assess safety and robustness of NPPs in the face of extreme natural events, in particular floods and earthquakes. In this process, overseen by the ENSREG, NPP operators conducted self-assessments that were later reviewed by national safety authorities and then peer reviewed by multinational teams. Although it was concluded that the level of safety is generally high and that no reactors needed to be taken offline for safety reasons, the need for improvements was identified in most plants evaluated.

Work at some plants has already been undertaken, such as improving seismic instrumentation, evaluating risks posed by seismically induced floods and fires, reinforcing structures against extreme weather phenomena, strengthening flood protection measures and ensuring an adequate backup of cooling water supply and mobile generators. The deadline for completing all required improvements was 2015. However, a March 2013 European Commission memo describes this deadline as an "indicative time frame", recognising that "some investments required will […] certainly go beyond 2015" (EU, 2013). As noted in the Summary Report of the ENSREG 2^{nd} National Action Plan Workshop, some countries were almost finished with their implementations, while others had clear schedules to complete their actions by 2016. Most of the countries were progressing adequately with the implementation of their national action plans, although some countries have rescheduled some specific actions up to 2020. The implementation of these additional safety measures and assessments was estimated to amount to about EUR 190 million per reactor (WNN, 2013b).

Following the stress tests, EU countries with nuclear power and policies to increase capacity continued with efforts to add new nuclear generating capacity (e.g. Bulgaria, the Czech Republic, Finland, Hungary, Romania, the Slovak Republic, Slovenia and the United Kingdom). Poland, currently without nuclear power, continued work towards building its first reactors while Lithuania continued new build efforts to replace two reactors that were shut down as a condition of entry into the EU. Other countries with nuclear power continued with the operation of reactors (e.g. the Netherlands and Spain) and countries opposed to nuclear power restated their anti-nuclear policy (e.g. Austria and Ireland). Reactions in other countries are outlined below.

Belgium

Seven operational reactors have accounted for over 50% of domestic electricity generation for a number of years. The government's 2003 law to phase out nuclear energy by limiting the operational lifetimes of the seven reactors to 40 years and not permitting construction of new plants continued in 2009, although the phase-out could be overridden if the country's security of energy supply is severely threatened.

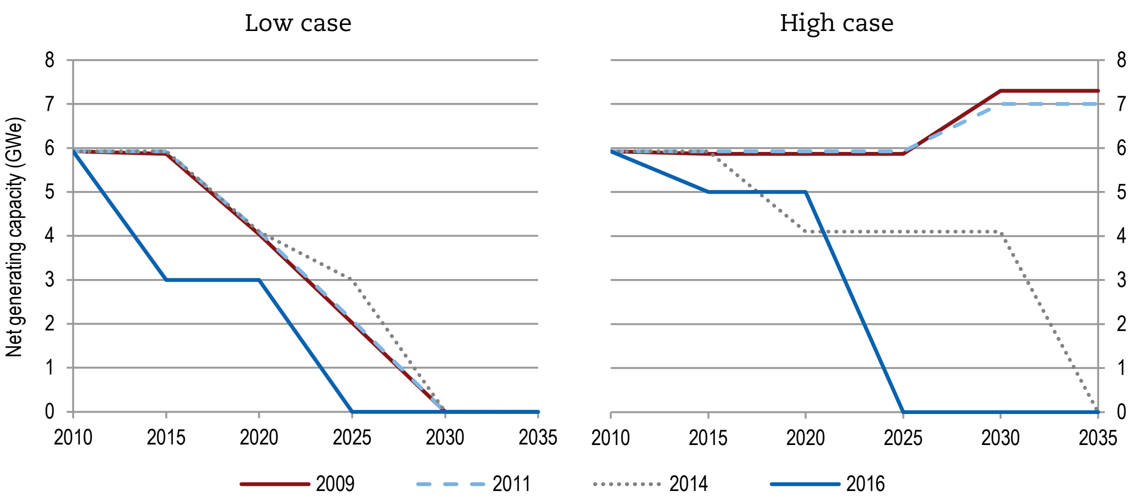
In late 2009, the government announced its intention to relax this policy by granting a one-time, ten-year extension to the three oldest units in the fleet (Doel 1, Doel 2 and Tihange 1). However, the legislation was not amended to enact this policy change, and after the Fukushima Daiichi accident, it was announced that the decision to extend the lifetime of the three oldest reactors would be put on hold until EU stress tests were carried out. However, the collection of an annual "contribution" from NPP operators (principally Electrabel, the majority owner and operator of NPPs in the country) of up to EUR 250 million in order to balance the budget continued, along with additional commitments to maintain 13 000 jobs in energy efficiency and to devote one-third of its research budget to renewable energy.

In June 2013, GDF Suez subsidiary Electrabel filed an appeal to the Constitutional Court of Belgium against an annual federal tax on nuclear power generation that had been increased in 2012 to EUR 550 million. In 2014, this claim was ruled unfounded and dismissed. Following the ruling Electrabel stated that the profitability of continued operation of the fleet was threatened since these payments, combined with various other taxes, are greater than the profits generated by the operation. It vowed to continue examining all potential legal means to defend its interests.

In July 2012, the government announced that the Tihange 1 reactor would be able to operate for a total of 50 years, advancing the closing date of the reactor by 10 years to 2025.

A series of unexpected reactor closures during 2012 to 2014, which in total represent more than 50% of the country's nuclear generating capacity, created concerns about the security of electricity supply. As a result, in late 2014, the government announced that the two oldest reactors (Doel 1 and 2), originally scheduled to close in February and December 2015, could continue operating for another ten years, pending regulatory approval. Electrabel stated that these life extensions would require significant investment that it could not make until a clear legal and economic framework was established. In late 2015, Electrabel agreed to pay EUR 20 million per year into the country's energy transition fund and received approval to restart Doel 1 and 2. The reactors are licensed to operate until the required phase-out of nuclear power in 2025 (WNN, 2015g). One can see the 2014 Red Book projections assuming the removal of the two units, even in the high case. If the current law remains, all 6 GWe will go offline between 2022 and 2025 as the reactor licences expire.

Figure 17. Capacity in Belgium: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

France

France relies heavily on nuclear power after a decision to build up capacity to reduce exposure to fluctuating oil prices following the two oil shocks (rapid price increases) in the 1970s. Currently 58 operational reactors produce about 75% (63 GWe) of national electricity generation. The industry employs some 200 000 professionals and electricity exports to neighbouring countries have amounted to as much as EUR 3 billion per year (WNA, 2015d).

Following the Fukushima Daiichi accident, the government called for a review of all nuclear facilities to assess resistance to flooding, earthquakes, power outages, failure of the cooling systems and operational management incidents. EDF mobilised 300 engineers to analyse each of the 19 EDF sites and a 7 000 page report was issued to the French Nuclear Safety Authority (ASN) as part of the post-Fukushima "stress tests". For other nuclear facilities identified as priorities (80 in total), Areva and the French Alternative Energies and Atomic Energy Commission (CEA) submitted reports to the ASN by 15 September 2011.

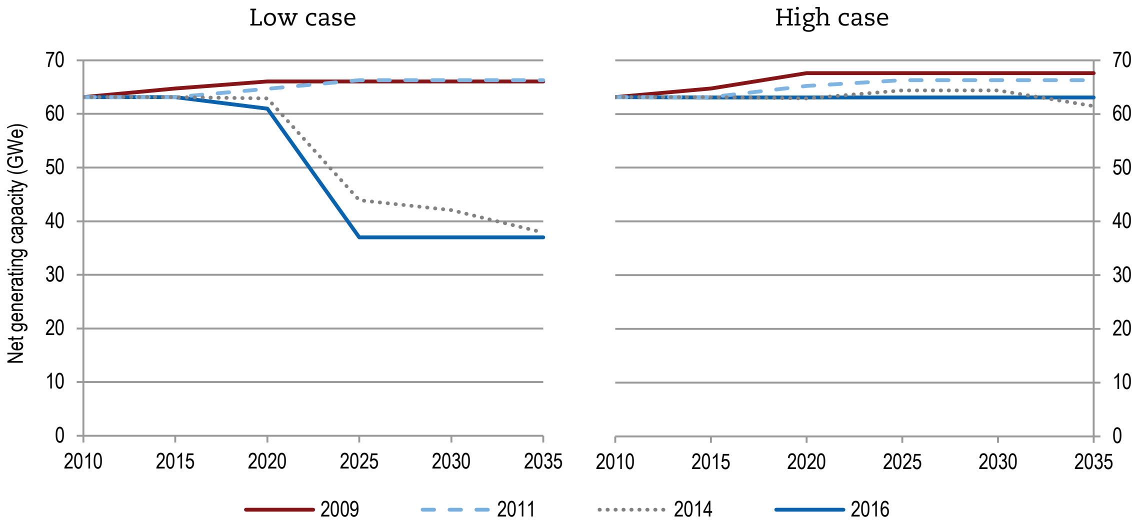
The French Institute for Radiological Protection and Nuclear Safety (IRSN) also undertook a six-month review of reactor safety. The IRSN review, released in conjunction with an ASN report, proposed a new set of safety requirements to ensure the protection of vital safety structures and equipment. EDF was able to integrate lessons learnt from the Fukushima Daiichi accident into its lifetime extension programme as it invests to prepare its fleet to operate for up to 60 years. Continuous investments and improvements through integration of operational experience have meant that the cost of the Fukushima-related safety upgrades have been less than 20% of the cost of the lifetime extension programme. Regional rapid response forces (FARN) were brought into service at the end of 2012, operating out of regional bases at the Civaux, Paluel, Dampierre and Bugey plants, in order to better respond to emergencies at nuclear facilities in France. In a 2014 report to parliament, EDF estimated that of the EUR 55 billion reactor life extension programme cost, post-Fukushima modifications amounted to EUR 10 billion (WNA, 2015d).

A national debate on the French energy transition was launched in late 2012 to gather the views of citizens on a number of key questions, including how electricity demand could be reduced through energy efficiency and the definition of suitable options for the future energy mix, their implementation roadmap to 2025 and associated costs, as well as any potential impacts each energy mix option would have on maintaining longer-term (2030 and 2050) commitments to reduce greenhouse gas emissions. It was also expected to define realistic renewable energy and new technology options, industrial and regional development strategies and outline how these could be achieved. The backdrop to this initiative is a pledge by the incumbent president, made just prior to his election, to shut down the two oldest reactors in France by the end of 2016 (both at the Fessenheim NPP; 880 MWe net each) and develop a plan to reduce the reliance on nuclear power generation from about 75% of domestic electricity generation today to 50% by 2025.

Following the public debate, legislation was drafted and presented to the government in 2014. In late October 2014, comprehensive legislation on the transition to a low-carbon economy was adopted by the French National Assembly. The bill sets targets to reduce greenhouse gas emissions by 40% by 2030 and 75% by 2050, reduce final energy consumption by 20% by 2030 and 50% by 2050, reduce primary consumption of fossil fuels by 30% by 2030, increase the share of renewable energy sources in final energy consumption to 23% by 2020 and 32% by 2030 and to reduce the share of electricity production by nuclear power to 50% by 2025. In early 2015, the legislation was debated by the Senate and a compromise bill was put forward that does not require the reduction in electricity production from NPPs to 50% by 2025. In June 2015, wording differences between the Senate and National Assembly versions of the legislation were being reconciled, and a final version of the bill was passed in late July 2015, specifying that the nuclear share of electricity generation would be reduced to 50% by 2025 and that nuclear generating capacity would be capped at 63.2 GWe – its current level. The multi-year programme plan (PPE) formalising these limits was signed into law by the government and published on 28 October 2016.

The Red Book projections appear to capture this uncertainty during the public debate, with the low case involving a significant reduction in nuclear capacity. Under the new 2015 law, the long-term projection should look more like the 2014 Red Book high case – a constant 63 GWe – with older units being shut down as new capacity becomes available.

Figure 18. Capacity in France: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Germany

Changes to the Nuclear Power Act (NPA) in 2002 enshrined the nuclear phase-out in German law, whereby each reactor was assigned a residual electricity output figure such that the total output corresponded to an average 32-year lifetime. Implementation of the law had already brought about the early shutdown of two reactors.

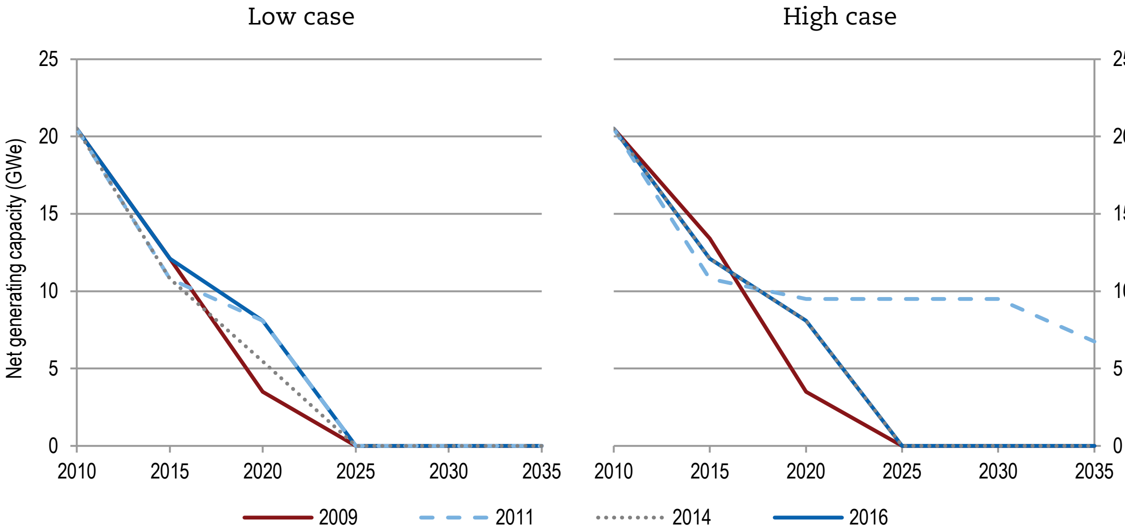
In December 2010, the NPA was amended to increase the assigned residual electricity output, in effect extending the operating lives of the existing reactors by an average of 12 years. Nuclear power stations that started their commercial operation up to and including 1980 were granted 8 more years of output and newer reactors were granted 14 additional years. However, immediately after the Fukushima Daiichi accident the German government launched a comprehensive safety review of all 17 operating NPPs while reassessing the risks posed by nuclear energy. The seven NPPs commissioned prior to 1980 were immediately shut down for the duration of a three-month moratorium and review.

On 30 May 2011, the German Cabinet announced that it had agreed to accelerate the nuclear phase-out by shutting down permanently the seven oldest reactors that had been taken offline during the review plus the Krümmel NPP which was offline for maintenance. The remaining nine operational reactors will be taken offline between 2015 and 2022 (in 2014, these reactors provided about 16% of domestic electricity generation). The parliament voted in favour of the accelerated exit from nuclear power in July 2011. A tax on spent fuel rods, under consideration since the December 2010 amendments, remained in place despite the accelerated shutdown schedule. This tax has been challenged by utilities operating reactors in the country who are also seeking compensation for the shutdown of eight reactors.

With reduced nuclear generating capacity, renewable energy sources have been added at a rapid rate through a subsidy programme which has driven up retail electricity costs to consumers. It has also been necessary to increase the use of coal-fired plants, which in turn increases greenhouse gas emissions (Sagener, 2014). The periodic abundant supply of very low-cost subsidised renewable energy to the grid has reduced the wholesale price of electricity to the point that large utilities (e.g. Rheinisch-Westfälisches Elektrizitätswerk AG [RWE] and E.ON) are suffering significant losses (Richter, 2013). The government recently moved to slow the pace of renewable development and reduce costs to consumers by changing the existing subsidy arrangements in order to make further growth more predictable and to avoid sharp price increases (WNN, 2014c).

The Red Book projections do not change significantly between the 2009 and 2014 editions. However, the 2011 edition reveals the true impact of Fukushima Daiichi in Germany – the reversal of the 2010 NPA amendment and the decision to accelerate the phase-out. In context, however, it is not as though Germany had been considering additional nuclear capacity, so the effect is only an issue of timing.

Figure 19. Capacity in Germany: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

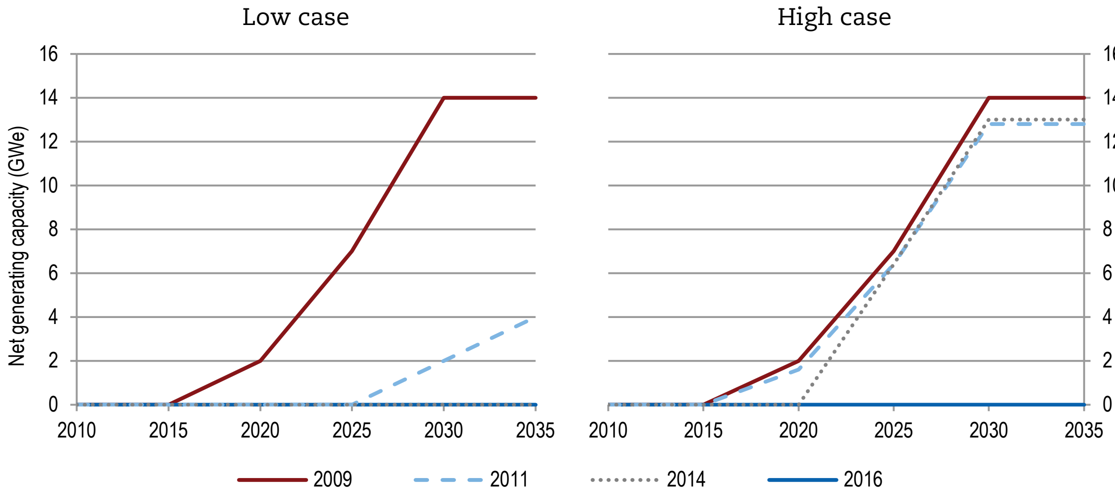
Italy

Italy is heavily reliant on imported fuels to meet over 85% of its energy needs and has high electricity prices and occasional electricity shortages. Prior to the Fukushima Daiichi accident a centre-right government elected in 2008 set in motion processes to bring about the removal a 20-year ban on nuclear power. A new national energy strategy in 2011 was expected to include rebuilding the nuclear sector, improving competition in electricity production, diversifying energy sources and reducing greenhouse gas emissions. Numerous legislative and organisational steps related to the new nuclear programme were undertaken beginning in 2008 and nuclear co-operation agreements were signed, with the goal of having the first new NPPs under construction by 2013.

Following the Fukushima Daiichi accident the Italian government put the nuclear development plan on hold for at least one year in order to reconsider the energy strategy following stress tests conducted by the European Commission. In mid-June 2011, Italians voted overwhelmingly against a return to nuclear power in a national referendum, and there does not seem to be any interest in revisiting the issue. The referendum result does not, however, restrict ongoing work on the disposal of radioactive waste, including the development of a national repository. These wastes are the product of four reactors that operated from the mid-1960s prior to a referendum that ended nuclear power in Italy following the Chernobyl accident.

The Red Book projections seem to show firm plans to re-establish nuclear capacity just prior to Fukushima Daiichi, as discussed above. A word of caution is warranted, though, as the Red Book high and low cases were taken from a single number entry in another publication – *Nuclear Energy Data 2009* (NEA, 2009).

Figure 20. Capacity in Italy: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Sweden

While actively promoting the installation of additional renewable energy sources, the government narrowly voted in favour of legislation that gave new life to the country's nuclear power programme in 2010 by allowing for the construction of replacement reactors once the existing reactors reach the end of the operational lifetime. This effectively overturned the 1980 ban on the construction of new NPPs and the phase-out of nuclear energy. The legislation specified that replacement reactors must be built on an existing site and can only begin operation once an older plant is permanently shut down. The government also made clear that it would not subsidise the development of new reactors despite the high upfront investment costs that can discourage such investments.

Although none of the ten currently operational reactors (a total of 9.7 GWe net, providing about 41% of the electricity generated in 2014) are expected to be retired from service before 2020, the legislation opened the possibility of developing the process of licensing and building new reactors, should utilities decide to do so. A second bill in the same year increased the amount of compensation paid by companies that own nuclear reactors and increased by four times the financial liability of these same owners.

In 2012, nationally owned Vattenfall, the largest Nordic utility, filed an application to build up to two reactors to replace its older units when they retire, at the same time noting that an investment decision would not be made for a number of years. In response to the application, the Swedish Radiation Safety Authority (SSM) indicated that the regulatory process may take up to 15 years in total and that regulations for new reactors would not be finalised until the end of 2014, at the earliest.

Following the Fukushima Daiichi accident, the government ordered a comprehensive review of the current reactor fleet ahead of the EU stress tests, indicating, however, that the 2010 legislative changes would not be reconsidered. In December 2012, the SSM submitted the national action plan (NAP) for the stress tests to the ENSREG. According to the NAP, NPP operators must provide the SSM possible solutions to improve safety. The activities of the NAP extend as far as 2015. In 2013, Vattenfall announced that it planned to invest USD 2.4 billion between 2013 and 2017 in modernising and upgrading its 5 most recently built units (Ringhals 3, 4 and Forsmark 1, 2 and 3) in order to continue operations for up to 60 years.

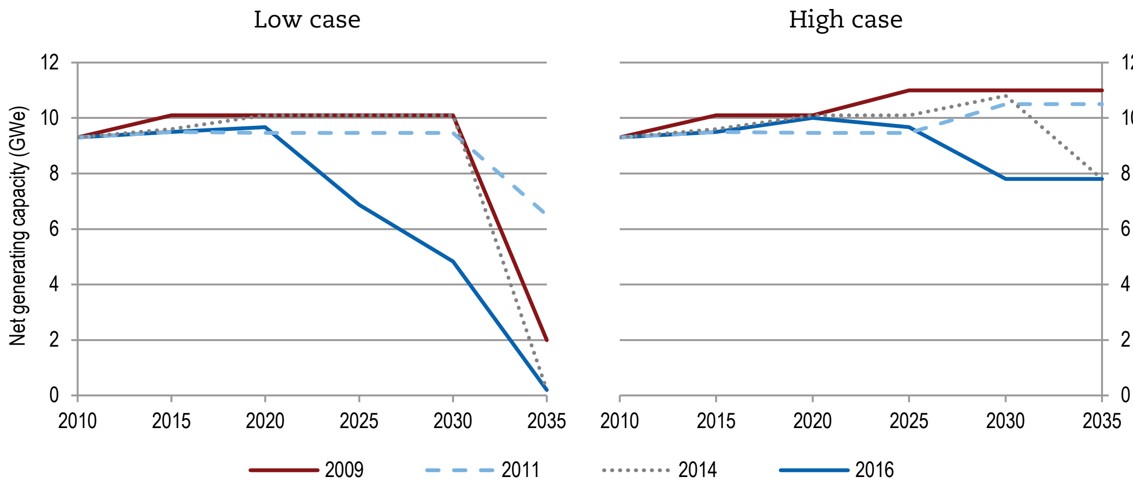
The results of an election in September 2014 brought to an end the possibility of constructing replacement reactors at existing sites, when a new coalition government set up an energy commission to drive the country towards total reliance on renewable energy sources. It indicated that current nuclear generating capacity should be replaced by renewable energy sources or made redundant by reduced demand through energy conservation. Other statements by the government noted that nuclear power needed to "bear a greater share of its economic cost" and nuclear waste fees should be increased and safety requirements further strengthened (WNN, 2014d).

In response to the proposed 17% increase in taxes from 2015, the operators of the NPPs said that older plants may have to be shut down earlier than expected because the increased taxes along with demanding and costly post-Fukushima safety upgrades reduces profitability. In November 2014, government-owned Vattenfall announced that it had been instructed to stop analysing the case for the construction of replacement reactors (Adomaitis, 2014), and in early 2015 SSM announced that it had stopped processing the application for replacement reactor construction in order to comply with the policy changes announced by the new government (NSNT, 2015).

However, in June 2016, the Swedish parliament announced an agreement to phase out over two years a tax on installed nuclear capacity and to allow the construction of up to ten nuclear reactors to replace existing plants. The agreement was described as supporting Sweden's goal to have a 100% renewable electricity system by 2040 but without requiring nuclear phase-out by that date (WNN, 2016c).

There is not much discernible change over the years in the Red Book projections until 2016, when the impacts of the policy and tax changed the outlook, which may change yet again given the recent announcement.

Figure 21. Capacity in Sweden: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Other countries in the region

A number of EU countries have maintained nuclear development plans throughout this time frame. Finland is nearing completion of its EPR at the Olkiluoto site and has continued to make progress towards construction of a VVER-1200 unit at Hanhikivi in 2018 (Milne, 2016). Hungary signed an agreement in 2014 to have Rosatom supply two VVER-1400 units at the Paks site and plans to move quickly upon resolution of European Commission concerns regarding the financial arrangements with Rosatom (WNN, 2016d). Romania continues to move forward with its plans to build two new reactors at its Cernavoda site. Poland has staffed up and strengthened its nuclear regulator, selected an owner/operator for a new nuclear plant, and narrowed its consideration to two potential sites. The project is expected to move ahead once the new Polish government, elected in late 2015, endorses the project. The United Kingdom recently completed a review of the proposed Hinkley Point C project and has given its approval for the project, to be built by French EDF with one-third of its financing from China's CGN (Moylan, 2016). The United Kingdom has maintained steady support for nuclear power since 2006, even as it went through a number of government changes. Most countries' plans appear to be largely unaffected by Fukushima Daiichi. In fact, financial factors seem to be much more influential to nuclear deployment plans.

Europe (non-EU)

Armenia

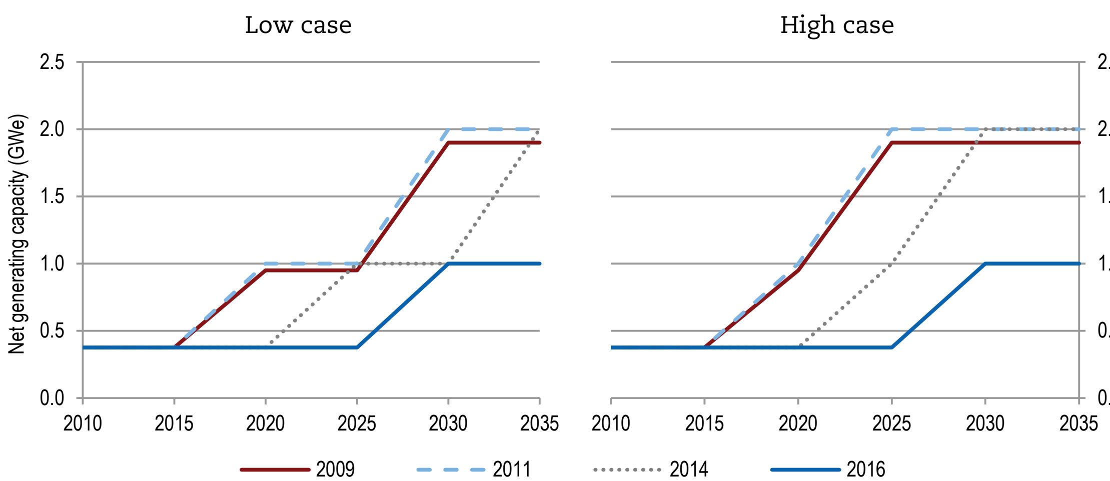
Two Russian-design reactors were connected to the grid (0.375 GWe each), one in 1976 and the second in 1980, each with a design lifetime of 30 years. Both reactors were shut down following a major earthquake in 1988. In 1995, the most recently commissioned of the two (unit 2) was brought back online to help alleviate severe power shortages the country had experienced. This reactor has continued operating, and in 2015 the Armenian-2 reactor (also referred to as Metsamor) accounted for 34% of national electricity generation.

Concerns have been expressed about the continued operation of this reactor, particularly following the Fukushima Daiichi accident, since the region is seismically active and the design has no primary containment structure. Armenia has, however, resisted efforts to close the plant, arguing that it is essential to the country's energy security and that significant resources have been directed towards safety and security upgrades (Torosyan, 2012).

In late 2014, it was reported that the government had decided to extend the operational lifetime of Armenian-2 by 10 years to 2026 given its significance in domestic energy supply, despite concerns of continued operation in a seismically active region heightened after the Fukushima Daiichi accident. An agreement was reportedly signed with Russia for a loan of USD 300 million to cover the costs of the life extension programme (WNN, 2014e).

The Armenian government announced an Energy Security Plan in July 2015 that calls for the extended operation of the Armenian-2 reactor and its replacement in 2027 with a newly constructed unit (Asbarez, 2015).

Figure 22. Capacity in Armenia: Changes in long-term projections



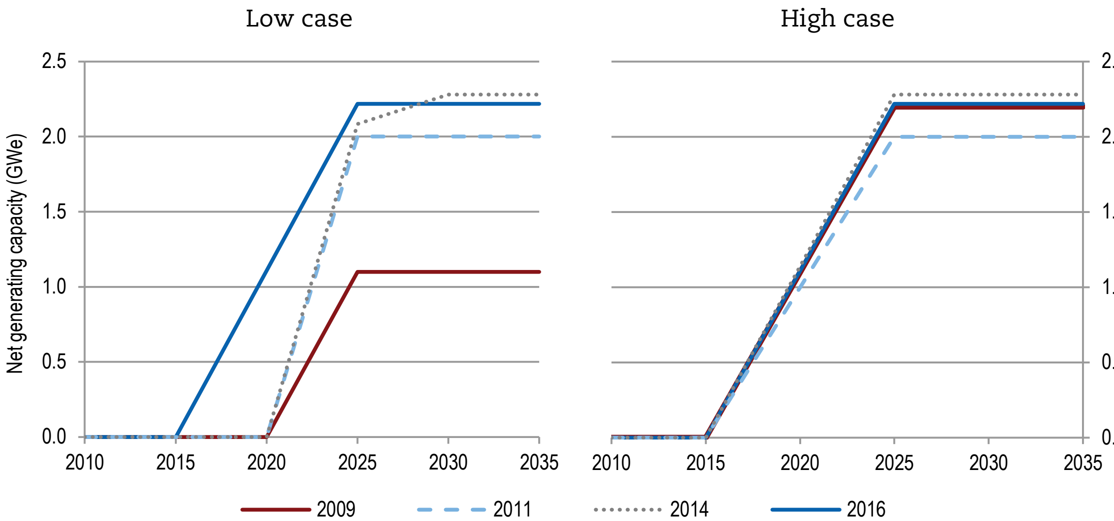
Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Belarus

The government of Belarus decided in 2007 that it would move quickly to deploy nuclear power. It was dependent on exports for over 80% of its fuel and energy resources and felt that nuclear power would greatly help its domestic energy security. Despite the Fukushima Daiichi accident, the government of Belarus continued to move towards the construction of nuclear generating capacity to meet future energy demand and to reduce greenhouse gas emissions. In October 2011, an agreement was signed with Atomstroyexport for the construction of the country's first NPP, consisting of two VVER units.

In 2012, a USD 10 billion agreement was signed with Atomstroyexport to build two 1 180 MWe VVER reactors (Belarusian 1 and 2, also referred to as Ostrovets 1 and 2), with Russian financial backing and expected completion dates in late 2018 and mid-2020 (Makhovsky, 2012). In early 2015, the project was continuing on schedule with over 3 000 Russian and Belarusian workers reportedly on-site, with more expected by the end of the year (Anon, 2015a).

Figure 23. Capacity in Belarus: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Russia

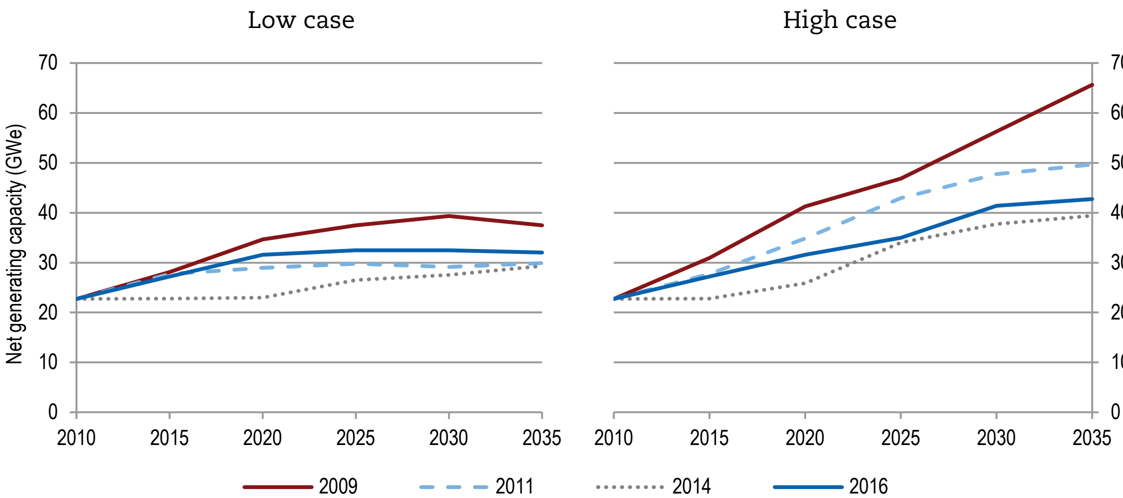
In 2015, a total of 35 operational reactors (25.4 GWe net) provided about 19% of the total electricity generated in the country and 8 reactors were under construction (6.6 GWe net combined). Recent capacity additions include the Beloyarsk 4 fast neutron reactor (0.8 GWe net) in 2015 and Rostov 3 (1.01 GWe net) in 2014.

Following the Fukushima Daiichi accident, the government ordered an urgent review of all NPP construction projects, both at home and abroad. In mid-2011, a USD 530 million safety upgrade programme was announced for additional power and water supply backup (e.g. mobile diesel generator sets and mobile pumping units) as a result of this review (WNA, 2015e). With these improvements, the government continued the implementation of a 2010 national energy strategy that envisioned the commissioning over 20 new reactors along with the continued development and eventual integration of fast neutron reactors into the fleet in order to close the nuclear fuel cycle. In August 2016, Russia announced its plans to build an additional 11 reactor units by 2030 (WNN, 2016e).

In January 2013, the nuclear safety regulator agreed to extend the operating licence of the Smolensk 1 RBMK reactor by 10 years to 2022 (for a total operational lifetime of 40 years) after an extensive modernisation programme (WNN, 2013c). In April 2014, Russia announced that the technology used to successfully resolve the graphite swelling in the Leningrad 1 reactor would be used to carry out similar work at all large RBMK reactors.

The 2014 and 2016 Red Book high case projections were considerably lower than for 2009 and 2011. New capacity plans were scaled back considerably over the 2008-2012 period due to economic factors, highlighting again the difficulty in the attribution of quantitative impacts. Given that context, the low case reductions do not appear significant.

Figure 24. Capacity in Russia: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Switzerland

In 2007, the Swiss government announced that the five operating reactors should be replaced at the end of their operational lifetime and in 2008 proposals to build three replacement reactors were filed. However, the replacement reactor process was abruptly terminated following the Fukushima Daiichi accident. Three days after the accident, the government suspended the approval process and ordered a safety review of the existing five operational reactors (Bellona, 2011). Later that same year, the Cabinet cancelled the approval process for replacement reactors and proposed that all five existing reactors be shut down at the end of 50 years of operation (i.e. between 2019 and 2034).

After thorough reviews (EU stress tests plus a national test programme), the safety authority (the Federal Nuclear Safety Inspectorate, or ENSI) concluded that since the cooling of cores and fuel rod storage pools would remain operational in the event of an earthquake followed by flooding, the power plants could remain in service. It nonetheless issued a series of requests in order to complete the analysis and the five operating plants were required to demonstrate that they were adequately protected against incidents caused by extreme weather events.

The five operating reactors in Switzerland (3.3 GWe) typically produce about 35-40% of the electricity generated in the country and two units (Beznau and Gösgen) also supply district heating. To ensure that Switzerland has a competitive and secure supply of electricity when nuclear power is brought to an end, a phased transformation of the energy system is planned. A reduction of energy and electricity consumption, combined with an increased share of renewable energy sources and the introduction of combined heat and power fossil fuel plants is expected to fill the gap created by the phase-out of nuclear power. Modernisation and enlargement of the electricity grid is also considered necessary to accommodate increased input from variable renewable energy sources.

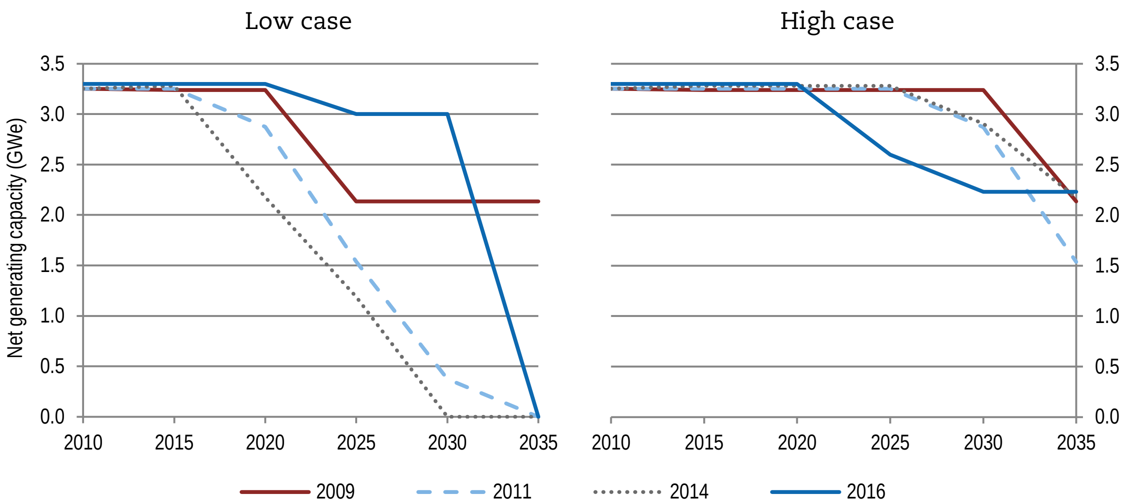
Switzerland's proposed new energy policy ("Energy Strategy 2050"), which documented the government's plan to phase out nuclear power, was submitted to parliament in 2014 after a year of discussion. The draft decree would allow NPP operators to submit a concept plan for extending the long-term operation of their reactors for a further ten years. The National Council and Council of States were initially divided on the planned phase-out, with the National Council supporting it and the Council of States objecting. More recent reports indicate that a new post-election National Council in 2016 may be more in alignment with the Council of States and less willing to impose policy limits on the reactors if the regulator deems them safe. In November 2016, a referendum proposing to more quickly phase out nuclear power was rejected by voters, and in May 2017 the implementing legislation for the Energy Strategy 2050 is to be put to a vote.

In 2013, it was announced that the Mühleberg reactor would be permanently shut down in 2019 (rather than 2022 as originally planned), owing to uncertainty surrounding the political and regulatory environment (WNN, 2013e). This announcement was made after legal proceedings that avoided closure of the plant in 2013. The owner now plans to invest some USD 225 million in various projects to 2019, including the implementation of measures to improve cooling water supply and cooling systems for the used fuel storage pools. Implementation of these measures will reportedly exceed the safety margin stipulated by the ENSI.

In early 2015, the ENSI ordered NPP operators to ensure that off-site emergency measures are strengthened through the establishment of off-site emergency centres and that the necessary equipment and staff are kept available at an off-site location in order to respond rapidly to an emergency. By the end of 2015, NPP operators were required to submit documentation to ENSI outlining how these measures would be achieved (WNN, 2015e).

In the Red Book projections, the possibility of increasingly early reactor retirements seems to be present in the low case.

Figure 25. Capacity in Switzerland: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

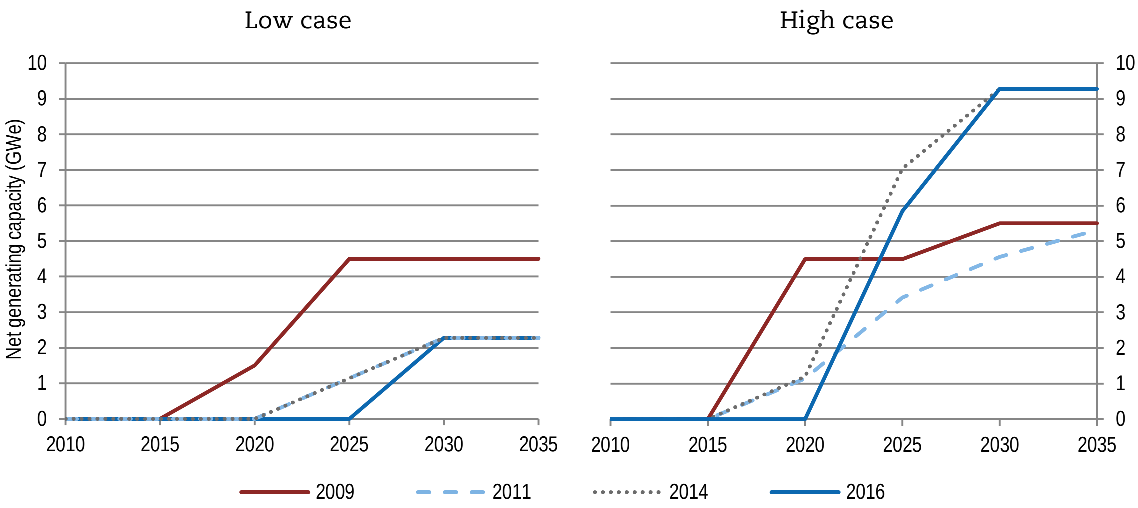
Turkey

Following the Fukushima Daiichi accident, the government stated that it was determined to move ahead with its nuclear development programme despite the regional earthquake hazard. Turkey's fast growing economy faces rapidly escalating electricity demand and nuclear energy is regarded as cost-effective means of meeting demand while reducing greenhouse gas emissions. Meeting future energy demand with domestic sources like nuclear power will help reduce annual expenditures of as much as USD 60 billion on fuel imports that currently provide 70% of the country's energy needs (Dalton, 2015).

In 2009, after an unsuccessful bidding process for the construction of the country's first NPP, an intergovernmental agreement (IGA) was signed with Russia to build four VVER 1.2 GWe units using its "BOO" model at the Akkuyu site on the Mediterranean coast at an estimated cost of USD 20 billion. Under the terms of the IGA – the first developed on the BOO model – Russia will retain the majority share of ownership of the NPP during its entire lifetime of operation and will provide fresh fuel, take back spent fuel for reprocessing, train personnel and decommission the facility (Rosatom, 2013). Construction was expected to begin in 2014 with commissioning of the four units planned for 2019, 2020, 2021 and 2022. However, in 2015 it was announced that work had fallen behind schedule by at least 18 months owing to shortcomings with the two submitted versions of the environmental impact assessment and other process delays, and the first reactor would not likely begin operating until 2022 at the earliest (Coskan and Parnuk, 2015).

Negotiations with countries and companies supplying nuclear reactors are also underway for a second NPP at the Sinop-İnceburun site on the Black Sea coast. The government has stated that its goal is to have this project under construction and both the Akkuyu and Sinop NPPs in operation by 2023. In late 2014, it was reported that Westinghouse, the State Nuclear Corporation of China and the Turkish power company Elektrik Üretim AŞ had signed an agreement to begin exclusive negotiations to develop and construct a four-unit NPP in Turkey, now planned near Igneada. As well as reactor technology (likely the AP-1000 or the Chinese CAP-1000 and CAP-1400 derivatives), the agreement also covers life cycle activities including operations, fuel, maintenance, engineering, plant services and decommissioning (Anon, 2015).

Figure 26. Capacity in Turkey: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

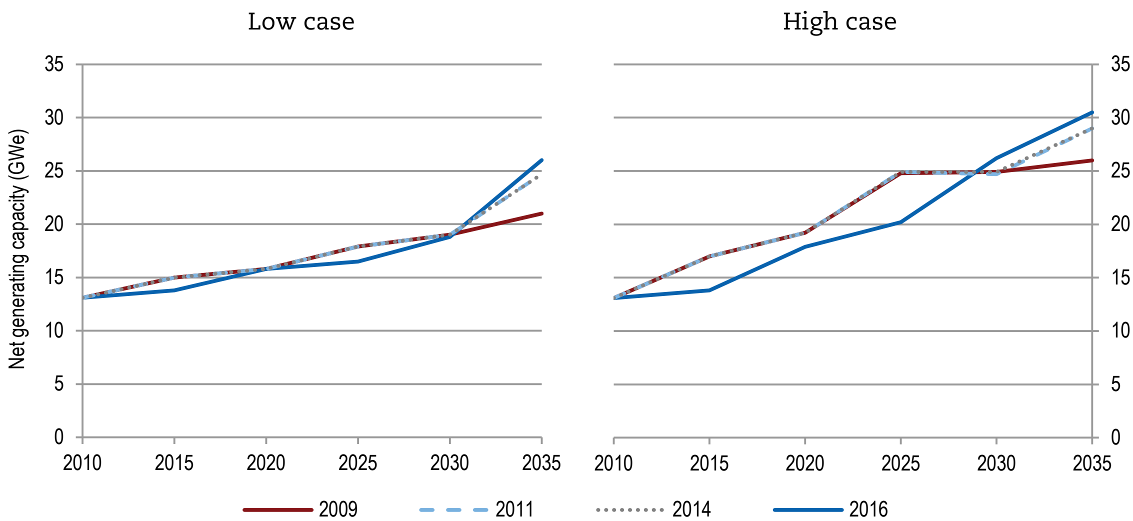
Ukraine

With 15 operational reactors (a combined installed capacity of 13.1 GWe net) supplying 56% of the electricity generated in 2015, the nuclear programme in Ukraine is a crucial component of national electricity supply. The Ukrainian government strategy calls for the nuclear share to be retained through 2030 at the current level of 45-50% of total national electricity generation. This is expected to require the construction of 12 new reactors, 10 of which with a capacity of about 1.5 GWe net, along with life extensions of reactors in the existing fleet. Following the Fukushima Daiichi accident, there is no indication that the government intends to change the nuclear development strategy.

Two partially constructed reactors (Khmelnitski 3 and 4) would add a total of 1.9 GWe generating capacity to the grid when completed. Construction of these two reactors originally began in the mid-1980s, but was suspended in 1990. In 2010 and 2011, agreements were signed with Russia to provide financing for the design, construction and commissioning of the two reactors (Bellona, 2010). Work to complete the reactors was expected to begin in 2015. However, in 2014, the Prime Minister of Ukraine said the Ukraine intends to revoke the agreement with Russia and to seek an alternative partner for the construction of the two units (WNN, 2014f). In September 2016, Energoatom and KHNP announced that they had signed a Memorandum of Understanding to complete construction of the two units (WNN, 2016f).

The Red Book estimates are high, given the actual 2015 capacity of 13 GWe, but are consistent in that the government has not wavered in its support of nuclear power.

Figure 27. Capacity in Ukraine: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Other countries in the region

Albania had reportedly been considering the construction of reactors but, following the Fukushima Daiichi accident, decided to postpone these plans in order to consider all potential environmental impacts of deploying nuclear energy.

North America

Canada

In 2015, 19 operational reactors supplied 17% of electricity generated in Canada and more than 50% of the electricity in Ontario, the province in which all but one of the operational reactors is located. All reactors in Canada are the CANDU heavy water type.

Following the Fukushima Daiichi accident, the government of Ontario stated that it remained committed to a policy of nuclear energy supplying 50% of the province's electricity, even though plans for new build had been suspended after an unsuccessful bidding process in 2009. A major refurbishment programme for select operational reactors in Ontario is underway in order to extend the operational lifetime of these units, although the number to be refurbished will depend on costs and efficiencies of the initial refurbishment projects. In January 2016, Ontario Power Generation, operator of the Pickering and Darlington nuclear plants, announced its intention to conduct refurbishments and submit licence applications to extend the operation of the plants to 2024 and 2055, respectively (Power Technology, 2016).

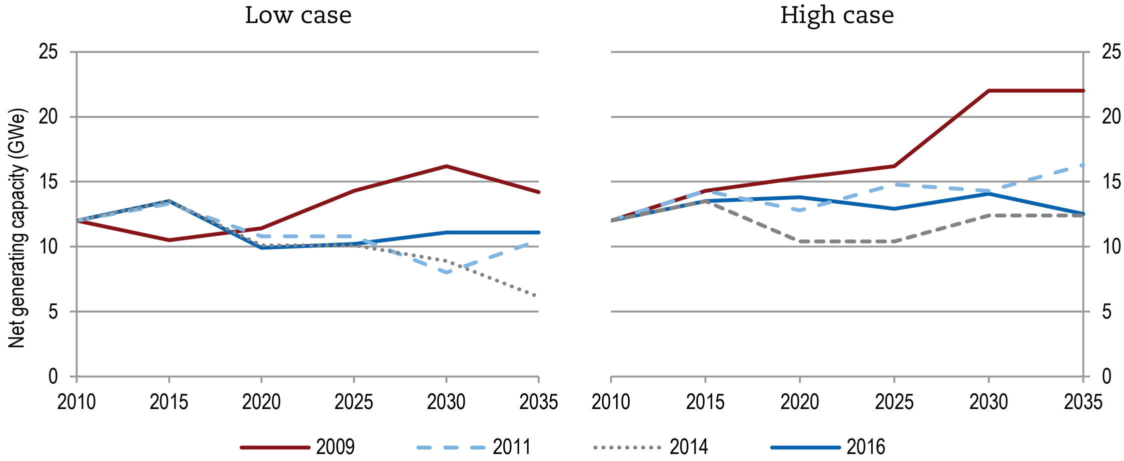
Immediately after the Fukushima Daiichi accident, on-site staff from the national nuclear regulator, the Canadian Nuclear Safety Commission (CNSC), performed walk downs at Canadian NPPs to verify the licensees' emergency preparedness for external hazards and severe accidents. A CNSC Task Force was then formed to conduct a major review of all nuclear facilities in Canada to examine the response of NPPs to external events of greater magnitude than previously planned for and the licensees' capability to respond to such events. The task force focused on severe natural hazards such as earthquakes, tornadoes or hurricanes that may cause a prolonged loss of electrical power that in turn could inhibit the operator's ability to continue cooling the reactors. It also addressed the need for an integrated response capability. The task force report released in October 2011 confirmed that all nuclear facilities in Canada are able to withstand and respond to all credible external events, such as earthquakes (CNSC, 2011). Nonetheless, the task force recommended certain design enhancements for severe accident management to prevent unfiltered releases of radioactive materials and control capabilities for hydrogen and other combustible gases. It also recommended that the adequacy and survivability of equipment and instrumentation be evaluated and improvements be implemented wherever practicable.

In August 2013, the CNSC released an integrated action plan report on lessons learnt from the Fukushima Daiichi accident, after consideration of all public and stakeholder recommendations and comments received during public consultations, as well as the outcomes of two independent reviews (CNSC, 2013). In order to address the 13 recommendations made by the task force, CNSC activities focused on strengthening reactor defence-in-depth and enhancing emergency response, as well as improving the regulatory framework, communications and public consultation and international collaboration.

The results of these actions and activities did not bring about the closure of any reactors, but a number of technical and procedural measures have been undertaken to improve safety and accident response capabilities. According to the CNSC, the Fukushima Daiichi accident caused the regulatory focus to shift from accident prevention to accident prevention and mitigation. Some of these recommended enhancements have already been implemented and others will be completed in the near future.

The Red Book projections for Canada after 2015 were NEA/IAEA estimates and in the 2014 document cite the Ontario government cancelling plans for addition Darlington units in 2013 and the decommissioning of Pickering units starting in 2020, which now has been delayed.

Figure 28. Capacity in Canada: Changes in long-term projections



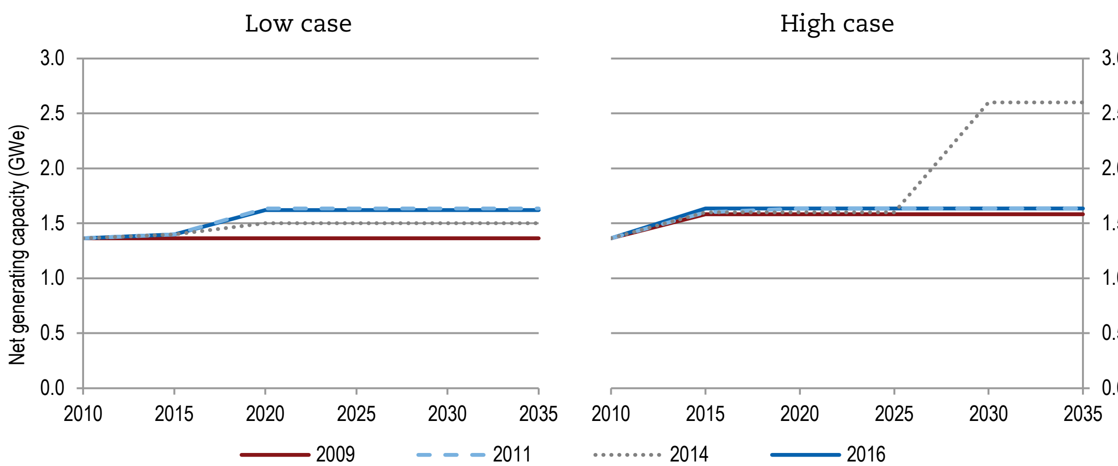
Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Mexico

A four-year USD 600 million refurbishment and uprate programme was performed on the two BWRs (a combined capacity of 1.4 GWe net) at Mexico's only NPP, Laguna Verde. These two reactors accounted for almost 7% of the electricity generated in Mexico in 2015. Following the Fukushima Daiichi accident, stress tests (similar to those in the EU) concluded that the NPP could cope with an event similar to that which occurred at Fukushima Daiichi. However, the Mexican regulatory body indicated that it would continue following actions taken internationally (SENER, 2013).

It was reported in November 2011 that the Minister of Energy announced that Mexico had abandoned plans to enlarge nuclear generating capacity, which in the high case would have seen the addition of as many as ten additional reactors (Rodriguez, 2011). Although this announcement was made after the Fukushima Daiichi accident, the declining interest in nuclear power had more to do with the discovery of significant natural gas reserves in the Gulf of Mexico as opposed to safety concerns with nuclear power. The discovery of these gas fields had reportedly caused the government to change all previous decisions on energy to reflect the increasing importance of natural gas. As recently as September 2015, the Ministry of Energy was quoted as considering additional nuclear capacity (Reuters, 2015).

Figure 29. Capacity in Mexico: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

United States

In 2015, 99 operational reactors contributed about 19% of the total electricity generated in the United States. The construction of four AP-1000 reactors (4.4 GWe in total) officially began in 2013, with two units each at Vogtle (Georgia) and Virgil C. Summer (South Carolina), and the first of these reactors expected to be in operation by 2020 at each site. The Tennessee Valley Authority (TVA) completed construction of the Watts Bar 2 reactor in Tennessee, a construction project resumed in 2007 after being stopped in 1988, and the reactor (1.2 GWe) started commercial operation in 2016.

As of August 2016, the US Nuclear Regulatory Commission (NRC) had granted licence extensions for an additional 20 years (to a total of 60 years lifetime operation) to 82 of the 100 operational reactors and was in the process of reviewing applications for 12 additional units (NRC website). NRC regulations do not limit the number of licence renewals and the industry is reportedly preparing applications for continued operation beyond 60 years.

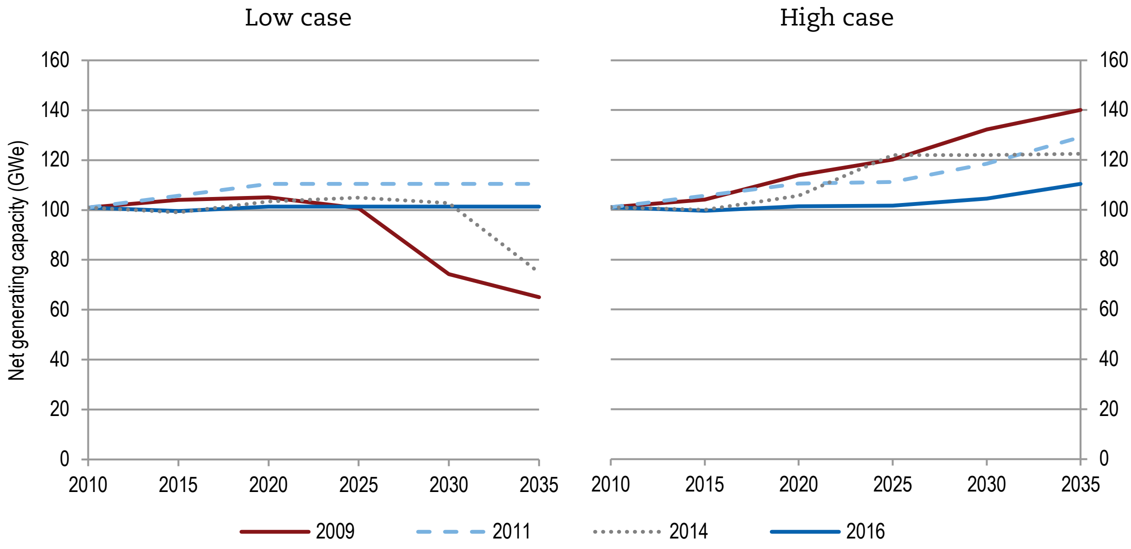
In response to the Fukushima Daiichi accident, the NRC and the nuclear industry initiated an immediate co-ordinated response as well as long-term actions to assure the safety of all operating and planned reactors. Following this review, the NRC stated that the existing fleet can continue operating safely. Orders were issued to enhance safety and these enhancements needed to be completed by 31 December 2016.

The nuclear industry, through the US Nuclear Energy Institute, developed a “diverse and flexible coping capability” (or FLEX) strategy to mitigate the effects of severe natural phenomena and to take steps to achieve safety benefits quickly. Implemented in 2012, the FLEX strategy was informed by the industry’s response to the 11 September 2001 terrorist attacks in the United States.

The NRC has also proposed rulemaking language for strengthening and integrating on-site emergency response capabilities. The final rule is likely to address accident mitigation strategies, integration of accident mitigation procedures, identification of command and control roles during an accident, conduct of drills and exercises, training and the inclusion of severe accident situations in examinations for reactor operators. The NRC is also addressing some aspects of the recommendations, such as a potential policy statement on defence-in-depth, through an overarching Risk Management Regulatory Framework initiative.

Although it began before Fukushima Daiichi, 17 reactor closures have been announced since 2011, mostly citing difficult market prices and systems but sometimes with repair costs contributing to the calculation. The current low price of natural gas and the financial incentives to renewables, such as production tax credits and renewable portfolio standards, make it quite difficult for nuclear plants to compete in liberalised markets. Nuclear utilities have pushed for financial “recognition” of the contribution that nuclear power makes in providing a baseload source of carbon-free electricity. This message may be starting to take hold, as the New York Public Service Commission recently approved a Clean Energy Standard that places a value on the carbon emissions avoided by non-emitting electricity sources, such as nuclear (PowerMag, 2016). Illinois took similar action later in the year to keep the Fitzpatrick and other plants operating, but not the Indian Point plant (WNN, 2016h). On this news, it appears that 4 of the 17 projected closures will be avoided.

Figure 30. Capacity in the United States: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Central and South America

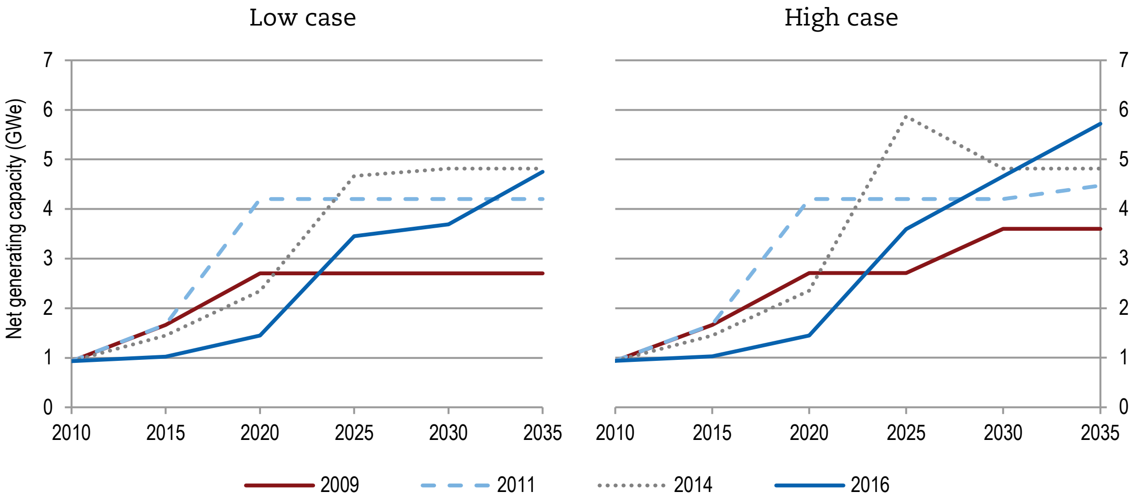
Argentina

Three operational PHWRs (Atucha 1, 2 and Embalse; 0.34 GWe, 0.7 GWe and 0.6 GWe, respectively) supplied 4.8% of national electricity production in 2015. The Embalse reactor (CANDU 6) is undergoing refurbishment to increase power output by about 6% and extend the life of the reactor by an additional 25 years. Construction of Atucha 2 was completed in 2014, following the revival of the project in 2006 after work was suspended in 1994. The completion of Atucha 2 was expected to raise electricity production from nuclear power to about 10% of the national generation total and eliminate the need to burn USD 1.5 billion of oil for electricity production (WNN, 2014g). Construction of the CAREM-25 small modular reactor was officially started in 2014. This domestically designed PWR prototype is being built with 70% of the components and related services sourced from Argentinean companies.

These recent developments are part of a USD 3.5 billion strategic plan for the nuclear power sector announced in 2006 to support government goals of diversifying electricity generation, reducing fuel imports and promoting energy sovereignty to address a number of issues in the electricity sector, including rising demand. The plan included the completion of Atucha 2 construction and the refurbishment of Atucha 1 and Embalse. Plans to develop national capabilities in the front end of the fuel cycle (mining uranium, conversion, enrichment, fuel fabrication and the reactivation of heavy water production) are also being implemented. Following the Fukushima Daiichi accident, the government indicated that it intended to continue with its nuclear development plan.

The Argentine government is also considering the construction of another two reactors to provide additional electrical generating capacity. It has been in discussion with a number of possible vendors from Canada, China, France, Japan, Korea, Russia and the United States. In 2014, a co-operation agreement was signed with Russia for the possible construction of Atucha 3 that included the intention to provide funding for the project (WNN, 2014h). Also in 2014, an agreement with the CNNC was signed towards the construction of an Atucha 3 pressurised heavy water reactor that includes long-term financing. This agreement has reportedly progressed into a commercial framework in 2015 to oversee the development of a number of contracts to construct the reactor. An agreement between the Presidents of Argentina and China was also signed for the co-operative participation in the construction of another reactor, in this case an ACP-1000 (Yao, 2015). The agreement reportedly includes maximisation of local materials and services and the supply of enriched uranium and fuel assemblies throughout the life of the reactor.

Figure 31. Capacity in Argentina: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Brazil

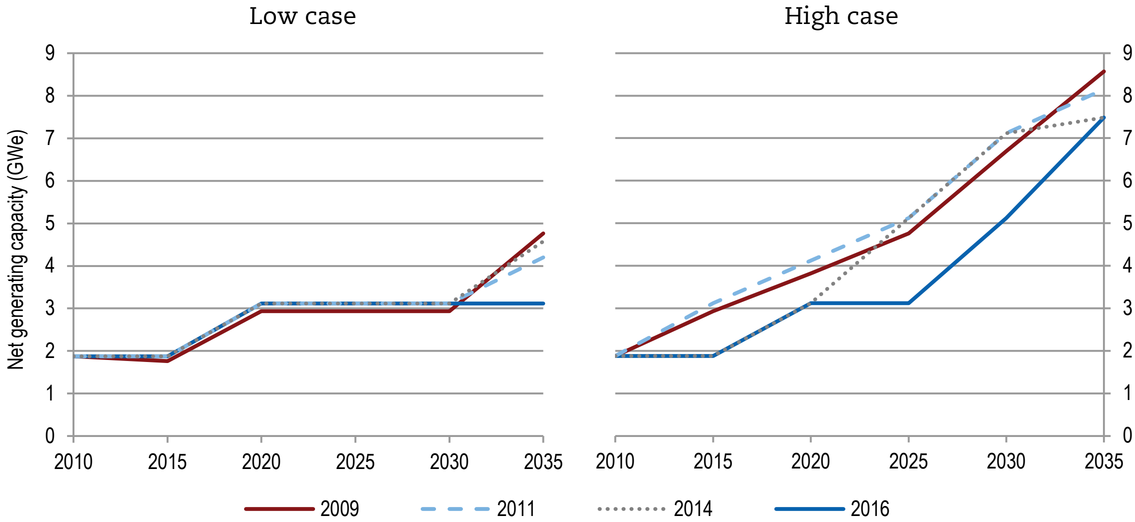
Two reactors (Angra 1 and 2; 0.6 GWe net and 1.3 GWe net, respectively) were operational in 2015, accounting for about 3% of the electricity generated in Brazil. Construction of the Angra-3 reactor (1.2 GWe net) was restarted in 2010, after being suspended in 1986, with completion of the USD 5.1 billion project expected in 2018.

In 2012, a report issued by government-owned Electronuclear, the agency responsible for the construction and operation of NPPs in Brazil, stated that the Angra 1 and 2 reactors had existing characteristics (e.g. a secondary emergency backup power system installed in a secure area and a passive cooling system) that made them already better prepared for an accident like Fukushima Daiichi. The report was based on the company's own safety inspections that focused on station black out, flooding and fire hazards. Despite the declared state of preparation, additional safety measures were planned to increase protection against flooding. Strengthened checks and guidelines were also implemented (Yang, 2012).

In 2013, a USD 150 million Fukushima Response Plan was announced that includes 30 studies and 28 projects to be undertaken through 2016 to improve site protection against assorted risks, increase cooling capabilities and reduce possible problems associated with radioactive contamination in the event of a serious accident (Zaragoza, 2013b). The total cost of the Response Plan includes about USD 40 million already spent by Electronuclear to improve safety as noted above.

Largely dependent on hydropower for electricity generation (70-75%), which is considered difficult to expand, controversial (particularly in the Amazon basin) and is susceptible to drought, the government has shifted near-term focus to the installation of renewable energy generating sources along with slight increases in coal and natural gas fuelled generation. Following the Fukushima Daiichi accident, the government of Brazil is reportedly continuing with a nuclear development programme, although the speed at which it is proceeding has slowed, and the scale of the possible expansion has been reduced (Ortiz, 2013). Nonetheless, the construction of an additional four reactors by the early 2030s (increasing installed nuclear generating capacity to as much as 6 GWe) in order to help meet rising electricity demand remains under consideration. In support of this programme, domestic enrichment capacity and fuel production capabilities are being expanded, as is uranium mining. The long-term goal of these activities is for Brazil to meet increased national demand for nuclear fuel and potentially international demand.

Figure 32. Capacity in Brazil: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Other countries in the region

A number of countries currently without nuclear power generating facilities have been considering the development of this capability, including Bolivia, Chile, Cuba, Uruguay and Venezuela. In 2014, the President of Bolivia announced that a high-level commission had been created to oversee the development of a nuclear reactor and in the following months nuclear co-operation agreements were signed with Argentina, France and Russia. Given the risk of strong seismic events in Chile, the government announced after the Fukushima Daiichi accident that it intended to reconsider nuclear development while monitoring the response of the Japanese authorities to the accident. Venezuela has also reportedly put its nuclear development plans on hold. Recently passed legislation in Uruguay promotes development of renewable energy sources, putting nuclear development plans on hold at least for the time being.

Africa

South Africa

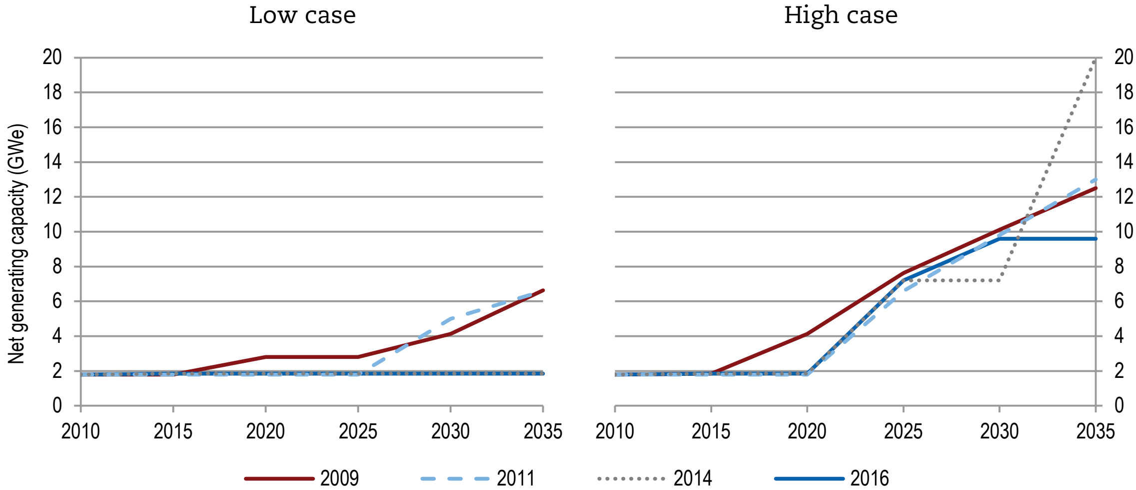
The only two reactors on the continent are located in South Africa. In 2015, these two units (Koeberg 1 and 2) accounted for about 5% of the total electricity generated in the country. Coal-fired plants dominate, providing about 90% of the country's electrical generating capacity. In order to meet rising electricity demand, address chronic and costly electricity shortages and reduce carbon emissions, South Africa's state-owned utility Eskom (producer of about 95% of South Africa's electricity) has planned for a fleet of up to 12 reactors since as early as 2007.

Following the Fukushima Daiichi accident, the government indicated that it would reconsider its nuclear development plans and reassess the safety of its nuclear facilities. Stress tests similar to those undertaken in the EU were carried out with the assistance of the IAEA. Results of these tests showed that the nuclear installations (the small Safari 1 materials test reactor and medical radioisotope producer and the Koeberg NPP) are adequately designed, maintained and operated and that no findings warranted the curtailment of operations or questioning the design margins of the facilities (NNR, 2012). A number of potential improvements to further reduce beyond design basis risks were identified, principally related to the testing and management of equipment required in severe accident response and the robustness of accident measures and emergency planning arrangements for beyond design basis events. The Koeberg NPP was found to be a robust design that is able to withstand potential earthquakes and tsunami-induced flooding. Following the test results the government stated that it is convinced that nuclear power would remain a necessary part of the energy strategy and plans to extend the operating life of the Koeberg NPP from 30 to 40 years were announced.

In 2011, the South African government approved the 2010 "Integrated Resource Plan" (IRP) that envisions increased reliance on nuclear generating capacity combined with development of capacity from renewable resources. Under the plan, electricity generation by nuclear power would be increased to 23% of national supply by 2030 through the addition of 9.6 GWe of nuclear generating capacity, with the first unit to be operational by 2023. The required build-up of generating capacity also includes gas-fired generation and renewable energy sources as a way of meeting demand and reducing dependence on coal-fired electricity generation, although coal will nonetheless remain responsible for half of the electricity generation in South Africa in 2030. The IRP also includes provisions to lower demand by energy efficiency initiatives.

Although controversial, the IRP remains government policy, but the schedule has been delayed. In late 2013, a revised IRP with lower energy demand projections indicated that the nuclear power component plan would not be needed until 2025. However, the government reaffirmed its commitment to increasing nuclear generating capacity, with the Department of Energy receiving Cabinet approval in December 2015 to request proposals for up to 9.6 GWe of nuclear capacity (WNN, 2015f). In November 2016, the department announced a slower build rate due to lower power demand projections and government budget deficit concerns, with the first unit online by 2037 and 20 GW of new capacity by 2050 (Vacchiatto, 2016).

Figure 33. Capacity in South Africa: Changes in long-term projections



Source: The 2009, 2011, 2014 and 2016 editions of *Uranium: Resources, Production and Demand*.

Other countries in the region

Although no other countries in Africa have NPPs at this time, several have expressed interest in developing nuclear power for electricity generation and desalination in recent years, including Algeria, Egypt, Ghana, Kenya, Morocco, Namibia, Niger, Nigeria, Tunisia and Uganda. Both Egypt and Nigeria reaffirmed plans to install nuclear generating capacity after the Fukushima Daiichi accident, with Egypt recently signing an agreement with Russia (WNN, 2015g) and the Nigerian government announcing plans to add nuclear capacity of one to four GWe (Vanguard article). In April 2016, the IAEA delivered a final Integrated Nuclear Infrastructure Review (INIR) report on Kenya's progress towards building a first plant, and the Kenyan government reiterated its support for deploying nuclear power. Ghana created the Ghana Nuclear Power Programme Organization (GNPPO) in 2012 to lead the development of a nuclear programme, and its parliament passed legislation in 2015 establishing a nuclear regulatory body. Ghana is expecting an IAEA INIR mission in 2017 ahead of a planned 2018 government decision whether to deploy (Ghana News Agency, 2015; WNN, 2016g).

In 2012, a commission to co-ordinate and promote the development of nuclear energy in Africa established by the African Union became fully operational. South Africa has agreed to host the African Commission on Nuclear Energy (AFCONE) in Pretoria.

Summary

The Fukushima Daiichi accident has had an effect on energy policies and programmes, and, as expected, these effects were much more acute in Japan. All Japanese reactors were eventually stopped and were made to undergo review by the newly formed Nuclear Regulatory Agency. As of September 2016, five reactors have been allowed to restart under the new regulatory framework, but only three reactors are currently operating. In 2015, the Japanese government adopted a policy for nuclear energy to comprise 20-22% of electricity generation in Japan in 2030. This is a strong statement of commitment to the continued importance of nuclear power. However, in light of the Third Strategic Energy Plan of 2010, which outlined a roughly 50% nuclear share in 2030, there has been an unquestionable impact.

Beyond Japan, most countries with existing nuclear power plants conducted thorough safety reviews of the plants. The European Union required a formal review (or “stress tests”) of all reactors in its member countries, and some neighbouring countries also participated. The United States implemented a similar formal review process for its operating reactors. As a result of these reviews, no reactors were required to shut down for safety reasons, but additional improvements were identified.

In terms of policies, European countries reinforced existing plans. Belgium and Germany, which had pre-existing nuclear phase-out plans, accelerated those plans. Other European countries reaffirmed their commitment to nuclear power, while those that were actively pursuing additional nuclear capacity either maintained that commitment or even increased future projections in some cases (e.g. Finland, Hungary, Poland and Turkey). Italy is the primary exception, where the government was strongly moving towards re-establishing nuclear power but completely abandoned those plans through a binding public referendum, which took place just months after the accident. France passed a law in 2015 after considerable public debate that limited nuclear capacity to its current level. The debate and outcome was certainly influenced to some degree by the events in Japan.

Asia has followed a similar trend, with most countries continuing in their pre-existing positions, even though public perception of nuclear energy has suffered. Apart from Japan, the other concrete exception to this trend is Chinese Taipei, which decided to phase out its six operating reactors and to mothball a reactor that had completed construction, as well as a second reactor that was largely complete. Progress on these plants has been halted for two years, awaiting a referendum that has not yet taken place and will decide their ultimate fate.

The remainder of the world has seen little substantive change. No effects have been identified in relation to existing plants or those under construction in the Americas, aside from costs to incorporate additional safety equipment. The Middle East and Africa have seen only increased plans and construction.

Looking at long-term projections before and after March 2011 provides a more quantitative indication of the changes that have taken place, but a number of factors make it difficult to attribute the cause of the changes. For example, a number of unrelated regional financial crises were occurring in the 2007 to 2009 time frame, which contributed to a global economic downturn. This new economic environment caused a number of countries and companies to re-evaluate the deployment of large,

capital-intensive expenditures. It also followed a period of quite optimistic projections of nuclear expansion, which continued through the 2011 publication of *Uranium: Resources, Production and Demand*. There is also a distinguished "lag" in many of the projections over time, likely the result of two things – a tendency to optimistically estimate the time to site, license and construct a nuclear unit and delays as development programmes were put on hold to conduct system-wide safety and hazard evaluations.

Overall, outside of Japan, there appears to be little ultimate change to energy policies, particularly quantitative, directly attributable to Fukushima Daiichi events. In general, countries with previous commitment to nuclear power remained committed, and those with plans to phase out nuclear power accelerated those plans. A few countries that seemed to be actively considering the adoption of nuclear power have delayed or deferred such decisions. Economic and market factors, environmental or climate change goals, and natural resource constraints, however, seem to be much larger drivers of deployment decisions and projections in the six years since March 2011.

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Impacts of the Fukushima Daiichi Accident on Nuclear Development Policies

The Fukushima Daiichi nuclear power plant accident has had an impact on the development of nuclear power around the world. While the accident was followed by thorough technical assessments of the safety of all operating nuclear power plants, and a general increase in safety requirements has been observed worldwide, national policy responses have been more varied. These responses have ranged from countries phasing out or accelerating decisions to phase out nuclear energy to countries reducing their reliance on nuclear power or on the contrary continuing to pursue or expand their nuclear power programmes.

This study examines changes to policies, and plans and attempts to distinguish the impact of the Fukushima Daiichi accident from other factors that have affected policymaking in relation to nuclear energy, in particular electricity market economics, financing challenges and competition from other sources (gas, coal and renewables). It also examines changes over time to long-term, quantitative country projections, which reveal interesting trends on the possible role of nuclear energy in future energy systems.

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