


International Energy Policy in the Aftermath of the Fukushima Nuclear Disaster

An Analysis of Energy Policies of the U.S., U.K., Germany, France, Japan, China and Korea

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INTERNATIONAL ENERGY POLICY IN THE AFTERMATH OF THE FUKUSHIMA NUCLEAR DISASTER:
An Analysis of Energy Policies of the U.S., U.K., Germany, France, Japan, China and Korea

Final Report

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EXECUTIVE SUMMARY

The disaster at the Fukushima Daiichi nuclear power plant in Japan on the 11th of March, 2011 has raised concerns about the future of the nuclear industry globally. On the global scale, the impacts of the accident on the nuclear power industry are expected to be largely dependent on how governments respond to it. Responses have been varied. Whereas some governments have adopted measures to radically redefine their nuclear and energy policies with strong responses restricting nuclear use and even nuclear moratorium, others have chosen the middle path by questioning the safety of nuclear plants and pushing for higher nuclear safety standards within their country but not completely ending their nuclear programs. Still others have responded mildly and continue to pursue a path of nuclear power development and expansion. This report explores the impact of the disaster on energy and electricity policy in six major energy-consuming nations: Japan, Germany, the United States, China, the United Kingdom, and France. It also considers the impact of the accident for South Korea's current and projected energy policy paths.

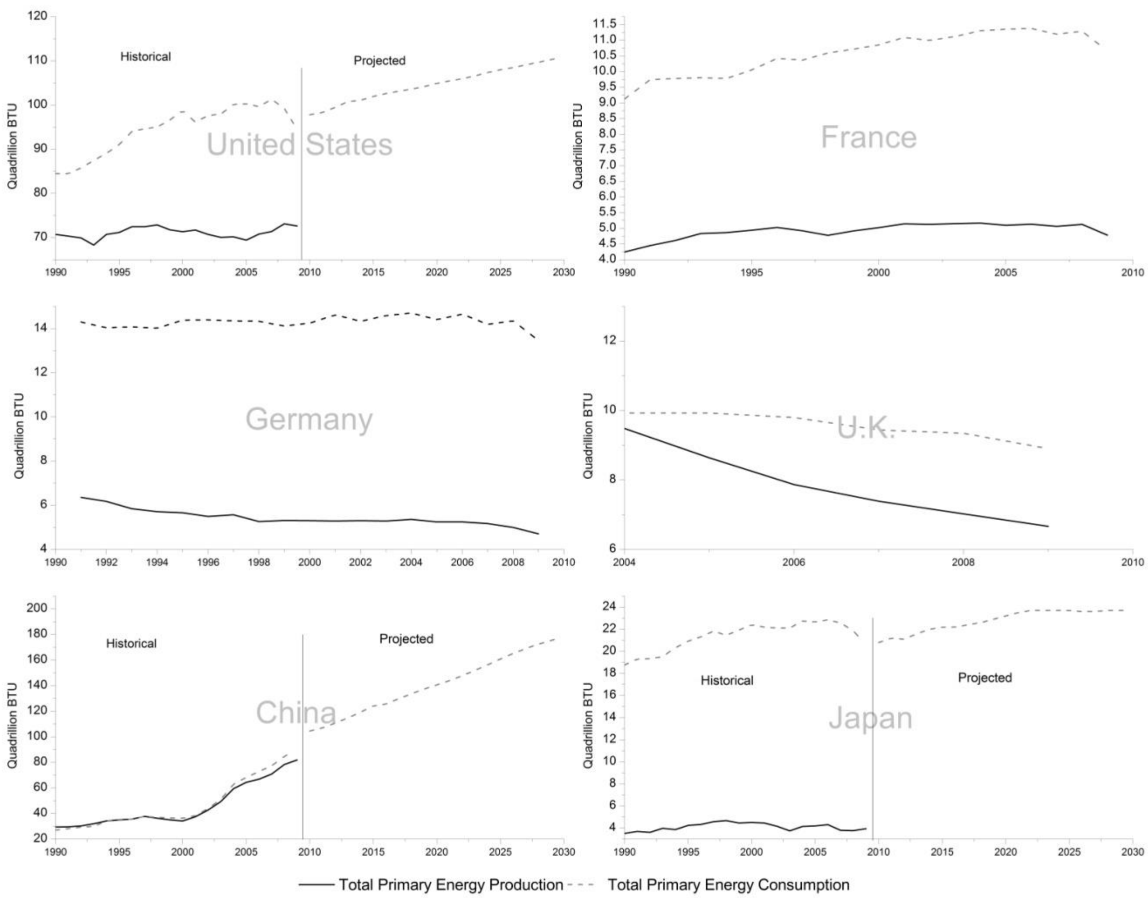
Part one explores the direct responses of each of the six focal nations to the accident as well as long-term changes to their nuclear policy initiatives. Japan and Germany saw strong pressure from civil society and citizen groups that catalyzed sweeping changes in government. Germany imposed an immediate moratorium on its oldest nuclear facilities and ultimately reinstated a nuclear phase-out plan that it only recently reversed. Japan saw governmental changes as well, and a nuclear phase-out plan has been established in the government's new energy policy in response to democratic pressure. This policy breaks with its previous path which sought to expand the share of nuclear power to 50% of the nation's total electricity generation capacity.

The United States and China demonstrated strong initial concerns but neither country has changed its long term nuclear policies. The U.S. reviewed the safety status of its existing nuclear fleet and reinvestigated the safety plans of proposed new reactor sites. However, the Nuclear Regulatory Commission still approved permits for new reactors despite objections made by the then-current NRC chairman about the sufficiency of the safety plans to account for lessons from Fukushima. Long-term nuclear policy remains a viable option for the U.S., although the decision to abandon plans for a nuclear waste storage facility under Yucca Mountain in Nevada is a notable event for the nation's nuclear policy. China imposed a moratorium on all sites under construction and all proposed nuclear plants until safety tests could be completed. It quickly approved sites under construction, but safety tests on proposed sites took much longer. The government imposed a cap on approval of new plans to slow the pace of development and ensure adequate safety issues are accounted for.

The United Kingdom and France both pursued safety reviews as well, but their governments quickly announced support for nuclear power following the accident in Japan. The U.K., which has a rapidly aging fleet and had plans to build a new generation of advanced reactors, resumed its plan to build. Despite some financing troubles for one of the proposed projects, the U.K. found alternative financing and is committed to building new nuclear capacity. France, too, announced support for its nuclear industry, which comprises over 70% of its total generating capacity. France also has a dynamic nuclear technology and operating industry as the home of one of the largest nuclear companies in the world, AREVA. However, following the election of François Hollande, France is exploring a new energy policy that will reduce its nuclear generation share to 50%. This is not a reaction to the Fukushima accident directly, but rather a part of the policy platform of Mr. Hollande's government.

Part two explores more general changes to energy, electricity and alternative energy policies in each nation prior to and following the Fukushima accident. Although the accident incited drastic changes in some industries in a few countries, long-term energy and electricity generation mix projections have largely remained the same. In some cases, such as the United States and China, post-Fukushima electricity demand and supply projections have actually increased. The figure below depicts primary energy supply and production. In the U.S., China, and Japan, long-term energy demands are projected to increase. Trends in France, U.K., and Germany have been steady or declining for many years, but with altered nuclear policies it is possible that primary fuel demand will rise at least in the short-term.

FIGURE E-1: PRIMARY ENERGY SUPPLY AND DEMAND IN MAJOR ENERGY-CONSUMING NATIONS



Electricity policies and projections largely mirror the trends in primary energy supply and demand. Post-Fukushima scenarios in the United States and China show vastly growing electricity consumption, and only a high carbon fee scenario poses any chance at significantly reducing BAU projections. Even low nuclear scenarios do not demonstrate any significant decrease in current nuclear consumption in either country by 2030. Germany and Japan obviously show radical changes in their share of nuclear and renewables following Fukushima, while the U.K. and France will largely maintain their current shares of nuclear and their current levels of demand.

TABLE E-1: PRE- AND POST-FUKUSHIMA ELECTRICITY SCENARIO PROJECTIONS, 2010-2030

Country	Pre- or Post-Fukushima	Scenario (2030)	Fossil fuels (TWh)	RES (includes hydro)(TWh)	Nuclear (TWh)
Germany	Pre-Fukushima	BAU (2030)	246	225	0
	Pre-Fukushima	Alternative (2030)	198	239	0
U.S.	Pre-Fukushima	BAU 2010 (2030)	3,273	852	886
	Post-Fukushima	BAU 2011 (2030)	3,140	684	914
France	Pre-Fukushima	Vision 2020 (2020)	74	123	460
	Post-Fukushima	BAU 2011 (2030)	31	170	426
U.K.	Pre-Fukushima	2010 BAU (2025)	369	56	9
	Post-Fukushima	2011 BAU (2025)	383	63	8.8
	Post-Fukushima	2011 BAU (2030)	380	65	8.8
China	Pre-Fukushima	BAU (2030)	6,392	1,377	426
	Pre-Fukushima	Low Carbon (2030)	4,122	1,960	1,073
Japan	Pre-Fukushima	2010 BAU (2030)	420	240	540
	Post-Fukushima	0 % scenario (2030)	650	350	0
	Post-Fukushima	15 % scenario (2030)	550	300	150
	Post-Fukushima	20 % scenario (2030)	500	300	200
	Post-Fukushima	25 % scenario (2030)	500	250	250

Renewable and energy efficiency policies do demonstrate some variation, but they largely represent policy dynamics that were ongoing prior to the accident. The United States, China, the U.K. and France were all pursuing expansion of renewable energy and energy efficiency. China had already demonstrated record improvements in energy intensity, the U.S. was benefitting from expanding efficiency and renewable markets through funding and programs initiated with American Reinvestment and Recovery Act money, the U.K. was in the midst of establishing large onshore and offshore wind farms to enhance its renewable generation mix, and France was pursuing a feed-in tariff regime to do the same. At the time of the accident many of these policies were ongoing or ramping up, and following Fukushima few experienced any drastic changes.

Japan and Germany were already global leaders in energy efficiency and renewable energy deployment by the time of the accident. Germany had largely demonstrated the viability of solar and wind production and the effectiveness of feed-in tariffs through its growing renewable energy industry and supply. Japan, too, was pursuing strong clean energy policies. Following the nuclear crisis, the main change in either nation's policy was that it accelerated its targets for renewable energy or energy efficiency to offset phased-out nuclear capacity. Although a concrete plan to increase clean energy remains somewhat vague, both maintain their commitments to increase renewables and efficiency.

Part 3 conducts an analysis of South Korea to compare its experience with those of the six nations in Parts 1 and 2. Following the Fukushima accident, the Korean government acted swiftly to monitor radiation levels, ensure safety at its own nuclear facilities, open lines of communication with the media and Korean citizens, and address future safety concerns through a reorganization of its primary nuclear regulatory body. Its long-term policy seems to maintain a role for nuclear power. Korea has a dynamic economy that has grown quickly. It has been in the process of implementing a number of structural and policy changes to its energy and electricity markets. The government committed to an expanding share for nuclear power, energy efficiency and renewable energy in its last national energy plan, and nuclear power will have a large share of the future generation mix in the next energy basic plan to be proposed in 2013. Moreover, Korea is an exporter of nuclear technology, and its support for it may be due in part for its desire to establish itself in the global nuclear marketplace.

Despite Korea's support for nuclear power, the technology remains an expensive capital option for its power generation. The research for this report explored energy options for Korean development. The terms of reference in the research contract called for CEEP to conduct its analysis under the assumption Korea observed a near-term moratorium on the construction of new nuclear plants. CEEP did evaluate the assumption; rather it applied the assumption in its modeling as stipulated in its contract.

Under the assumption of a moratorium, CEEP conducted a scenario analysis to 2030 to project the energy and cost paths of three scenarios. Under the BAU Scenario, energy efficiency and renewable energy grow according to historical rates while nuclear power, coal, and natural gas capacity grow based on historical rates and planned capacity additions by the government. A Low Carbon Scenario (LCS), which proposes enhancing the diffusion of energy efficiency measures and technologies compared to the BAU, depicts a path in which a large share of existing and planned coal capacity can be phased-out. A Low Nuclear Scenario (LNS) projects a path with enhanced deployment of renewable energy technologies that allows Korea to forego a portion of its planned nuclear capacity in addition to elimination of its coal plants. The figures and tables on the following pages depict the generation mix and cost comparison for each of these paths for Korea.

Pursuing these alternative paths allows Korea to reduce its reliance on coal and nuclear energy while also meeting its requirements for the future. The alternative paths also can help the government meet carbon emissions reductions targets by 2030. A cost analysis based on the projections depicted above led to additional conclusions about the viability of the alternative paths. Based on the average OECD costs of building and maintaining new nuclear, coal, and natural gas capacity as well as the falling costs of energy efficiency and renewable energy technologies, the alternative paths that enhance efficiency and renewables can be implemented at a lower lifecycle cost than the nuclear power and coal power dependent BAU. Additional benefits from lowered CO_2 emissions costs further improve the cost effectiveness of the alternatives. The table below summarizes the cost comparisons.

FIGURE E-2: KOREA'S ELECTRICITY SUPPLY MIX UNDER THE BAU SCENARIO

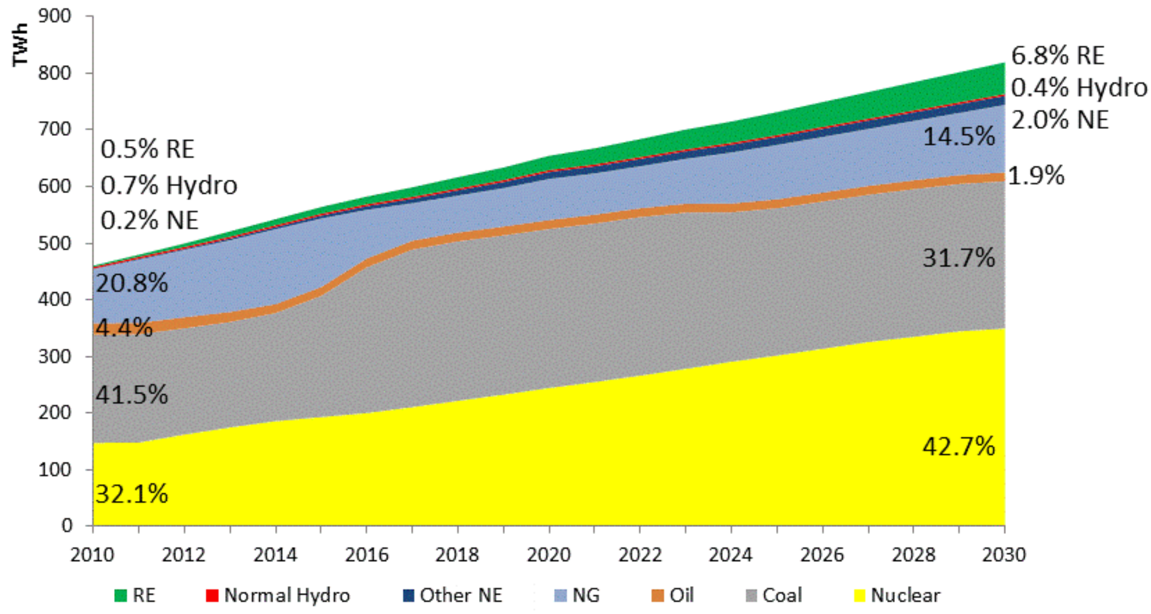


FIGURE E-3: KOREA'S ELECTRICITY SUPPLY MIX UNDER THE LOW CARBON SCENARIO

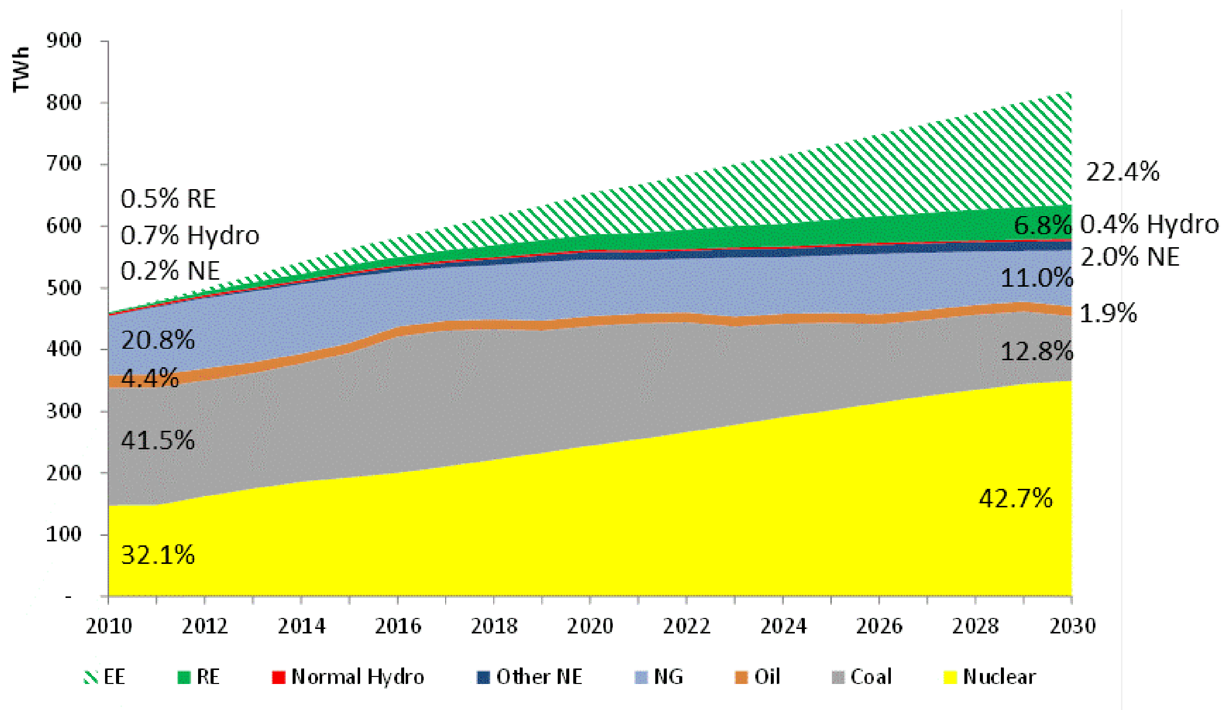


FIGURE E-4: KOREA'S ELECTRICITY SUPPLY MIX UNDER THE LOW NUCLEAR SCENARIO

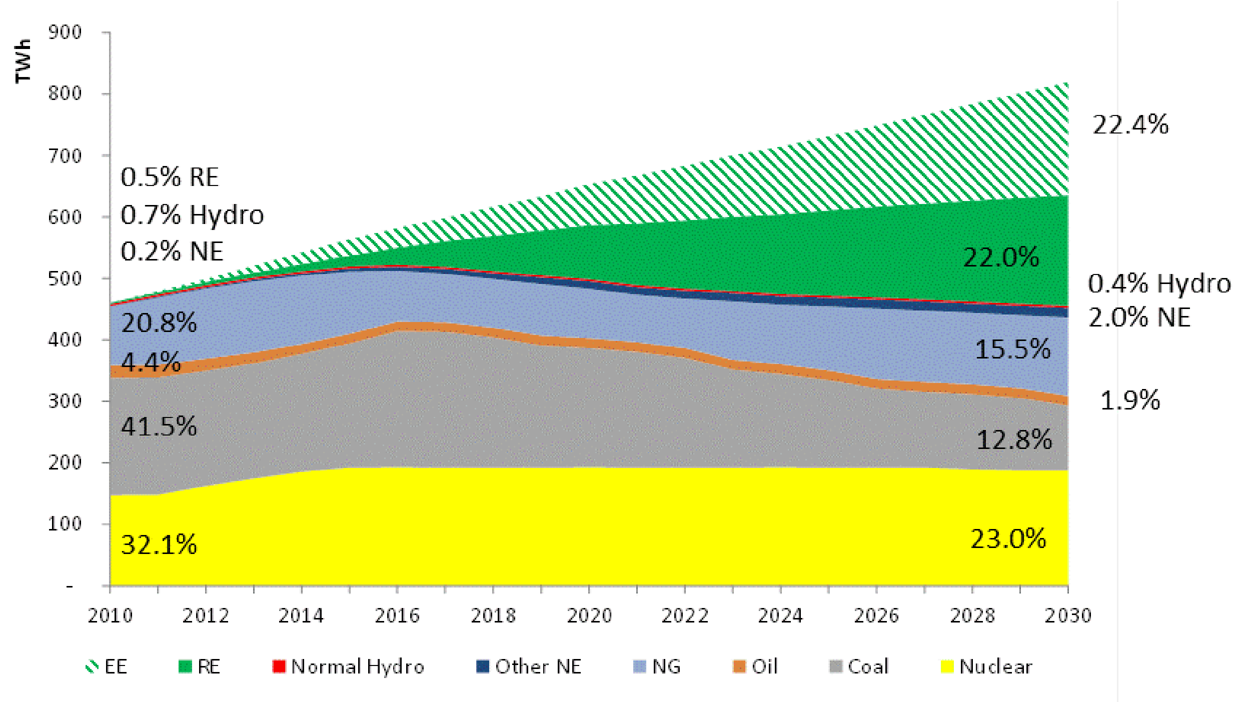


TABLE E-2: COST COMPARISONS FOR THE THREE KOREAN SCENARIOS (million US $s)

	BAU		LCS		LNS	
Basis of Investment Cost Values	Korean	OECD	Korean	OECD	Korean	OECD
Coal	12,036	31,035	7,236	18,200	7,236	18,200
Nuclear	52,585	146,196	52,585	146,196	12,519	32,364
NG	8,041	14,855	8,041	14,855	8,041	14,855
EE	-		30,199		30,199	
Renewables & NE	66,976		66,976		169,324	
Total Investment Costs	**139,638**	**259,062**	**165,037**	**276,426**	**227,319**	**264,942**
Δ Investment Costs Compared to BAU scenario	**-**	**-**	**25,399**	**17,364**	**87,681**	**5,880**
O&M and Fuel Cost Savings Compared to BAU	-		-39,488		-65,022	
Additional O&M Costs for Renewables Compared to BAU	-		-		21,990	
Δ Total Costs Compared to BAU Scenario	**-**	**-**	**-14,089**	**-22,124**	**44,649**	**-37,152**

In order to pursue either of the alternative paths (i.e., LCS and LNS), Korea should enhance its support for energy efficiency and renewable energy. It has already taken important policy steps to do so, but participation in bi-lateral, regional and international partnerships will allow it to augment the benefits of efficiency and renewable energy. Both represent new market opportunities as well. These paths are technologically, financially, and politically feasible, and they also provide significant benefits in the form of improved energy security and lower carbon emissions.

PART 1. THE VULNERABLE NUCLEAR PROMISE

1.1 Responses to the Fukushima Daiichi Accident

The disaster at the Fukushima Daiichi nuclear power plant in Japan on the 11th of March 2011 has raised concerns about the future of the nuclear industry globally. Impacts of the accident on the nuclear power industry are expected to be largely dependent on how governments respond to the accident. Such responses have varied. Some governments have adopted measures to radically redefine their nuclear and energy policies. Germany, for example, has elected to schedule retirement of the country's plant stock. Other governments have taken a more moderate approach. Countries such as the U.K are pushing for improved safety, but still plan to maintain their current nuclear programs.

This section of the report explores the responses to the Fukushima accident by government, the nuclear industry and civil society in six countries: The United States, the United Kingdom, Germany, France, Japan and China.

1.1.1 United States

Government

After the Fukushima accident, the U.S. government conducted a review of nuclear safety at 104 nuclear reactors and 65 plants. Officials emphasized the importance of safety and security of nuclear power generation in the light of Japan's accident. The Obama administration called for and continues to favour what it calls a "balanced approach of combining nuclear power with fossil fuel and clean. On March 16, 2011, Dr. Steven Chu, former Department of Energy Secretary, reiterated the administration's nuclear R&D and new reactor construction policies. He emphasized that the administration would take lessons from Japan's event and support expansion of nuclear power. President Obama engaged with Chilean officials to advance a nuclear program in Chile on March 18, 2011 (Barrionuevo, 2011).

After the nuclear accident in Japan, the Nuclear Regulatory Commission (NRC) reviewed safety procedures at the country's nuclear plants and started to monitor the nuclear accident in Japan. Two experts were dispatched by the NRC at an early stage of the Fukushima accident to discuss the incident with regulatory counterparts in Japan. Eleven NRC members gave technical support. The NRC set up an internal task force to study the accident and to review national regulations. The task force issued a report, *Recommendations for Enhancing Reactor Safety in the 21st Century*, released in July 2011, which includes measures for enhancing safety and emergency responses and improving safety of extended operation of nuclear power plants (Miller *et al.*, 2011). The NRC adopted short- and long-term actions to improve nuclear power plant safety in the U.S (NRC, 2011).

In summary, the U.S. government focused on safety improvements in nuclear power plants, with particular attention paid to cooling procedures of operating reactors and enhanced safety design for newer plants.

Industry

The nuclear industry in the U.S. established a Fukushima Response steering committee consisting of the Electric Power Research Institute (EPRI), the Institute of Nuclear Power Operation (INPO), and the Nuclear Energy Institute (NEI). They adopted a 'joint leadership model' to facilitate cooperation between the committee and industry groups. This committee identified nuclear safety as a top priority. In 2011, the committee issued a report, *The Way Forward: U.S. Industry Leadership in Response to the Accidents at the Fukushima Daiichi Nuclear Power Plants*, which includes recommendations for improvements to nuclear safety based on lessons from the accident. The report also developed a set of guidelines for responding to a nuclear incident (NEI, 2011), and the nuclear power industry discussed an investment plan of $1 billion to set up a regional repository of emergency response equipment. Under the NRC's direction after the Fukushima accident, the U.S. nuclear industry began to review the safety of reactors (Wingfield, 2011).

Civil Society

Several NGOs and environmental groups in the U.S. have historically opposed nuclear power, but have made little progress in light of the financial and institutional advantages enjoyed by the industry. In 2010, the American University School of Communication disclosed that the nuclear industry had spent over $600 million lobbying the federal government, and donated more than $60 million directly to candidate campaigns between 2000 and 2010 (Pasternak, 2010). The Fukushima accident galvanized opposition groups, however, providing both publicity and momentum to the anti-nuclear movement.

"Beyond Nuclear," an anti-nuclear power consortium, launched a "Freeze our Fukushima's" campaign in 2011, pressing for the shutdown of all Mark I boiling reactors, the same type of reactors involved in the Fukushima accident (Beyond Nuclear, 2011). The Union of Concerned Scientists has been critical of the U.S. response, arguing that the voluntary reforms enacted by the nuclear industry since the accident fail to protect against "beyond-design-basis events," such as natural disasters or terrorist attack (UCS, 2012a). The group published a set of 23 recommendations to strengthen regulations governing reactor safety, spent fuel storage, and emergency preparedness. The group also urged the nuclear industry to place more value on human life and provide meaningful public participation in decisions related to nuclear power (UCS, 2011).

The Civil Society Institute conducted a survey in March, 2011, that showed more than 50% of Americans were against construction of new nuclear reactors in response to the crisis. About 78% of the respondents said renewable energy and improvement of energy efficiency could substitute for nuclear energy. A second survey, also conducted in March, 2011 by the Pew Research Institute, about 52% of the respondents were against nuclear energy (Ehreiser, 2011).

Later, these numbers approached previous levels of support for nuclear power. A survey conducted in September, 2011, by Bisconti Research Inc. revealed that 62% of respondents agreed with using nuclear energy and 35% of respondents were against nuclear energy. Also, the survey showed that about 82% of respondents believed that lessons had been learned from Japan's accident, and 67% of Americans thought that the government should put more focus on nuclear plant safety. About 67% of respondents supported the expansion of existing nuclear power plants and 28% were against the policy (WNA, 2011a).

1.1.2 United Kingdom

Government

The initial government response to the Fukushima disaster came from the Office of Nuclear Regulation (ONR), an agency of the U.K. Health and Safety Executive. Immediately after notification by the Japanese of the incident, all nuclear site licensees were required to provide site operation information on plant safety. The requested information included:

- The robustness of plant cooling systems in normal and emergency conditions.
- The ability of plants to withstand seismic events and the availability of systems for detecting such events and initiating appropriate counter actions.
- The ability of plant systems to maintain safe operating conditions with the occurrence of unforeseeable events such as sudden flooding.
- The potential for hydrogen and other combustible gases release from plants under normal and emergency conditions and the availability of robust systems for detecting these gases and initiating the necessary protective actions (ONR, 2011).

On March 14, 2011, the U.K. Secretary of State for Energy and Climate Change mandated the British Chief Inspector of Nuclear Installation, Michael Weightman, to study the Fukushima accident and the implications it had for the U.K.'s nuclear industry. The September 2011 review sought to identify lessons for enhancing the safety of the U.K. nuclear industry.

According to the report, since the U.K. is far removed from any seismically active tectonic boundaries, the likelihood of suffering an earthquake of the same magnitude is minimal. Likewise, a study carried out after the occurrence of the 2004 tsunami offered further support of the low likelihood of exposure to waves generated from submarine seismic activity (ONR, 2011).

The scope of the review was limited to nuclear safety and emergency response. Other issues pertaining to nuclear power were considered outside the purview of the reviewers. The report focused expressly on technical issues relating to "external hazards, radiological protection, reactor physics, severe accident analysis, human factors, management of safety, civil engineering, electrical engineering, nuclear fuel, spent fuel storage and emergency arrangements" (ONR, 2011). Recommendations were made for further action by the nuclear power industry to follow the 'principle of continuous improvement'; that as far as is reasonably practicable, nuclear operators should conduct periodic reviews and implement technical improvements to reduce risk and promote safety.

The U.K. government retained a pro-nuclear stance even after the Fukushima accident. The government review concluded that there was "no reason for curtailing the operation of nuclear power plants or other nuclear facilities in the U.K." (ONR 2011: vii). The U.K. government declined to curtail the development of nuclear power, but it recommended that appropriate measures be put in place to ensure the safety of nuclear power plant operations especially in the event of unforeseeable natural or other disasters.

Industry

No noticeable changes occurred in the U.K. nuclear energy market following the Fukushima disaster. In its report, *Global Nuclear Fuel Market: Supply and Demand 2011-2030*, the World Nuclear Association projected that nuclear power will experience "very little noticeable impact from events at Fukushima" (WNA, 2011b). In the U.K., like China, India and South Korea, the prospect for the further development and expansion of nuclear energy is expected to remain high.

Civil Society

Significant reaction to the Fukushima incident came from anti-nuclear activist groups like the Stop Nuclear Power Network and Greenpeace. These groups saw the accident as catalyst for the U.K. government to re-evaluate its position on expanding the role of nuclear energy. The Stop Nuclear Power Network, for instance, was instrumental in organizing rallies calling for an end to the use of nuclear energy and a subsequent shift to cleaner, decentralized energy sources derived from renewables.

In August 2011, Greenpeace sued the U.K. government for its failure to address additional safety concerns, seeking to forestall future construction of nuclear power plants (Greenpeace U.K., 2011). According to Greenpeace, even though the government review identified areas of concern that merited further research, the U.K. government interpreted the report's conclusions as a 'green light' to expand its nuclear fleet (Greenpeace, 2011). Greenpeace continues to argue that the British government has ignored the safety implications of the crisis for the continued operation of nuclear power plants in the country.

1.1.3 Germany

Government

In March, 2011, Chancellor Angela Markel announced that seven nuclear power plants constructed prior to 1980, with a capacity of 8.4 GW, should be shut down because of the event in Japan. Following a popular surge in anti-nuclear sentiment, the government announced its desire to phase out all reactors by 2017. The government approved licences for the construction of new coal and gas power plants and expanded its plans to install wind power energy. The revised policy raised concerns about additional GHG emissions, but the government expects that energy efficiency improvements and a heavier reliance on renewable energy will offset the GHG emissions from new fossil fuel plants.

Chancellor Merkel created an Ethics Commission to analyze the impacts a nuclear phase out, including the ramifications on energy supply security. The commission included former politicians, church representatives and researchers. Chancellor Merkel also sought to form a German Reactor Safety Commission to assess the nuclear power plants in Germany in light of lessons learned from Fukushima

(Vogel, 2011). Due to increasing anti-nuclear pressure, the Federal Cabinet approved a policy package called Energy Turnaround. The package included a phase out of all nuclear power plants by 2022 and draft bills to help facilitate the transition to renewable energy sources (Lang, 2011a). Germany has already begun to shift its sources of generation. Shares of renewable and lignite-fired power have increased, and gas and bituminous coal generation has remained unchanged (Siemens, 2012).

Industry

When the nuclear phase-out decision was announced in 2010, Germany's major utility companies expressed strong objections. In March 2011, RWE, one of the major utility companies, asserted that the requirement to shut down all nuclear plants would be difficult to achieve. The country's major grid manager, E.ON objected to the decision to phase out nuclear power, claiming that the "premature shutdown of its nuclear power plants constituted an infringement of its fundamental rights of property and occupational freedom" (Lang, 2011b).

Germany faces significant challenges. It hopes to achieve a nuclear phase-out by 2022, while simultaneously limiting carbon emissions. Furthermore, there is a possibility that a portion of German energy will be provided by foreign sources, threatening the profits of German-based utilities and nation's overall energy security (CEZPsp.PR; Gloystein, 2011).

Civil Society

The nuclear disaster at Chernobyl stimulated public concern in Germany over the advisability of relying on nuclear power. When the tsunami struck the Fukushima nuclear reactor, although thousands of miles from the country, German civil society responded immediately, objecting strenuously to the country's persistent reliance on nuclear power.

In regional elections held in the southern state of Baden-Wurttemberg and in the northern city-state of Bremen, the anti-nuclear Green Party won an overwhelming majority over their conservative counterparts, the Christian Democratic Union. With such strong anti-nuclear sentiments among the public, Chancellor Merkel reversed plans to extend the life of existing nuclear plants, electing instead to close them much earlier. Dr. Claudia Kemfert, an energy professor at the Hertie School of Governance in Berlin, was quoted in the *New York Times* as saying that in Germany, political groups, civil society organizations and faith groups all oppose nuclear power (Dempsey, 2011). Such consensus against nuclear power has not been repeated in the West, but the challenge to nuclear power is widening in much of Europe, the U.S., and Canada.

1.1.4 France

Government

To understand the state of the French energy industry, it is necessary to understand the evolution of nuclear power within the nation (Topcu, 2011). The decision to 'go nuclear' in France was taken in 1974 in response to the international oil crisis. The pro-nuclear lobby argued that energy independence would give France a competitive advantage in industry. Over the next several decades, the country built up the largest share of nuclear power in the world: more than 75% of its total generation mix. Nuclear power became a part of the French national identity. As a result, institutional inertia has impeded a significant shift away from nuclear dependence. After the Chernobyl disaster, France was the only European nation to continue reactor construction, and in 2006, they began construction on two 'third generation' designs in Flamanville and Penly. As a signatory of the Kyoto Protocol, France views its nuclear history and future nuclear ambitions as a source of national pride, placing the nation ahead of the climate curve.

Former President Nicolas Sarkozy, a steadfast supporter of nuclear power, stated that nuclear retrenchment would be like "cutting off an arm," adding that "the accident in Japan is not a nuclear accident; it was due to a tsunami. A tsunami in central France would be a novelty" (Le Monde, 2011). Later, Sarkozy reiterated his position, stating that a phase out of nuclear energy would cost France its industrial competitiveness and energy security, pulling the nation back into the "Middle Ages" (Elysee, 2011). Most left-leaning parties called for an outright withdrawal from nuclear power, while the Communist Party and the National Front (far right) expressed their continued commitment to a nuclear power regime. During a Socialist Party presidential debate prior to national elections, frontrunners Martine Aubry and now President François Hollande discussed nuclear options, the former favoring a gradual nuclear phase-out while the latter favored a reduction to 50% of electric power by 2025 (Dive, 2011).

In 2012, the Sarkozy government lost power to a coalition of the left-leaning parties. Socialist François Hollande was elected to the presidency in April 2012. A coalition of parties supportive of the president won a majority of seats in the National Assembly two months later. The defeat of the conservative government was not itself a direct result of the Fukushima accident, but concern over nuclear safety surely enhanced the political clout of the anti-nuclear parties in France.

Prior to the political turnabout in France, the energy sector was in the process of expanding its nuclear fleet, with new generation reactors scheduled for construction throughout the country. The Fukushima accident lent strength to the changing political winds in France. The new governing coalition has pledged to reduce the share of electricity generated from nuclear power to 50% by 2025.

The current governing coalition remains fragile, however. Events since the 2012 election, such as economic stagnation in the European Union, have relegated the debate about nuclear power to the margins of political discussion. The future role of nuclear power in France will depend on whether the ruling coalition will be able to overcome existing institutional inertia in the energy sector.

Industry

In the immediate aftermath of the Fukushima accident, then Prime Minister Francois Fillon asked the French Nuclear Safety Authority (ASN) to conduct safety audits on all French nuclear facilities. This was in line with European proposals, spearheaded by the European Nuclear Safety Regulators Group (ENSREG), which called for safety checks and "stress tests" on the entire European nuclear fleet (ASN, 2011; ENSREG, 2011). The Ministry for Ecology, Energy, Sustainable Development and Planning supported this approach, stating in a press release that France must "demand the highest level of nuclear safety" using a "transparent methodology" for assessment (MEESDP, 2011).

Electricité de France (EDF), the electricity service provider in France, stated that it would work with the ASN to carry out all the necessary stress tests on its reactors. EDF contends that it is committed to continually improving safety at all of its reactors, and that it will incorporate important lessons from the Fukushima disaster (EDF, 2011). The director for the ASN has been critical of EDF, however, insisting that a major accident cannot be ruled out in France.

The French nuclear industry giant AREVA announced plans in mid-December, 2011, to eliminate 1,500 jobs within its German division, a response attributable to the German government's policy to phase out its nuclear program. In addition, AREVA suspended plans to build a $3 billion uranium enrichment operation in Idaho in the United States. In spite of these cost-cutting measures, AREVA lost approximately €1.5 billion in 2011, making it a financially disastrous year for the company (Keller, 2011).

Civil Society

National television channels have given disproportionately more airtime to the supporters of nuclear power. The National Scientific Research Center in Paris has accused the French media of being complicit in spreading government and nuclear industry propaganda. Conversely, the nuclear industry, and by extension the French government, have accused environmental groups of exploiting the Fukushima incident to generate an emotional response against the use of nuclear power.

Following the German government's decision to take all its 30-plus-year-old reactors offline, the major anti-nuclear group Sortir du Nucléaire promoted a similar strategy. In 2011, it issued a press release asking President Sarkozy to close all 16 reactors built before 1981 (Sortir du Nucléaire, 2011). The demonstrations organized by Sortir du Nucléaire only attracted about 1,000 people, whereas German demonstrations attracted 60,000 (Le Point, 2011).

In April 2011, about 3,800 protesters marched on the nuclear facility in Fessenheim, located near the Swiss-German border (Israel, 2011a). The facility, located within an active seismic zone, has become a major area of concern following the Fukushima disaster. Three months after Fukushima, another march organized in Paris attracted as many as 5,000 participants (20 Minutes, 2011).

The Commission for Independent Research and Information on Radioactivity (CRIIRAD), an NGO created after Chernobyl to monitor and assess nuclear pollution, claimed that information regarding airborne radioactivity from the Fukushima disaster has been concealed. They also charge that the U.S. and Canada, the two countries best equipped to determine the radioactivity approaching France and Europe, have failed to adequately monitor the environment following Fukushima accident (CRIIRAD, 2011).

Public support for nuclear power tends to vary with the polling firm and the nature of questions asked. For example, a poll conducted by EDF shortly after the Fukushima disaster revealed that 55% of citizens were opposed to a nuclear phase out. Another poll by the Green Party showed that 19% favored a rapid phase-out, while 51% favored a progressive curtailment of the nuclear program over the next 25 to 30 years (Israel, 2011b).

1.1.5 Japan

Government

In the immediate aftermath of the Fukushima disaster, the Japanese government established three overriding priorities: cool down damaged reactors at the stricken Fukushima nuclear power plant; relieve stress placed on the energy grid as a result of diminished energy production; and bring stability to society.

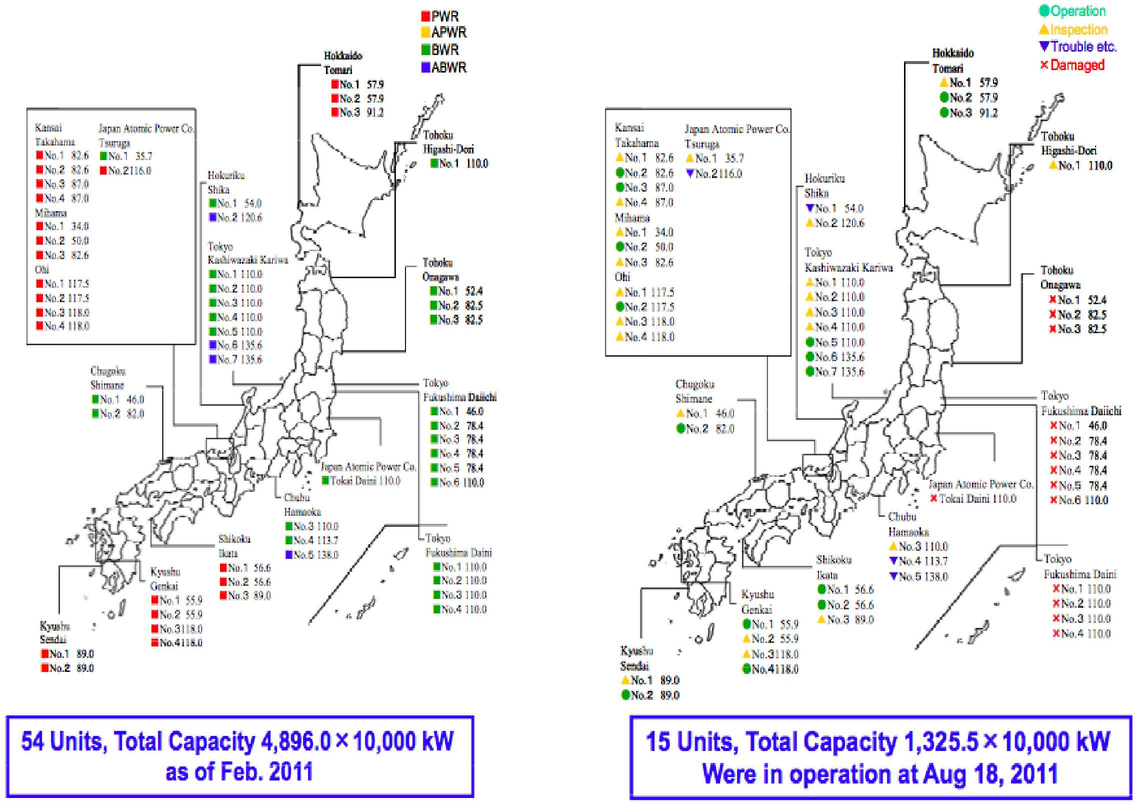
Although the government made efforts to address the nuclear accident, it was criticized for its lethargic response, lack of transparency, and betrayal of public trust.

In particular, leaking radioactivity from the Fukushima reactors was not disclosed for months. As a result, the local population was exposed to radioactive emissions similar to those from the Chernobyl accident (Bradsher *et al.*, 2011). In addition, in an attempt to conceal the danger posed to the public, the government manipulated safety standards following the accident. For example, the government lowered the permissible level of radiation exposure for children at a school. Rather than arming exposed residents with knowledge, the government choose to misled its people and conceal its own negligence. In addition, the government manipulated safety standards for radioactive materials rather than increase public awareness of those standards: For example, the government lowered the permissible level of radiation exposure for children at a school (Tabuchi, 2011a).

The Japanese evacuation zone established a 19-mile radius around the Daiichi power plant, smaller than the exclusion zone suggested by the U.S. In addition, sites outside the evacuation zone were advised to evacuate. However, the evacuation advisories were cancelled in September 2011 (Tabuchi, 2011d).

Regarding nuclear safety, the Japanese government policy measures have not appeared successful. On the other hand they have been more effective in terms of response to the shortage of power. The earthquake resulted in the automatic shutdown of nuclear reactors as well as thermal power plants around the epicenter. Besides automatic shutdown, several nuclear plants were taken off grid for safety tests or maintenance. Only 15 nuclear reactors of Japan’s 54 nuclear reactors remained in operation by August 11, 2011 (Morita, 2011).

FIGURE 1.1: CHANGES IN JAPANESE NUCLEAR CAPACITY IN OPERATION



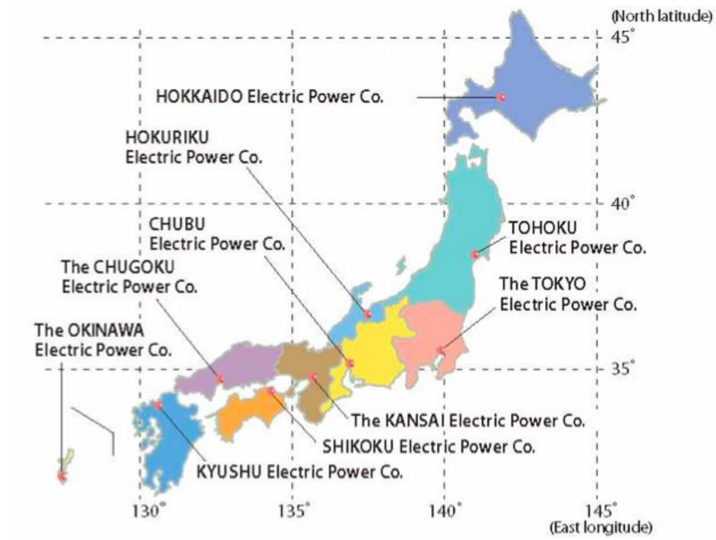
Total number of nuclear reactors in service and total electricity capacity generated in Japan before (left) and after (right) the Fukushima accident.
Source: (Morita, 2011)

Industry

Moments after the earthquake, all nuclear reactors and thermal power plants near the epicenter were shut down automatically. Several additional nuclear plants were taken off grid for safety tests or maintenance. Only fifteen of Japan's 54 nuclear reactors remained in operation five months after the earthquake (Morita, 2011).

Tokyo Electric Power Company (TEPCO), which maintains the Fukushima nuclear power plant, and Tohoku Electric Power Company, which together serve the northern part of the Island of Honshu and 44% of the total Japanese population, were both heavily impacted by the earthquake In 2009, TEPCO produced around 300 TWh, of which 30% was generated by nuclear power; Tohoku Electric Power Company's generation and net power purchase was 87 TWh, with about 23% generated from nuclear power (Hayes *et al.*, 2011). Generating capacity at TEPCO fell to 31 GW following the disaster (International Energy Agency, 2011b).

FIGURE 1.2: ELECTRIC POWER COMPANIES IN JAPAN



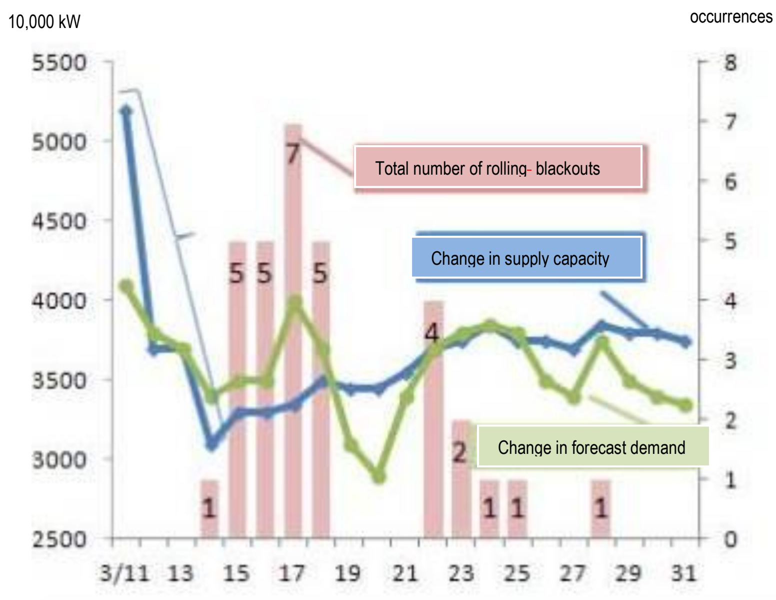
Source: Hayes *et al*., 2011

The earthquake and consequent loss of power undermined the reactors' cooling systems, leading to a series of catastrophic explosions, nuclear meltdown and radioactive material release. Controlling the radioactive emissions became a priority for TEPCO. TEPCO established a two-step plan in its *Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station* to achieve a cold shutdown within 9 months (Government-TEPCO Integrated Response Office, 2011; TEPCO, 2011).

A number of nuclear and thermal power plants were taken offline following the earthquake and tsunami. Furthermore, grid to grid power transfers were complicated by the different power frequencies utilized in each region. This hampered efforts to restore electricity in the region supplied by TEPCO (The Federation of Electric Power Companies of Japan, 2011).

To avoid grid collapse, TEPCO initiated a series of rolling blackouts, which continued through the end of March. Power was cut off sequentially for about three hours at a time in five districts.

FIGURE 1.3: TEPCO EMERGENCY RESPONSE STRATEGY FOLLOWING



Source: METI, 2011b

Over the longer-term, TEPCO has resorted to expanding its thermal capacity to compensate to the loss of nuclear power generation. The government temporarily exempted TEPCO from any type of environmental impact assessment for expanding and building thermal plants (Daniel, 2011).

Civil Society

Public distrust of the government grew steadily in the months following the accident, largely as a consequence of the government's failure to inform and protect its people from radiation exposure. As a result, citizens became more proactive, testing radiation levels independently. Testing revealed several radiation hot spots in Tokyo, feeding public anxiety (Tabuchi, 2011f).

As public opposition to nuclear power increased, the political will to construct new nuclear reactors crumbled. On September 19, 2011, thousands marched on Tokyo in opposition to nuclear power (The Economist, 2011), and according to a poll conducted two months after the disaster, the majority of respondents showed low confidence in the nuclear safety (Tabuchi, 2011b).

1.1.6 China

Government

Days after the Fukushima disaster, the State Council, the chief administrative authority of China, announced that it would suspend approvals for new nuclear power stations and conduct comprehensive safety checks of all nuclear projects, including those under construction. At the time of the accident, about 34 reactors had been approved by the central government of which 26 were under construction (WNA, 2011c).

As a response to the disaster, several supplementary safety measures were announced in May 2011. According to the State Oceanic Administration, China will limit the construction of reactors along the coastline in the future. This represents a significant change in policy, considering that all of China's operating nuclear reactors, and most of those under construction, are located along the coastline. Meanwhile, China's National Nuclear Safety Administration will add staff, including nuclear inspectors, to strengthen overall safety levels (Aibing, 2011).

Industry

After the Fukushima incident, most nuclear power projects were suspended in China, although the government affirmed that it still plans to pursue its nuclear power plan. According to the National Energy Agency (NEA), the suspended projects will restart, and new nuclear power projects will be launched once the State Council approves the Nuclear Safety Plan and the Nuclear Power Development Revised Plan, both of which were submitted to the State Council in the January of 2012. The China Nuclear Energy Association (CNEA) announced that it is very likely that nuclear power projects will resume in 2012. China plans to install 70 GW of nuclear power capacity (compared to a current capacity of 41 GW) in order to reach the goal of raising the proportion of non-fossil energy to 15% by 2020.

The emphasis on nuclear safety will likely encourage the incorporation of the third generation nuclear reactors, such as the AP-1000 and EPR (European pressurized water reactor) reactors, both of which are believed to be safer than current designs. According to market predictions, investments in new nuclear technology will reach US$63 billion by 2015 and US$158 billion by 2020.

Civil Society

Green Earth Volunteers, a Chinese environmental NGO, hosted a journalist symposium on March 16, 2011, to provoke discussion about the present and future status of China's nuclear industry. The seminar drew a large audience and included a briefing by nuclear safety official Zhao Yamin. The Heinrich Böll Foundation also hosted a seminar in Beijing on March 25th to provide information to Chinese journalists on nuclear safety issues. On April 26th, on the 25th anniversary of the Chernobyl disaster, a local NGO named Blue Dalian organized nuclear awareness activities at different campuses in Dalian, and held an evening candle-light vigil to commemorate the tragedy. These activities drew official attention from the provincial government and led to interrogations of those students who participated in the activities. Chinese "netizens" took advantage of the Internet to proactively disseminate information about the potential risks of nuclear power (Bo, 2011).

Chinese media were permitted to address issues relating to nuclear power. The Chinese newspaper *Southern Metropolitan Daily* published a detailed map with the names and locations of all existing, under-construction, and proposed Chinese nuclear plants. It is the first known instance of publicly released information on China's overall nuclear power plan. *Caijing* magazine also published a special edition detailing current policies and future challenges within the Chinese nuclear industry. However, this arrangement was short-lived, and the government soon resumed its censorship of the press (Bo, 2011).

1.1.7 Conclusion

The Fukushima Daiichi nuclear disaster caused by the earthquake and tsunami in Japan has generated mixed global reactions. The initial government response in Germany and Japan was the strongest. Both countries announced plans for an eventual phase out of nuclear power. The response of the Chinese and U.S. governments were comparatively mild. Both countries revised nuclear safety standards, and safety audits were conducted in all existing facilities. France and the U.K. had the weakest response. The Fukushima Daiichi disaster did not provoke any change in the U.K. government's official stance. Similarly, then French President Sarkozy remained ardently pro-nuclear; however, regime change in France may signify a change in direction.

Although the government response led to the decommissioning of several facilities in Japan and Germany, the nuclear industry in the U.S. and France proactively committed themselves to safety. Chinese nuclear projects faced a temporary ban. The U.K. industry continued with its plans to develop nuclear power and achieve its Kyoto emission targets.

Civil society everywhere was shaken by the intensity of this disaster. Anti-nuclear protests occurred in countries all over the world. The fact that the Fukushima nuclear disaster occurred only a month before the 25th Anniversary of the Chernobyl Nuclear Disaster galvanized the already intense public backlash against nuclear power.

1.2 Nuclear Energy Policies

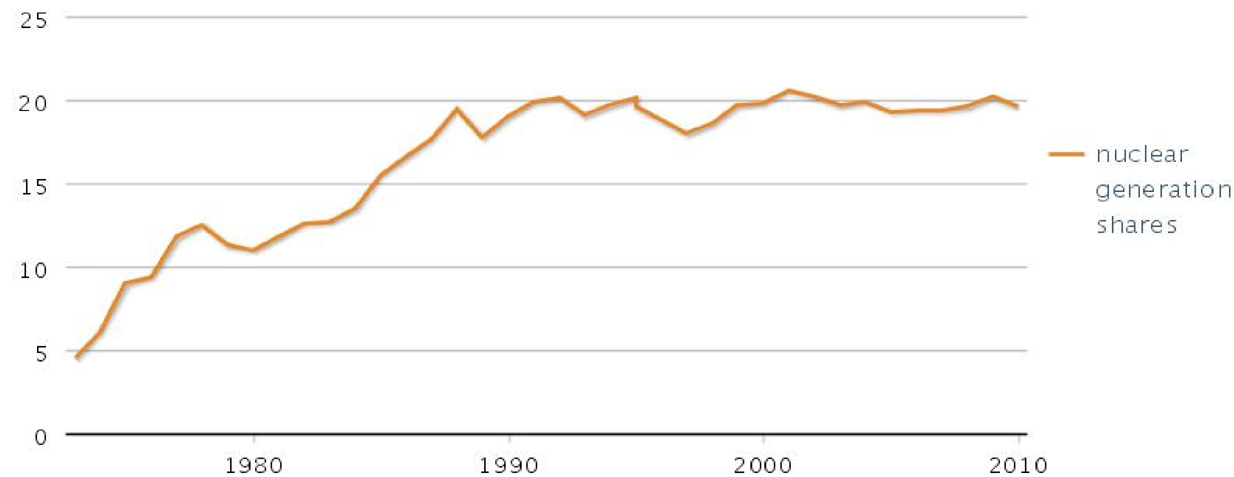
Prior to the Fukushima accident, nuclear power was experiencing a renaissance, as many nations sought low carbon, large-scale sources of energy, especially in developing and industrializing nations such as China. This coincided with the invention of a new generation of reactors that claimed to improve safety while reducing operating and regulatory costs. For the first time in decades, numerous new reactor contracts and licenses were issued. Operating licenses for existing reactors were extended *en masse*. , However, the Fukushima accident revived memories of past disasters, including Three Mile Island in 1979 and Chernobyl in 1986, and led many to question the viability of policies that would increase dependence on nuclear power.

In this chapter, the evolution of nuclear energy policies in the United States, the United Kingdom, Germany, France, Japan, and China are presented to provide an understanding of the dynamics driving nuclear energy policy following the Fukushima accident. Although several significant policy shifts have occurred, the Fukushima disaster has failed to elicit a meaningful shift in long-term nuclear power policy in many countries.

1.2.1 United States

The nuclear power industry in the United States, following a period of rapid development in the 1960s and early 1970s, has suffered from a great deal of political and economic volatility over the past two decades. Despite strong opposition as a result of construction costs, safety, and environmental impact, nuclear reactors are nonetheless a key source of baseline energy production; due primarily to relatively cheap price of electricity produced and to the industry's powerful lobbying influence. Nuclear power has comprised roughly20% of the U.S. energy mix since the late 1980s (Figure 1.4).

FIGURE 1.4: NUCLEAR SHARE OF ELECTRICITY NET GENERATION, 1973-2010 (% share)



Source: EIA, *Monthly Energy Review*, 2010

Currently, there are 104 operational nuclear reactors in the U.S., comprising more than 101 gigawatts of electricity (GWe) of installed capacity. The last license approved prior to 2011 was issued in 1996 for a Tennessee Valley Authority reactor that began construction in 1973 (WNA, 2011a). The early 1970s were a period of increasing anti-nuclear sentiment, and some analysts predicted the imminent demise of nuclear power (Morone and Woodhouse, 1989). The industry survived, however, and at the turn of the century the United States reconsidered nuclear power in response to the challenges of climate change and growing energy demand. The first major piece of legislation to address new nuclear capacity was the Energy Policy Act of 2005 (EPAct). To promote energy security and reduce carbon emissions, the EPAct established the Next Generation Nuclear Plant (NGNP) program. The NGNP was tasked with developing a next-generation, high-temperature nuclear reactor that could be used to generate either electricity of molecular hydrogen (Ehresman, 2011). The EPAct includes incentives for the nuclear industry, including (WNA, 2011a):

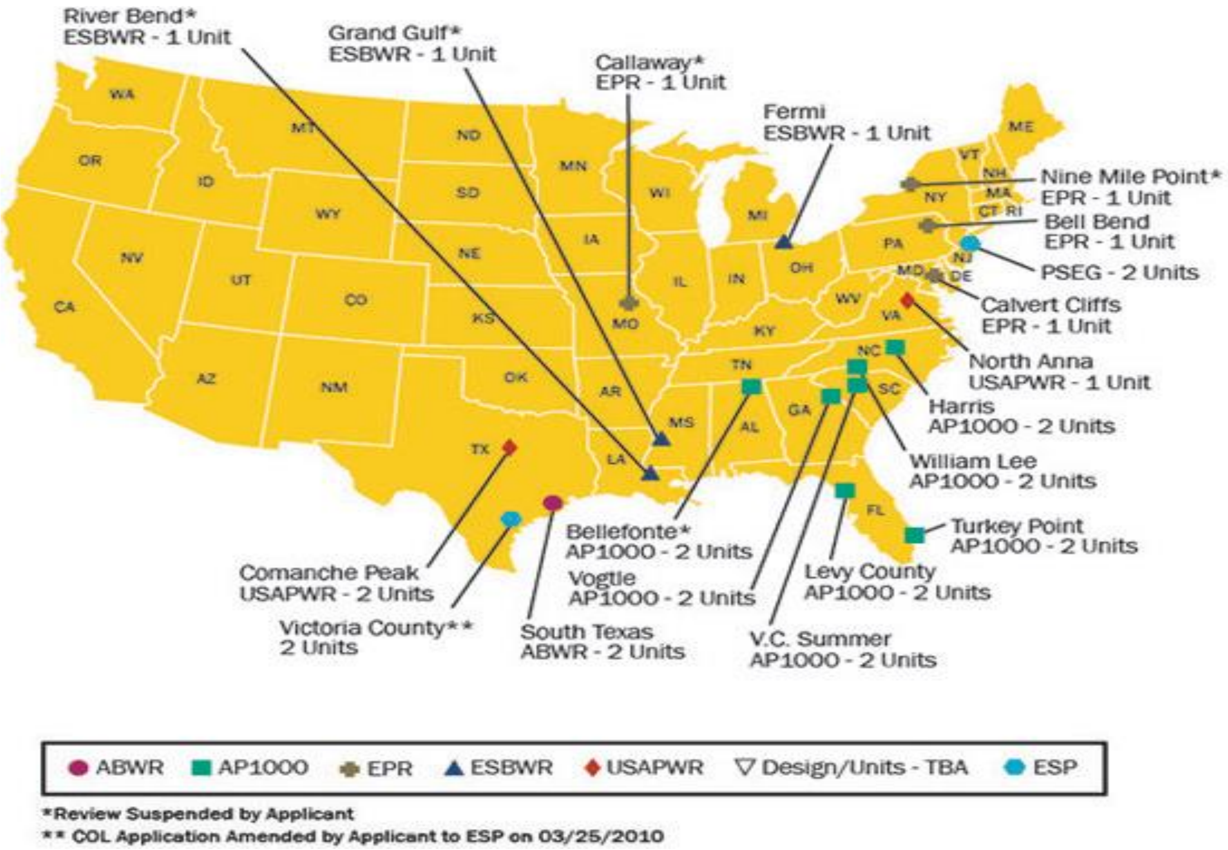
- A production tax credit of 2.1 ¢/kWh for the first 6,000 megawatts of electricity (MWe) of new nuclear capacity in the first eight years of operation (the same rate available to wind power on an unlimited basis),
- Federal risk insurance of $2 billion to cover regulatory delays in full-power operation for the first six advanced new plants,
- Federal loan guarantees for advanced nuclear reactors or other emission-free technologies of up to 80% of the project cost,
- Extension for 20 years of the Price Anderson Act for nuclear liability protection,
- Support for advanced nuclear technology.

Among these incentives, the loan guarantees for new reactors were especially important. Research into new technology was slowed by regulatory requirements put in place to ensure public safety following past nuclear mishaps. Indeed, some have suggested that without government support for new nuclear capacity, interest in new reactors would disappear (Gertner, 2006). However, other policies have also contributed to the growing interest in new nuclear. In 2002, the Department of Energy (DOE) created the Nuclear Power 2010 Program, to encourage utilities to apply for combined construction and operating license (COL), a licensing procedure that allowed multiple applications to proceed through regulatory agencies simultaneously. The program also provides funding for license applications.

Concern over energy security and growing carbon emissions, in particular, have fuelled additional efforts to diversify the U.S. energy mix and promote durable 'clean' technologies. President Obama requested that nuclear power be included among the clean energy sources earmarked to provide 80% of electricity in the U.S. by 2035. This proposal, called the Clean Energy Standard, encourages expansion of the nuclear industry (Brown, 2011).

These incentives resulted in numerous applications for reactors using advanced new designs (Figure 1.5). In 2010, the NRC reviewed thirteen applications to build 22 new nuclear reactors, and five applications for certification of new reactor types. Four reactors in Georgia and South Carolina, using a COL application, were nearing approval in early 2011. The lack of affordable or clean options has prompted many nuclear plant operators to seek license extensions for existing plants. Many licenses were legally set to expire after 40 years, but the NRC has thus far approved 71 20-year renewal applications, extending the operational lifetime of many plants to 60 years.

FIGURE 1.5: PLANNED REACTORS IN THE U.S.



Source: NRC, 2012

The U.S. nuclear industry and nuclear policy makers responded to the Fukushima accident with commitments to improve safety and regulation. However, nuclear policy largely remained unchanged. The NRC, despite internal conflict and external criticism, approved the first new operating licenses in over a decade on February 9, 2012, less than a year after the Fukushima disaster. The NRC voted to approve Southern Company's application to build and operate two new nuclear reactors at its Vogtle plant near Augusta, Georgia, which already houses two operating reactors. Signficantly, the license was issued as a COL making the Vogtle units the first new reactors to receive construction approval since 1974 (EIA, 2012g). Two reactors at the V.C. Summer plant in South Carolina were also approved with a COL in March 2012.

Days after the NRC issued licenses for the Vogtle nuclear power plant expansion, a coalition of environmental and anti-nuclear groups filed a federal lawsuit seeking an injunction to prevent construction. The plantiffs argued that the public was "being kept in the dark about the huge safety and financial risks on the project" (Swatz, 2012) and that the publicly-subsidized project was "socializing the risk and privatizing the profits" (UCS, 2012b). A three judge panel on the Washington, D.C., Circuit Court of Appeals, dismissed by the lawsuit after finding no merit in the argument that the NRC had failed to consider the consequences of severe accidents similar to Fukushima. (Barber, 2013; Schoenberg 2013).

Construction costs for the two new reactors, expected to be fully operational by 2018, are expected to exceed $14 billion (UCS, 2012b).

Although the licenses received approval, the Fukushima accident may still slow the proliferation of U.S. nuclear power. More stringent regulations and delays could undermine the long-term feasibility of nuclear power. Already, several planned projects in the U.S. have been canceled following the accident, and exorbitant capital costs have discouraged many utilities from investing in new nuclear capacity. Even the approved site Georgia is suffering from delays and budget shortfalls as a result of expensive financing costs, slow approval processes, and supplier conflicts (Bonner, 2012). The U.S. has not experienced a drastic shift in its nuclear energy policy. Although the Fukushima disaster has sharpened public awareness of (and opposition to) nuclear power, the U.S. government has nevertheless elected to pursue gruadual expansion to meet growing demand.

United Kingdom

In the 1990s, nuclear power accounted for up to 25% of U.K.'s annual electricity generation. This gradually declined in the 2000s as old plants were closed down and age-related problems affected the productive capacity of other plants. In 2010, nuclear power supplied 62.14 TWh of electricity corresponding to 16.4% of total generation (WNA, 2011b); however, 17 of the 18 operational reactors are designated to be retired by 2023 (Table 1.1).

TABLE 1.1: EXISTING NUCLEAR REACTORS IN THE U.K.

Plant	Type	Present Capacity(MWe)net	First Power	Expected Shutdown
Oldbury 1	Magnox	217	1967	February 2012
Wylfa 1&2	Magnox	2x490	1971	End 2012
Dungeness B 1&2	AGR	2 x 545	1983 & 1985	2018
Hartlepool 1&2	AGR	2 x 595	1983 & 1984	2019
Heysham I-1 & I-2	AGR	2 x 580	1983 & 1984	2019
Heysham II-1 & II-2	AGR	2 x 615	1988	2023
Hinkley Point B 1&2	AGR	2 x 610, (at 70%;430MWe)	1976	2016
Hunterston B 1&2	AGR	2 x 610, (at 70%;420 MWe)	1976 & 1977	2016
Torness 1&2	AGR	2 x 625	1988 & 1989	2023
Sizewell B	PWR	1188	1995	2035
Total: 18 units		**10,745 MWe**		
AGR: Advanced gas-cooled reactor				
PWR: Pressurized water reactor				

Source: WNA, 2011b

In 2008, the U.K. Department of Business, Enterprise and Regulatory Reform (BERR) presented a White Paper on Nuclear Power to Parliament. The White Paper set out a roadmap for the future development of nuclear power in the U.K. as a part of meeting the four primary energy-related objectives: reduce greenhouse gas emissions by 60% in 2050 compared to 1990 levels; ensure a reliable supply of energy; promote competition in the U.K. energy market; and ensure that all homes are adequately and affordably heated (BERR, 2008).

The conclusions of the White Paper were as follows:

- Nuclear energy and other low-carbon sources have a significant role to play in the U.K.'s future energy mix.
- Privatization of the nuclear power industry will provide incentive to invest in new nuclear capacity.
- The nuclear industry must cover the full cost of waste management and decommissioning (BERR, 2011).

In order to promote this transformation, the U.K. adopted a set of policies designed to promote the further development of the nuclear power industry. The important elements of the new nuclear energy policy include:

1. Promoting greenhouse gas emissions reductions and ensuring energy supply security. According to the White Paper, under the most likely scenarios for gas and carbon prices over the long term, nuclear technologies will prove to be an economically viable option. To encourage investment, the government intends to further strengthen the European Union Emissions Trading Scheme (EU-ETS) program in the U.K.
2. Improving the planning system for major electricity generating stations in England and Wales by developing a simplified framework for the approval of nuclear development requests, making the application and approval process less cumbersome.
3. Establishing criteria for Strategic Site Assessment (SSA) for the verification of the suitability of sites for nuclear power development in accordance with the Strategic Environmental Assessment Directive.
4. Instituting a process of justification (in accordance with the Justification of Practices Involving Ionising Radiation Regulations 2004), to verify whether or not the economic, social or other benefits of specific nuclear power technologies outweigh the health detriments.
5. Implementing Generic Design Assessments (GDA) so that newly-developed, industry-preferred designs can utilize existing licensing process.
6. Developing the necessary legislative apparatus to ensure that nuclear power operators meet their full decommissioning costs and their full share of waste management and disposal costs.

This may also enhance investor confidence by providing greater protection against future liability (BERR, 2008; WNA, 2011b).

Between 2018 and 2023, the U.K. expects to add 19GWe (19,000MWe) of new nuclear capacity. The first addition, a 1,670 MWe capacity plant owned by EDF energy, is expected to be brought online in 2018. The U.K. nuclear industry therefore seems to have experienced what might be best described as rejuvenation in the industry.

TABLE 1.2: PROPOSED REACTOR PROJECTS IN THE U.K TO BE COMPLETED BETWEEN 2018 AND 2023

Proponent	Site	Type	Capacity (MWe gross)	Start-up
EDF Energy	Hinkley Point C-1	EPR	1670	2018
EDF Energy	Hinkley Point C-2	EPR	1670	2019
EDF Energy	Sizewell C-1	EPR	1670	2020
	Sizewell C-2	EPR	1670	2022
Horizon (RWE + E.ON)	Oldbury B	EPR x 2 or AP1000 x 3	3340-3750	2022
Horizon (RWE + E.ON)	Wylfa B	EPR x 3 or AP1000 x 4	Approx 5000	2020
NuGeneration (Iberdrola + GDF Suez			Up to 3600	2023
Total planned & proposed			**Up to approx 19,000 MWe**	

Source: WNA, 2011b

The U.K. has not repudiated nuclear power; however, the Fukushima accident has indirectly affected the nation's nuclear energy policy. Britain's Horizon project, which envisioned the construction of up to six nuclear power plants, was delayed when the German utilities RWE and E.ON abandoned the project (Nuclear Street, 2012). Both companies cited escalating costs and the German government's decision to abandon nuclear power as reasons for withdrawing from the venture (Gosden, 2013). This setback was temporary, however. The Japanese energy corporation, Hitachi, acquired Horizon from RWE and E.ON and plans to begin construction of nuclear reactors multiple sites (Gloystein, 2012).

The Scottish government has committed to a nuclear phase out in the future (Hannan, 2012). Initially, regional government officials argued in favor of a phase out of existing facilities and cancelation of planned projects. Under internal and external pressure, Scotland has adopted a more flexible policy, still committed to a phase out sometime in the future, but allowing limited operation and construction at existing sites. A transition away from nuclear may be easier for Scotland. The country has access to a sizable and largely untapped renewable resource: wind energy. If harnessed, this alternative energy source has the potential to compensate for any shortfalls suffered during a nuclear phase-out.

1.2.2 Germany

Germany has 17 installed nuclear reactors which account for 15% of installed power capacity and supply about 28% of the country's electricity demand. Nuclear electricity reached 133 TWh in 2010. Many of the nuclear units are large, and together they provide 20.3 GWe of capacity. The last unit was completed in 1989. Six units are boiling water reactors (BWR), while 11 units are pressurized water reactors (PWR). All of the units were built by Siemens-KWU. An additional PWR has not operated since 1988 because of a licensing dispute. Germany's gross electricity production in 2009 was 597 TWh, which accounted for 6,400 kWh per capita.

Prior to the nuclear accident in Japan, German nuclear policy was marked by two distinct phases. In 1998, a coalition government sought to implement a drastic nuclear phase-out policy. In 2001, a compromise struck between the government and utilities led to a more gradual phase-out plan and a restriction on new reactors. Thus, the predominant plan in Germany over the past decade has to gradually reduce its existing nuclear capacity. However, the pressure to meet growing domestic energy demand and GHG emissions reductions targets forced the German government to reconsider this policy.

In 2009, the newly-formed governing coalition decided to abandon the phase-out plan that had guided energy policy since 1998 (WNA, 2012a). Instead, the government took actions to extend the operational life of its existing fleet. Old reactors were given 8-year license extensions, while newer plants received were granted 14-year extensions. The government sought to increase the lifetime limits of nuclear reactors, from 32-years (as mandated in the phase-out policy) up to 60 years. This promised to increase utility profits (and government revenues) substantially.

After the nuclear accident in Fukushima, the German government once again drastically altered its nuclear policy. The government announced it would immediately work to decommission seven of the oldest operational nuclear power plants built before 1980. The German government also contemplated a nuclear phase-out by 2022. Despite heavy opposition from German utilities, these legislative proposals were approved by the German Bundestag and the Federal Council Bundesrat in June and July of 2011 (German Energy Blog, 2011).

The following table provides a timeline for the phase-out of the country's nuclear fleet (WNA, 2012a):

TABLE 1.3: GERMAN NUCLEAR REACTORS AND PHASE-OUT TIMELINE

Plant	Type	MWe (net)	Commercial operation	Operator	Provisionally scheduled shut-down 2001	2010 agreed shut-down	2011shutdown closure plan
Biblis-A	PWR	1167	2/1975	RWE	2008	2016	yes
Neckarwestheim-1	PWR	785	12/1976	EnBW	2009	2017	yes
Brunsbüttel	BWR	771	2/1977	Vattenfall	2009	2018	yes
Biblis-B	PWR	1240	1/1977	RWE	2011	2018	yes
Isar-1	BWR	878	3/1979	E.ON	2011	2019	yes
Unterweser	PWR	1345	9/1979	E.ON	2012	2020	yes
Phillipsburg-1	BWR	890	3/1980	EnBW	2012	2026	yes
Kruemmel	BWR	1260	3/1984	Vattenfall	2016	2030	yes
Total shut down (8)		**8,336**					
Grafenrheinfeld	PWR	1275	6/1982	E.ON	2014	2028	2015
Gundremmingen-B	BWR	1284	4/1984	RWE	2016	2030	2017
Gundremmingen-C	BWR	1288	1/1985	RWE	2016	2030	2021
Grohnde	PWR	1360	2/1985	E.ON	2017	2031	2021
Phillipsburg-2	PWR	1392	4/1985	EnBW	2018	2032	2019
Brokdorf	PWR	1370	12/1986	E.ON	2019	2033	2021
Isar-2	PWR	1400	4/1988	E.ON	2020	2034	2022
Emsland	PWR	1329	6/1988	RWE	2021	2035	2022
Neckarwestheim-2	PWR	1305	4/1989	EnBW	2022	2036	2022
Total operating (9)		**12,003**					
Total (17)		20,339					

Source: WNA, 2012a

As a result of nuclear retrenchment, Germany will progressively lose a large share of its generating capacity. Since the accident, and to cover the energy shortfall created by the moratorium on the seven oldest operational reactors, Germany has increased its consumption of coal, natural gas, and imported energy. However, over the long term, Germany plans to compensate for this loss by improving energy efficiency and increasing its reliance on renewable alternatives. The growing demand for energy and resistance from major utilities will make the realization of this transition difficult.

1.2.3 France

Nuclear power dominates the French energy portfolio, accounting for more than 75% of its generation mix. The French have become one of the few examples of a "nuclear nation," transitioning to large-scale, commercial nuclear power as the principal source of grid power during the 1970s. Since that time, France has been a global leader in nuclear power production, research, operation, and technology. Furthermore, its nuclear shift gave rise to the largest nuclear corporation in the world, known today as AREVA, a French company that is 90% owned by the state. Both AREVA and the French utility EDF are leading exporters of nuclear technology and operational expertise, designing reactors and managing nuclear projects in numerous countries around the world.

In 1999, the French parliament established three primary goals for its energy policy: secure a stable supply of energy, minimize environmental damage related to power production (especially GHG emissions), and provide secure disposal for radioactive wastes. A main component of the French energy policy, the "Programme fixant les orientation de la politique énergétique" (Program to Direct Energy Policy), or POPE, was enacted in 2005. It contained four main goals for French energy policy that mirrored the recommendations made by parliament in 1999:

- Establish energy independence and supply security
- Ensure a competitive price for energy
- Preserve human and environmental health
- Build social and territorial cohesion by guaranteeing energy access

In order to achieve these goals, multiple policy goals were identified, including at least three which had a direct impact on the domestic French nuclear industry:

- Control demand and reduce energy intensity by 2% annually through 2015 and 2.5% through to 2030 using policies such as tax incentives, certification of end use units (electricity consuming devices and buildings for example), public education campaigns, regulation of physical waste and energy waste.
- Diversify the nation's energy portfolio and attain 10% renewable energy by 2010. Under this scenario, current nuclear power capacity is maintained until at least 2020. In addition, a new Type III demonstration reactor (see below) is to be built by 2015 in order to renew the current nuclear fleet beyond 2020.
- Promote research and development in the energy sector. Part of the R&D portfolio includes the development of the Type III reactor, radioactive waste disposal, and "optimization" of nuclear production.

The 2005 POPE set the stage for the development of a new generation of nuclear reactor, known in Europe as the European Pressurized Reactor, or EPR. Construction on a new 1,600 MW EPR reactor began in Finland in 2005. This reactor was designed by AREVA. One of AREVA's subsidiaries, AREVA NP, is 34% owned by the German multinational Siemens. The project has been plagued by construction delays and financial difficulties. Originally slated to open in 2009 at a cost of €3.7 billion, construction and financial difficulties have forced repeated postponements. No date has been set for final completion of the reactor (BBC, 2012).

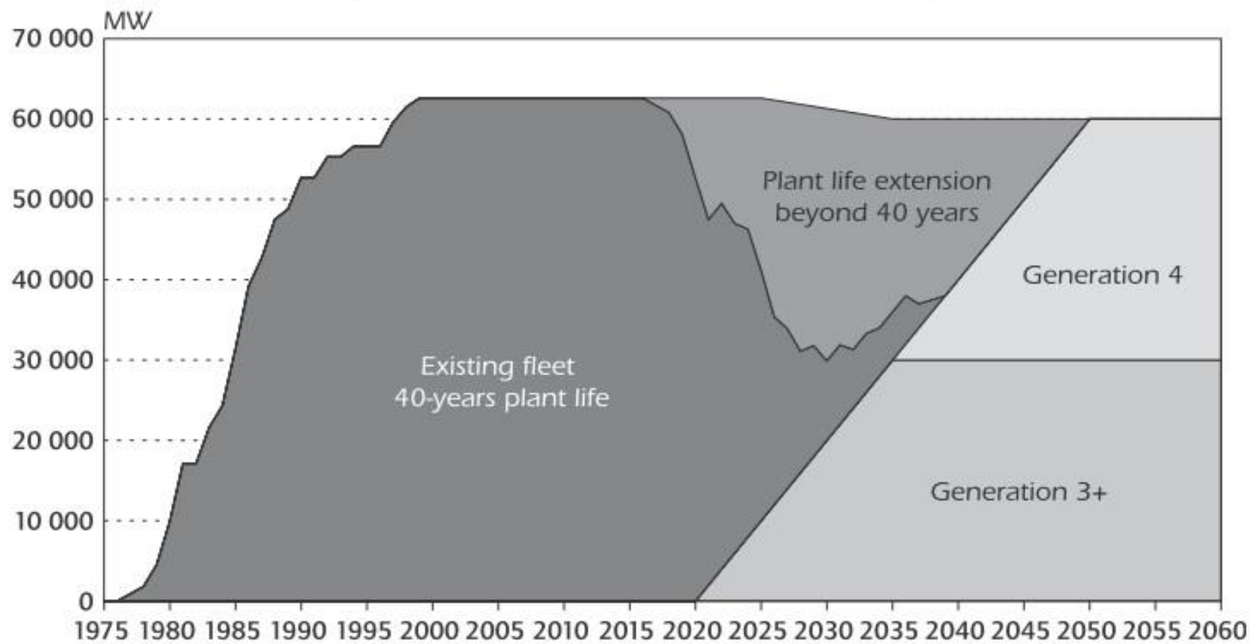
In France, an EPR reactor is currently under construction in Flamanville. This facility is being constructed through the joint efforts of AREVA and EDF, the French nationally owned electric utility operator. Ground breaking commenced in 2007, and the 1,650 MW facility was to be operational by 2014 at a cost of €3.3 billion. But new nuclear safety regulations and construction problems such as poor weld quality =have pushed the construction costs to €6 billion and the time scale for completion to 2016 (NEInt., 2011).

An agreement to build a second French EPR in Pleny was reached in January 2009, and ground breaking was scheduled to begin in 2012 (WNN, 2009). However, in the wake of the Fukushima disaster, construction was delayed to allow for more public consultation on the project. EDF, which owns the Pleny facility, has stated that the project will proceed once public consultation and debates have been completed (Reuters, 2011).

A main component of French nuclear industry is the exportation of nuclear technology France had hoped that the EPR design would entice other countries to import the technology. However, the delays experienced at the two facilities in Finland and in France have muted some of the original enthusiasm. A €20 billion deal between AREVA and the United Arab Emirates to build four 1,400MW EPF reactors in the UAE was scuttled when the Emirati government decided to award the contract to a South Korean consortium (England *et al.*, 2009). Despite this setback, two additional EPR reactors designed by AREVA are currently being constructed in China in collaboration with the Guangdong Nuclear Power group at a cost of €8 billion (NEInt., 2007).

In June of 2006, France enacted the Act on Transparency and Security in the Nuclear Sector which created the independent Nuclear Safety Authority, or ASN (IEA, 2010a). The ASN consolidates commissioning, safety regulation, and licensing extensions of facilities. ASN is currently focused on recommendations to extend the lifetime of a number of aging reactors that are approaching the thirtieth year of their 40 year design life. Many of these reactors will pass their fortieth year of operation from 2015-2020 (Figure 6.1).

FIGURE 1.6: THE COMPOSITION OF THE NUCLEAR REACTOR FLEET OVER TIME



Source: IEA, 2010a

France began a process of privatization and deregulation of state owned energy production in 2000, and since then a number of conflicts have arisen (IAEA, 2006). Although the government owns a substantial portion of EDF, issues surrounding the benefits generated by the nuclear fleet as a result of the EU Emissions Trading Scheme remain largely unresolved. Construction cost write-offs impose huge expenses on the government. Many argue that this is a form of lemon socialism, and that the money could be better spent if it were devoted to reducing electricity prices for consumers. On the other hand, in its efforts to liberalize the energy market, the European Commission sees genuine socialism as an obstacle towards developing a free market for energy (IEA, 2010a). In order to accelerate market liberalization and ensure that the nuclear industry is able to squeeze the greatest amount of profit from public treasuries the Conseil Politique Nucléaire, or CPN, was created in 2008 by presidential decree. Since its founding, the CPN has primarily focused on promoting efficiencies and synergies between AREVA and EDF.

Prior to the Fukushima accident, France favored maintaining, even expanding, its dependence on nuclear energy. In addition, the French government and nuclear industry recognized that international demand for nuclear power was increasing, and moved to capture a large share of the global market. In the months following the accident, French leaders initially remained steadfast in their support for nuclear power, despite growing doubt amongst the public. Domestic reactor construction continued. However, in 2012 the French nuclear industry was given its first major jolt with the election of the Socialist François Hollande to the French presidency.

President Hollande has pledged to reduce France's dependence on nuclear power, announcing plans to reduce the share of nuclear energy in the power supply to 50% from 75% by 2025. He also promised to close the ageing Fessenheim nuclear plant within 5 years. However, just before President Hollande's inauguration on May 15, 2012, ASN gave EDF an extension to run the 900 MW Fessenheim 1, provided it renovates the reactor building foundation before June, 2013.

The election of François Hollande may represent a significant shift in France's energy policy, but the government has yet to release a more detailed plan of achieving its reduction targets.

1.2.4 Japan

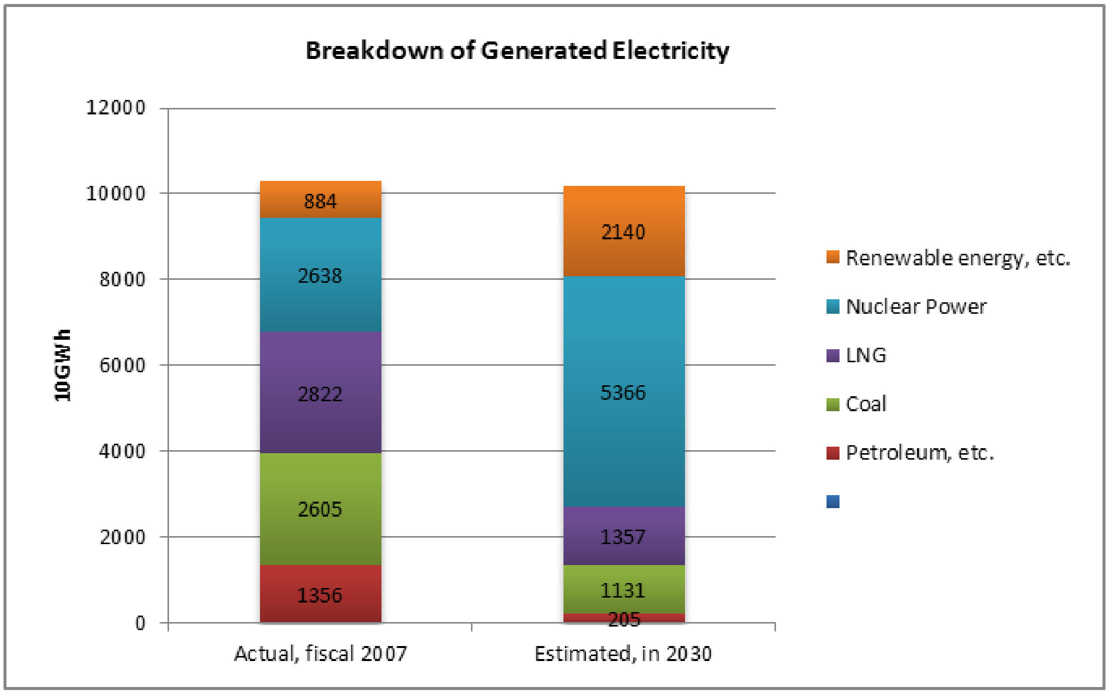
Nuclear power has been generated in Japan since the enactment of the Atomic Energy Basic Law in 1955. Several nuclear energy-related organizations such as Atomic Energy Commission, Science & Technology Agency, and Japan Atomic Energy Research Institute (JAERI) were established under this law (WNA, 2012b).

Japan suffers from a lack of domestic sources of energy, which forces it to rely on imported energy supplies to meet its domestic demand. Coal, although cheap, requires large, uninterrupted shipments from overseas, typically from Australia. Furthermore, coal complicates Japan's carbon emissions targets. Likewise, natural gas also poses significant challenges, including price volatility and unreliability of liquid natural gas supplies in Asian markets. The relative stability of nuclear power, despite requiring imports of uranium fuel supplies, created greater flexibility in managing the country's energy mix. For these reasons, nuclear power was expected to play an increasingly important role in Japanese energy policy.

Today, nuclear energy accounts for about 30% of the total electricity generated. According to the previous energy plan (before the Fukushima crisis), the share of nuclear power in the nation's electricity mix was expected to rise to 50% by 2030. The Strategic Energy Plan of Japan, the country's most recent national energy plan, proposed nine additional nuclear units by 2020, and another five or more by 2030 (METI, 2010). However, the Fukushima disaster has prompted Japan to re-evaluate its current energy plan and nuclear policies.

Dependence on nuclear power will be decreased, but not completely eliminated. In addition, the 2011 Energy White Paper (METI, 2011) pointed out the necessity of a mid- and long-term decrease of dependence on nuclear power (WNA, 2012b). Former Prime Minister Kan argued for a complete phase out of nuclear power in July, 2011, which is significant because no previous Japanese prime minister had argued for a nuclear moratorium. However, he failed to persuade the public and was replaced by Yoshihiko Noda later that year (Fackler, 2011).

FIGURE 1.7: BREAKDOWN OF GENERATED ELECTRICITY AND TARGETS IN THE LAST NATIONAL ENERGY PLAN



Source: METI, 2010

In contrast to Kan, Prime Minister Noda has catered to the interests of the business community. He pushed to restart the country's nuclear reactors once stress tests indicated that they were capable of withstanding an earthquake and tsunami (Tabuchi, 2011b). On November 1, 2011, a nuclear reactor at the Genkai plant was reactivated (Tabuchi, 2011e). The Japanese government also approved bringing additional reactors back online on June 16, 2012, despite public opposition. Kansai Electric Power Co. in western Japan restarted two reactors in Ohi following the government's decision, which helped avert a power shortage in Japan's second-largest megalopolis. The decision to restart the reactors as summer power-cuts loomed was seen as a victory for Japan's still-powerful nuclear industry; but, the Japanese people have grown wary of nuclear power since Fukushima. Surveys show that about 70% want to abandon atomic energy over time. 170,000 anti-nuclear protesters marched through central Tokyo on July 16, 2012, to show their opposition to atomic power and ratchet up the pressure on Prime Minister Noda to alter to Japan's nuclear commitments.

While the Japanese government refuses to completely phase-out nuclear power, it has strengthened nuclear safety protocol. After the disaster, Japan's pro-growth nuclear policy was widely criticized. In addition, nuclear safety protocols failed to prevent reactor meltdown following the earthquake. In response, the government removed the Nuclear and Industrial Safety Agency (NISA) from the Ministry of Economy, Trade and Industry. NISA, along with the Nuclear Safety Commission, was placed under the jurisdiction of the Ministry of the Environment on August 15, 2011 (WNA, 2011d).

Although Japan gradually seeks to decrease its own dependence on nuclear power, it still plans to export nuclear technology, and is pursuing a $13 billion project to build two reactors in Vietnam. This contradictory nuclear policy has been roundly criticized by antinuclear advocates (Tabuchi, 2011c).

In an effort to reduce Japan's dependence on nuclear power, participants of the Energy and Environment Conference, held on June 29, 2012, generated three development scenarios and presented them to the Japanese government. One of these scenarios, the 0% scenario, envisions a complete phase out of nuclear energy by 2030. To achieve this target, renewable energy increases from the current level of 10% to 30%. Fossil fuel use would also increase slightly, from 65% to 70%. The cost of fossil fuel import reaches ¥17 trillion, similar to the current amount.

A second scenario envisions a gradual decrease in nuclear energy to 15% of the total generation mix by 2030. The last scenario envisions a small reduction in nuclear energy generation. Under this scenario, nuclear power supplies 20-25% of total energy consumption by 2020. The Japanese public and the government under former Prime Minister Kan voted in favour of a phase out of all of the nation’s nuclear capacity in 2012, but the government under new Prime Minister Shinzo Abe has pushed for a scale down rather than full phase out in nuclear energy (McCurry, 2013).

1.2.5 China

Before China had a nuclear energy industry, it had a nuclear weapons program. As such, its weapons program serves as the foundation of China’s nuclear energy industry today. As the Chinese economy evolved from a communist centrally-planned economy to a capitalist market-driven system, the nuclear industry also experienced significant changes. In May 1982, the Ministry of Nuclear Industry (MNI) was created from the Second Ministry of Machine-Building, and was subsequently reorganized and renamed the China National Nuclear Corporation (CNNC) in 1989. This name change reflected the shift from ‘‘military oriented use’’ to a ‘‘combination of military and civilian uses.” After heated controversy during the 1980s and 1990s, the government decided to promote the domestic development of pressurized-water reactor (PWR) technology, and with this political support, China developed its own nuclear reactor designs (CNP-300, CNP-600, CNP-1000, and CPR-1000) by the end of 2005 (Zhou *et al.,* 2011).

In recognition of the rising importance of nuclear energy, in 2008 China relocated the nuclear energy division of the State Administration of Science Technology and Industry for National Defense (SASTIND) (the former Commission of Science Technology and Industry for National Defense, or COSTIND) to the newly established National Energy Bureau (NEB), which is organized under the National Development Reform Commission (NDRC). China also took measures to standardize its nuclear energy design and manufacturing in order to enhance efficiency and safety. China currently operates 14 reactors with a capacity of 11,271 MW (Table 1.3). As of 2010, this represented less than 2% of China’s total installed capacity.

TABLE 1.4: CHINA'S OPERATING NUCLEAR REACTORS

Units	Province	Net capacity (each)	Type	Operator	Commercial operation
Daya Bay 1&2	Guangdong	944 MWe	PWR (French M310)	CGNPC	1994
Qinshan Phase I	Zhejiang	279 MWe	PWR (CNP-300)	CNNC	April 1994
Qinshan Phase II, 1-3	Zhejiang	610 MWe	PWR (CNP-600)	CNNC	2002, 2004, 2010
Qinshan Phase III, 1&2	Zhejiang	665 MWe	PHWR (Candu 6)	CNNC	2002, 2003
Ling Ao Phase I, 1&2	Guangdong	935 MWe	PWR (French M310)	CGNPC	2002, 2003
Tianwan 1&2	Jiangsu	1000 MWe	PWR (VVER-1000)	CNNC	2007, 2007
Ling Ao Phase II, 1&2	Guangdong	1037 MWe	PWR (CPR-1000)	CGNPC	Sept 2010, Aug 2011
Total: 14		**11,271 MWe**			

Source: WNA, 2011c

China's civilian nuclear program consists of three main components: government organizations, the nuclear industry, and research organizations. While government agencies play the most important role, planning and approving reactor projects, the other stakeholders play a role in implementing these projects.

In China, only three state-owned enterprises are licensed to own and operate nuclear power plants. They are the CNNC, the China Guangdong Nuclear Power Corporation (CGNPC), and China Power Investment Corporation (CPIC). Among the three, CNNC is the largest operator. In addition to its nuclear plants, CNNC also owns all Chinese nuclear construction companies and fuel cycle facilities. In 2004, China created the State Nuclear Power Technology Company (SNPTC) to oversee technology transfers and monitor the selection process of advanced PWR technology.

Several key organizations manage China's nuclear energy industry. The Standing Committee of the State Council guides all other governmental bodies, and is the driving force behind major policy decisions. The National Development and Reform Commission (NDRC) drafts the nation's five-year development plans, and is responsible for the selection of energy projects such as power plant installations. The National Energy Commission (NEC), created in March 2008, was given the authority to devise a comprehensive energy development strategy and oversee energy-related issues that had been previously distributed amongst several different ministries. Meanwhile, the China Atomic Energy Agency (CAEA) plans and manages nuclear-related research projects. It writes the regulations that govern the use of nuclear technologies, gives guidelines on nuclear material management, and encourages cooperation with international organizations. The CAEA was formerly under the control of COSTIND and is now under the control of the newly established Ministry of Industry and Information Technology. The National Nuclear Safety Administration (NNSA), which is under the Ministry of Environmental Protection (MEP), licenses, regulates, and supervises nuclear power plant operation.

Prior to Fukushima, China emphasized two priorities above all others: economic growth and energy security. The nation must constantly augment its power capacity to satisfy growing economic demand. To do so, China has elected to utilize relatively inexpensive energy sources, including coal, of which the country enjoys ample reserves. Recent concerns over the environmental and health impacts of coal and its long-term ability to meet demand have led Chinese officials to seek alternative sources of energy. Due to its ability to generate cheap energy with low emissions, nuclear power was an obvious choice for large-scale development.

The ''Medium- and Long-term Nuclear Power Development Plan'' (2005–2020), which outlines China's plan to increase nuclear capacity to 40 GW by 2020, provides an insight into China's current nuclear energy policy. According to this plan and a 2007 white paper entitled ''China's Energy Policy,'' nuclear energy is an indispensable energy source for the future of China. Furthermore, the white paper suggested that the government should transform nuclear energy from a moderate development role (as outlined in the 10th Five-Year Plan) to an active development role as outlined in the 11th Five-Year Plan (State Council Information Office, 2007). Figure 1.8 depicts the site of current and planned nuclear projects in China.

Figure 1.8: Current and proposed reactor sites in China

Source: the Radioactive Safety Center of the Ministry of Environmental Protection, 2008

Since 1998, the Chinese government has supported nuclear power development with preferential tax policies. Nuclear power companies receive a 75% tax rebate every year during the first five years of reactor operation. The amount of the rebate decreases to 70% in the following five years, and to 55% for the third five-year period (Order 2008, No. 38) (Zhou, *et al.*, 2011). In addition to governmental support, plant operators can recruit public or private stakeholders, such as provincial or national utilities and local investment companies. Although all plant operators must hold a 50% stake in each project, the remaining half can be funded by outside investors.

Fukushima created a moderate level of turmoil for the Chinese nuclear industry, especially in light of the geographic proximity of the crisis to the Chinese mainland. It revealed the risks posed by natural disasters to many coastal reactor sites (Figure 1.9). Consequently, the government's response following the disaster was relatively strong compared to other nations. Two of the most significant initiatives the crisis spawned were a moratorium on new project licensing and a comprehensive safety review of existing and proposed sites.

Many existing reactors quickly resumed operation following the review, and construction of previously approved reactors recommenced following a revision of safety standards. The moratorium on approval of new reactor projects remained in place throughout 2012, pending certification of a new regulatory and safety plan. This plan is expected to be approved and the moratorium lifted before the end of 2012 (Aibing, 2011). Overall, however, China's commitment to nuclear power remains intact, with the National Energy Administration declaring nuclear power as the future foundation of the power sector (WNA, 2011c). The Fukushima disaster did, however, prompt greater caution by the Chinese government. Many planned reactor sites were shifted away from the coast. And the government extended its nuclear development plan father into the future, extending the timeline for the construction of new installations (Aibing, 2011).

In order for China to continue with its current ambitious and aggressive nuclear development path, several challenges must be addressed. Incomplete and weak nuclear regulation, an inadequate nuclear workforce, transparency in the policymaking process, insufficient research and development capabilities, and lagging public participation are some of major challenges the Chinese nuclear industry faces. Nonetheless, development and deployment of nuclear technology is expected to progress quickly once the regulatory and safety reforms necessitated by the Fukushima disaster have been fully implemented.

1.2.6 Conclusion

The responses to the Fukushima amongst the major energy-consuming nations considered in this research varied from strong reactions to relatively modest ones. Likewise, the impact of the crisis on long-term nuclear policy is mixed. Germany has reversed a pro-nuclear stance to commit to a nuclear phase out by 2022. Japan has backed away from a policy aimed at increasing its dependence on nuclear power. Other nations have made little to no significant changes to their energy plans following the accident. The United States and the United Kingdom continue to pursue nuclear development plans despite regulatory delays and economic complications. China has reaffirmed its goal of making nuclear the foundation of its power sector. France has faced a unique set of circumstances since the accident, and its nuclear policy has changed following an election that removed a pro-nuclear government and replaced it with a coalition that seeks to reduce the nation's nuclear dependence. Not a direct consequence of Fukushima, the success of this new course is yet to be determined. Overall, despite several notable exceptions, the nuclear crisis in Japan seems to have had a limited impact on long-term nuclear policy in many nations.

PART 2. ENERGY MIX AND POLICY IMPLICATIONS

The primary energy profiles briefly discussed in the first section below provide an initial understanding of the energy situation of the major energy consuming nations discussed in this report. The primary emphasis in each profile is on the fossil fuels, particularly coal and natural gas production and consumption. Total primary energy supply and demand are discussed briefly to indicate the potential energy futures of the major energy consuming nations. This section also examines (expected) price developments for several of the countries. For a more comprehensive discussion of the natural gas and coal energy markets, the International Coal and Gas Market Outlook ("ICGM," PA Consulting Group, 2012) reviewed and assessed projected demand, supply, and forecasted prices for coal and natural gas in the economies of South Korea, China, India, Japan, the United States, the United Kingdom, Germany and France. The ICGM Outlook also assesses the impact that a nuclear moratorium scenario in East Asia and OECD Europe would have on global coal and gas markets.

The second section of this chapter explores the electricity generation profiles of the countries of interest. A central emphasis in this section is determining the extent to which the Fukushima accident influenced electricity generation development pathways. As such, the section analyzes the projections for electricity generation made prior to the Fukushima accident and compares these to projections made after the accident. In line with the larger narrative of this report, the section focuses specifically on the contribution of nuclear energy in the electricity generation profile. The range of contributions in terms of shares of nuclear electricity gives an indication as to the flexibility in energy development pathway to reduce nuclear energy dependency.

2.1 Primary Energy Profiles: Historical and Projected

The International Coal and Gas Market Outlook ("ICGM," PA Consulting Group, 2012) reviews and assesses projected demand, supply and forecasted prices for coal and natural gas in the economies of South Korea, China, India, Japan, the United States, the United Kingdom, Germany and France. The ICGM Outlook also assesses the impact that a nuclear moratorium scenario in East Asia and OECD Europe would have on global coal and gas markets. For the purpose of this section, we will focus on the data for China, Japan, the United States, the United Kingdom, Germany and France.

In addition, data for these analyses were collected from various publications of the U.S. Energy Information Agency, EU Energy Commission, Economist Intelligence Unit as well as market data from commodity exchanges.

Overall, data indicate coal demand is projected to rise by 50% between 2008 and 2038, largely due to growth in consumption in Asia, especially China. The demand for coal will also increase in the U.S.; it is expected to decrease in Japan, Germany, the U.K and France. China would single handedly account for 67% of global coal supply rise over the next twenty years.

The U.S. supply of coal too would increase, albeit not as rapidly as China. Europe's domestic production of coal, however, sees a decline. Asian nations in general, and China specifically, are projected to be the largest importers of coal. The share of U.S. exports to Europe will continue to grow while those to the Americas will fall as a share of exports. The price of coal is expected to be driven by the increased demand in China and other Asian countries. Domestic price for coal in the U.S. is expected to rise. In the long term, however, U.S. coal export prices are expected to remain relatively flat.

Natural gas consumption is projected to grow in the U.S., Japan and China. The U.S. will continue to be the largest consumer of natural gas, but considering natural gas is promoted by the Chinese government as the preferred energy source, the rate of increase in demand for natural gas will be highest in China. France, U.K. and Germany are projected to have declining rates of natural gas consumption. The U.S. is projected to be the largest producer of natural gas in OECD, with increase in shale gas production offsetting decline in other categories. The U.S. also contributed 18% of world natural gas trade. In East Asia and Europe, natural gas prices are projected to increase in the short run but gradually decrease in the long run. In the U.S., however, gas prices are projected to rise partly because of the capital expenses incurred for infrastructure related to unconventional gas production as well as tighter environmental regulations.

In case of the nuclear moratorium scenario, coal is project to fill the gap between demand and supply in Asia, Europe as well as in the U.S. Demand for natural gas will continue to grow through all the three nuclear moratorium scenarios projected, but the impact on pricing will be small.

2.1.1 Supply, Demand and Price Trends

United States

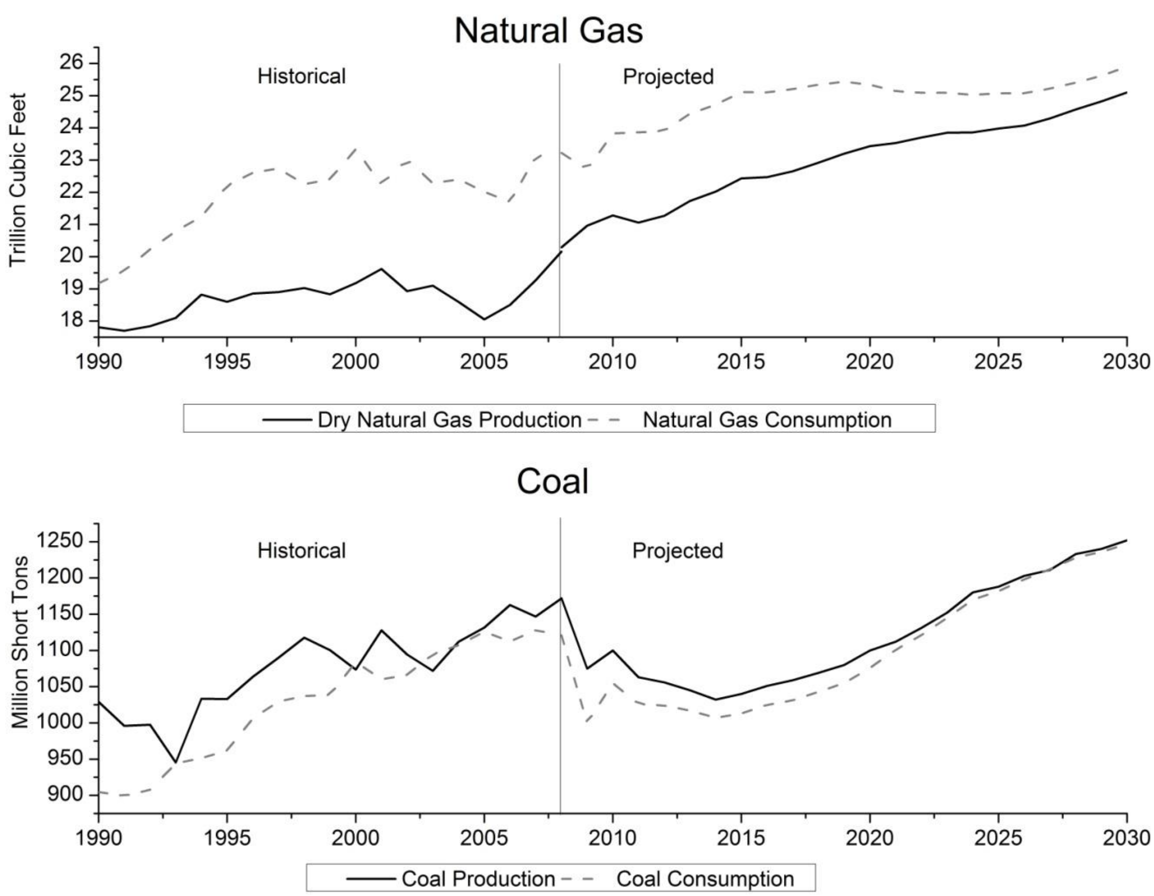
Natural gas and coal output in the U.S. has steadily risen over the 1990-2008 period (see Figure 2.1). Trailing only Russia, the U.S. is the world's second largest natural gas producer. Whereas conventional gas resources in the U.S. are limited, unconventional gas sources, especially shale gas, are abundant. New extraction techniques make extraction of unconventional natural gas sources economical, leading to a recent increase in natural gas production in the U.S. Therefore, as demonstrated in Figure 2.1, gas supply projects are expected to increase to 26,482 PJ per year by 2030 at an average annual growth rate of 0.92%. By this point, shale gas will comprise 47% of total domestic gas production, and tight gas, another unconventional source, will comprise as much as 22%. The key uncertainty in the natural gas market is the short- and long-term effects of hydraulic fracturing – the technique used to extract shale gas – and, with growing concerns and evidence of the negative environmental and social consequences of this technique, future regulations and legislation that might restrain the shale gas industry.

The U.S. is currently the largest global consumer of natural gas – and it will remain in this position according to future demand projections. Over the next two decades, however, demand growth in the U.S. will be a modest 0.45% per year. In 2030, the demand for natural gas is projected to reach 27,326 PJ per year. The primary sectors responsible for this growth are the industrial and power sectors. With the new shale gas extraction techniques coming online, and thus increased U.S. domestic production, U.S. imports of natural gas should decrease substantially at an average rate of 10.6 % per year. This fall in import demand will affect the global natural gas market as the bulk of the demand for imported gas shifts to markets in Europe, South America and Asia.

The graph for natural gas in Figure 2.1 shows fairly stable annual output over this time period, but beginning in 2006 output begins to increase. Recently, new extraction techniques for unconventional natural gas sources, principally hydraulic fracturing and horizontal drilling, have led to growth in gas output. Much of the expanding capacity was in response to prices spikes which took place in the middle of the last decade (EIA, 2011).

Coal production in the United States is expected to grow at a rate of 0.8% per year. Total production will increase from 23,373 PJ to over 26,693 PJ by 2030, representing a 0.74% increase. Motivated by the growing domestic consumption, the vast domestic coal reserves – which account for 27 % of current global reserves – allow for the supply increase. While coal exports are projected to continue to Europe and the Americas, the U.S. share of coal imports by those regions is expected to decline slightly. Growth in domestic consumption will drive the coal markets over the next two decades. Demand for coal will rise at an annual rate of 0.8% reaching 24,688 PJ by 2030. This represents a total growth in coal consumption of 0.82%.

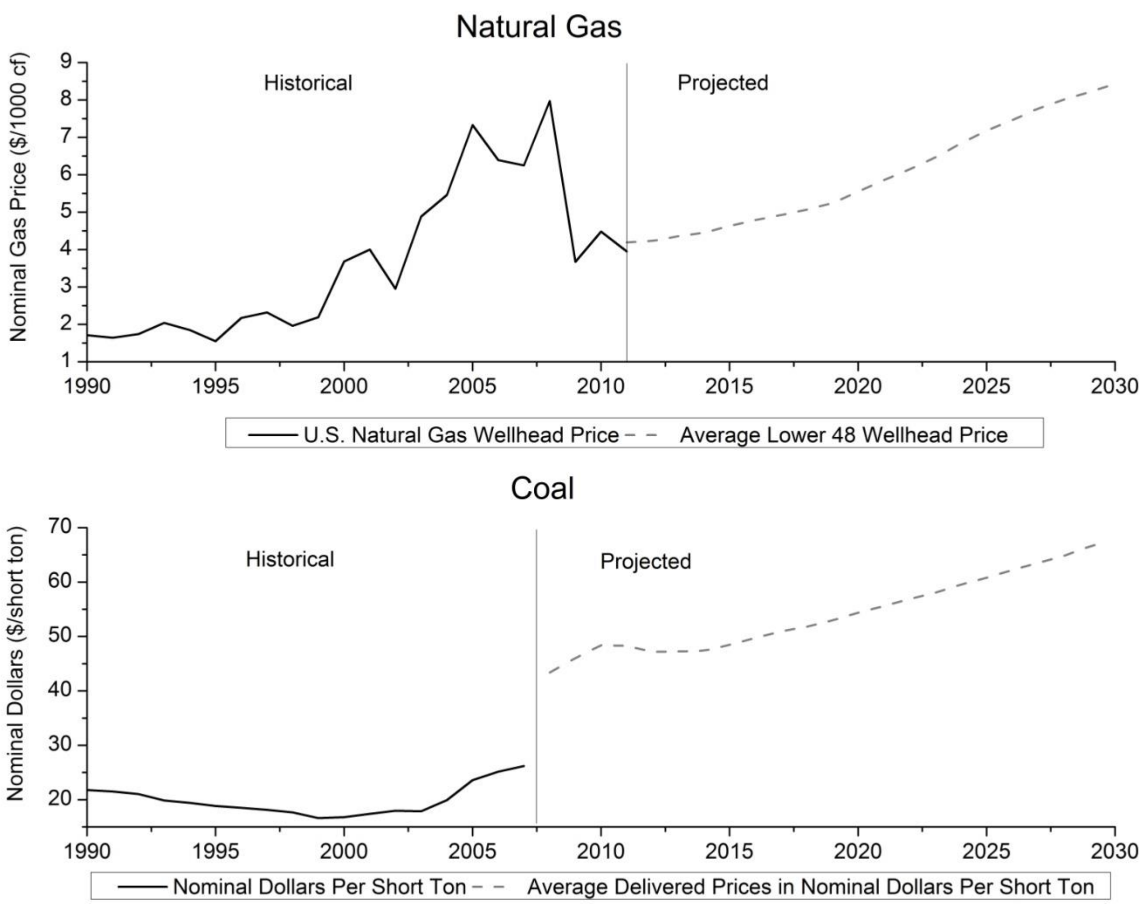
FIGURE 2.1: a) U.S. DRY NATURAL GAS PRODUCTION AND CONSUMPTION, 1990-2030
b) U.S. COAL PRODUCTION AND CONSUMPTION, 1990-2030



Source: EIA, 2011a

Figure 2.2 shows the volatile history of average annual U.S. natural gas prices. Natural gas prices fell sharply in 2009, but have since stabilized. Due to its perceived favorable competitive position relative to coal – due, in part, to the low-carbon nature of natural gas – the rising demand for natural gas is expected to drive prices up. Also, much of this increase in prices will result from additional production costs associated with unconventional gas resource extraction. In both short-term and long-term projections, the price of natural gas in the U.S. market steadily rises by an average growth rate of 2.4 % per year until 2030. The historically experienced price volatility, however, is likely to continue, complicating the projection.

FIGURE 2.2: a) U.S. PRICE DEVELOPMENTS FOR NATURAL GAS, 1990-2030
b) U.S. PRICE DEVELOPMENTS FOR COAL, 1990-2030



Source: EIA, 2011a

U.S. coal product prices are expected to increase to $15.35 – $73.13 per metric ton by 2016. Long-term forecasts are difficult to determine, but, as demonstrated in Figure 2.2., the Energy Information Administration Reference Case projects a steady price increase throughout the 2008-2030 period. As can be seen, consumption has largely remained stable, rising slightly over the period. In 2010, with the recovery of the economy and the growth in the electric power sector, consumption rose markedly. Much of the general increase in consumption is due to growth in natural gas generation capacity, representing 81% of all new capacity between 1995 and 2010 (EIA, 2011). Consumption does not mirror the volatility in gas prices seen during this time, which can be seen in the next section.

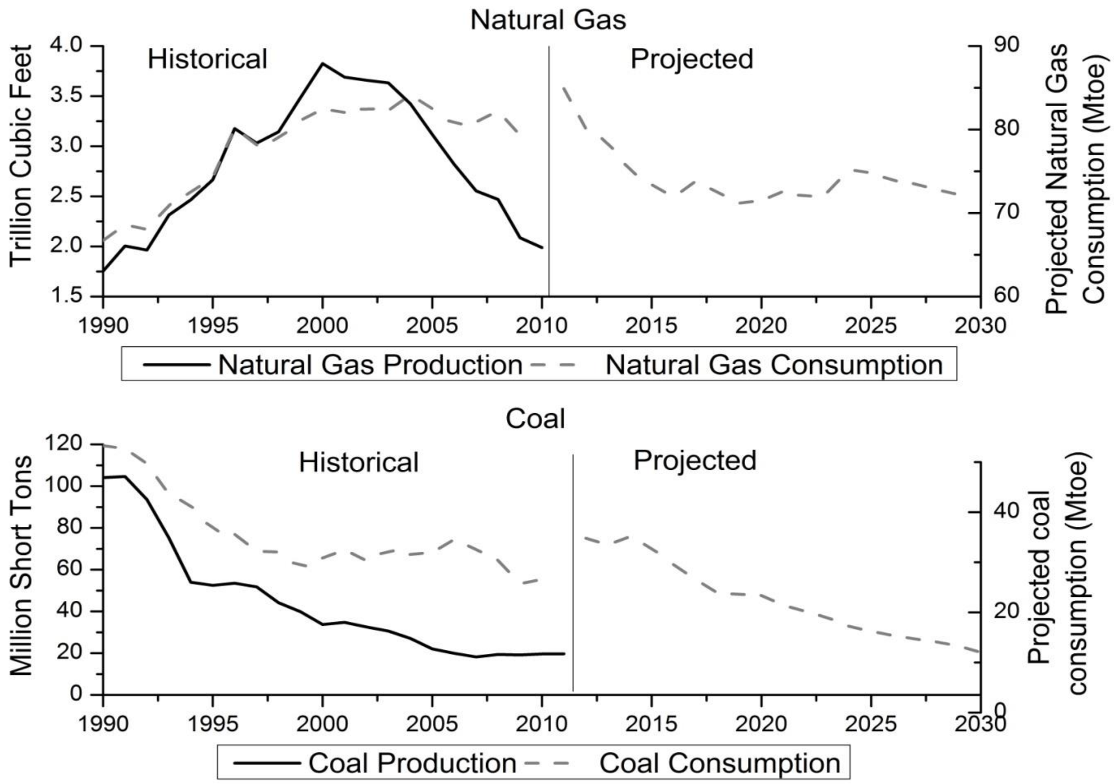
United Kingdom

In the U.K., as in most of OECD Europe, natural gas production is projected to fall at an average annual rate of 0.3% per year. Demand for natural gas in most of Europe is projected to increase, but demand in the U.K. will fall over the period between 2012 and 2030 to 2,276 PJ per year. This represents an average rate of -1.9% per year over this period. As demonstrated in Figure 2.3, the U.K. Department of Energy and Climate Change (DECC), expects demand to level off at around 70 metric tons of oil equivalent (Mtoe).

The production of coal in the U.K. has substantially decreased since 1990. Whereas 1990 production levels exceeded 100 million short tons, 2011 annual production levels have fallen well below 20 million short tons (Figure 2.3). Production of coal has recovered slightly since 2007, U.K. coal production continues to be at a much lower level than historical levels. The decline in domestic coal production has been offset by a substantial growth in imports (Figure 2.4). Total production in OECD Europe will decrease from 6,262 PJ to 5.064.3 PJ per year by 2030. Part of this decrease will be compensated by increased imports. For instance, in 2030, the share of imports from South America and Eurasia to OECD Europe – including the U.K. – will increase to 31 % and 27 %, respectively.

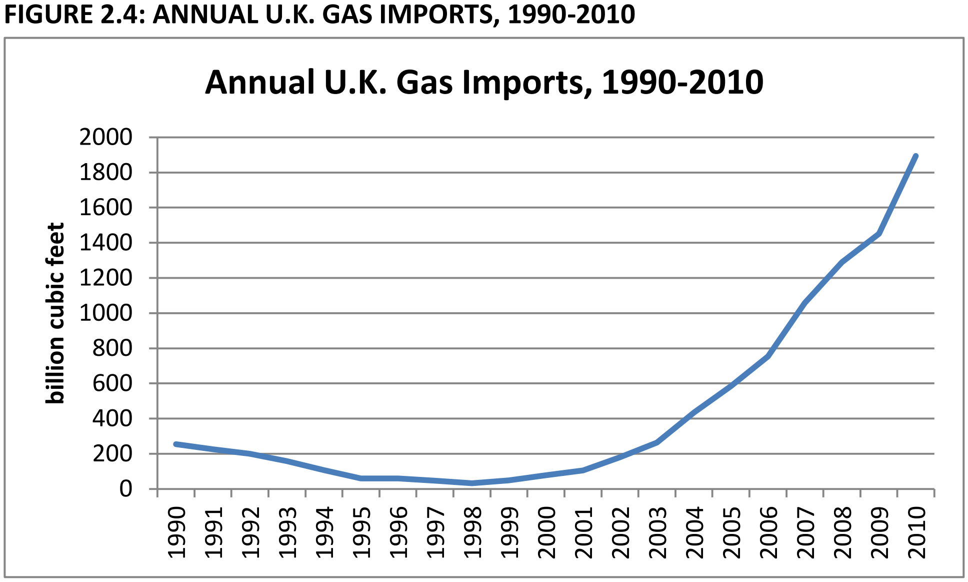
Similar to OECD Europe coal production levels, the U.K. DECC projects that the demand for coal in the U.K. will decline further throughout the 2010-2030 period to a level right above 10 Mtoe; representing an average annual rate of – 2.5% per year. Much of the decline will occur in both the industrial and power sectors. However, new coal-fired plants currently planned or under construction will likely offset reductions in coal consumption of retiring plants.

FIGURE 2.3: a) U.K. NATURAL GAS PRODUCTION AND CONSUMPTION, 1990-2030
b) U.K. COAL PRODUCTION AND CONSUMPTION, 1990-2030



Source: EIA, 2012d

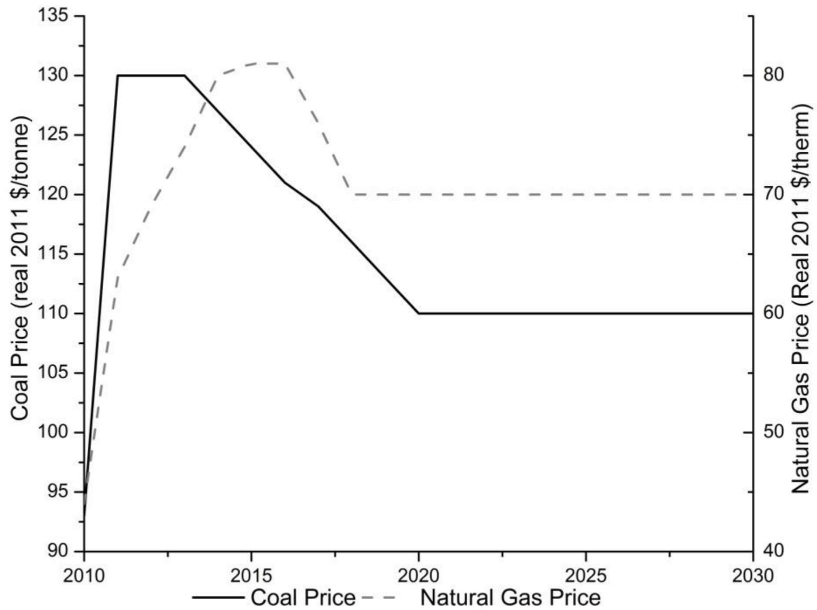
FIGURE 2.4: ANNUAL U.K. GAS IMPORTS, 1990-2010



Source: EIA, 2011a

The U.K DECC 'Central' scenario – a scenario that depicts a business-as-usual development pathway – projects coal and natural gas prices to rise rapidly until around 2015, and to then stabilize after 2020 (Figure 2.5). In terms of natural gas, the DECC projects a plateau of $70/therm. For coal, the DECC projects a coal price of $124/metric ton (in real 2011 dollars) in 2015, falling to $110/metric ton in 2020. However, it is highly complicated to adequately project coal and natural gas prices and, as such, the DECC maintains a range of $45 - $100 per therm for natural gas in 2030, and a range of $80 - $155 per metric ton of coal in 2030.

FIGURE 2.5: NATURAL GAS AND COAL PRICES, 2010-2030



Source: DECC, 2012

Germany

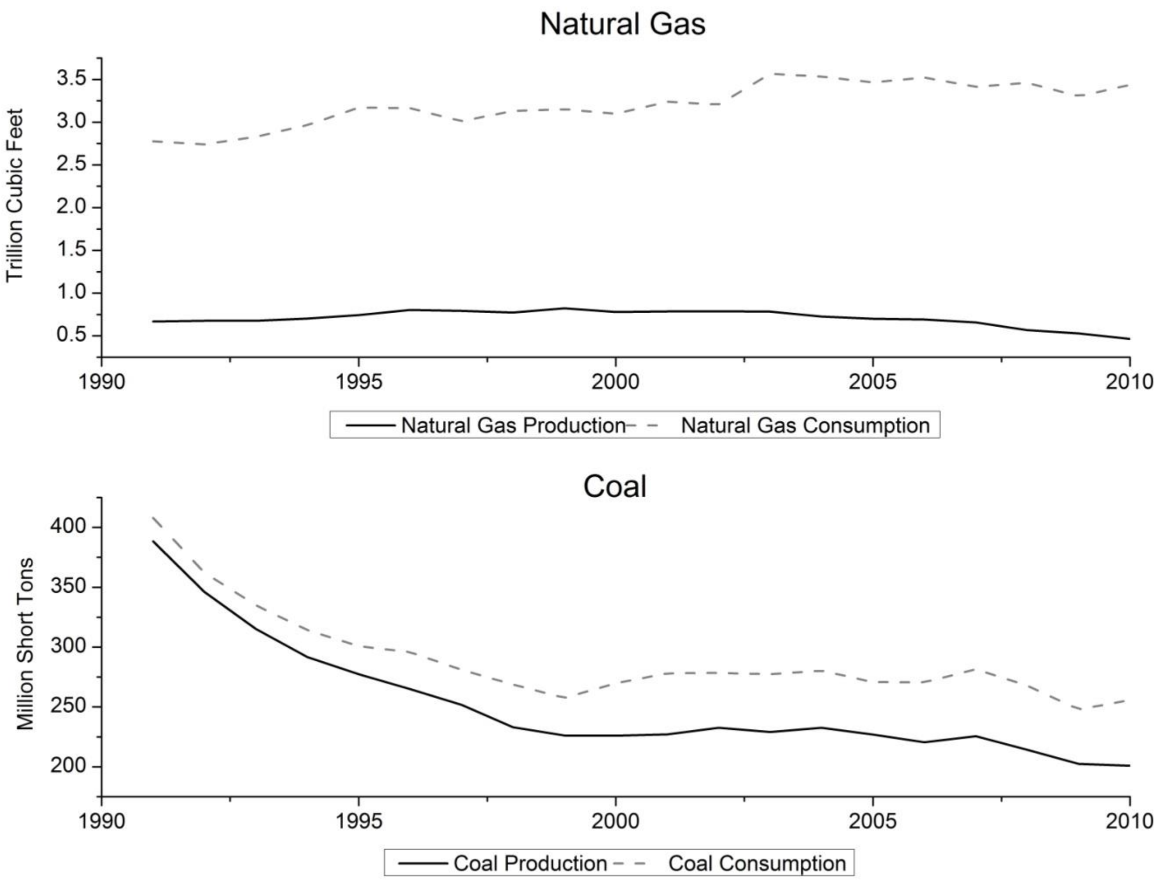
Natural gas production and consumption levels have remained largely stable in Germany. As shown in Figure 2.6, natural gas consumption greatly exceeds domestic production. As such, Germany relies to a large extent on natural gas imports to meet its natural gas needs.

Since reunification, German coal production has declined, primarily for economic reasons, although reductions in production in the last decade have been much smaller than the decline during the 1990s. Like the U.K., German coal imports have increased drastically, largely because coal comprises 43% of the power sector in terms of annual electricity generation. Much of the coal consumption which has not been met by domestic sources has been supplied by imports, which have more than doubled since reunification (See Figure 2.7).

Coal demand in Germany is expected to decline during the period 2012-2030 (PA Consulting, 2012). Total consumption is expected to decrease from 1,518 PJ to 740 PJ by 2030, representing an average annual rate of -3.9% per year. This annual decline is higher than in the rest of OECD Europe (-0.55% per year), including both the U.K. and France. Much of the decline will occur in the power sectors.

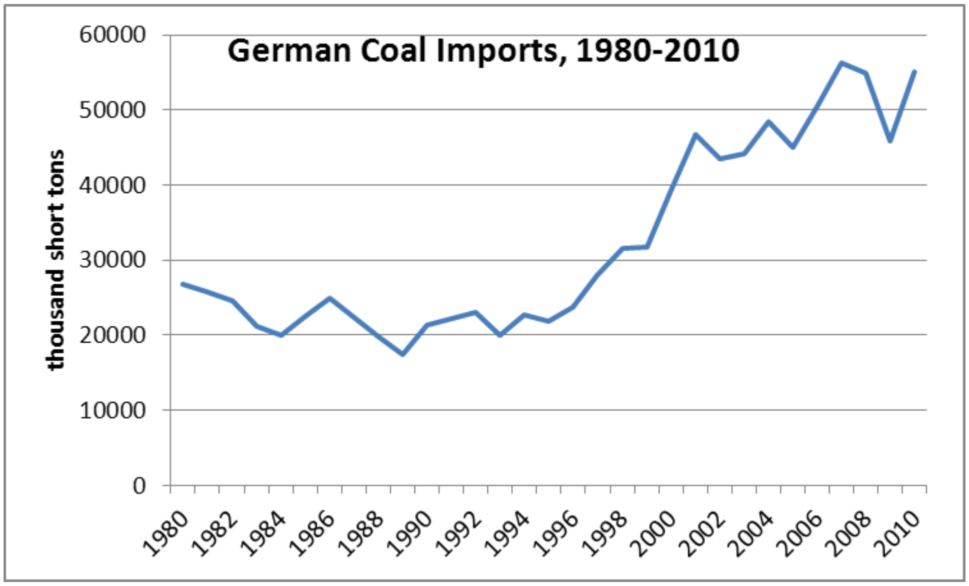
However, new coal-fired plants currently planned or under construction will likely offset reductions in coal consumption of retiring plants. Furthermore, the new policy to phase out nuclear generation will most likely lengthen the lifetimes of up to 13 GW of older coal plants.

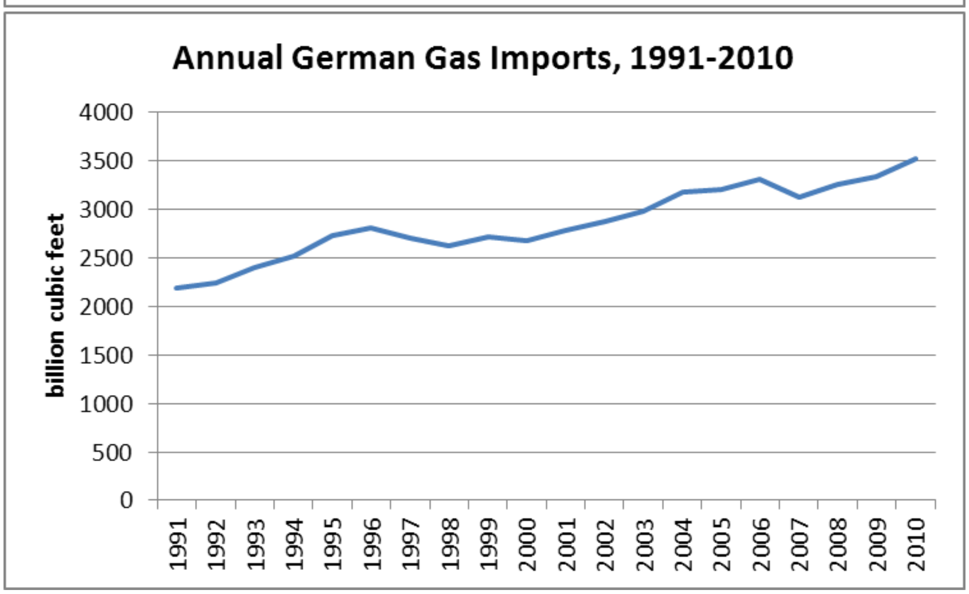
FIGURE 2.6: a) GERMAN NATURAL GAS PRODUCTION AND CONSUMPTION, 1990-2030
b) GERMAN COAL PRODUCTION AND CONSUMPTION, 1990-2030



Source: EIA, 2011a

FIGURE 2.7: a) GERMAN NATURAL GAS IMPORTS, 1980-2010
b) GERMAN COAL IMPORTS, 1980-2010



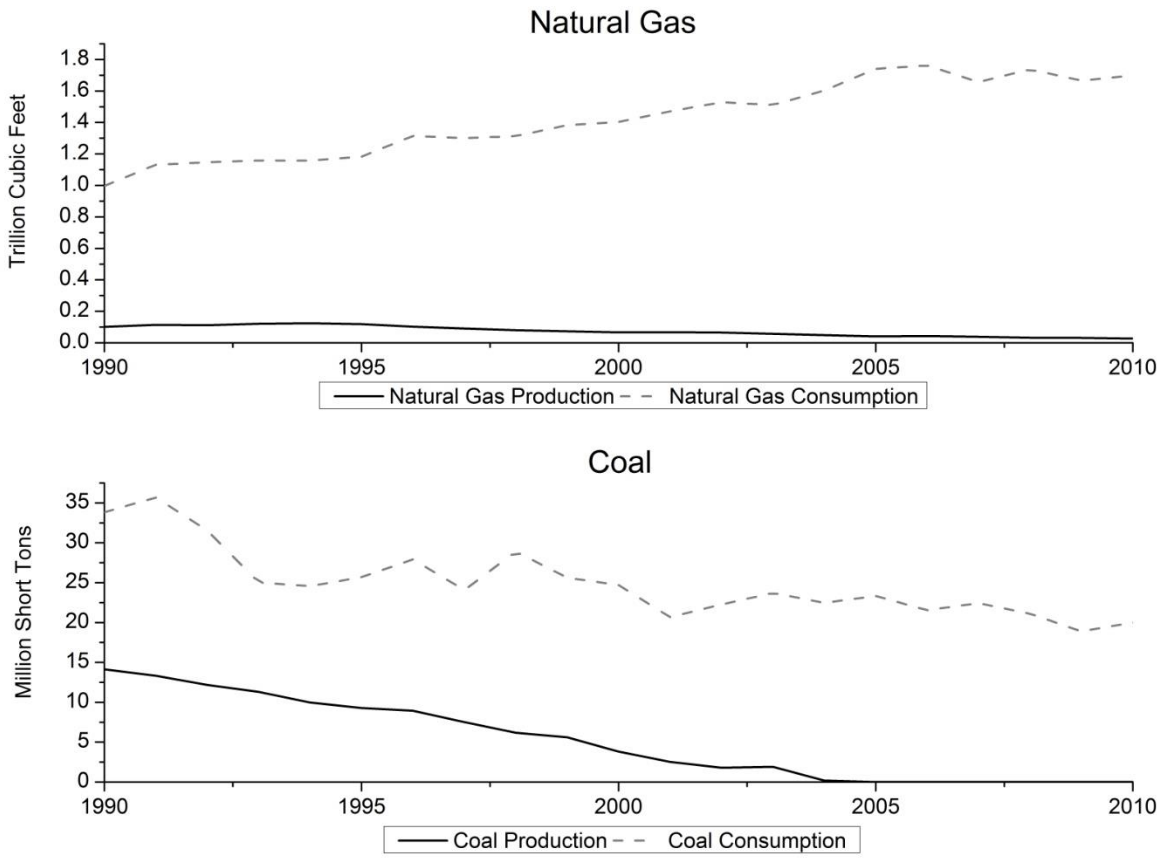


Source: EIA, 2012d

France

As recently as the 1990s, France produced several million short tons of coal annually (see Figure 2.8). However, the continued decline in French domestic coal production eventually led to a production of zero short tons in 2005. Unlike the U.K. and Germany, though, coal imports have not risen to substitute for domestic production. Similarly, the majority of natural gas consumed is imported since domestic production has fallen throughout the 1990-2030 period.

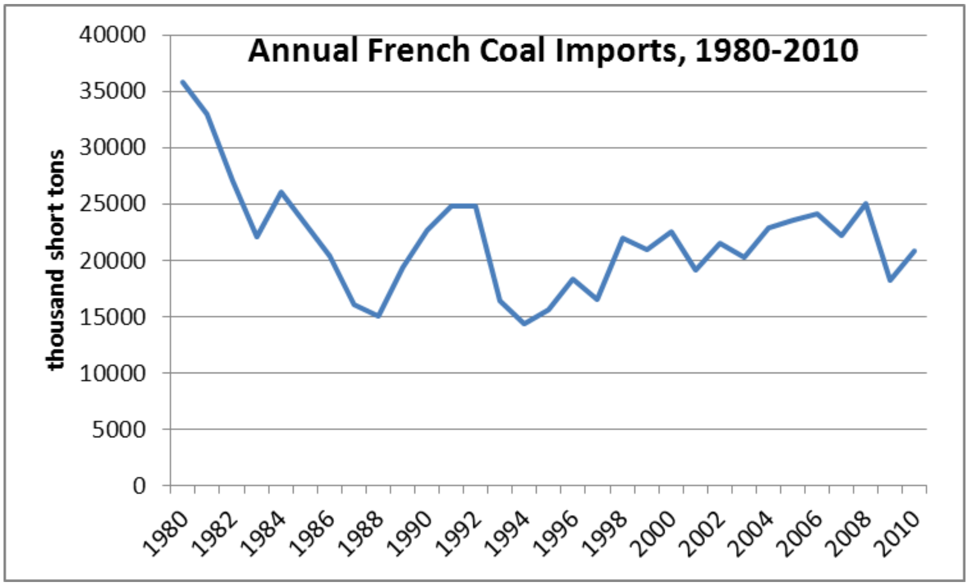
FIGURE 2.8: a) FRENCH NATURAL GAS PRODUCTION AND CONSUMPTION, 1990-2030
b) FRENCH COAL PRODUCTION AND CONSUMPTION, 1990-2030



Source: EIA, 2012d

Although domestic coal and gas production have fallen significantly, imports have not risen equally to compensate for lost domestic production. In fact, over the past few decades, coal imports have also fallen in absolute terms, as the Figure 2.9 below depicts.

FIGURE 2.9: FRENCH NATURAL GAS IMPORTS, 1980-2010



Source: EIA, 2011a

Japan

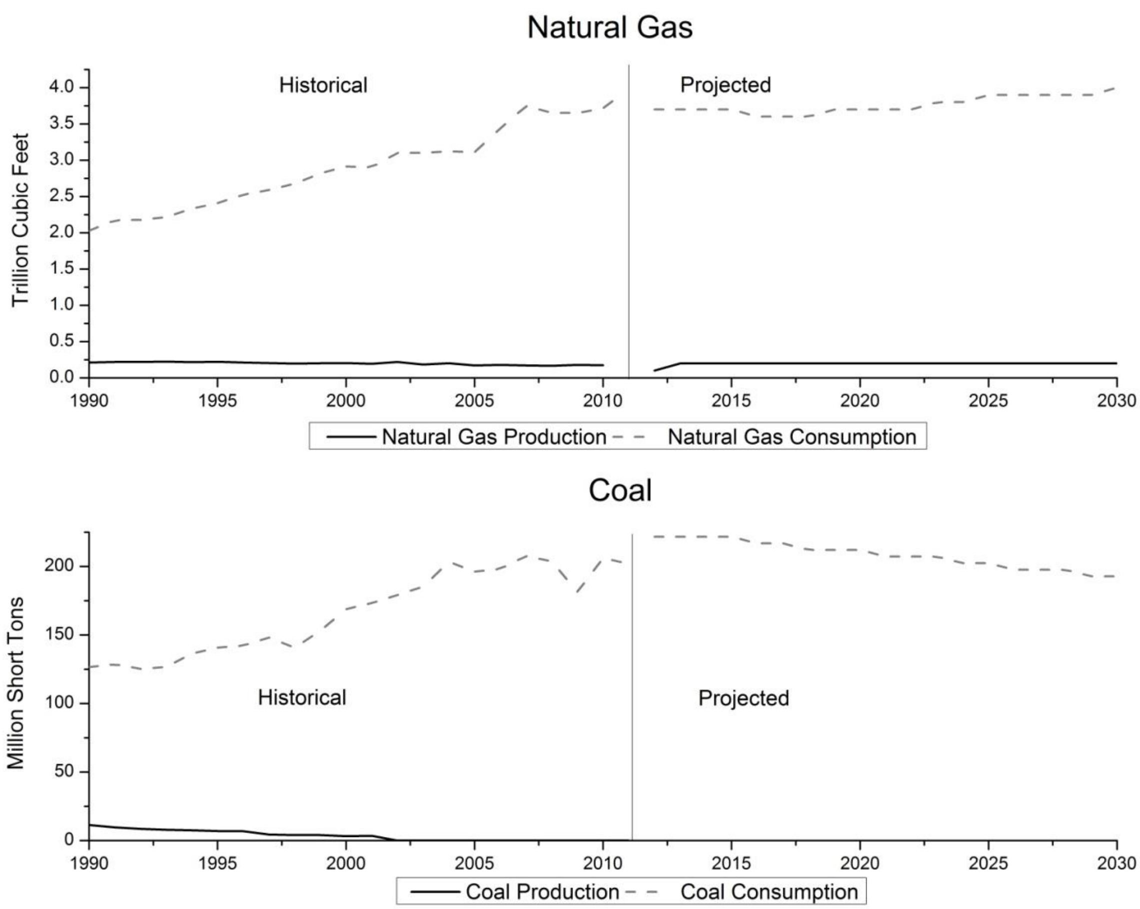
Japanese domestic production of natural gas is at very low levels relative to consumption and, while the level of consumption of natural gas has steadily increased over time, the production of natural gas has stagnated. The current natural gas production meets only 5% of domestic demand and, while growth is projected in natural gas consumption (Figure 2.10), it is projected to remain a small source of Japan's energy supply. To meet its demand, Japan relies heavily on imports, especially imports of liquid natural gas (LNG). Japan currently is the largest global importer of LNG, responsible for nearly 60% of all LNG imports in Asia (EIA, 2011). To offset the loss of nuclear generation capacity due to the Fukushima nuclear accident, imports of gas and other energy sources have substantially increased (Brown, 2012).

Japan has not produced coal domestically since 2001, but has produced small amounts of coal historically, as seen in Figure 2.10. Japan has overwhelmingly relied upon foreign imports for most of its supplies of fossil fuels, especially coal. Those foreign imports have increased since the nuclear accident in 2011 as Japan seeks to replace its nuclear capacity with alternative sources. Imports from the United States, for example, jumped 119% (Brown, 2012). Still, Japan imports the greatest amount of coal in Asia, depending particularly on Australian imports, which supply 60% of its coal. Recently, Japanese companies have sought to diversify their coal supplies by exploring or investing in coal production in both Russia and Canada.

Historically, Japan has been the largest coal consuming nation in OECD Asia. In terms of demand for coal, the overall trend has been a doubling in consumption. However, Figure 2.10 shows that consumption is predicted to decrease somewhat from 2012 to 2030. Total consumption in 2030 is projected to be 4,220 PJ, down from 4,853 PJ in 2012. The decrease in demand will be driven primarily by two sources. First, the Japanese population is declining, thus reducing future demand projections.

Second, the Japanese government has made numerous commitments to alternative energy sources to reduce its GHG emissions, which will shift consumption away from coal.

FIGURE 2.10: a) JAPANESE NATURAL GAS PRODUCTION AND CONSUMPTION, 1990-2030
b) JAPANESE COAL PRODUCTION AND CONSUMPTION, 1990-2030

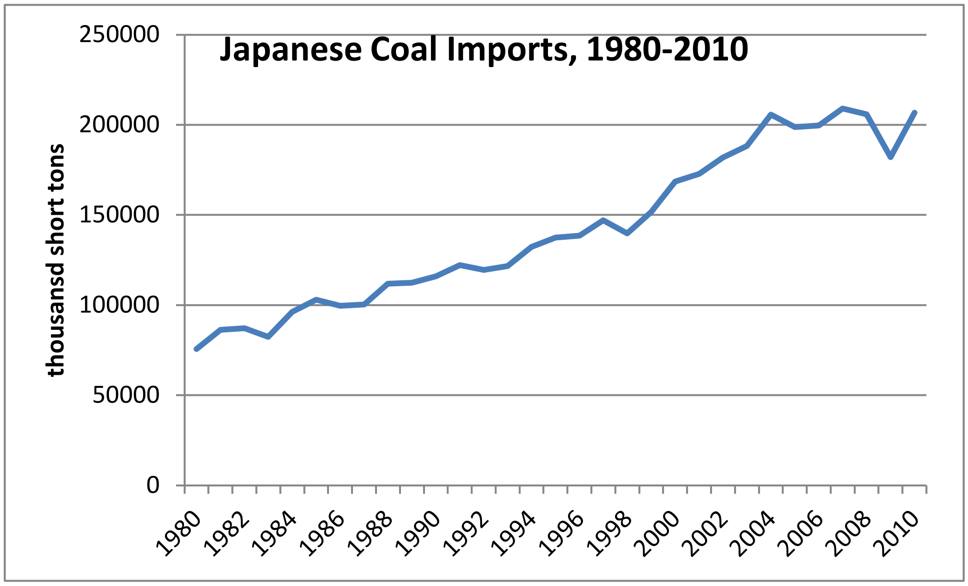


Source: EIA, 2011a

The graph below (Figure 2.11) shows annual coal imports since 1980.

Japanese coal prices are tied to Australian futures prices in the short-term and the Australian coal price long-term outlook. Australian futures prices will decrease from (US) $105.98 to $99.46 per metric ton by 2017. Long-term Australian export prices will also decrease significantly by 2023 due to increasing domestic production in China. These trends would result in lower Japanese coal prices, but demand is not expected to shift towards coal due to the smaller population and expansion of alternative energy discussed earlier.

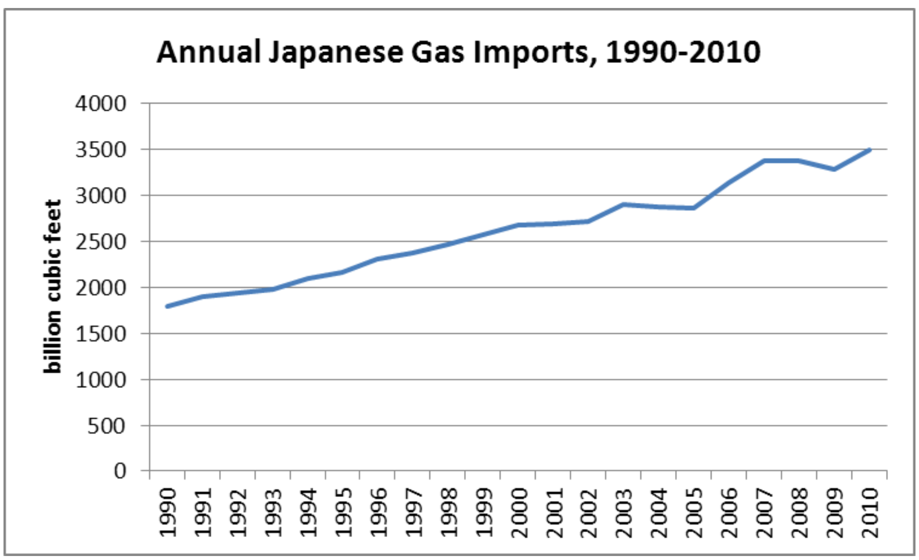
FIGURE 2.11: JAPANESE COAL IMPORTS, 1980-2010



Source: EIA, 2012d

To make up for its low level of domestic natural gas production, Japan depends on imports of natural gas, especially liquid natural gas (LNG) supplies, as shown in the figure below.

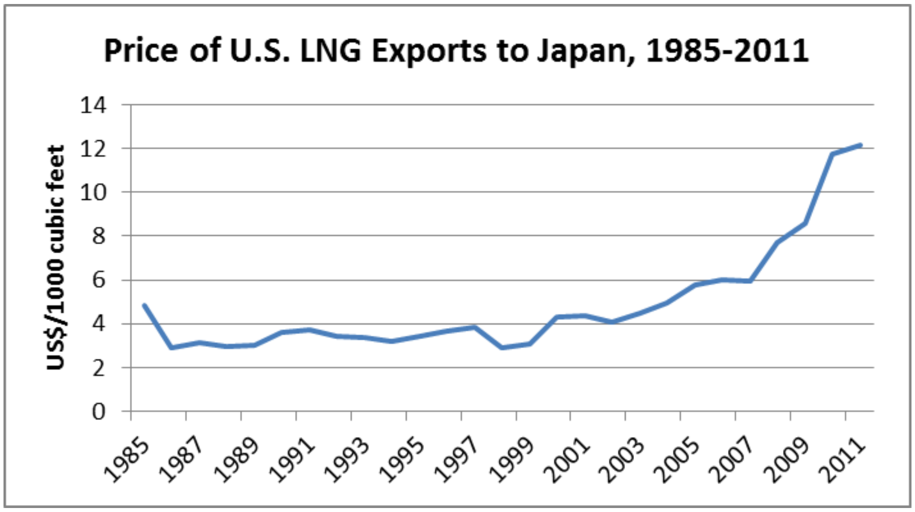
FIGURE 2.12: JAPANESE NATURAL GAS IMPORTS, 1990-2030



Source: EIA, 2011a

LNG price contracts are typically indexed to oil prices. Therefore, short-term and long-term market contract prices often do not match spot market gas prices. Projected global spot market gas prices are low, but contract prices for gas are expected to increase with rising oil prices. Over the next decade, though, contract gas prices indexed on the Japanese Crude Cocktail basket will begin to fall, reaching current price levels by 2030 (US$12/MMBtu). In order to estimate the average price of natural gas products in Japan, U.S. gas export prices to Japan can be applied to discern historical movements in domestic gas prices. Figure 2.13 depicts LNG prices from 1985-2011, which have risen dramatically since 2007.

FIGURE 2.13: U.S.-JAPAN LIQUID NATURAL GAS EXPORT PRICES, 1985-2011



Source: EIA, 2011a

China

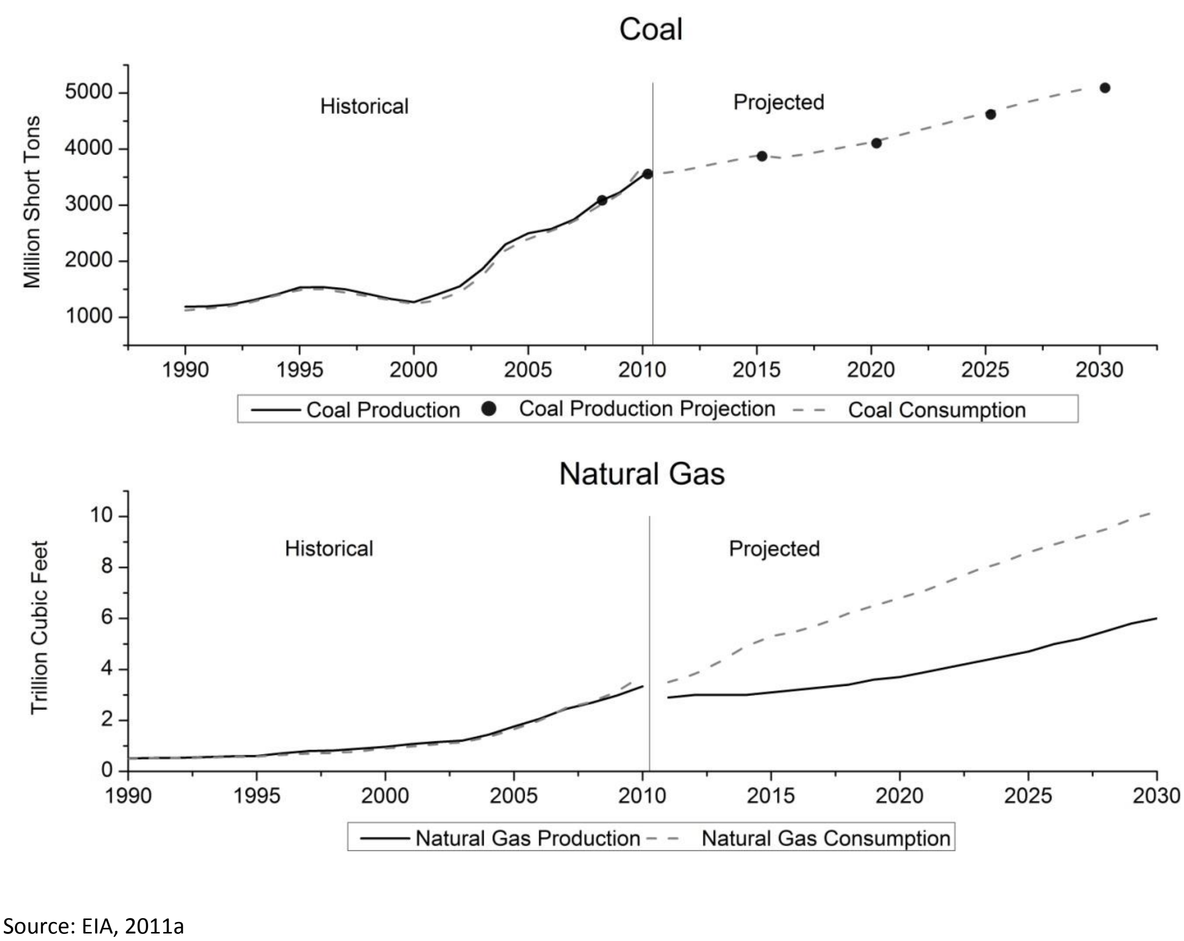
China is looking to exploit new sources of energy to continue its economic expansion, and gas offers both potential for supply and a relatively cleaner alternative to traditional coal combustion. To help alleviate the pollution associated with coal, China has begun to utilize larger amounts of natural gas, increasing domestic production and exploration. Although conventional reserves are limited, Chinese interests are exploring shale gas and tight gas as sources for gas development and production (PA Consulting Group, 2012). Nonetheless, domestic production of gas in China has grown substantially since 1990, as seen in Figure 2.14. In line with production, the Chinese demand for natural gas has also grown as domestic resources have been developed.

The recent trends are projected to continue. China will increase its projected domestic gas production considerably over the next 20 years, growing at an average annual rate of 3.9% from 3,165 PJ to 7,702 PJ per year. China has limited conventional gas resources; however, the country has significant potential to increase gas production exists through development of coalbed methane and shale gas resources. Currently, China is exploring potential shale gas sites with several international companies, and the government already offers a production subsidy for coalbed methane. Despite its efforts to extract its domestic gas resources, China will remain a large net importer of natural gas since the projected production levels fall short of meeting consumption. The government has been promoting gas consumption, with the result that demand for natural gas will rise considerably between 2012 and 2030. The government’s natural gas share target is 10% of the primary energy mix by 2020, or 9,000 PJ. Projected gas demand is expected to grow from 4,009 PJ to 7,174 PJ per year by 2020 and to 10,762 PJ per year by 2030. This represents an average annual growth rate of 5.6% - the highest global growth rate for natural gas.

China has aggressively expanded its domestic production of coal in pursuit of energy to feed its rapid economic growth and rising demand for energy. China is currently the largest coal producing nation in the world, driven largely by demand for coal from its power and industrial sectors. Most of the increase in supply has taken place over the past decade, and although China continues to seek alternative sources of energy, coal production most likely will continue to expand in the future. China benefits from substantial coal reserves representing 18% of coal deposits globally. To tap those resources, China has invested heavily in expanding domestic coal production. In fact, 67% of the future increase in global coal production will originate in China over the next two decades. Chinese supply will increase an average 1.7% per year, rising to 106,455 PJ in 2030.

Despite having large reserves of its own, China does import nearly 200 million short tons of coal each year to supplement domestic supplies (EIA, 2011). The actual amount imported depends on the domestic coal prices as well as the demand for coal in the electricity generation sector (Kebede and Taylor, 2011).

FIGURE 2.14: a) CHINESENATURAL GAS PRODUCTION AND CONSUMPTION, 1990-2030
b) CHINESE COAL PRODUCTION AND CONSUMPTION, 1990-2030



Source: EIA, 2011a

The increase in Chinese production in response to domestic and global demand growth will have considerable effects on global markets as a result - China will play a large role in the global coal market. Although coal will represent a decreasing share of the power sector, the growth in electricity consumption will also drive growth in total coal demand, requiring on average an additional 18 GW of coal capacity over 20 years.

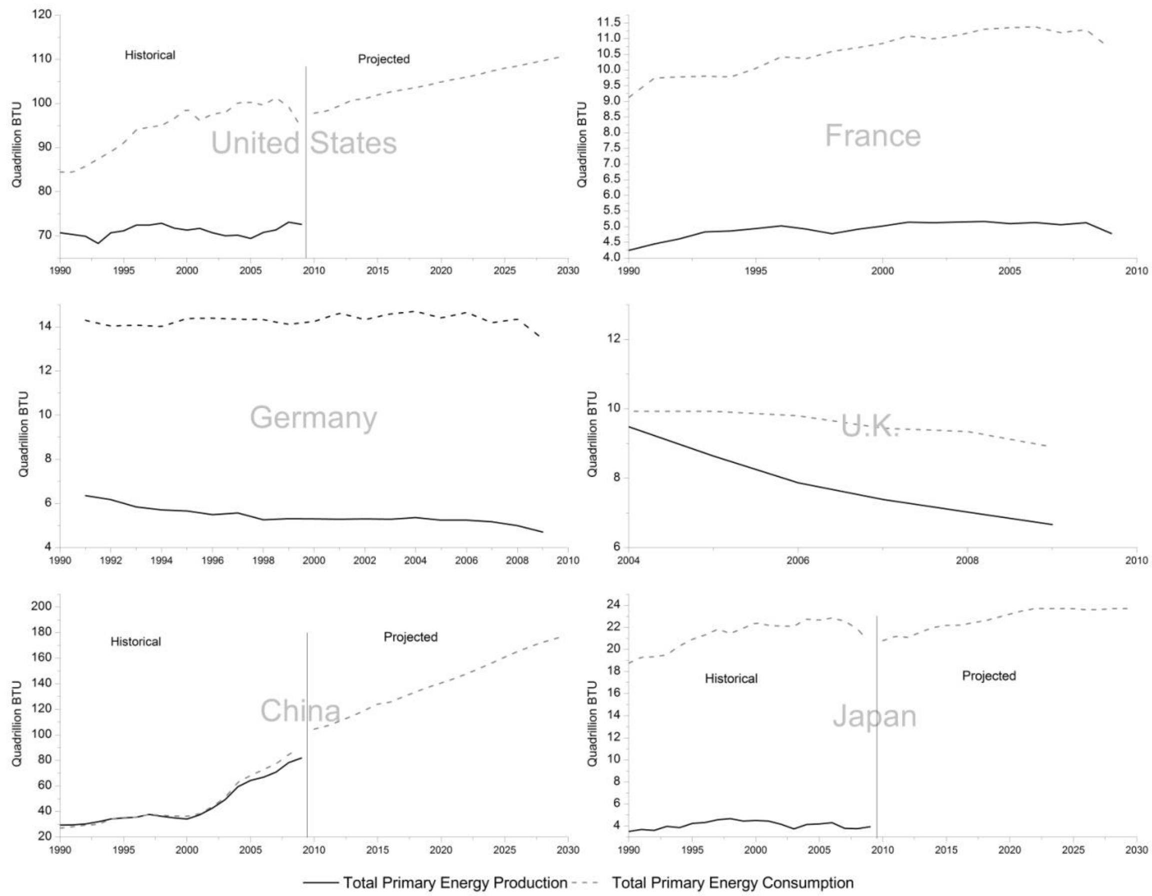
Natural gas contract prices in China, as for all of Asia, are typically indexed to oil prices. Thus, although projected global spot market gas prices will be low, contract prices for gas are expected to increase with rising oil prices. By the next decade, however, contract gas prices will begin to fall, returning to current price levels by 2030 (US$12/MMBtu). Prices in China may also shift due to renegotiated gas requirements and a gas agreement with Russia. A change in Chinese prices may lead to lower gas prices throughout Asia.

As indicated above, China is one of several Asian nations expected to drive coal markets over the next few decades. Rising Chinese demand and domestic production have already impacted on the global coal trade, and will continue to do so both in the short-term and long-term. Short-term prices, as projected by futures markets, will rise over the next few years in U.S. and European markets, but market prices will fall in Indonesia, South Africa, and Australia as a result of shifts in Chinese production and European demand. Long-term Australian export price projections, which are tied to Chinese demand and supply, are expected to fall considerably over the next decade reflecting the increased domestic Chinese coal production.

Total Primary Energy Supply and Demand

The total primary energy consumption and production for each of the six major energy consuming countries is depicted in Figure 2.15. The figure clearly shows that most countries experienced and expect growth in energy consumption. Given this consideration, this chapter now turns to the electricity generation profiles of the six major energy consuming countries to determine the response to the Fukushima nuclear accident and how these countries aim to provide the energy to meet the demand.

FIGURE 2.15: TOTAL PRIMARY ENERGY SUPPLY AND DEMAND, 1990-2030



Source: EIA, International Energy Statistics, 2012d

2.1.2 Supply, Demand and Price Projections

The following section details the analysis conducted by the PA Consulting group regarding projected coal and natural gas trends to 2030, as reported in *EE Frontiers*. This section reports the results of that analysis and therefore closely resembles the projections depicted in the previous section.

United States

The future domestic coal supply in the United States will benefit from its large coal reserves, which represent 27% of current global reserves. Coal production in the United States is expected to grow at a rate of 0.8% per year. Total production will increase from 23,373 PJ to over 26,693 PJ by 2030, representing a 0.74% increase. This supply increase will be in response to growing domestic consumption. Coal exports will continue to Europe and the Americas, but the U.S. share of the total coal imports into those regions is expected to decline slightly.

Despite the headway being made by renewable energy sources in the U.S., growth in domestic consumption will drive the U.S. coal markets over the next two decades. Demand for coal will rise at an annual rate of 0.8% reaching 24,688 PJ by 2030. This represents total growth in coal consumption of 0.82%. Although coal demand for electricity generation is expected to rise by 2030, growth will be below that of average growth in coal consumption for all sectors over the same period. Coal-fired generation will decline as a result, decreasing to 43% of total generation.

Short-term coal prices can be predicted using futures prices for coal derivatives. U.S. coal product prices are expected to increase to a lowest price of $15.35 and a high price of $73.13 per metric ton by 2016. Long-term forecasts are much more difficult to generate, but projected average domestic prices should not rise above $60/metric ton, while exports prices will rise to over $150/metric ton by 2030.

Although conventional gas resources in the U.S. are limited, nonconventional sources, especially shale gas, have led to a rapid increase in domestic production over the past few years. Therefore, gas supply projects are expected to increase to 26,482 PJ per year by 2030 at an average annual growth rate of 0.9%. By then shale gas will comprise 47% of total domestic gas production, and tight gas, another unconventional source, may comprise as much as 22%. The key unknown moving forward in the gas industry is the short-term and long-term effects of hydraulic fracturing ("fracking"), the technique used to extract shale gas. With growing concern, and evidence, over the negative consequences of fracking, future regulations and policy may have a detrimental impact on expanding gas production.

The United States currently is and will continue to be the largest global consumer of natural gas. However, demand growth over the next two decades is expected to be a modest 0.45% per year, reaching 27,326 PJ per year in 2030. Most of this growth will be driven by the industrial and power sectors. As a result of increasing domestic production, U.S. imports will decrease significantly over this period, falling at an average rate of 10.6% per year. This fall in import demand will lead to shifts in gas export markets globally as more highly valued resources move to markets in Europe, South America, and Asia.

Natural gas prices in the United States have fallen recently due to expanding domestic production, but in both short-term and long-term projections the price of gas steadily rises to 2030 by an average growth rate of 2.4% per year. Much of this increase in prices will result from additional production costs associated with unconventional gas resource extraction; furthermore, additional price increases can be expected if the U.S. producers begin to export gas. There is a great deal of variation in prices, though, and as mentioned for projected supply, shale gas regulation may result in different price outlooks than those considered by *E&E Frontiers*.

United Kingdom

Coal supply in the U.K. is linked to OECD European production, which is projected to decrease at a rate of 1.1% per year. Total production in OECD Europe will decrease from 6,262 PJ to 5.064 PJ per year by 2030; however, Russian coal production and exports to Europe are projected to increase during this time. By 2030, the share of imports in from South America and Eurasia to OECD Europe, including the U.K., will increase to 31% and 27%, respectively.

Coal demand in the U.K., as in much of OECD Europe, will decline during the period 2012-2030 as the power industry shifts towards cleaner burning fuels and alternative energy sources (PA Consulting, 2012). Total consumption is expected to decrease from 1,472 PJ to 927 PJ by 2030, representing an average annual rate of -2.5% per year. This average annual decline is higher than in the rest of OECD Europe (-.55%/year), but lower than the projected decrease for Germany. Much of the decline will occur in both the industrial and power sectors. However, new coal-fired plants currently planned or under construction will likely offset reductions in coal consumption from retiring plants.

Forecasted coal prices are difficult to determine due to shifting movements in coal trade, but according to *E&E Frontiers,* futures prices and market trends can be used to project short-term and long-term prices. Short-term futures prices in the Netherlands increase to 2017 from (US) $99.66 to $103.06 per metric ton. Long-term, U.S. export prices are expected to increase slightly, although coal supply and demand from China and other Asian nations will drive prices in the global coal market.

In the U.K., as in most of OECD Europe, gas production is projected to fall at an average annual rate of 0.3% per year. By 2035 production will fall to 8,757 PJ per year from current levels of 9,284 PJ. Although conventional sources are in decline, unconventional sources such as shale gas and coalbed methane exhibit significant potential. The U.K. has already begun production of coalbed methane. Furthermore, Russian gas production tops global production. Therefore, Russia will become a major supplier to Europe, and several projects will increase gas imports into Europe, topping 16,000 PJ by 2035.

Demand for natural gas in most of Europe is projected to increase, but demand in the U.K. will fall over the period between 2012 and 2030 to 2,276 PJ per year. This represents an average rate of -1.9% per year over this period.

Natural gas price forecasts in Europe can be predicted using futures prices from exchange markets. Short-term spot market prices are expected to increase in Europe drastically over the next few years, including in U.K. markets from about €22 to €25 per MWh, which is similar to trends in both German and Dutch gas futures markets. Longer-term prices, however, are more difficult to predict due to the structure of gas markets which include both contracted and spot prices for gas supplies. If current trends in favor of spot market prices, which are not indexed to oil, prices likely would fall.

Germany

Like the U.K., German coal supply is linked to OECD Europe production, which is projected to decrease at a rate of 1.06% per year. Coal demand in Germany is expected to decline during the period 2012-2030 (PA Consulting, 2012). Total consumption is expected to decrease from 1,518 PJ to 740 PJ by 2030, representing an average annual rate of -3.9% per year. This annual decline is higher than in the rest of OECD Europe (-0.55% per year), including both the U.K. and France. Much of the decline will occur in the power sector. However, new coal-fired plants currently planned or under construction will likely offset reductions in coal consumption from retiring plants. Half of the 20 GW of new coal plants currently under construction in Europe are located in Germany; furthermore, the new policy to phase out nuclear generation will most likely lengthen the lifetimes of up to 13 GW of older coal plants.

In OECD Europe, natural gas will enjoy rising demand due to growing use of gas for electricity generation; the projected consumption in Germany will decrease by 1.2% per year on average. This will result in reduction in annual consumption from 4,247 PJ to 3,392 PJ by 2030. However, due to recent Germany policies to replace nuclear generation capacity and reduce GHG emissions, natural gas could experience a period of growing demand for electricity generation.

France

Coal demand in France, similar to trends in Germany and the U.K., will decline at an average annual rate of 2.2% between 2012 and 2030. Total consumption will drop to 276 PJ from 413 PJ per year. The use of coal in industry will fall, and the share of coal used to generate electricity is also projected to decrease.

In OECD Europe, natural gas will enjoy rising demand due to growing use of gas in electricity generation; however, the projected consumption in France will decrease by 1.4% per year on average. This will result in reduction in annual consumption from 1,738 PJ to 1,358 PJ by 2030.

Japan

Japan has no substantial coal reserves, and therefore projected production is negligible. As a result, Japan imports more coal than all other Asian countries; Japan depends heavily on Australian imports, which supply 60% of its coal. Recently, Japanese companies have sought to diversify their coal supplies by exploring or investing in coal production in both Russia and Canada.

Although Japan has historically been the largest coal consuming nation in OECD Asia, coal demand is expected to decrease from 2012 to 2030. Total consumption in 2030 is projected to be 4,220 PJ, down from 4,853 PJ in 2012. The decrease in demand will be driven primarily by two sources. First, the Japanese population is declining, thus reducing future demand projections. Second, the Japanese government has made numerous commitments to alternative energy sources to reduce its GHG emissions, which will shift consumption away from coal.

Japanese coal prices are tied to Australian futures prices in the short-term and the Australian coal price long-term outlook. Australian futures prices will decrease from (US) $105.98 to $99.46 per metric tonne by 2017. Long-term Australian export prices will also decrease significantly by 2023 due to increasing domestic production in China. While, these trends would result in lower Japanese coal prices, demand is not expected to shift towards coal due to the declining population and expansion of alternative energy discussed earlier.

Japanese natural gas production only meets 5% of domestic demand, and is projected to remain a minor contributor to its gas supply. Current production of 106 PJ per year is projected to increase an annual average of 3% per year, rising to 211 PJ by 2035. Currently, Japan is among the largest global natural gas importers. Most of its imports are liquefied natural gas (LNG) supplies, amounting to 3,798 PJ in 2012. These imports will rise, but at a rate of only 0.2% per year, to 4,009 PJ in 2035.

Japanese natural gas demand over the next two decades will rise from 3,904 PJ to 4,220 PJ per year, driven primarily by efforts to replace the nuclear capacity lost after the accident at Fukushima. Especially for the short-term, gas demand is expected to increase as new contracts have been signed and gas exports have been diverted to Japan. However, as with coal, long-term demand for gas will decline with the population and the movement towards alternative, low carbon fuels. Ultimately, long-term projections will be affected by any changes in Japanese energy policy to reduce the nuclear share of power generation. Such a shift would favor natural gas as a substitute both in the short-term and long-term.

LNG price contracts are typically indexed to oil prices. Therefore, short-term and long-term market contract prices do not often match spot market gas prices. Projected global spot market gas prices are low, but contract prices for gas are expected to increase with rising oil prices. By the next decade, though, contract gas prices indexed on the Japanese Crude Cocktail basket are projected to fall, returning to current price levels by 2030 (US$12/MMBtu).

China

China benefits from substantial coal reserves representing 18% of coal deposits globally. Due to its recent economic growth and rise in energy demand, China has invested heavily in expanding domestic coal production, and 67% of the future increase in production globally will originate in China over the next two decades. Chinese supply will increase an average 1.7% per year, rising to 106,455 PJ in 2030. The increase in Chinese production in response to domestic and global demand growth will have considerable effects on global markets as a result.

China will play a large role in the global coal market in the coming years due to its recent demand growth. The *E&E Frontiers* report projects that demand for coal will increase at an annual average rate of 1.8%, with consumption rising to 112,363 PJ by 2030. Growth in demand for coal is driven primarily rising energy demand due to the rapid economic growth in China. Although coal will represent a decreasing share of the power sector, the growth in electricity consumption will also drive growth in total coal demand, requiring on average an additional 18 GW of coal capacity over 20 years.

China is one of several Asian nations expected to drive coal markets over the next few decades. Rising Chinese demand and domestic production have already impacted on the global coal trade, and will continue to do so both in the short-term and long-term. Short-term prices, as projected by futures markets, will rise over the next few years in U.S. and European markets, but market prices should fall in Indonesia, South Africa, and Australia as a result of shifts in Chinese production and European demand. Long-term Australian export price projections, which are tied to Chinese demand and supply, fall considerably over the next decade indicating the effects of increasing domestic Chinese coal production.

China will increase its domestic gas production considerably over the next 20 years, growing at an average annual rate of 3.9% from 3,165 PJ to 7,702 PJ per year. China has limited conventional gas resources; however, significant potential to increase gas production exists through development of coalbed methane and shale gas resources. Currently, China is exploring potential shale gas sites with several international companies, and the government already offers a production subsidy for coalbed methane. Despite its efforts to extract its domestic gas resources, China will remain a large net importer of natural gas. *E&E Frontiers* reports that up to 40% of its annual consumption will be met by imports by 2035, which will rise from 950 PJ in 2012 to 4,853 PJ in 2035.

Chinese demand for natural gas will rise considerably between 2012 and 2030, in part from a governmental program promoting gas consumption. The government's gas share target is 10% of the primary energy mix by 2020, or 9,000 PJ. Projected gas demand grows from 4,009 PJ to 7,174 PJ per year by 2020 and 10,762 PJ per year by 2030. This represents an average annual growth rate of 5.64%, which would be the highest global growth rate for natural gas.

Natural gas contract prices in China, as for all of Asia, are typically indexed to oil prices. Thus, although projected global spot market gas prices will be low, contract prices for gas are expected to increase with rising oil prices. By the next decade, though, contract gas prices will begin to fall, reaching current price levels by 2030 (US$12/MMBtu). Prices in China, however, may shift due to renegotiated gas requirements and a gas agreement with Russia. Such a change in Chinese prices may lead to lower gas prices throughout Asia.

2.2 Electricity Mix Profiles: Historical and Projected

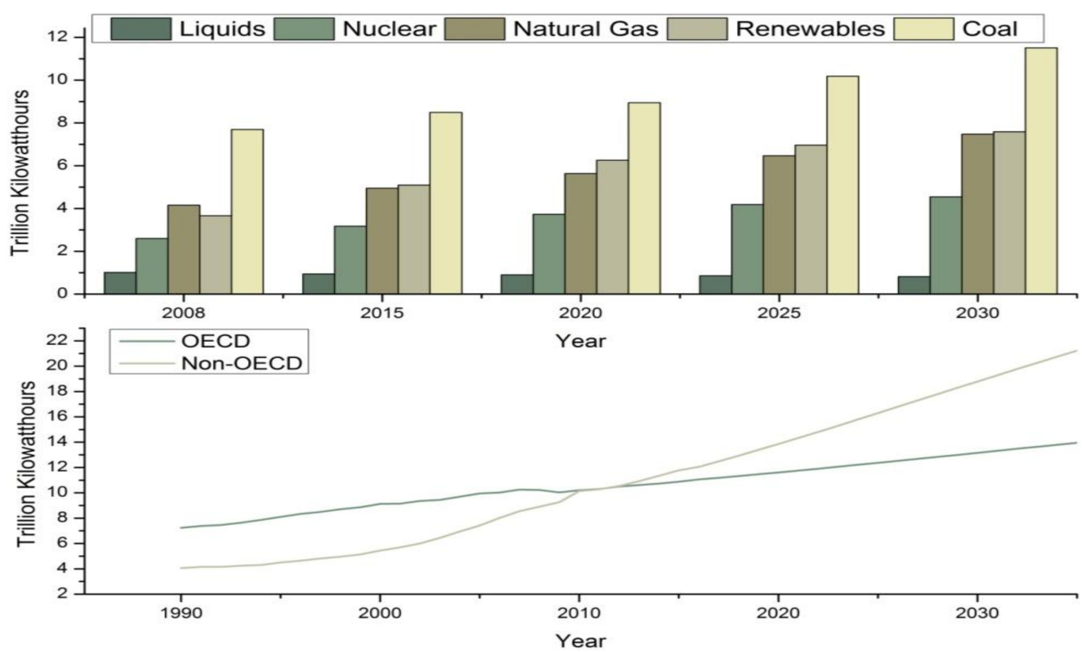
In the previous chapter, this report outlined the historical and projected changes in supply, demand, and prices of energy. The clear messages from that chapter are that natural gas and coal supply and demand are projected to increase in the future, that prices are expected to rise, and that prices of conventional energy show high volatility. The expected increase in demand – and therefore in supply – most often corresponds with an expected increase in electricity generation, the main topic of this section. To further detail the developments in the electricity generation – both in a historical as well as projected sense – this section explores the electricity generation mix of the major energy consuming countries discussed in this book. In this, the scenarios developed for electricity generation of each of these countries are examined in detail. As we will see, an overall picture will emerge after understanding the scenarios for each of the individual countries. However, to get a sense of the worldwide (expected) developments, this chapter first turns its attention to an overview of the global electricity generation mix and its projected development.

2.2.1 Global Electricity Generation Mix Overview

To get a sense of the global dynamics of electricity generation, this section briefly outlines the expected developments in the global market of electricity generation. Three major relevant trends can be discerned in the global developments. First, the world net electricity generation will become increasingly dependent on coal, natural gas, and renewable energy (see Figure 2.16a). In fact, the Energy Information Administration's (EIA) projected developments in the world net electricity generation over the 2008-2030 period – as outlined in their International Energy Outlook (IEO) 2011 Reference Case – show natural gas doubling its generation share and coal increasing by 167% (EIA, 2011a). The EIA projects renewable energy will grow the fastest over this time period (by 221.6%), but remains a considerably smaller net electricity contributor to world electricity generation than natural gas. As can be seen in Figure 2.16a, substantial increases are also expected for nuclear electricity generation (it is projected to increase by 188% over the 2008-2030 time period), but coal remains the dominant electricity resource.

The second dominant trend that can be discerned is the regional shift in importance in the world electricity generation market. Whereas OECD countries generated the majority of net electricity in 2008, non-OECD countries are projected to overtake the OECD sometime around 2013 and will account for the predominant share of global net electricity generation in the future (see Figure 2.16b). China, India, and the remaining Asian countries, in particular, will comprise a significant share of world net electricity generation. For instance, the IEO 2011 Reference Case – their 'business-as-usual' case – shows that from 2008 to 2035 non-OECD countries increase their net electricity generation by an average of 3.3% per year, whereas non-OECD Asia (including China and India) are expected to have annual increases that average 4.0%. When compared to the OECD net generation growth of an expected 1.2% over the same time period, the regional shift in net electricity generation is apparent.

FIGURE 2.16: a) WORLD NET ELECTRICITY GENERATION BY FUEL, 2008-2030
b) OECD AND NON-OECD NET ELECTRICITY GENERATION, 1990-2035

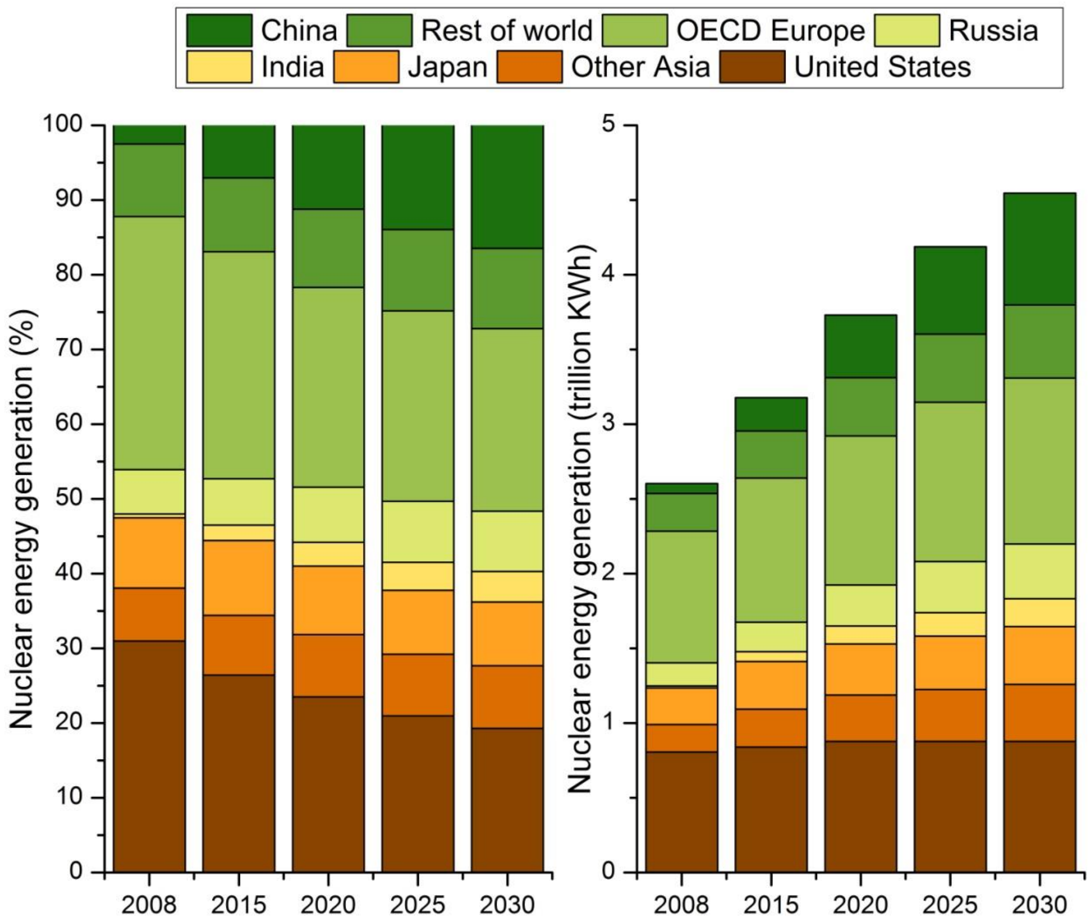


SOURCE: EIA, 2011a.

It is important to note that the IEO 2011 nuclear projections do not reflect consideration of policy responses to Japan's Fukushima Daiichi nuclear disaster (see the individual country assessments for a reflection of the disaster). The world electricity generation from nuclear energy in the world's major regions/countries is shown in Figure 2.17. At the time these projections were generated, a drastic increase was expected for the non-OECD countries and especially China. However, for the foreseeable future, the regions where nuclear energy predominates – again, these projections illustrated here do not include Fukushima policy response – remain the United States and OECD Europe. As the

International Atomic Energy Agency (IAEA) shows, with an overall total of 435 reactors, the United States (having 104 operating reactors at the time of this writing), France (58), Japan (50), Russia (33), and the Republic of Korea (23) lead the world list in nuclear reactors (IAEA, 2012). However, with China at an expected average growth rate of 10.3% per year in nuclear power, India at an average rate of 10.8%, and non-OECD Asia overall averaging 9.2%, the Asian region is expected to install the most nuclear power capacity over the period from 2008-2035. In fact, in 2011, China leads with nearly 44% of the world's active reactor projects under construction (EIA, 2011a).

FIGURE 2.17: WORLD NET ELECTRICITY GENERATION FROM NUCLEAR POWER BY REGION, 2008-2030



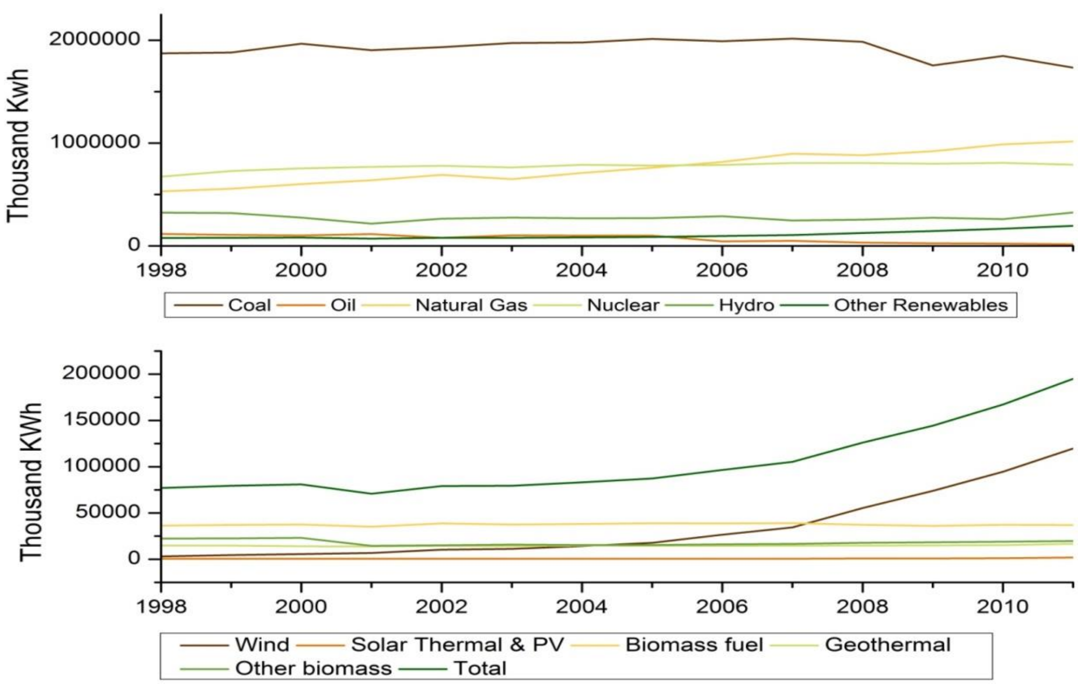
SOURCE: EIA, 2011a.

2.2.2 Historical Electricity Generation Mix in Major Energy Consuming Nations

United States

In the United States, the coal dominates the electricity generation mix (Figure 2.18a). In 2011, the share of electricity generated using coal was approximately 42%, whereas natural gas accounted for 25%, nuclear for 19%, and renewables (including conventional hydro) for 13% (EIA, 2012) of the country's 4,000 TWh of electricity. In Figure 2.18a, the developments over time show that the historical electricity generation mix very much resembles the contemporary electricity generation mix. However, it does show that, while coal has been the predominant source of electricity, its share recently started to decline. In fact, coal generation decreased 29 TWh over 2011-2012 (EIA, 2012b). The decline is partially due to low natural gas prices which increases the competitiveness of natural gas in the electricity market, as evidenced by the sharp increase in the use of natural gas. In fact, as the July 6th edition of the EIA's *Today in Energy* highlighted that for the first time in history, the amount of generation from natural-gas fired plants was essentially equal to that from coal-fired facilities (EIA, 2012c). The next largest single source of electricity, nuclear energy, meanwhile only increased 17% over the period from 1998-2011 – as evidenced by the nearly flat line of its share in Figure 2.18a. No new facilities came on line during that time but existing plants were able to increase their output through "uprates" – refueling with more enriched uranium fuel to produce more thermal energy and thus more electricity (NRC, 2011). Finally, 'other renewables' such as wind, solar thermal and photovoltaic (PV), and biomass, showed a significant increase in the latter half of the time period. This is represented in more detail in Figure 2.18b. As can be seen in Figure 2.18b, electricity generated by wind especially has increased sharply over the time period (almost 4000% since 1998), driven in part by favorable tax policies. While solar also increased sharply (about 362% over the time period), it remains a small contributor to overall electricity generation.

FIGURE 2.18: a) U.S. NET GENERATION BY ENERGY SOURCE, 1998-2012
b) U.S. NET GENERATION BY OTHER RENEWABLES

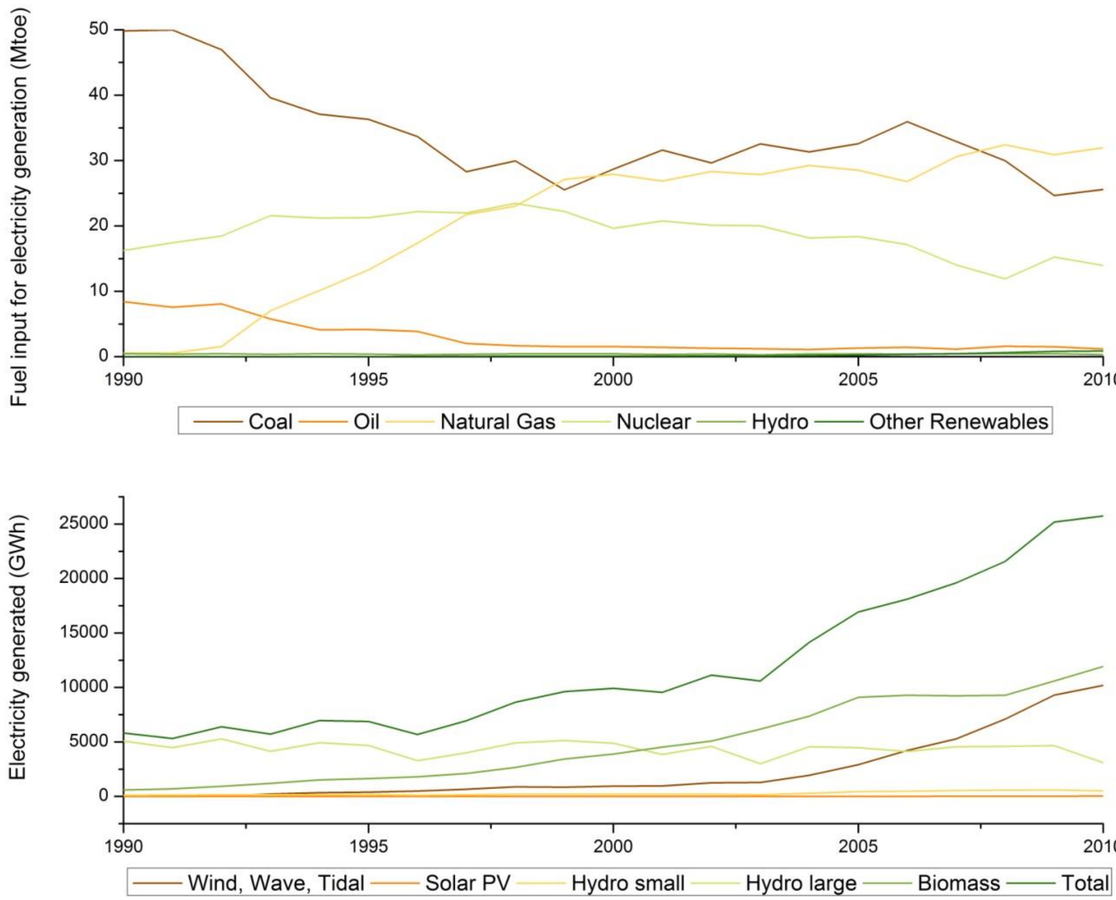


SOURCE: EIA, 2012a.

United Kingdom

The Digest of U.K. Energy Statistics (DUKES), a statistical summary by the DECC, contains the energy statistics for the United Kingdom. The historical fuel inputs for electricity generation, in million tons of oil equivalent (Mtoe), are illustrated in Figure 2.19. The U.K.'s 'dash for gas' can be clearly discerned from the figure: Coal inputs for electricity have fallen by 49% over the 1990-2010 period, while gas increased from practically nothing to a 40% share (DECC, 2012a). With total electricity generated in the U.K. in 2010 at 381 TWh, the nuclear industry's 16.3% share (62 TWh) positions it as the third largest contributor to the electricity generation mix. At 27 TWh, all renewable sources together represent about 7% of that mix. As seen in 2.19b, wind (10 TWh) and biomass (thermal renewables and wastes) (13 TWh) represent the lion's share of U.K.'s renewables portfolio.

FIGURE 2.19: a) U.K. FUEL INPUT FOR ELECTRICITY GENERATION BY MAJOR SOURCE IN MTOE
b) U.K. RENEWABLE SOURCES USED TO GENERATE ELECTRICITY

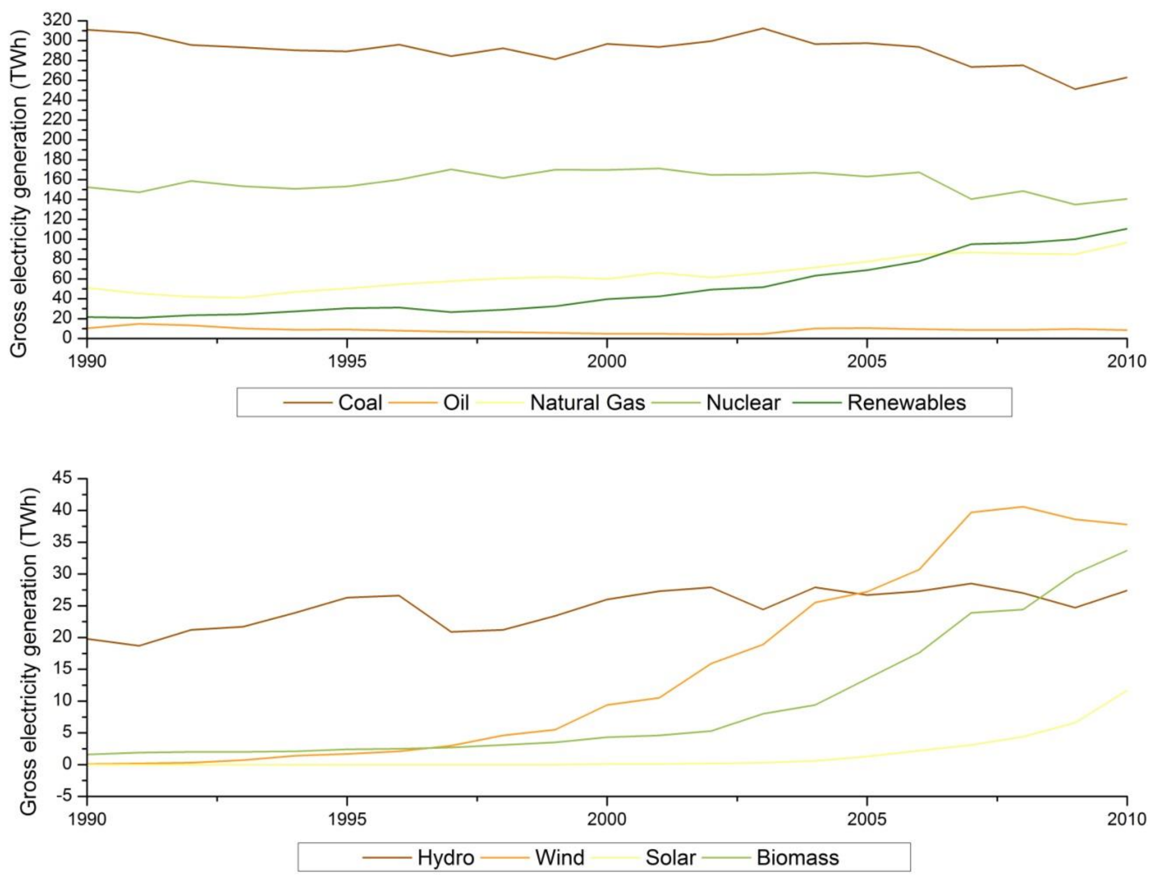


SOURCE: DECC, 2011a

Germany

The Directorate General for Energy (DGE) in the European Union collects and publishes the essential energy statistics in "EU Country Factsheets." The data for Germany from those Factsheets are shown in Figure 2.20a and 2.20b. In Germany, electricity generation from coal makes up about 42% of the gross electricity generation and, as such, is the largest source of electricity (EC, 2012). Nuclear (22.4%) and natural gas (15.4%) are the next largest single sources of electricity. The combined share of all renewables is 17.6%, of which wind is the largest contributor followed by biomass. A rapid increase in renewables is observed over the 1990-2010 time period, during which wind energy, especially, increased rapidly. In addition, solar energy followed an exponential growth pattern and started to pick up speed in the final years between 1990 and 2010.

FIGURE 2.20: a) GERMAN GROSS ELECTRICITY GENERATION BY MAJOR SOURCE, 1990-2010
b) GERMAN GROSS ELECTRICITY BY RENEWABLES, 1990-2010

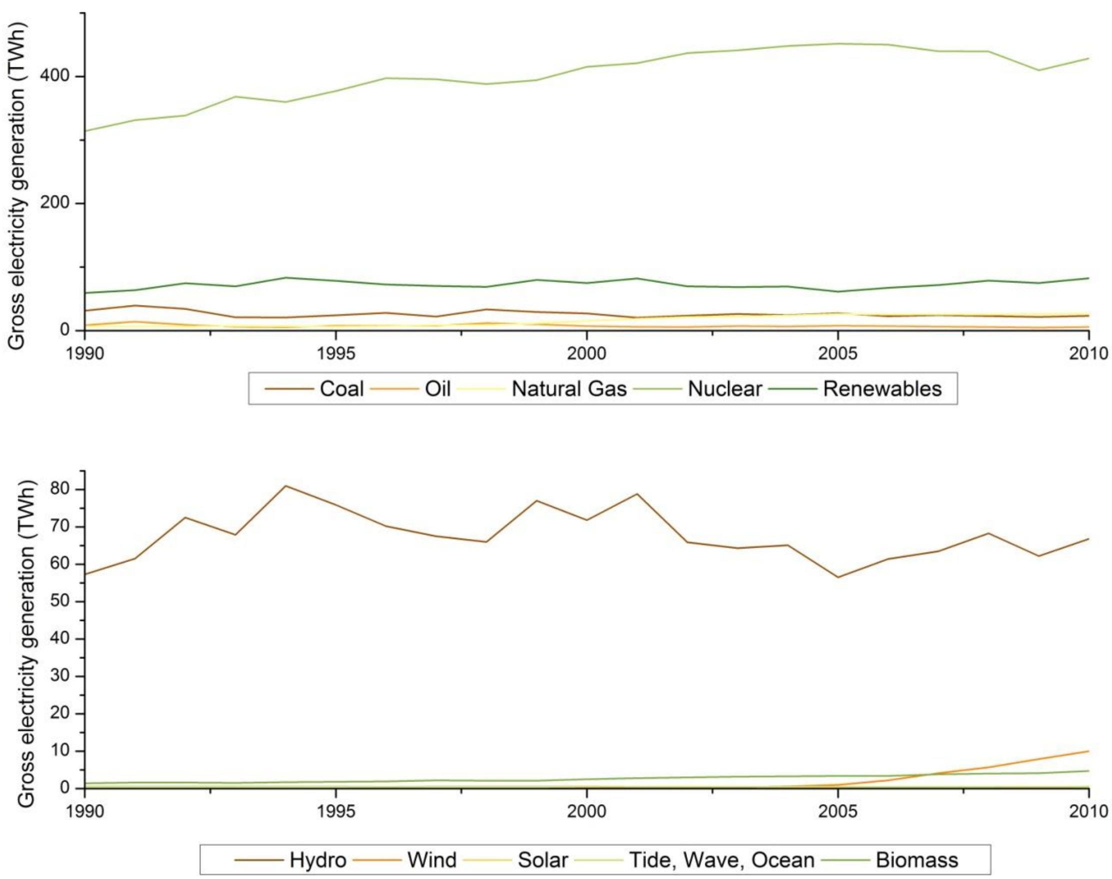


SOURCE: EC, 2012

France

As a result of the ambitious "Messmer Plan" of the 1970s, which laid out a program to obtain all of France's electricity needs from nuclear power, the electricity generation mix in France has been dominated by nuclear energy (see Figure 2.21a). Hydroelectric power is the second largest contributor to the electricity supply (see Figure 2.21b), remaining fairly constant between 60 – 80 TWh over the entire 1990-2010 time period (EC, 2012). Fossil fuel contributions come primarily from coal, supplemented by smaller amounts of oil and natural gas. Non-hydro renewables were virtually non-existent for most of the historical electricity generation period, but have risen to 15.8 TWh in 2010 signaling a shifting priority for the French electricity industry driven by the national renewable energy action plan and European Union initiatives on clean energy (see Figure 2.21b).

FIGURE 2.21: a) FRENCH GROSS ELECTRICITY GENERATION BY MAJOR SOURCE, 1990-2010
b) FRENCH GROSS ELECTRICITY GENERATION BY RENEWABLES, 1990-2010

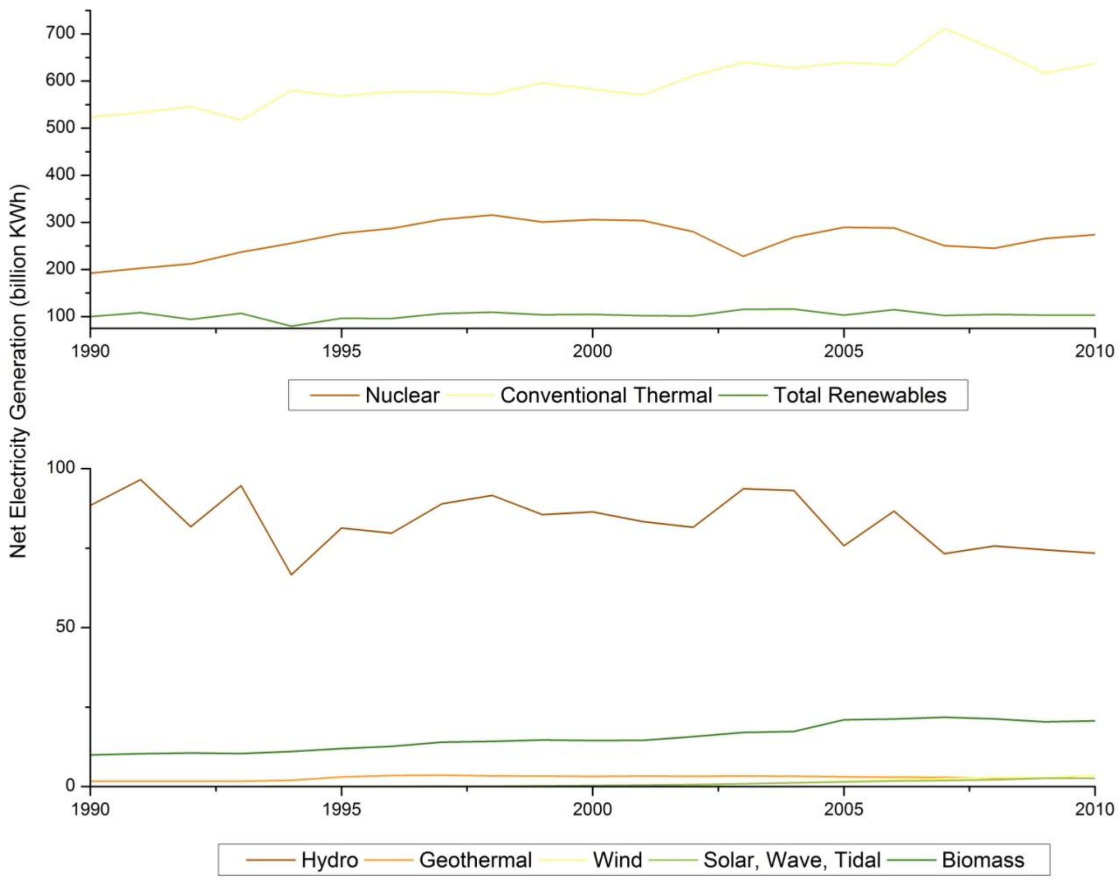


SOURCE: EC, 2012

Japan

The “International Energy Statistics” database – compiled by the EIA – provides an overview of Japan’s historical electricity generation mix (Figure 2.22a and 2.22b). Clearly, Japan primarily has relied on conventional fossil fuel sources, principally oil, coal, and natural gas, for its electricity supply (EIA, 2012d). At around 10%, renewable energy sources combined to make up the smallest share in Japan’s electricity supply, of which hydroelectric electricity (approximately 72% of all renewables) is the predominant source of electricity followed by biomass (approximately 20%). In 2010, Japan´s nuclear electricity sector produced 27% of the electricity generated in Japan.

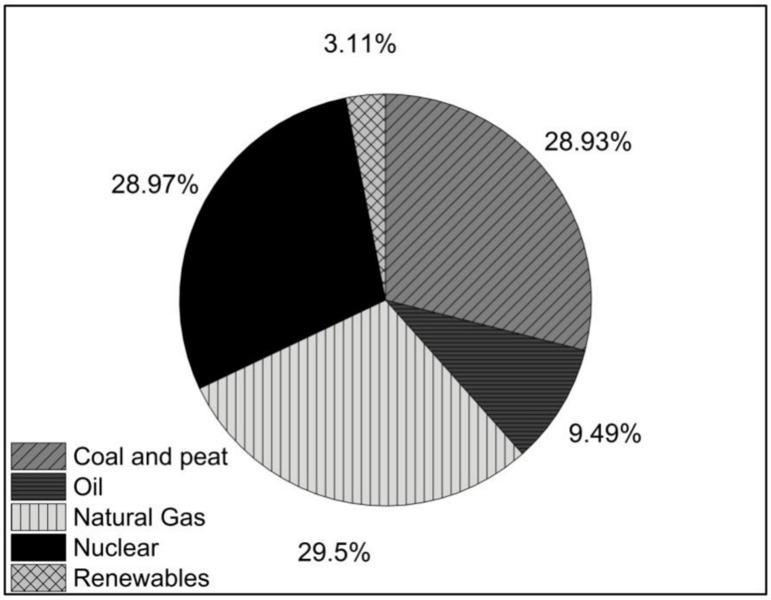
FIGURE 2.22: a) JAPANESE NET ELECTRICITY GENERATION BY MAJOR SOURCE, 1990-2010
b) JAPANESE NET ELECTRICITY GENERATION BY RENEWABLES, 1990-2010



SOURCE: EIA, 2012d.

The category 'conventional thermal' shown in these figures is an aggregation of oil, natural gas, and coal. To provide a more detailed perspective, Figure 2.23 contains a 2009 overview of Japan's electricity generation (International Energy Agency (IEA), 2011a). Natural gas (29.5%) makes up the majority of the 'conventional thermal' electricity generation in Japan, closely followed by coal (and peat) at 28.9%. Oil (at 9.5% of Japan's electricity generation) makes up the final component of the category. Overall, Japan is highly dependent on energy imports -- it is only 16% self-sufficient for domestic power supply as indicated in an EIA Country Analysis Brief (EIA, 2012e). For instance, as detailed in the previous chapter, Japan doesn't produce coal domestically but is fully dependent on coal imports to generate the 28.9% share of the electricity mix.

FIGURE 2.23: JAPAN'S ELECTRICITY GENERATION MIX, 2009



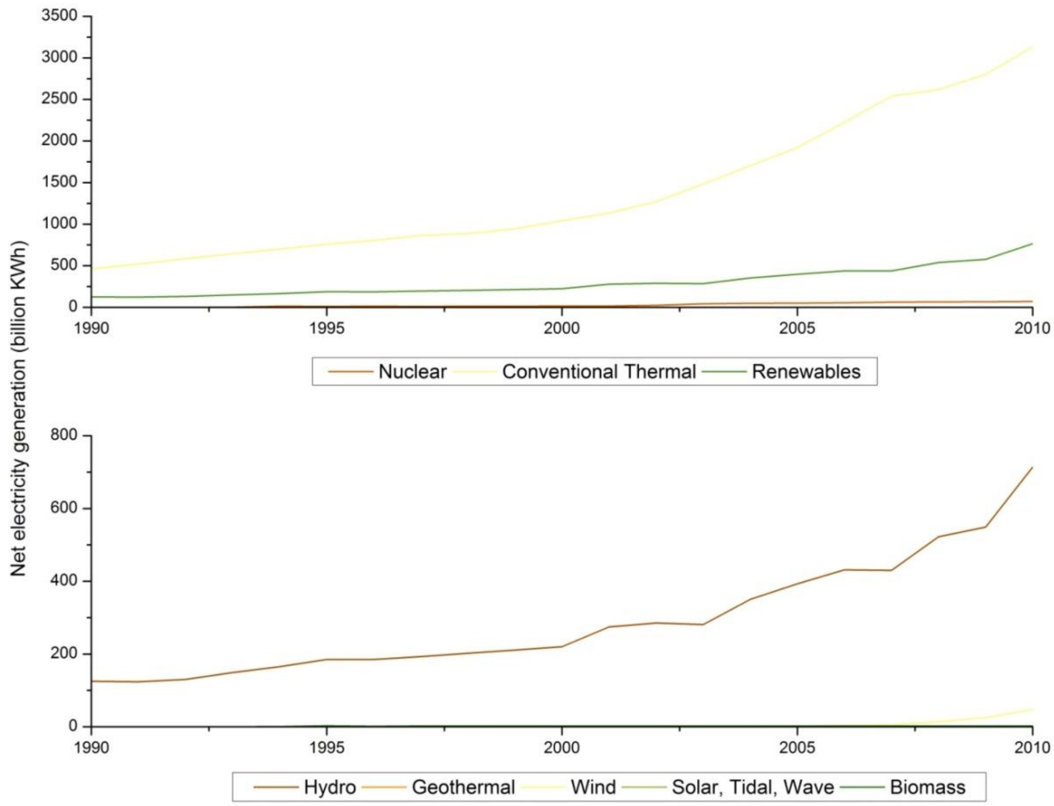
SOURCE: IEA, 2011a.

China

Conventional thermal sources currently account for about 79% of total power generation and over 77% of the installed capacity in China (Figure 2.24). In 2010, China generated about 3,130 TWh from conventional thermal sources, about 70 TWh from nuclear energy, and 764 TWh from all renewables combined (including conventional hydro and biomass) (EIA, 2012d). Out of the renewables, the majority of electricity is generated by hydroelectricity (713 TWh) followed by wind (48 TWh). In fact, China is the world's largest producer of hydroelectric power as its installed capacity of 197 GW accounts for over a fifth of worldwide total installed capacity.

As discussed earlier, China actively promoted nuclear power as a clean source of electricity generation prior to the Fukushima nuclear accident. With nuclear power at approximately 2% of electricity generation in China, the contribution of the sector might seem inconsequential, but many of the major developments taking place in the Chinese electricity sector involve nuclear power. For instance, as of 2011, China had only 14 operating reactors but had an additional 26 reactors under construction. In fact, as outlined in the first section, China plans to substantially increase its nuclear power generating capacity (EIA, 2011a).

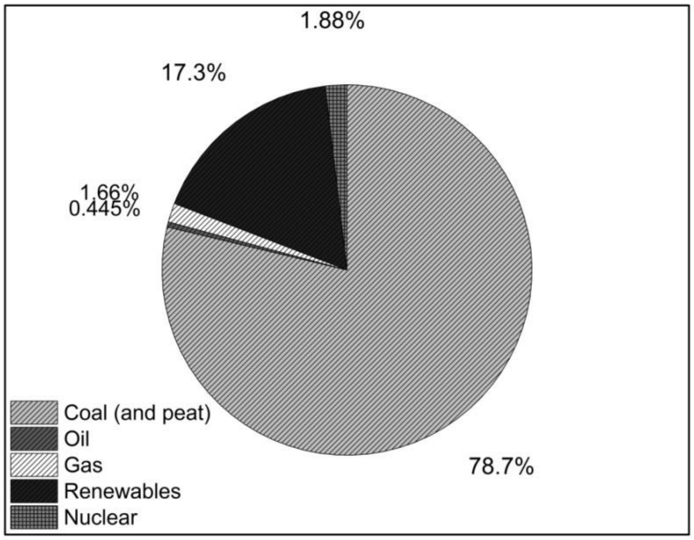
FIGURE 2.24: a) CHINESENET ELECTRICITY GENERATION BY MAJOR FUEL SOURCE, 1990-2010
b) CHINESE NET ELECTRICITY GENERATION BY RENEWABLES, 1990-2010



SOURCE: EIA, 2012d

Again, to get a better understanding of China's energy dynamics, it is important to disaggregate the 'conventional thermal' aggregate into its constituent sectors of oil, natural gas, and coal. The IEA provides a 2009 disaggregated overview of China's electricity generation (IEA, 2011c). Figure 2.25 shows the shares of coal, oil, natural gas, nuclear and renewables in 2009 in China. Clearly, of the conventional thermal fuels, coal (78.7%) dominates the electricity generation mix, followed by renewables (17.3%) – predominantly hydroelectricity – and smaller shares are generated by nuclear (1.88%), gas (1.66%), and oil (0.445%).

FIGURE 2.25: CHINESE ELECTRICITY GENERATION MIX, 2009



SOURCE: IEA, 2011b

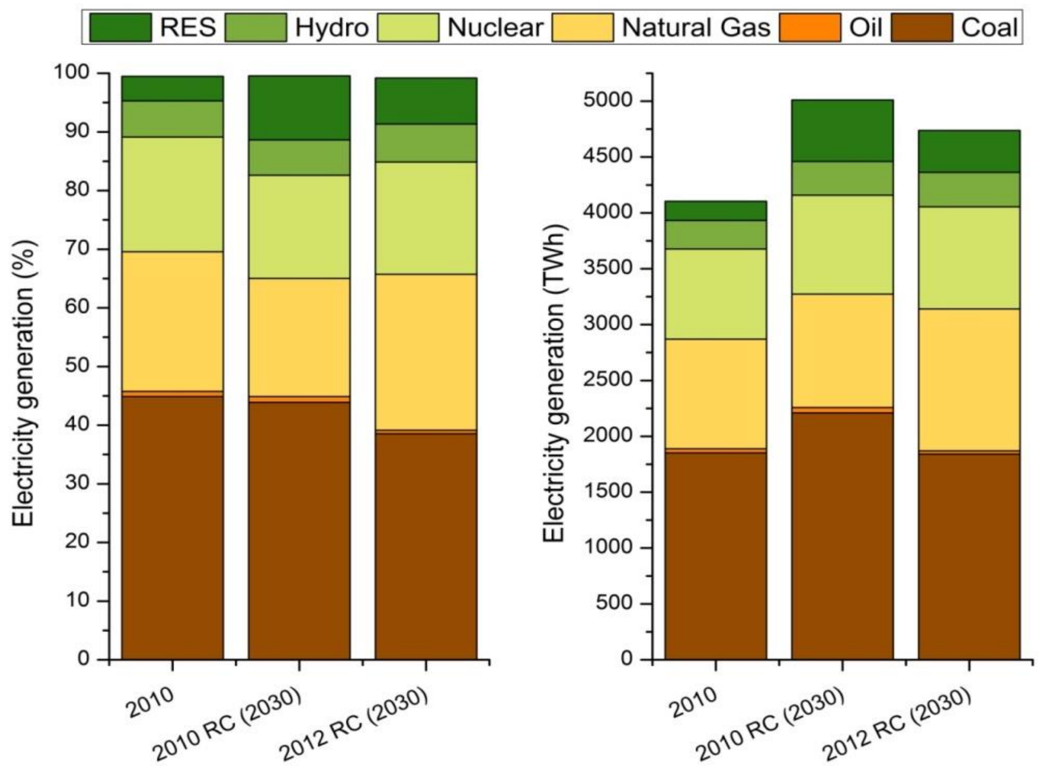
2.2.3 Future Generation Mix Projections

Now that we have a clear overview of the supply, demand, and price developments plus a picture of the electricity generation mix – and thus the extent of dependency the major consuming countries face towards any particular fuel – this section explores the projected electricity generation mixes. An important aspect we aim to elucidate is whether the projections for the fuels – and in particular nuclear power – changed after Fukushima, and thus from the data presented above. As such, each section contains scenarios made by the respective country prior to the Fukushima accident, and scenarios made after the Fukushima accident – if these are available. Thus, we can get a sense of the impact of the disaster in Japan on global developments of nuclear energy.

United States

The EIA's Annual Energy Outlook (AEO) contains a number of scenarios for projected electricity generation mix to the year 2035. The 'Reference Case' reflects a set of assumptions that together form a business-as-usual (BAU) scenario. The AEO is an annual publication and, as such, has provided U.S. energy projections both prior to and after the Fukushima disaster. In Figure 2.26, the Reference Case (RC) from both AEO 2010 and AEO 2012 are given together with the actual electricity generation mix of 2010. We would expect the AEO 2012 RC projection to incorporate any policy changes following the Fukushima accident. However, the changes from the 2010 RC scenario to the 2012 RC scenario are limited. The primary differences are that the 2010 RC scenario incorporates less natural gas (an increase of 25% between the two scenarios) and more coal (a decrease of 40% between the two scenarios), and generates 5% more electricity in total. Importantly, the forecast for nuclear energy in 2030 in the 2012 RC is 3% higher (914 TWh compared to 886 TWh) than the 2010 RC, suggesting that the Fukushima nuclear accident had only minor effect on the newest projections. The projections for renewable energy have decreased in the new BAU scenario (from 550 TWh to 375 TWh).

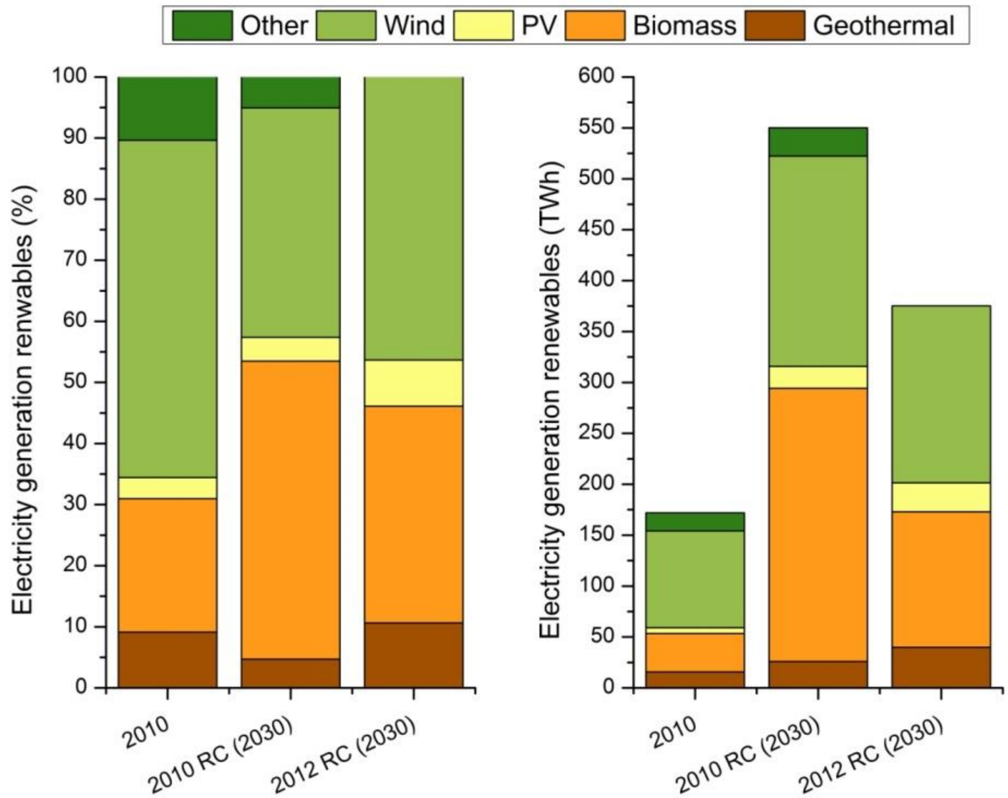
FIGURE 2.26: U.S. ELECTRICITY GENERATION MIX BY SCENARIO PRE- AND POST-FUKUSHIMA



SOURCE: EIA, 2011b; EIA, 2012f.

The renewable energy sources (RES) depicted in Figure 2.26 can be further disaggregated into individual components. As seen in Figure 2.27, wind energy remains a dominant renewable energy source in both projections. Biomass similarly maintains its share in both projections. As mentioned, the overall contribution of renewables decreased in the most recent projections.

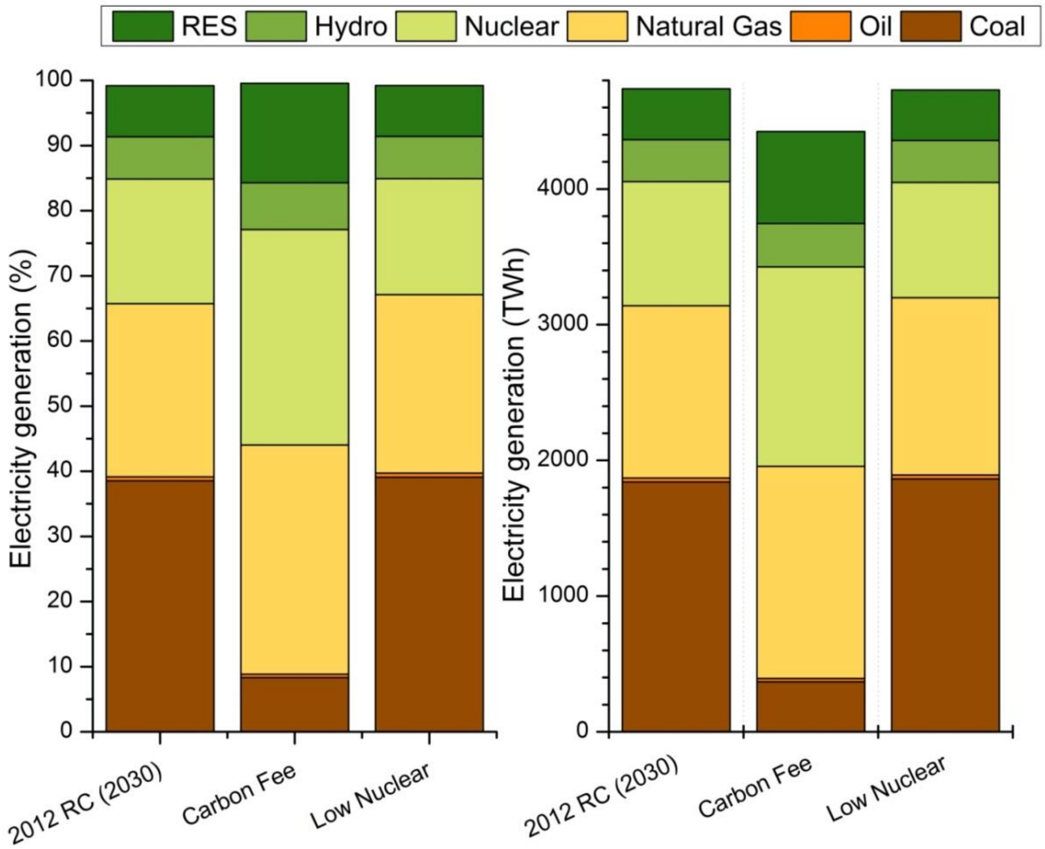
FIGURE 2.27: U.S. RENEWABLE ELECTRICITY GENERATION BY SCENARIO PRE- AND POST-FUKUSHIMA



SOURCE: EIA, 2011b; EIA, 2012a; EIA, 2012f

The EIA maintains a variety of scenarios – each with its own assumptions – that together give an overview of the range of potential developments in terms of electricity mix. For instance, in their greenhouse gas (GHG) price scenario, the EIA models the electricity generation mix under a CO_2-emission price of US$25 per ton beginning in 2012. Throughout the scenario, this price increases to eventually reach US$75. Figure 2.28 depicts three scenarios: the 2012 RC, a scenario in which a carbon fee is implemented, and a ‘low nuclear’ scenario. These scenarios are apt in the context of this chapter since a) the 2012 RC acts as a proxy 2011 post-Fukushima BAU scenario; b) the carbon fee scenario represents the scenario with the highest contribution by nuclear energy in the electricity generation mix; and c) the low nuclear scenario represents the projected maximum reduction in nuclear energy over the time period to 2030. As can be seen in Figure 2.28, the low nuclear scenario is very similar to the RC 2012 scenario.

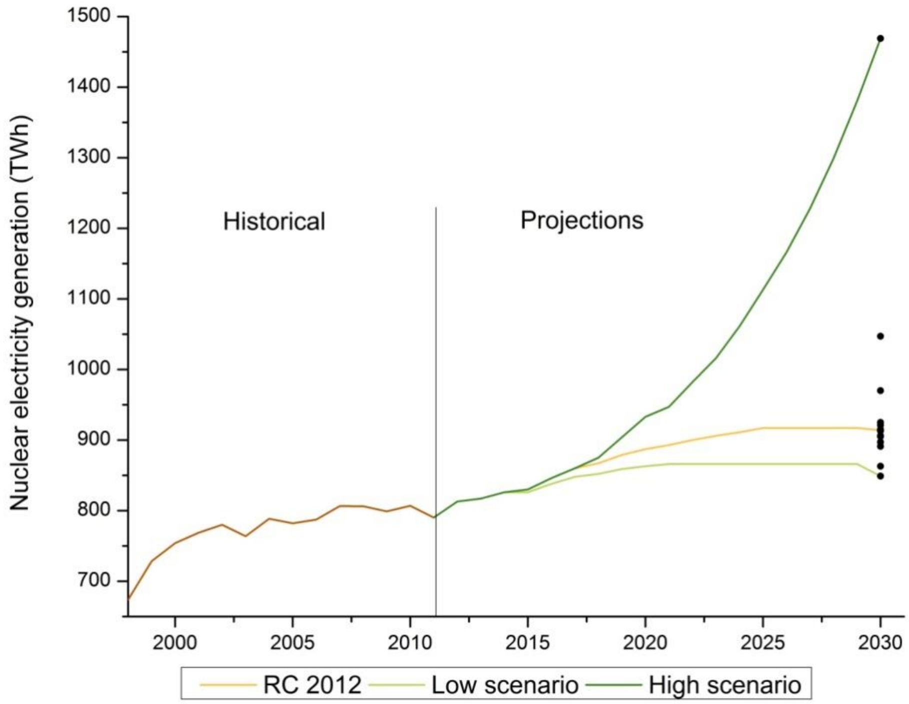
FIGURE 2.28: U.S. ELECTRICITY GENERATION BY A LOW NUCLEAR AND CARBON FEE SCENARIO



SOURCE: EIA, 2011b; EIA, 2012a; EIA, 2012f

The EIA presents 31 different scenarios – each based on their own set of particular assumptions and developments over time. To get a sense of the range of possibilities, Figure 2.29 depicts the range of nuclear electricity generation over this range of scenarios. The 'low nuclear' scenario and the '$25 per ton carbon fee' scenario – both already presented in Figure 2.28 – form the low nuclear and the high nuclear scenarios. As can be seen in the Figure 2.29, the $25 carbon fee scenario realizes a significantly higher trajectory for nuclear energy than all the other scenarios. This finding highlights the trade-off often made in politics between low-carbon nuclear electricity and high-carbon coal-fired electrical generation: under a carbon-constrained scenario, nuclear energy is often seen as the more attractive option. Most other scenarios, however, present a much lower share of nuclear energy in the electricity generation mix. In fact, most (except for the $15 per ton carbon fee scenario) are very similar to the Reference Case 2012 scenario (EIA, 2012f).

FIGURE 2.29: U.S. NUCLEAR ELECTRICITY GENERATION SCENARIO RANGE



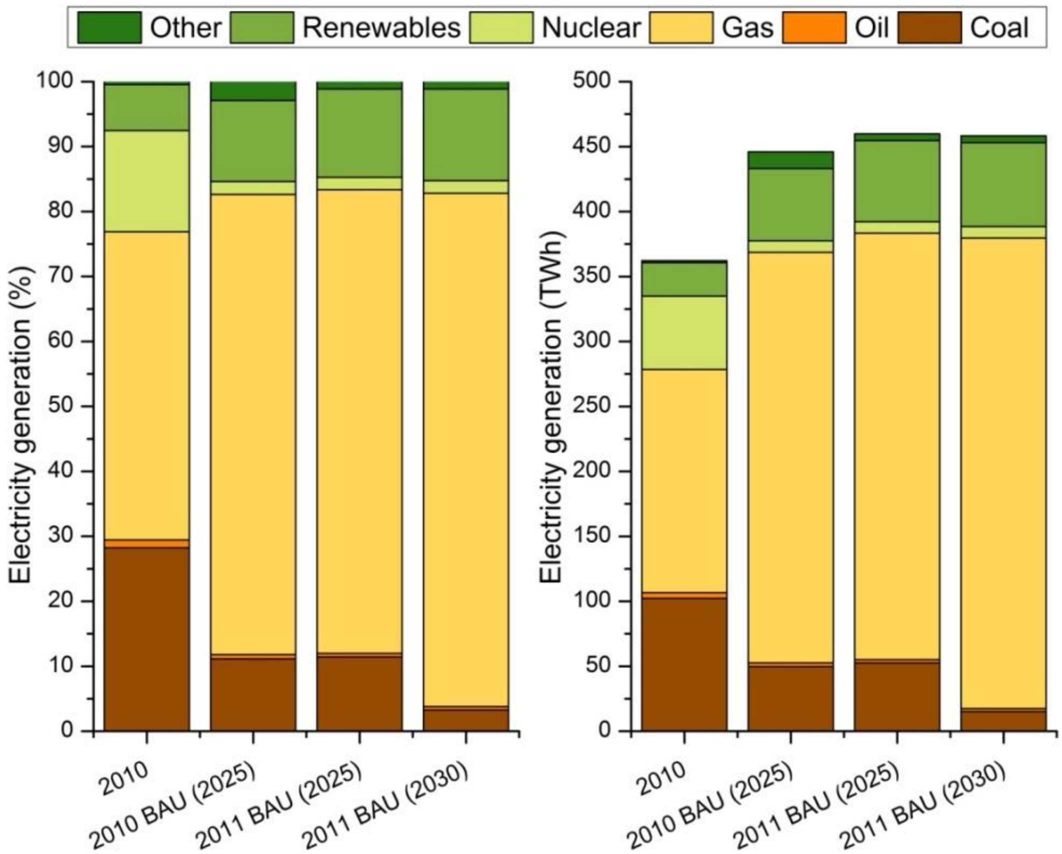
SOURCE: EIA, 2011b; EIA, 2012a; EIA, 2012f

United Kingdom

In October of 2011 the U.K. Department of Energy and Climate Change (DECC) published the most recent energy generation projections for the U.K. through 2030 (Department of Energy and Climate Change (DECC), 2012b). The DECC 'Central Scenario' corresponds to a BAU development pathway. In addition, the DECC published five alternative scenarios. These scenarios were developed based on three key factors: fossil fuel prices, economic growth, and low carbon policies. Since these scenarios were developed post-Fukushima, it is important to compare them to the DECC 2010 data to provide an indication of the change in scenarios – particularly for the share of nuclear electricity. This comparison is presented in Figure 2.30.

The 2011 BAU scenario only takes into consideration those policies which existed before the adoption of the U.K. Low Transition Carbon Action Plan in 2008. The scenario contains central estimates of growth and fossil fuel prices. Under this scenario, natural gas is the largest contributor to electricity generation, accounting for 158.7 TWh of the total 374.8 TWh of electricity generated. Coal accounts for 105.7 TWh, nuclear accounts for 60.6 TWh, and renewables account for 31.0 TWh. Total electricity generation increases by 26.7% and reaches 474.8 TWh by 2030 compared to 2011 levels. Natural gas remains the largest contributor to electricity generation through 2030; its use as an electricity source increases by about 128.3% and accounts for 76.3% of the 474.7 TWh total electricity to be generated. The significance of coal in electricity generation is drastically reduced over time; coal generated electricity accounts for a mere 15 TWh of the total electricity generated. There is also an 85.5% reduction in nuclear generated electricity. Renewable electricity on the other hand experiences a scale-up, with capacity increasing by 108.7% between 2011 and 2030.

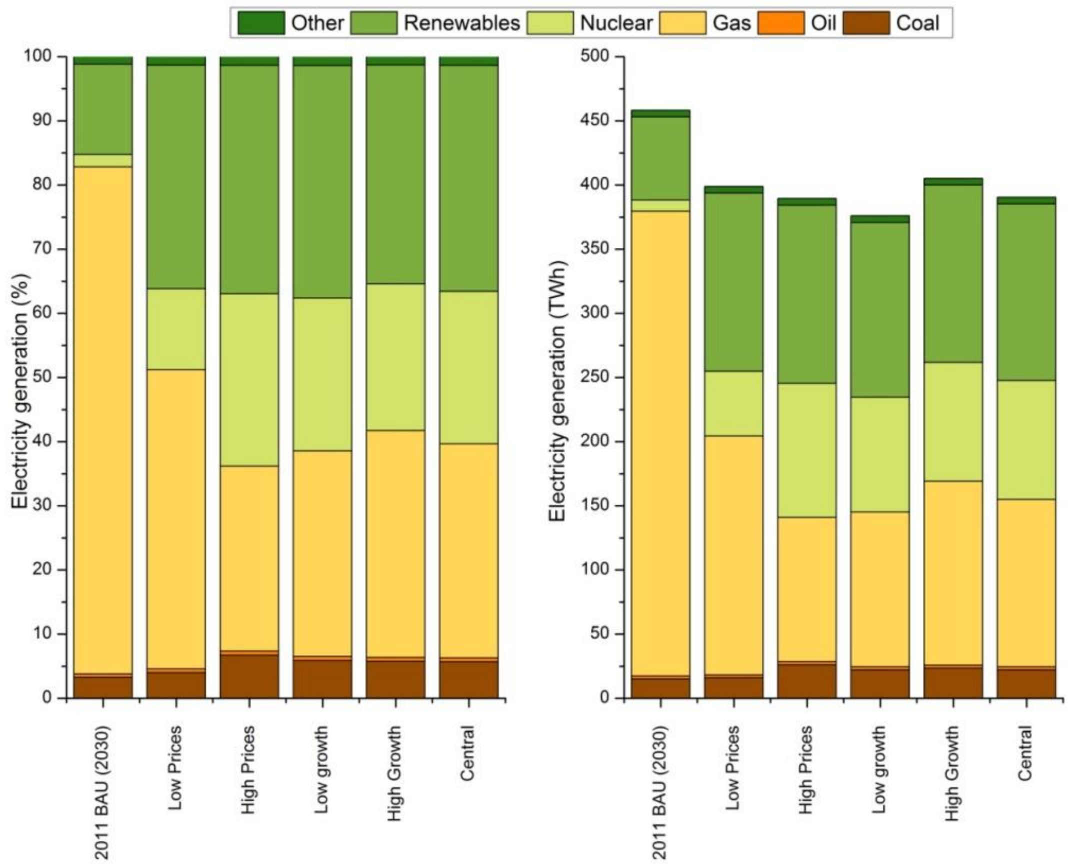
FIGURE 2.30: U.K. ELECTRICITY GENERATION BY SCENARIO PRE- AND POST-FUKUSHIMA



SOURCE: DECC, 2012b

The DECC developed a set of additional scenarios that cover a range of developments. These are presented in Figure 2.31. Of these, the 2011 BAU scenario outlines the lowest share of nuclear energy. These scenarios also account for changes in projections following the Fukushima accident.

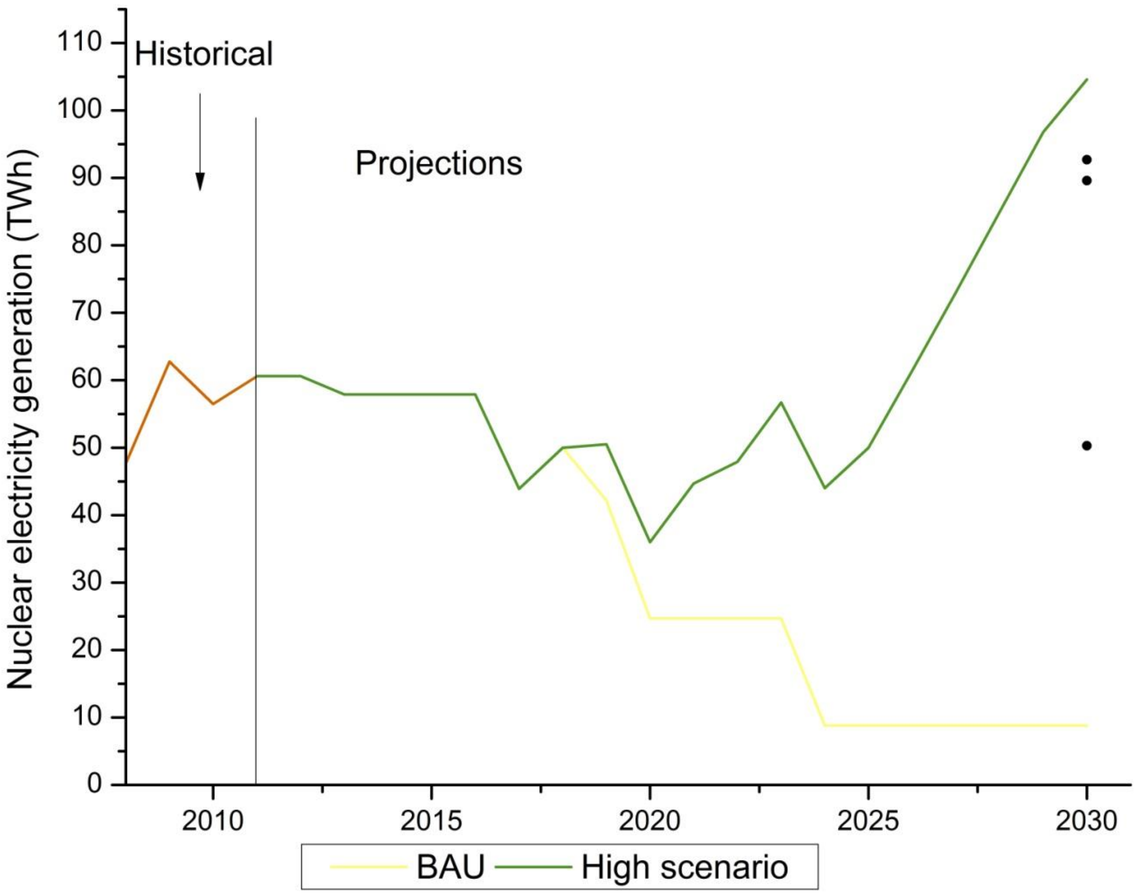
FIGURE 2.31: U.K. SCENARIOS FOR ELECTRICITY GENERATION PORTFOLIO BY 2030



SOURCE: DECC, 2012b

The range of nuclear energy shares in the scenarios differs substantially. To get a sense of the range of possibilities in the different developed scenarios, Figure 2.32 depicts the projections in contrast with the historical developments. The 'high fossil fuel prices' scenario results in the largest projected share of nuclear energy due to the trade-off between carbon-intensive fossil fuels and low-carbon nuclear energy. This scenario incorporates all agreed upon and sufficiently advanced policies whose impacts can be estimated, but assumes higher fossil fuel prices in its projections. Total electricity generated increases from 362.9 TWh in 2011 to 406.0 TWh in 2030. Renewables are the fourth most important electricity source in 2011 (8.6% of total electricity generated) but rise to become the most important electricity generation source by 2030, accounting for up to 34.2% of total electricity generated in that year. Nuclear electricity also experiences a significant 72.6% increase by 2030 compared to 2011 levels. There are reductions in the use of both coal and natural gas under this scenario. The amount of nuclear electricity generation appearing in the other scenarios falls between that in the BAU scenario and the 'high fossil fuel prices' scenario (see Figure 2.32).

FIGURE 2.32: U.K. SCENARIO PROJECTIONS FOR NUCLEAR ELECTRICITY GENERATION, 2010-2030

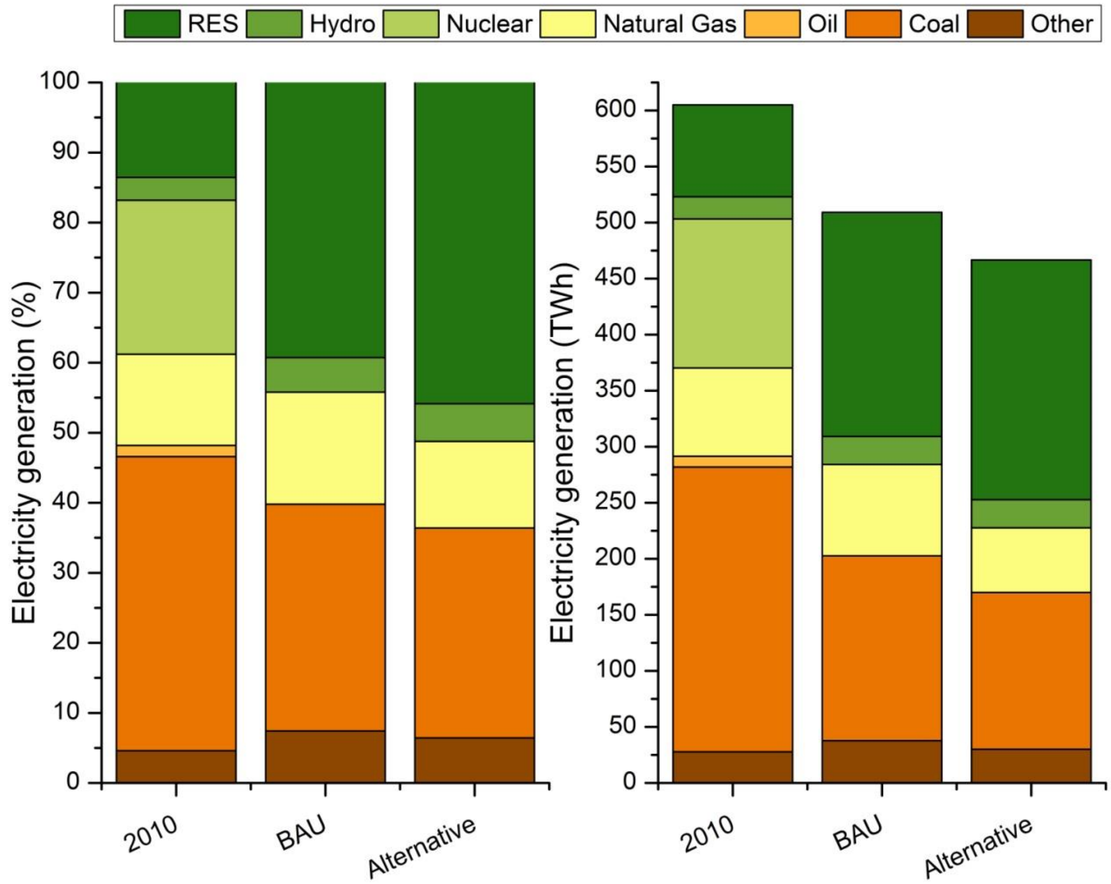


SOURCE: DECC, 2012b

Germany

As discussed in the previous sections, Germany responded more strongly to the Fukushima disaster than did most other countries. While previously slated to discontinue its nuclear energy program, the Fukushima disaster led Germany to renew this commitment. This becomes clear when one considers the electricity generation mix projections for Germany. For instance, Figure 2.33 depicts a BAU scenario and an alternative, low nuclear scenario for Germany. As is clear from the figure, nuclear energy will be phased out altogether from the electricity generation mix. Instead, Germany will focus its efforts on substantially increasing its renewable energy share. However, it is also important to recognize that while overall electricity generation within Germany is projected to decrease, a portion of this decrease will be covered by increased imports.

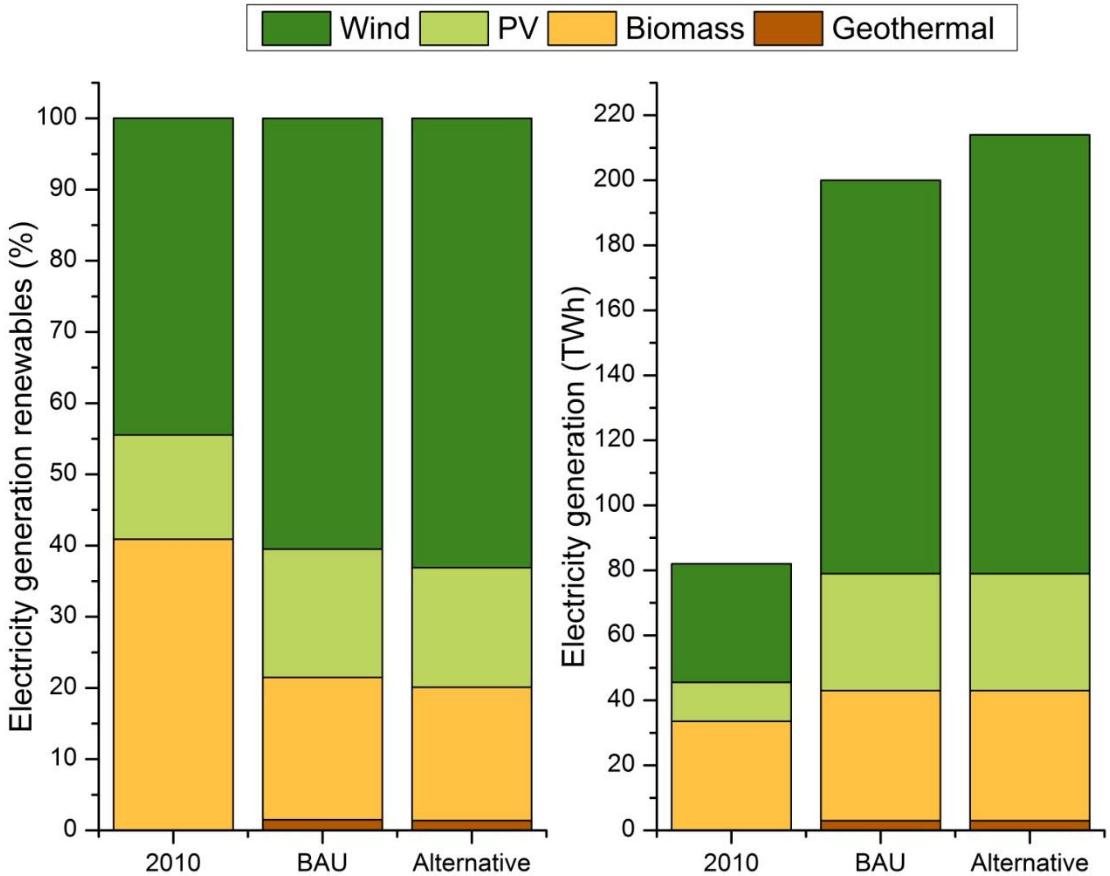
FIGURE 2.33: ELECTRICITY GENERATION MIX BY SCENARIO FOR GERMANY



SOURCE: (EWI, GWS, & Prognos AG, 2010)

Germany's renewable energy contribution already constitutes a sizeable share of the electricity generation mix. Still, both the BAU scenario and the Alternative scenario project a significant increase in renewable energy. Figure 2.34 breaks down the 'renewables' aggregate to illustrate which electricity sources are projected to be the dominant renewable electricity contributors in 2030. From Figure 2.34, it becomes clear that wind energy in particular is projected to increase substantially both its share and its absolute contribution to the electricity generation mix. PV energy in both scenarios substantially increases its absolute contribution but maintains a similar share in the electricity generation mix. Finally, biomass and geothermal energy maintain their contribution to the electricity mix until 2030.

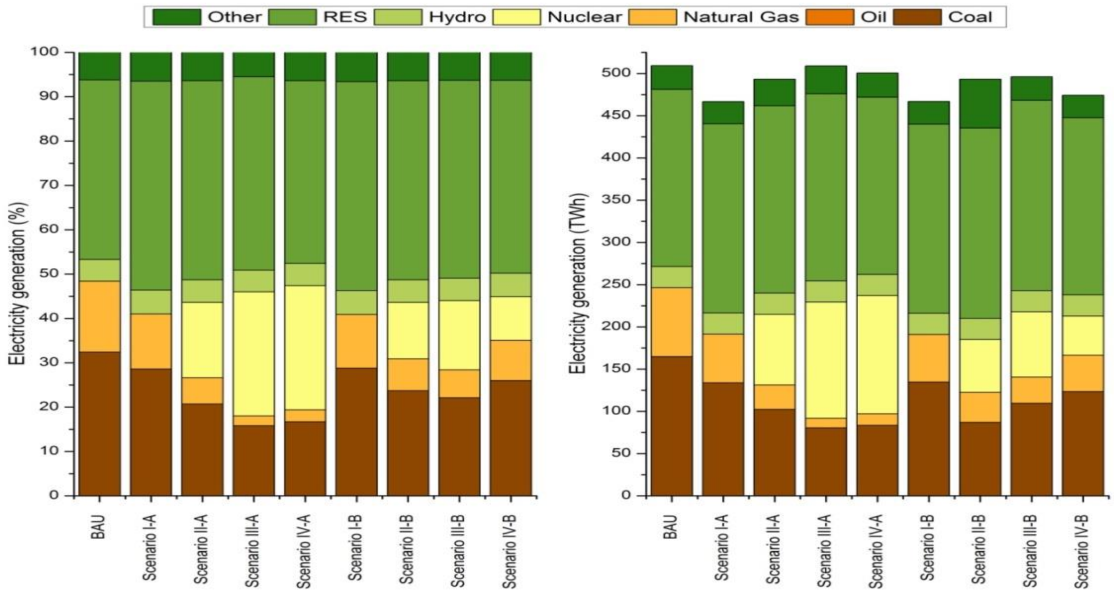
FIGURE 2.34: GERMAN ELECTRICITY GENERATION MIX BY SCENARIO FOR RENEWABLES



SOURCE: (EWI, GWS, & Prognos AG, 2010)

Similar to the EIA AEO 2012 projections, German economists created a number of different scenarios – of which the BAU and Alternative scenarios are just two. These scenarios were presented in the December 2010 report 'Scenarios for an Energy Policy Concept of the German Government' by the Institute of Energy Economics of the University of Cologne (EWI, GWS, & Prognos AG, 2010). Some of these scenarios model the extension of nuclear energy in Germany's electricity generation mix. Figure 2.35 depicts those scenarios. The scenarios have similar electricity generation portfolios, but some retain a share of nuclear energy – the scenarios that postpone the moratorium on nuclear energy – while the BAU and the Scenario I-A and I-B eliminate nuclear energy from the electricity mix. As can be seen, the reduction of nuclear energy in these three scenarios that maintain the moratorium results in a higher absolute contribution by fossil fuels. Again, this signifies the trade-off between fossil fuels as carbon intensive fuels and nuclear energy as a low-carbon fuel source.

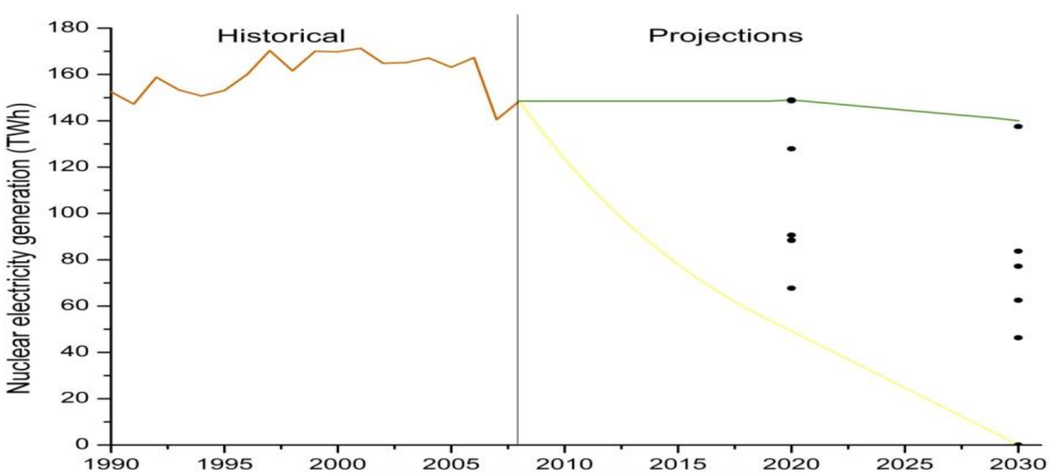
FIGURE 2.35: SET OF ELECTRICITY GENERATION SCENARIOS FOR GERMANY, 2030[1]



SOURCE: EWI, GWS, & Prognos AG, 2010

The range of nuclear energy in the electricity generation mix compared among scenarios and with historical levels of generation is illustrated in Figure 2.36. The BAU scenario is the scenario that maintains the fastest decline in nuclear energy, while all the other scenarios maintain slower rates of decline. Clearly, even the 'high nuclear scenario' (i.e. the scenario that results in the largest contribution of nuclear energy in 2030) leads to a decline in overall use of nuclear energy in the generation mix. In other words, none of the scenarios developed by Germany predict growth in the nuclear energy sector.

FIGURE 2.36: RANGE OF NUCLEAR ELECTRICITY GENERATION IN GERMANY, 1990-2030



SOURCE: EWI, GWS, & Prognos AG, 2010

[1] Scenarios I-IV correspond to nuclear operating extensions of 4, 12, 20 and 28 years beyond 2010, and different assumptions regarding population growth, energy demand, energy prices, and other variables; Scenario A assumes a cost of nuclear energy of 25€ (US$33.80) per kW while Scenario B assumes a dynamic lifecycle cost higher than A

France

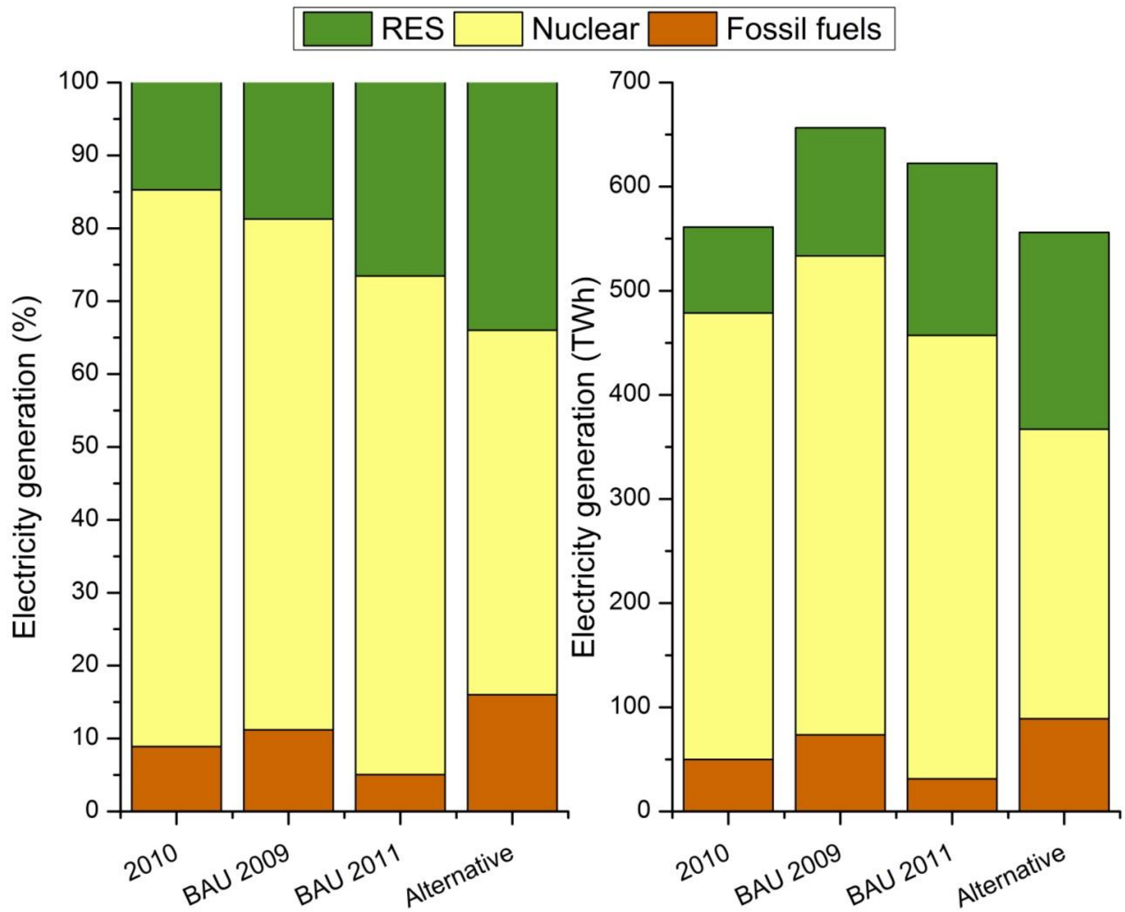
In 2009, the Union Française de l'Électricité (UFE) developed its Vision 2020 for the French electricity sector. Presented as a full-fledged action plan to enable the electricity sector to supports France's climate change targets, this plan outlined a scenario until 2020 (UFE, 2009a; 2009b). While originally developed with the purpose of illustrating the extent of carbon dioxide emission reductions France could achieve, the plan offers an insight into a pre-Fukushima mind-set of electricity development. As such, we use this plan as a pre-Fukushima BAU plan ('BAU 2009').

In 2011, the UFE presented a new report 'Electricity for 2030 – the choices for France?' (UFE, 2011). The scenarios developed here have accounted for both the disaster in Japan and Germany's decision to abandon their nuclear program so it reflects an up-to-date perspective on the French electricity development pathway. The 70% nuclear scenario (described here as the 'BAU 2011' scenario) as well as the 50% nuclear scenario (described here as an 'Alternative' scenario) are used to indicate the French electricity planning. The 70% nuclear generation scenario assumes that decisions already made in 2009 and the Grenelle environmental plan[2] will be realized (UFE, 2011). This scenario assumes that the lifetime of the existing nuclear fleet is extended and the two EPRs are commissioned, the 2020 renewable targets are met, and the development of renewables remains virtually stable until 2030.

The 50% nuclear generation scenario can be used as an alternative scenario as it resembles the new stance towards nuclear energy adopted by François Hollande (elected president of France in 2012). The development of renewables by 2030 is assumed to be higher than under the "70% nuclear" scenario. The additional electricity needed to satisfy demand and the back-up to compensate the intermittent nature of renewable generation is provided by thermal power plants. Together, these scenarios offer an insight into the changes in French policy and electricity mix following the Fukushima disaster on French electricity planning. The different scenarios as well as the current electricity generation mix are presented in Figure 2.37.

[2] Grenelle was a round-table forum bringing together the French government, local authorities, NGOs, trade unions, and the private sector actors who are tasked with establishing environmentally-related goals and targets.

FIGURE 2.37: FRENCH ELECTRICITY GENERATION MIX PROJECTIONS PRE- AND POST-FUKUSHIMA



SOURCE: UFE, 2009a; 2009b; 2011

As seen in Figure 2.37, the BAU 2011 maintains a similar electricity generation portfolio compared to the earlier developed scenario. While fossil fuel energy generation declines somewhat and renewable energy sources (RES) increase their share, the share of nuclear energy remains almost the same. However, with total generation decreasing slightly, the absolute contribution of the nuclear energy sector does decrease slightly in the BAU 2011 scenario.

The authors of the UFÉ report state that as the percentage of nuclear power decreases, the increase in total installed capacity in general and fossil fuel generation in particular is due to the intermittent nature of renewable energy technologies. As a result, a phase out of nuclear power will mean an increase in both renewable technologies to compensate for the loss of nuclear capacity and in thermal technologies to compensate for the intermittency of renewables.

Japan

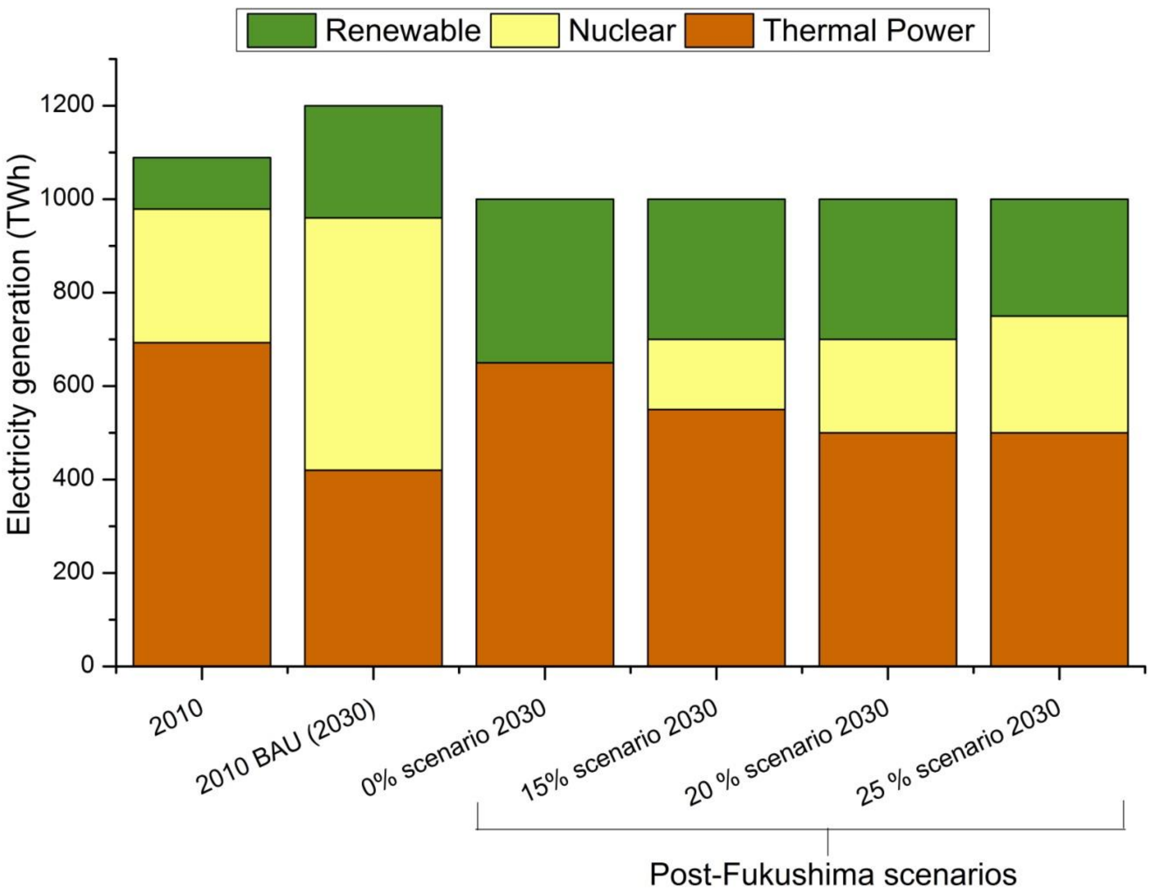
The importance of nuclear energy to Japan's electricity mix prior to the Fukushima accident is reflected in its the 2009 Long-term Energy Supply and Demand Outlook (which, in some scenarios, had nuclear accounting for about 50% of the total electricity generated in 2030) (The Energy Supply and Demand Subcommittee of the Advisory Committee for Natural Resources and Energy, 2009), and the 2005

Nuclear Energy National Plan which established guidelines for further expansion of Japan's nuclear energy portfolio (Ministry of Economy, Trade and Industry (METI), 2006). The June 2010 *Basic Energy Plan* then outlined goals to increase the share of renewable energy from 10% to 20% in 2030 and nuclear energy from 30% to 50% (Izumo, 2012). The plan established a 30% reduction in CO_2 emissions by 2030 and an increase in the Energy Independence Ratio (self-sufficiency plus self-development rate) from 38% in 2007 to 70% in 2030 as its primary objectives. To achieve these ends, the plan relied to a great extent on nuclear as one of the primary sources of energy for the 2030 energy mix (Yamashita, 26 June, 2012). It also detailed that new nuclear power plants were to be constructed and existing nuclear power plants replaced. As a result, for this analysis, the Basic Energy Plan forecasts are used as a 2010 BAU scenario (see Figure 2.38).

However, as detailed in previous sections, the outlook for nuclear energy in Japan has drastically changed since the March 2011 earthquake and tsunami. The National Policy Unit (NPU) Energy and Environment Council was tasked with the formulation of government-wide short-, mid-, and long-term innovative energy and environmental strategies, and released its Options for Energy and the Environment Decision in July 2012 (NPU, 2012). In this, they elaborated on three viewpoints to promote energy reform together with four energy option perspectives that culminated in the scenarios outlined in this decision. In terms of energy reform, the Energy and Environment Council outlined the need to shift to clean energy sources (renewable energy and energy conservation) and to secure green growth (through the promotion of green investment and innovation). The ambitious goals associated with this approach included increasing the share of renewable energy to over 25-30% and reducing energy consumption by 10% through 2030. In addition, the Council prescribed the development of a Framework for Green Development Policy and the promotion of regulatory reform to support a distributed energy system and to ensure Japan would be an active contributor to the international discussions on the interface between energy and the environment. In terms of energy options, securing nuclear safety and reducing future risks, strengthening energy security, contributing to the solution to climate change, and restraining costs were the key priorities outlined by the Council.

In light of these considerations, the Energy and Environment Council developed three scenarios for future energy development. All three scenarios met the following four prerequisites: a) reduce dependence on nuclear energy; b) reduce dependence on fossil fuels; c) maximize the usage of renewable energy and promote energy conservation; and d) reduce CO_2 emissions. They proposed three strategies depending on the share of nuclear energy in the electricity generation mix. These scenarios range from 0% nuclear (the '0% scenario'), 15% nuclear (the '15% scenario'), to 20-25% nuclear (the '20-25% scenario'). These, together with the 2010 BAU scenario, are illustrated in Figure 2.38 to provide an idea of the extent of change in policy direction. The post-Fukushima scenarios clearly maintain lower nuclear energy shares compared to the 2010 BAU scenario developed prior to the developments in Fukushima.

FIGURE 2.38: JAPANESE ELECTRICITY GENERATION MIX PROJECTIONS PRE-FUKUSHIMA AND POST-FUKUSHIMA



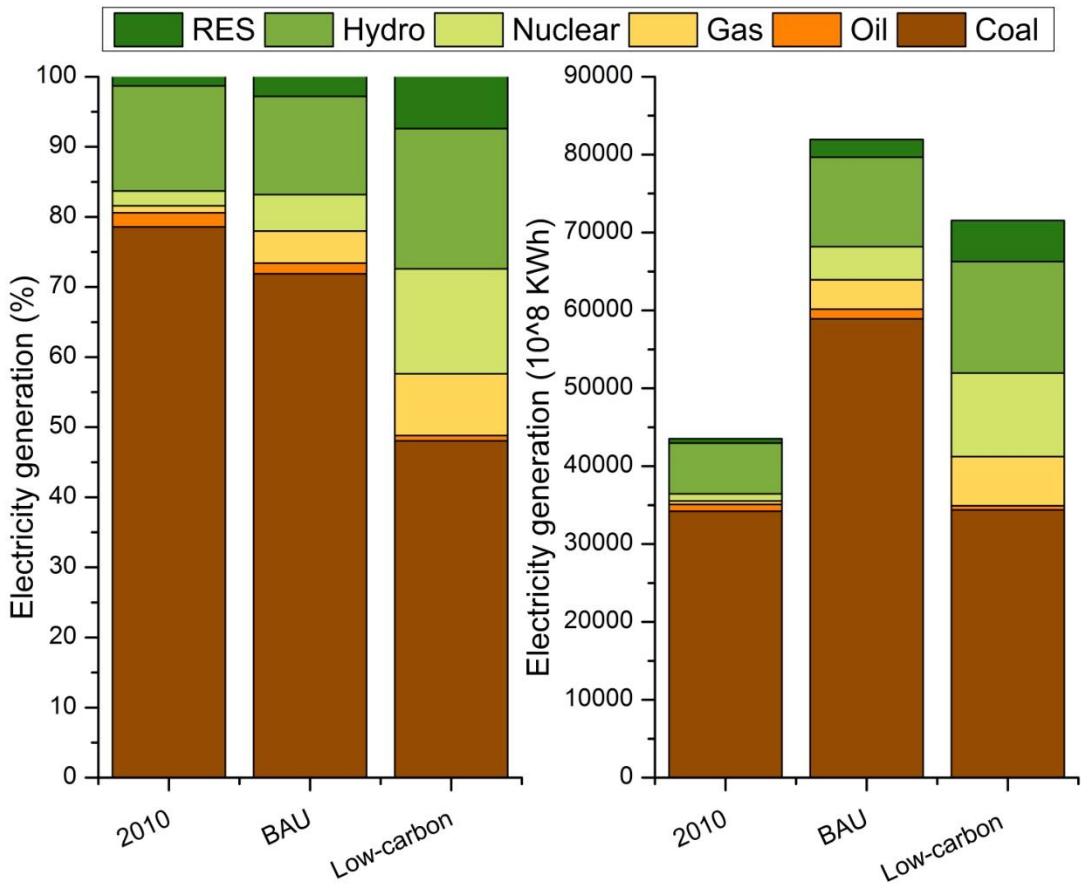
SOURCE: EIA, 2012d; NPU, 2012

China

According to the analysis of the Energy Research Institute (ERI), three scenarios were developed based on the level of effort taken by the government to realize a low carbon future: the Baseline (BAU) scenario, Low-Carbon (LC) scenario and Enhanced Low-Carbon (ELC) scenario. Since the possibility of playing out the Enhanced Low-Carbon scenario is low, the remaining two scenarios will be examined here (see Figures 2.39 and 2.40).

The Baseline scenario assumes existing policies and measures will continue, and incorporates the government's current efforts to increase efficiency and control emissions. Under this scenario, the share of electricity generation from fossil fuels declines gradually from 82% in 2010 to 78% in 2030 and 65% in 2050. Because of the large amount of reserves, coal will continue to be the largest contributor to power generation even as other, cleaner fuels increase market share. This is despite the commitment by the Chinese government to shut down many small and inefficient coal power plants as outlined in the *12th Five Year Plan (2011 – 2015)*. Electricity generation from coal increases 72.2% and would account for 72% of the total electricity to be generated by 2030. In line with the national policy to control emissions, there is a clear increase in nuclear generated electricity, reaching 3.6 times the level of 2010 by 2030. Meanwhile, the share of renewable electricity generation grows only slightly from 16% of the total in 2010 to 17% in 2030.

FIGURE 2.39: ELECTRICITY GENERATION MIX IN CHINA, 2010 & 2030



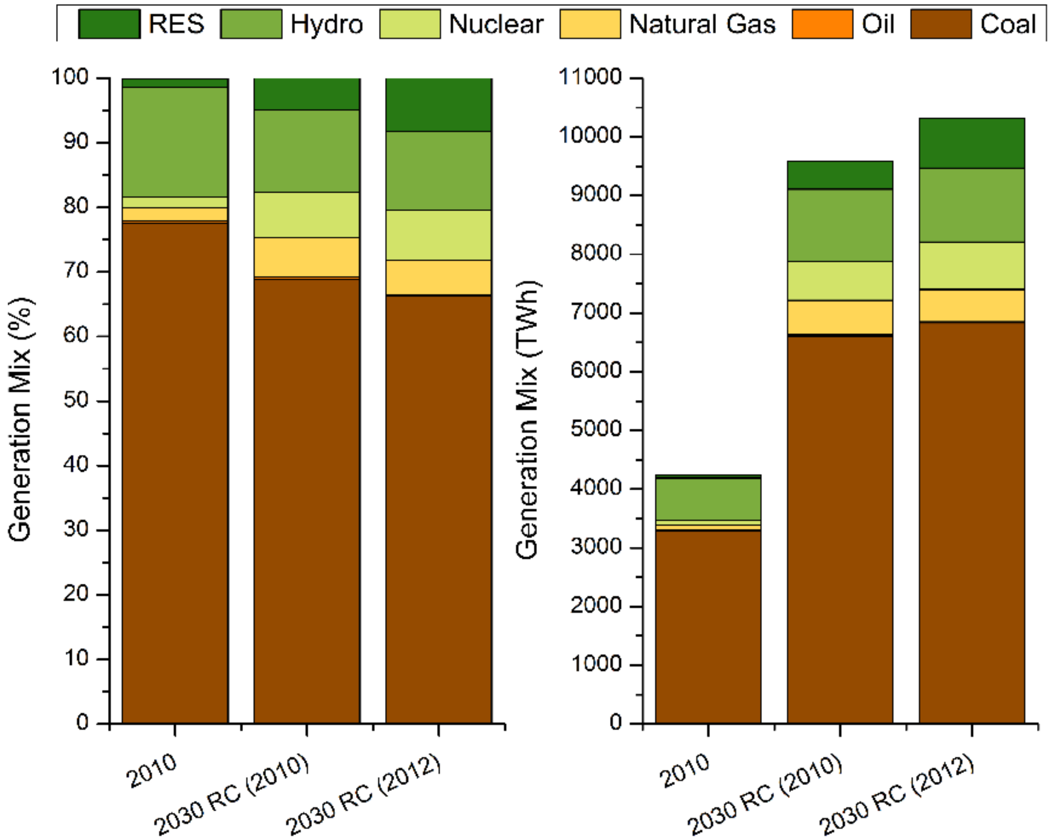
SOURCE: EIA, 2012d; ERI, 2009

The LC scenario assumes that China will develop a lower carbon future by reducing the share of energy intensive industries in the economy, disseminating current energy efficiency technologies, and aggressively diversifying the electricity generation mix. Under this scenario, the share of fossil fuels in generating electricity drops drastically from 82% in 2010 to 58% by 2030. Looking further, this decreasing trend continues and the share of fossil fuels reaches less than half (49%) of the total electricity generation in 2050. However, coal continues to be the main source of electricity generation, followed by hydropower and nuclear. Compared to the baseline scenario, is the LC scenario includes a significantly greater amount of nuclear generated electricity. Nuclear increases by 6.5 times accounting for 1,073 TWh of total generated electricity by 2030.

These ERI projections are the most recent projections issued by Chinese government; however, they fail to capture any potential changes in projections as a result of shifts or policy decisions following the Fukushima accident. To provide a more updated BAU outlook for China, the IEA's *World Energy Outlook*

2012 provides new projections. Compared to the *World Energy Outlook 2010* reference case projections, it is possible to see the changing trends in share of nuclear and other fuels resulting from the Fukushima accident. Figure 2.40 below illustrates these changes.

FIGURE 2.40: IEA ELECTRICITY GENERATION IN CHINA, 2010 & 2030

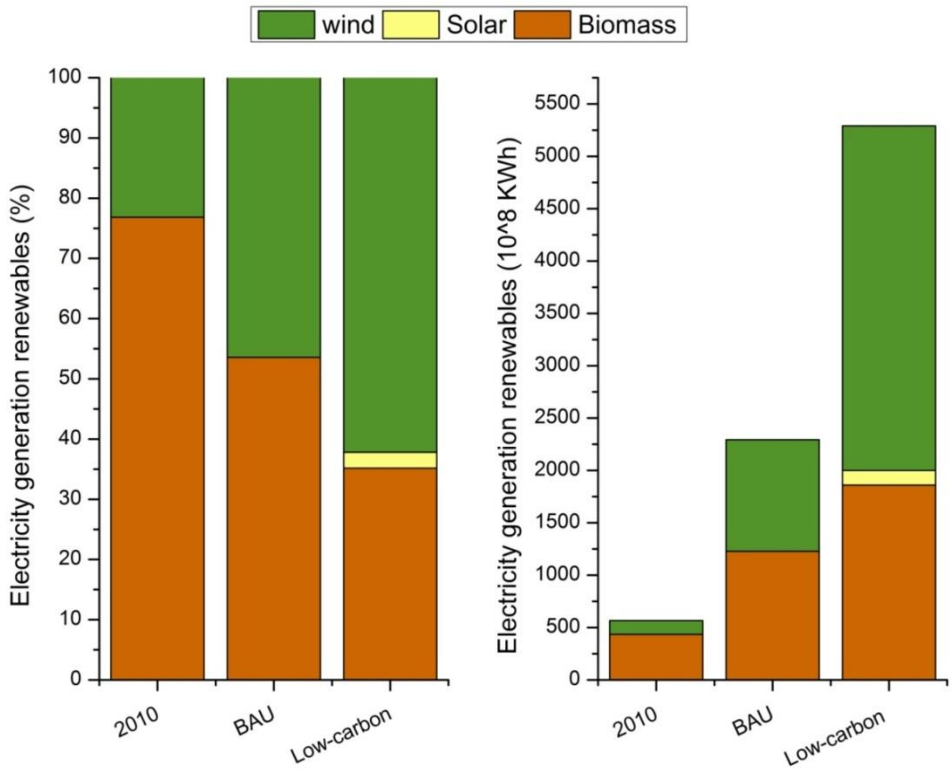


Source: IEA, 2012; IEA, 2010d

As is clear from the above projections, absolute nuclear generation (TWh) rises in the post-Fukushima BAU scenario compared to the pre-Fukushima scenario, and its relative share of the generation mix increases slightly. The most noticeable differences, however, are that total demand is rising in the post-Fukushima BAU, and that BAU scenario also projects a growing share of renewables in China's electricity mix. This seems to indicate that, although coal, gas and nuclear do not change much between the two scenarios, the government will place greater emphasis on renewable sources to meet a larger share of the nation's energy demand.

Along with the increase in nuclear, the share of renewables in electricity generation grows from 16% in 2010 to 27% by 2030. This amounts to 1,960 TWh of renewable electricity by 2030. As shown in Figure 2.40, the majority of renewables (outside of hydroelectricity) will be provided by biomass and wind under both the low-carbon and BAU scenarios. In the BAU scenario, both wind and biomass provide about half of the renewable energy each, whereas in the low-carbon scenario wind is clearly the predominant contributor to renewable electricity. Solar energy is projected to remain a small contributor to the overall electricity mix.

FIGURE 2.41: CHINESE ELECTRICITY GENERATION BY RENEWABLES



SOURCE: EIA, 2012d; ERI, 2009

2.2.4 Conclusion

From the above, it becomes clear that the various countries responded differently to the developments at Fukushima. While Germany and Japan have developed a strong response to the disaster – each substantially reducing the projections for the contribution of nuclear energy in their generation portfolio and instead relying on renewable energy, imports, and energy efficiency – the other four major energy consuming nations show a weaker response. Also, it becomes clear that nuclear energy and fossil fuel energy are often juxtaposed in climate change plans and low nuclear plans: nuclear energy in climate change plans substitutes for fossil fuels while low nuclear scenarios utilize higher shares of fossil fuel energy. Additionally, renewable energy is slated to grow substantially in all scenarios in all countries, but remains – when excluding conventional hydroelectricity – a marginal energy source. The findings presented in this chapter for the pre-Fukushima and post-Fukushima projections are illustrated in Table 2.1.

TABLE 2.1: PRE- AND POST-FUKUSHIMA PROJECTIONS PER COUNTRY

Country	Pre- or Post-Fukushima	Scenario (2030)	Fossil fuels (TWh)	RES (includes hydro)(TWh)	Nuclear (TWh)
Germany	Pre-Fukushima	BAU (2030)	246	225	0
	Pre-Fukushima	Alternative (2030)	198	239	0
U.S.	Pre-Fukushima	BAU 2010 (2030)	3,273	852	886
	Post-Fukushima	BAU 2011 (2030)	3,140	684	914
France	Pre-Fukushima	Vision 2020 (2020)	73.5	123	460
	Post-Fukushima	BAU 2011 (2030)	31.4	170	426
U.K.	Pre-Fukushima	2010 BAU (2025)	369	56	9
	Post-Fukushima	2011 BAU (2025)	383	63	9
	Post-Fukushima	2011 BAU (2030)	380	64.7	9
China	Pre-Fukushima	BAU (2030)	6,392	1,377	426
	Pre-Fukushima	Low Carbon (2030)	4,122	1,960	1,073
Japan	Pre-Fukushima	2010 BAU (2030)	420	240	540
	Post-Fukushima	0 % scenario (2030)	650	350	0
	Post-Fukushima	15 % scenario (2030)	550	300	150
	Post-Fukushima	20 % scenario (2030)	500	300	200
	Post-Fukushima	25 % scenario (2030)	500	250	250

*projections are until 2030 unless noted otherwise **Germany and China do not have pre-crisis projections, alternative only

2.3 Energy Efficiency and Renewable Energy Development and Policy

As is seen in the previous sections, the accident in Fukushima has already had an impact on future electricity mix projections and national energy policies. In pre-Fukushima analyses, policy emphasized energy security, environmentally sustainable, low cost but large-scale sources of energy. This led many to view nuclear as the only viable option to replace large-scale coal generation capacity in the future, while natural gas would fill power quality and peaking capacity roles. The severity of the Fukushima accident reignited numerous debates surrounding the safety of nuclear power, leading to a variety of consequences for national energy policies. While several countries have merely revised safety regulations, others have fundamentally altered the targets and goals of long-term nuclear and overall energy policies.

Regardless of the extent of the immediate changes in policy, the accident has given many policymakers cause to reevaluate future energy infrastructure development plans. During such reevaluation, energy efficiency and renewable energy systems have commanded an ever greater share of attention. Thus, this chapter will focus its attention on the energy efficiency and renewable energy profiles and policies of the United States, United Kingdom, Germany, France, Japan, and China. It will begin with an examination of pre-Fukushima trends and policies. Finally, policy changes since the accident, whether or not a direct result of that crisis, will be discussed, as well as their implications for future of energy policy.

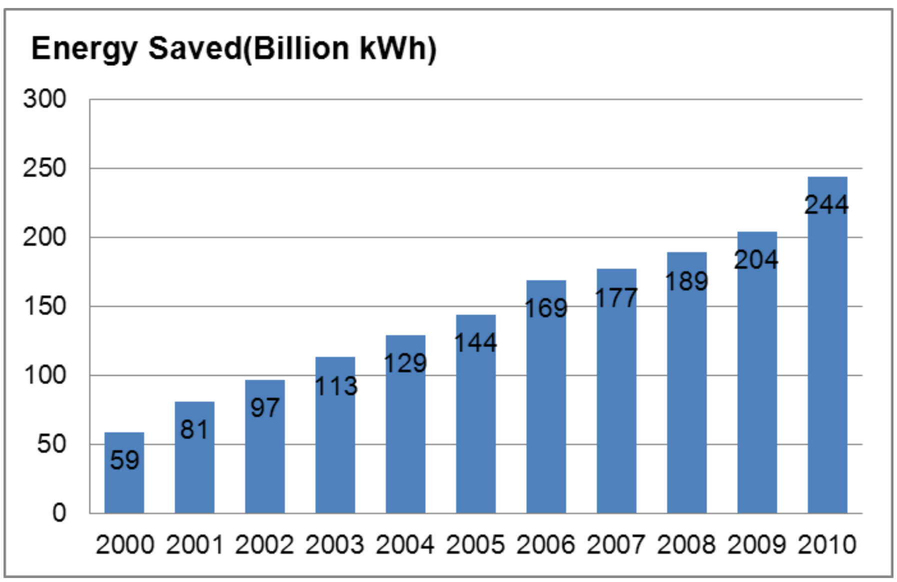
2.3.1 Energy Efficiency Trends and Policy

United States

Energy efficiency has been considered a major factor of the cost effective energy strategy for the U.S. when faced with energy price volatility and constraints of greenhouse gas emissions. In the late 1970s, due to a looming energy crisis, President Jimmy Carter called on the American public to use energy more efficiently; those ideas were codified in the Energy Policy Act of 1992.

Also in 1992, The U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy launched the ENERGY STAR program to protect the environment and save money by promoting the use of energy efficient goods. During its initial phase, ENERGY STAR was a voluntary labelling program for products such as computers, and monitors. Since 1995, the program has expanded to cooling & heating equipment for home and offices. In 2010, ENERGY STAR led to energy cost savings amounting to US$18 billion. According to the EPA (2010), the ENERGY STAR program led to a reduction of over 195 million metric tons (mmt) of greenhouse gas emissions and a parallel investment of US$102 billion in energy efficiency and other climate-friendly technologies. Cumulatively, over 240 TWh of electricity, equal to 5% of total U.S. electricity demand in 2010, has been saved through the program (EPA, 2011) (See Figure 2.42).

Figure 2.42: U.S. ENERGY STAR BENEFITS, 2000-2010



Source: EPA, 2011

Energy Efficiency Resource Standards (EERS), set by both state and federal policy, establish long-term energy efficiency goals. EERS encourage energy use reductions through energy efficiency programs such as rebates and incentives. The American Clean Energy Security Act of 2009, the most prominent attempt to pass a national efficiency standard, set a 5% energy efficiency target. The baseline savings from energy efficiency would have been 5% of national electricity sales by 2020. Unfortunately, the bill failed to pass the Senate despite sufficient support in the U.S. House of Representatives.

In 2010, most states struggled to achieve their energy saving goals set by their EERS policies. Thirteen states succeeded in achieving 100% of their goals and three states accomplished 90% of their goals. In 2011, 24 states passed a special long-term energy savings goal through energy efficiency improvements, which is a policy under the EERS. To achieve energy efficiency targets, the state level EERS policies focused on utility and building energy sectors (ACEEE, 2011).

The American Council for an Energy-Efficient Economy (ACEEE) released *The Long-Term Energy Efficiency Potential* in January, 2012 (Laitner *et al.,* 2012). The report included three scenarios: Reference, Advanced Scenario, and Phoenix Scenario. The scenarios are summarized by Table 2.2.

TABLE 2.2: ENERGY EFFICIENCY DEVELOPMENT SCENARIOS IN THE U.S.

Scenario	Description
Reference Case	A continuation of trends projected by EIA for the 2030-2050 period
Advanced Scenario	Penetration of known advanced technologies
Phoenix Scenario	Advanced technologies, greater infrastructural improvements and some displacement of existing stock to make way for newer and more productive energy efficiency technologies, as well as configuration of the built environment that reduce energy requirements for mobility

Source: Laitner *et al.*, 2012

Energy use will be reduced by 59% by 2050 under the Phoenix scenario and 42% under the Advanced Scenario. Electricity demand will significantly decline in both the Advanced and the Phoenix Scenarios. In particular, the Phoenix scenario shows the generation resource mix shifting from conventional sources to combined heat and power (CHP) and non-fossil fuel sources. The proportion of non-fossil fuels increases from 32% in the reference scenario to 40% in the Advanced and the Phoenix Scenarios.

Projected energy efficiency moderately increases in the Reference Case due to the improvement of the generation efficiency and increased the share of electricity production by CHP. The electricity use significantly decline in the Advanced and Phoenix Scenario. ACEEE expects that electricity efficiency will improve through increased investment in the more efficient power generation and CHP. By 2050, electric system efficiency will grow to 40% in the Advanced Scenario and 48% in the Phoenix Scenario, versus about 36% in the Reference case. The ACEEE also posits that losses in the electrical transmission and distribution systems (T & D) will decrease over time.

The most recent large-scale initiative in pursuit of enhanced efficiency was the American Recovery and Reinvestment Act of 2009, known commonly as the “stimulus bill.” Although not the principal focus of the legislation, officials considered efficiency investments as a key way to promote economic activity and support domestic job growth (EPA, 2012). New industrial efficiency goals were also recently established by executive order in August, 2012 (Colman, 2012). Although the federal government has had limited success in advancing efficiency, many states have been much more effective at improving energy use. Changes that have been made in efficiency at all levels generally have been in response to previous policies or future goals rather than in response to the Fukushima specifically.

United Kingdom

As in the U.S., the U.K. government became concerned about energy efficiency savings in the mid-1970s and the 1980s. Gains from energy efficiency have grown steadily since. During the past decade, the U.K. continued to pursue aggressive energy efficiency policies to improve energy consumption and reduce waste. Much of this focus has been through weatherization programs and more efficient appliances or equipment. Savings from energy efficiency between 2000 and 2007 are shown in the table below.

TABLE 2.3: EFFECTS OF ENERGY EFFICIENCY ON ENERGY USE (TWh), U.K., 2000-2007

Year	Actual energy used	Saving due to better insulation	Saving due to improved efficiency	Total saving
2000	519.8	203.5	211.8	415.3
2001	534.5	211.5	232.7	444.1
2002	526.7	210.0	237.7	447.7
2003	535.8	222.1	249.7	471.8
2004	547.3	235.4	259.6	495.1
2005	530.4	260.2	288.5	548.8
2006	516.7	251.0	280.9	531.9
2007	498.5	218.4	261.4	479.8

Source: DECC – DUKES/1970-2008 Data, 2011

In 2004, the EU published its Energy End-Use Efficiency and Energy Services Directives, which mandated a 9% energy-savings target in member countries by the year 2016. In response, the U.K. Government published its Energy Efficiency Action Plan in 2007. The action plan was developed as part of government's efforts to reduce CO2 emissions and promote energy security, but pushed beyond the EU requirements, setting an ambitious target of an 18% energy savings target for 2016. That translated into a reduction of 272.2 TWh in energy use. Energy efficiency was perceived as the lowest cost option for reducing CO_2 emissions and increasing productivity in ways which reduce the country's reliance on imported energy sources (DEFRA, 2007).

The Energy Efficiency Action Plan clearly spelled out policy prescriptions and measures for energy efficiency in the U.K., as summarized below.

- Household Sector – Energy efficiency of buildings is a principal component of the action plan. Energy performance standards are to be raised to ensure the delivery of zero-carbon homes by 2016. Potential savings are estimated to be between 1.1 and 1.2 MtC per year by 2020. A Code for Sustainable Homes should also drive the efficiency improvements in new homes. Energy efficiency retrofits for existing homes will be achieved through the provision of a scheme known as the Energy Efficiency Commitment. Energy efficiency for products used in the home will increase under the Market Transformations Program, a government and industry driven effort to adopt ambitious minimum performance standards that ensure the delivery of sustainable home products (DEFRA, 2007).

- Non-Household Sector – Emissions reductions in the energy intensive industrial sector is expected to be achieved through the provisions of the EU Emissions Trading Scheme and other agreements intended to provide strong incentives for energy intensive industrial centers to achieve emissions reductions.

- Public Sector – The action plan laid out rigorous energy efficiency requirements for the public sector: government buildings, schools, hospitals, etc. A significant aspect of public sector action is committed to the development of funding mechanisms to finance energy efficiency initiatives in the public sector.

- Transport Sector – As part of its efforts to encourage energy efficiency in the transport sector, the U.K. Government pushed for the inclusion of aviation in the EU Emissions Trading Scheme (as of 2012, aviation emissions are included). To encourage the purchase of energy efficient vehicles, vehicles excise duties on inefficient vehicles were to be raised under this action plan. Together with the larger EU community, the U.K. committed to raising the fuel efficiency of new cars and vans. The U.K. Government is also expected to invest heavily in the public transport sector to promote sustainable travel behavior by expanding the public transportation options available to the general public (DEFRA, 2007).

The U.K. government has also established the Carbon Trust to help in the communication of the importance of energy efficiency to commerce, industry and the public sector. The Trust will also promote the expansion of smart metering to all major businesses by 2012 (DEFRA, 2007).

When it became increasingly apparent that the EU was on its way to achieving only half of its 2020 target given the progress of country efforts under the older Energy End-Use Efficiency and Energy Services Directives target, the EU released its new Energy Efficiency Plan 2011 on March 8, 2011, prior to the Fukushima disaster. The new action plan aims to further improve upon energy efficiency activities as part of efforts towards achieving this 2020 plan. It also is expected to provide a stronger framework for achieving the 2020 target (EC, 2011).

The U.K. government, however, under its 2007 U.K. Energy efficiency action plan (EEAP), had already adopted a far more ambitious target than that stipulated by the 2004 EU Directive on Energy Efficiency. It is therefore unclear if the U.K. will revise its energy efficiency target under the more stringent EU Energy Efficiency Plan.

TABLE 2.4: ENERGY SAVINGS FROM U.K. EFFICIENCY POLICIES

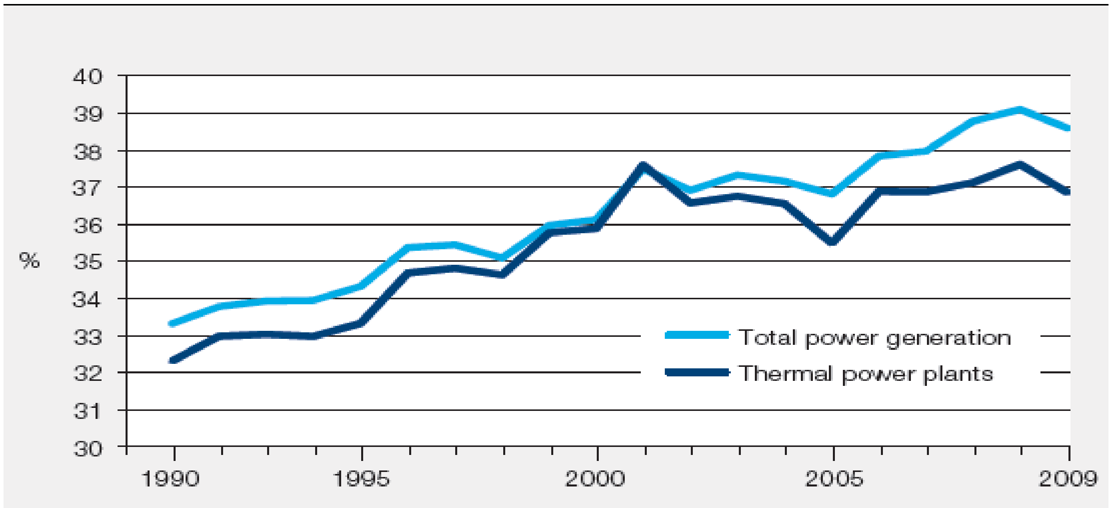
Energy efficiency improvement programmes, energy services, and other measures to improve energy efficiency planned for achieving the target	Annual energy savings expected by end of **2010**		Annual energy savings expected by end of **2016**		Annual energy savings expected by end of **2020**	
Measures in the Household Sector:	**TWh**	**MtC**	**TWh**	**MtC**	**TWh**	**MtC**
Energy Efficiency Commitment Phase 1 (EEC1)	3.1	0.3	3.1	0.3	3.1	0.3
Energy Efficiency Commitment Phase 2 (EEC2)	7.8	0.5	7.8	0.5	7.8	0.5
Carbon Emission Reduction Commitment (CERT)	14.2	1.0	15.5	1.1	15.5	1.1
Supplier Obligation	0.0	0.0	31.2	2.2	50.2	3.5
Northern Ireland Energy Efficiency Levy	0.4	0.0	0.4	0.0	0.4	0.0
Fuel Poverty Schemes	2.7	0.4	2.8	0.4	2.8	0.4
Energy Performance of Buildings Directive (EPBD)	3.5	0.2	7.6	0.4	10.1	0.6
Building Regulations England & Wales 2002	11.4	0.6	12.5	0.7	12.5	0.7
Building Regulations E&W 2005/6	13.2	0.7	33.8	1.8	49.4	2.6
Building Regulations Scotland 2007	1.8	0.1	4.7	0.2	6.8	0.4
Building a Greener Future	0.0	0.0	4.2	0.2	22.6	1.2
Billing and Metering	2.6	0.2	5.8	0.4	5.8	0.4
Product Policy	6.6	0.6	11.2	1.0	14.2	1.3
Package of Measures	1.4	0.1	1.5	0.1	1.5	0.1
Measures in the Private and Public Sectors:	**TWh**	**MtC**	**TWh**	**MtC**	**TWh**	**MtC**
Building Regulations E&W 2002	5.9	0.4	6.5	0.4	6.5	0.4
Building Regulations E&W 2005/6	3.2	0.2	12.0	0.7	19.0	1.2
Building Regulations Scotland 2007	0.5	0.0	1.9	0.1	3.1	0.2
Carbon Reduction Commitment (CRC)	1.1	0.1	6.3	0.6	11.8	1.1
Product Policy	2.2	0.2	8.1	0.7	12.1	1.1
Energy Performance of Buildings Directive	0.0	0.0	4.8	0.4	8.1	0.6
UK Emissions Trading Scheme (UKETS)	3.5	0.3	3.5	0.3	3.5	0.3
Carbon Trust programmes	14.6	1.1	14.6	1.1	14.6	1.1
Private sector specific:						
Climate Change Agreements (CCAs) excl EUETS	3.9	0.3	3.9	0.3	3.9	0.3
Smart metering	1.3	0.1	2.1	0.2	2.7	0.2
Carbon Trust SME fund	1.2	0.1	1.3	0.1	1.3	0.1
SME measures	1.2	0.1	1.2	0.1	1.2	0.1
Public sector specific:						
Devolved Administrations	3.7	0.3	4.1	0.3	4.1	0.3
Revolving Loan Fund	1.1	0.1	1.2	0.1	1.2	0.1
Measures in the Transport sector:	**TWh**	**MtC**	**TWh**	**MtC**	**TWh**	**MtC**
Voluntary Agreement Package	34.1	2.3	45.5	3.2	48.0	3.5
Future Agreements	1.0	0.1	10.6	0.7	25.7	1.8
Local Authorities Policies	2.7	0.2	3.0	0.2	3.0	0.2
Total Energy and Carbon Savings	**149.9**	**10.6**	**272.7**	**18.8**	**372.5**	**25.7**

Source: DEFRA, 2007

Germany

The German government recently decided to change from a conventional fuel based energy system to one driven by renewable sources and to expand energy efficiency in order to achieve the goal of energy security and mitigate climate change. The efficiency of German thermal power plants improved from 27% in 1990 to 32% by 2009 from 27%. Figure 2.43 shows the increasing trend of power generation efficiency. In particularly, the efficiency of CHP in the industrial sector has improved since 2003. However, in 2006, the efficiency of CHP power plants was 11% - still below the EU average of 17%.

FIGURE 2.43: EFFICIENCY OF POWER GENERATION AND THERMAL POWER PLANTS IN GERMANY



Source: ABB, 2011a

Germany aims to halve its primary energy consumption by the year 2050. This will require efficiency improvements in energy conversion as well as a lower total final consumption of energy. Merely improving energy efficiency could reduce electricity consumption in Germany by more than 25% by 2050 compared to 2008 scenarios (Wade *et al.*, 2011). As one small step to meeting the 2050 targets, Germany's National Energy Efficiency Action Plan, adopted in 2007, calls for an energy saving target of 9% in the period 2008-2016 (Schlomann *et al*., 2009).

Post-Fukushima, there have been changes to the policies which will be vital to achieve Germany's radical energy transition. As mentioned previously, the European Union Commission's Energy Efficiency Plan, adopted in August 2011, lays out a 20% energy savings target by 2020. Its commitment to the EU Energy Efficiency Directive imposes a binding commitment, while allowing flexibility in the means of realizing the policy's stated targets (BMU, 2012). In addition, Germany has committed to energy efficiency as a central pillar of its future energy policy. The shift in German energy policy towards increased dependence on renewable will require that energy efficiency meet a larger share of the nation's future projected demand, despite the success of Germany's previous energy efficiency policies.

France

President Nicolas Sarkozy initiated the Grenelle de l'Environnement in May of 2007. The Grenelle was a round-table forum bringing together the French government, local authorities, NGOs, trade unions, and the private sector actors who are tasked with establishing environmentally-related goals and targets in eight different areas: curbing climate change and energy demand, preservation of biodiversity and natural resources, establishment of an environment that fosters public health, sustainable production and consumption, institutional reforms for an ecological democracy, promoting employment opportunities in ecological development, genetically modified organisms, and waste management. A 23% reduction target in energy consumption by 2020 came out of the Grenelle round-table discussions (Article 19, Section II). Additionally, a 38% reduction in building energy consumption was targeted for 2020 (Article 5).

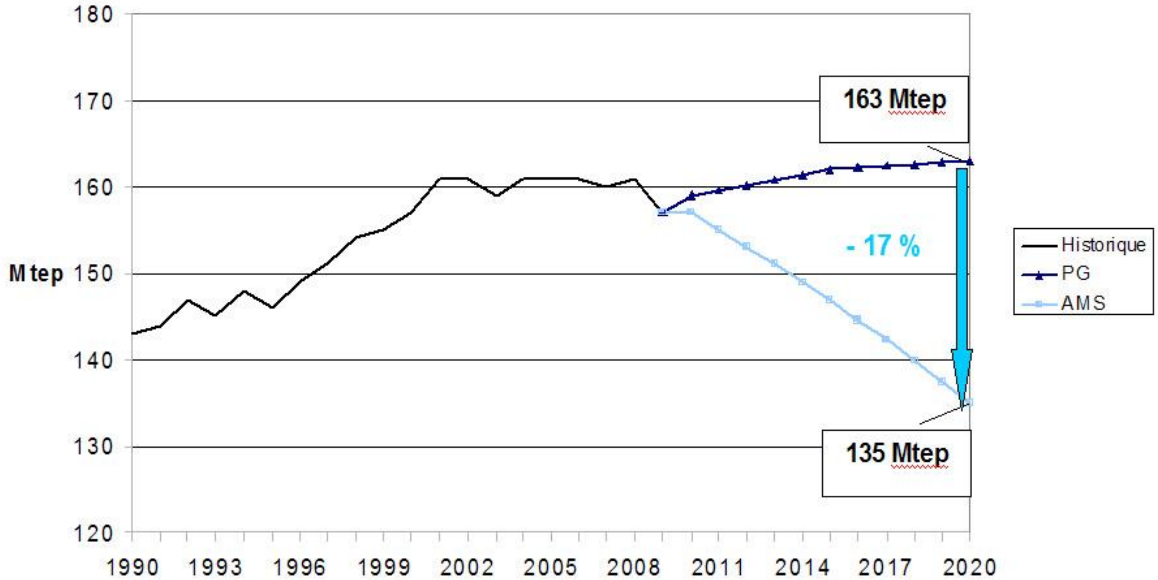
In accordance with the European Directive *2006/32/EC* on energy efficiency within European Union member states, in 2008 France adopted a National Energy Efficiency Action Plan (NEEAP) in which they targeted 9% energy savings over the period 2008-2016. The NEEAP took place following deliberations in the Grenelle de l'Environnement efficiency workgroup tasked with controlling the demand for energy. Policies adopted to achieve energy efficiency goals have taken the form of a white certificate scheme, appliance and lighting rating schemes, and building energy regulations (IEA, 2010), as discussed below.

A tradable white certificate scheme has been in place in France since 2006 and has achieved a reduction of 216.8 TWh over cumulative lifetime of end-use technologies through 30 September, 2011. The initial white certificate targeted 54 TWh of lifetime cumulative energy savings. By the end of the period, French energy suppliers had achieved reductions of 65 TWh, surpassing the target by 20%. This scheme has also cut €4.5 billion (US$6 billion) off energy bills over its lifetime. The energy savings target for the 2010-2013 period was a cumulative 345 TWh.

The building sector is a major area of opportunity for achieving the desired energy reduction targets. According to the Grenelle, existing buildings achieve a 38% reduction in primary energy consumption by 2020. The new design and thermal requirements of the Réglementation Thermique (enacted in 2011 for non-residential buildings and effective in 2013 for all structures) are expected to save 150 TWh of energy between 2013 and 2020. To finance retrofits to existing buildings, and renewable energy installations in new and existing buildings, the French government implemented a sustainable development tax credit scheme (the tax ended in December of 2012). France still offers a zero interest loan option for building renovations.

Several developments in energy efficiency policy in France have occurred since the Fukushima accident. In June 2011, a review of efficiency potential was conducted during a national round table forum, with final recommendations presented on December 20, 2011. It was determined that 17% savings in final energy consumption could be achieved by 2020 if the 2008 Grenelle recommendations ("AMS" in the figure below) were adopted. This represented a 17% savings as compared to the BAU scenario ("PG" in the figure below). As per conclusions of the Energy Efficiency round table, a 23% energy savings target by 2020 and 38% reduction in building energy consumption goal for 2020 were deemed feasible. France also seeks a 20% energy savings target by 2020, in line with the European Directive on Energy Efficiency. So far, savings have fallen short of that mark.

FIGURE 2.44: ENERGY EFFICIENCY POTENTIAL IN FRANCE, 2011-2020

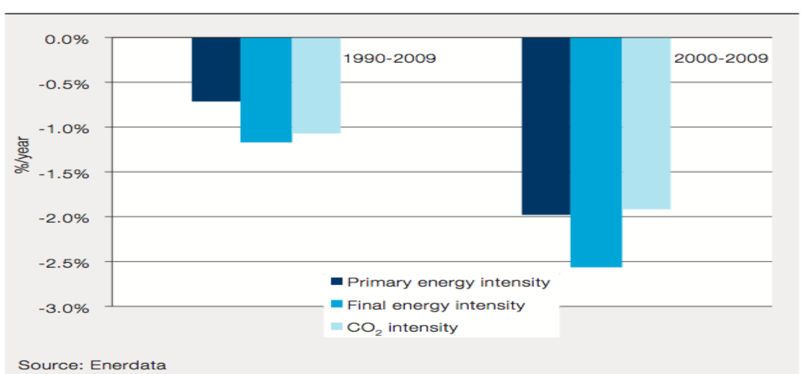


Source: Ministry for Energy, Ecology, Sustainable Development and Planning, 2012

Japan

Between 1990 and 2009, the primary energy intensity (total energy consumption per unit of GDP) of Japan decreased annually by 0.7%, as shown in Figure 2.45. Interestingly, the final energy intensity (final energy consumption per unit of GDP) decreased at a faster rate. According to ABB, the share of low generation efficiency fuels such as coal and nuclear power has increased, leading to that result. In other words, there has been an increasing decline in primary energy consumption. ABB also found that substitution of natural gas and nuclear power for oil has resulted in effective efficiency improvements (1.1%/year).

FIGURE 2.45: ENERGY INTENSITY AND CO_2 INTENSITY IN JAPAN, 1990-2009



Source: ABB, 2011b

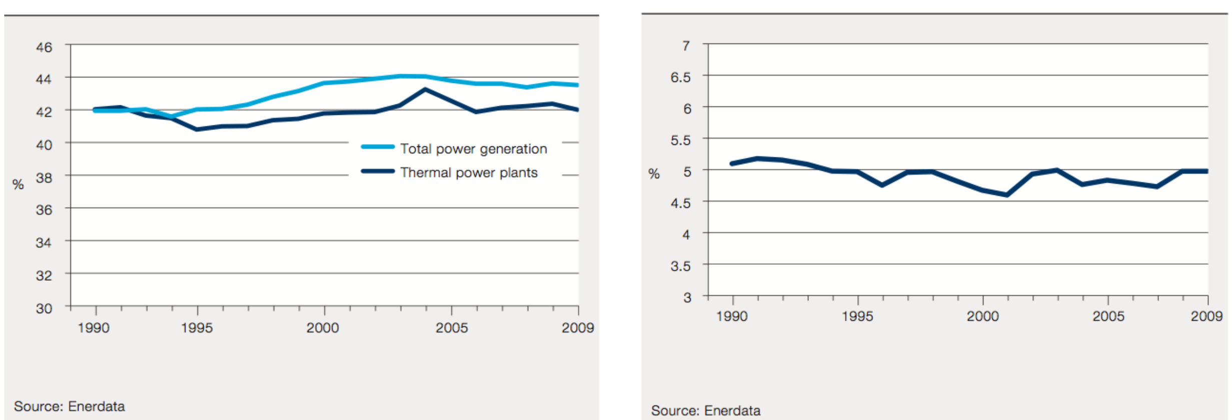
After two oil shocks in the 1970s, the Law on the Rational Use of Energy (the "Energy Conservation Law" or ECL) was passed in 1979. This law required manufacturers and commercial sector interests to actively manage their energy efficiency, established energy efficiency standards for houses and buildings, and rate energy efficiency in products such as appliances. Through several amendments, as of now this law covers all sectors (Sakamoto, 2009), divided into four categories: factories, buildings, transportation, and equipment or appliances (Murakoshi *et al.*, 2010).

The ECL requires factories whose energy consumption is larger than 1,500 tons of oil equivalents (toe) to employ an energy manager, submit a report on energy consumption, and improve energy efficiency more than 1% annually. Since the mid-1970s, various financial and fiscal incentives have been put in place to encourage energy conservation and efficiency in industry (Murakoshi *et al*., 2010). Besides this mandatory measure, Japanese industries established voluntary energy efficiency targets and CO_2 reduction plans as well.

Standards for energy efficiency of equipment (including cars) were first implemented in 1979. Following revisions in 1998, the ECL was transformed into the Top Runner program, which set efficiency standards for the top 21 products sold in Japan. The most efficient model in each category became the baseline level of efficiency for all other models to achieve. Those baselines are updated regularly, creating increasingly more efficient products. The scope of the program also has been expanded: as of February 2010, 23 categories of equipment were targeted. This measure has surpassed expectations (Murakoshi *et al*., 2010).

Efficiency in the thermal power sector has increased slightly since 1994, reaching 42% in 2009, which is above those of Germany, USA; and similar to the level in the U.K. (ABB, 2011; The Federation of Electric Power Companies, 2011). This improvement in power sector came from a switch of energy sources to natural gas, and from the rise in the use of gas combined cycle technology. T&D losses in Japan have been around 5% over 1990 to 2009, which is better than the average T&D losses in the OECD countries. These date are shown in Figure 2.46.

FIGURE 2.46: EFFICIENCY OF POWER GENERATION AND T&D LOSS FOR JAPAN

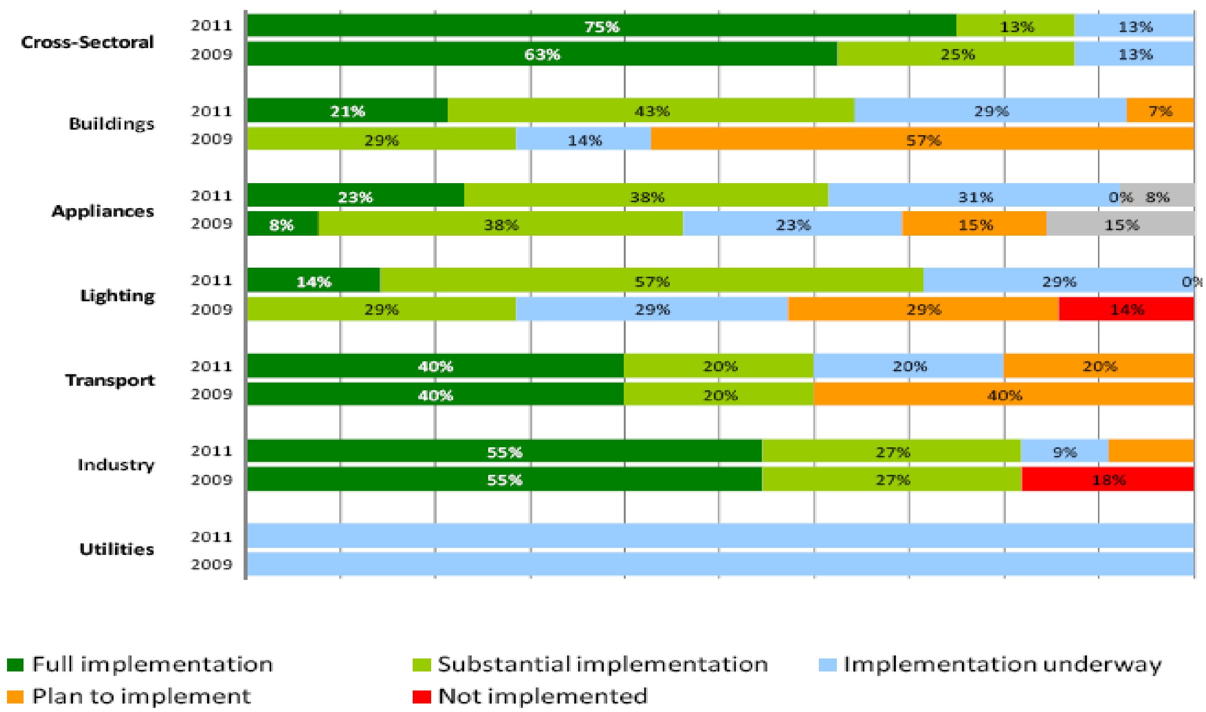


Source: ABB, 2011

According to the ABB, although the efficiency of total power generation has increased slightly, the per kWh CO_2 emissions have also increased, exceeding the 1990 levels. This comes from the increased use of coal and gas in the power sector since 1998. The increased use of coal and gas more than offset the emissions decreasesthat had resulted from the spread of nuclear power between 1990 and 1998.

For Japan, the long-term energy supply and demand outlook (2008) aimed at improving energy efficiency by 30% by 2030. There has been an overall improvement of 30% in energy efficiency since the 1980s. The forthcoming policy goals clearly indicate that energy efficiency will be given top priority. Japan has also incorporated IEA recommendations into its plans, the only nation to have implemented or to be in the process of implementing all 25 best practices established at the G8 summits in 2006, 2007 and 2008. As a result, there has been a shift in the approach to energy efficiency. Between 2009 and 2011, there has been significant increase in the percentage of IEA policies in full implementation in cross-sectoral, buildings, lighting, and appliances, and a gradual beginning in transport and industry sector (See Figure 2.47).

FIGURE 2.47: IEA RECOMMENDATION IMPLEMENTATION IN JAPAN, 2009 VS. 2011



Source: IEA, 2011d: 77

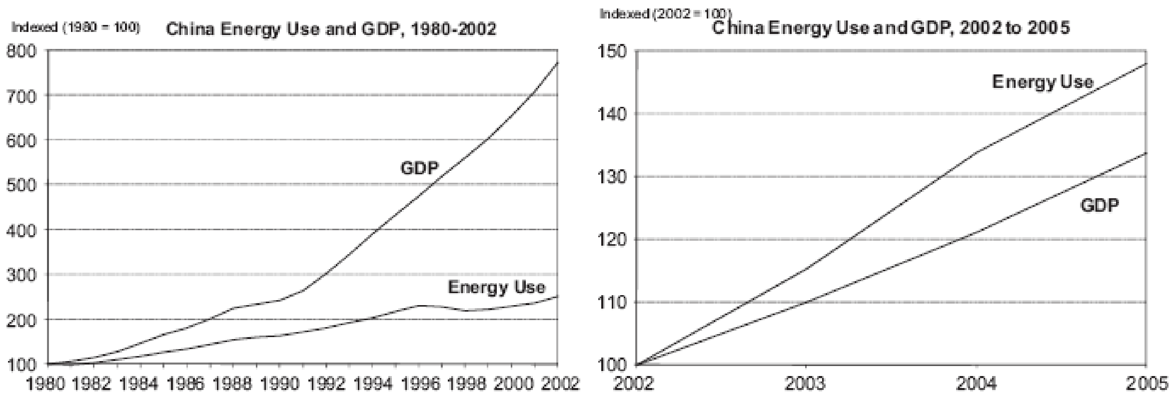
The Fukushima accident created an energy supply crisis in Japan. The immediate response by the government was to make up for lost nuclear capacity with gas and oil plants; however, another key focus has been on energy conservation and efficiency (Nakano and Pumphrey, 2012). METI conducted a review of the power sector and its industrial structure in order to determine ways to promote efficiency and conservation. This resulted in a series of revisions to the Energy Conservation Law in early 2012, which will be implemented to help curb electricity demand and stabilize peak periods (IEEJ, 2012). As noted above, the Energy and Environment Council issued new commitments to sustainable energy policies, including a reduction in energy consumption of 10% in 2030. Efficiency and conservation will be a crucial in reducing energy consumption in Japan, while renewable energy sources come on line and take up a larger share of gross generation.

China

China has emphasized energy efficiency and conservation as one of its top priorities. From 1980 to 2002, China succeeded in limiting energy demand growth by implementing various aggressive energy-efficiency programs. Energy use per unit of gross domestic product (GDP) declined by about 5% per year during this period. This great improvement in China's energy productivity is the result of various factors such as more efficient use of coal, the switch from coal to oil, industry restructuring (rapid growth of equipment manufacturing industries), and a desire to avoid higher energy prices.

In contrast, energy use per unit of GDP increased at an average of 3.8% per annum during the period of 2002 through 2005. The contrast between the two periods, 1980 - 2002 and 2002 - 2005, is depicted in Figure 2.48 below. To deal with this rapid growth in energy demand, in November 2005 the Chinese government announced a mandatory goal (restricted target) of 20% reduction in energy intensity between 2006 and 2010 based on the 11th Five Year Plan (FYP).

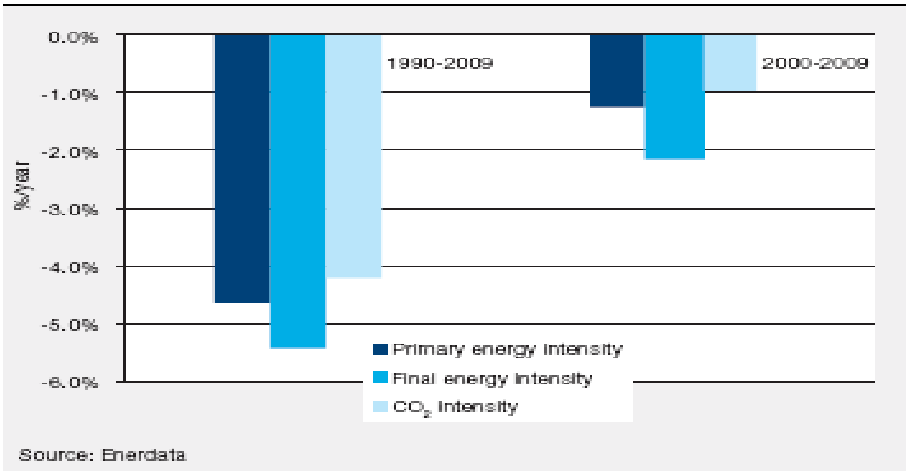
FIGURE 2.48: ENERGY INTENSITY IN CHINA, 1980-2002



Source: Zhou *et al*., 2010

China's total primary energy intensity dropped quickly at a rate of 4.6% per year between 1990 and 2009. This trend is related to the high energy intensity apparent in the 1990s. As can be seen in Figure 2.49, Chinese total energy intensity has gradually fallen to 1.3% per year since 2000. In the case of final energy intensity (final energy consumption per unit of GDP), the reduction was faster than that of primary energy intensity. The difference is mainly due to the increasing losses in power generation as a result of more electricity being produced than before. CO_2 intensity declined more slowly than the total energy intensity because of the more prevalent use of coal in that electrical generation.

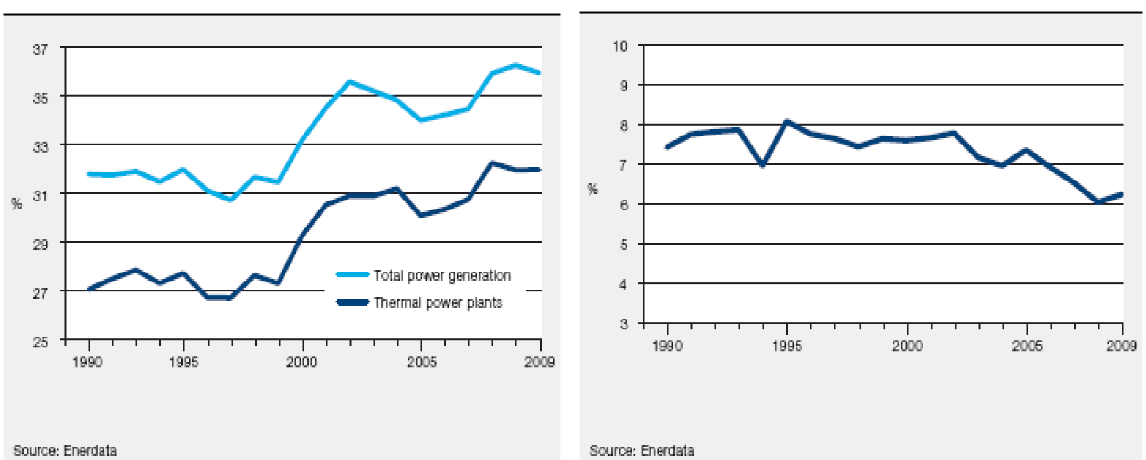
FIGURE 2.49: CHINESE ENERGY AND CO2 INTENSITY TRENDS, 1990-2009



Source: ABB, 2011c

The Chinese efficiency of power generation, 36%, is low compared to the international standard. The average efficiency of thermal power generation was only 32% in 2009, which is 8 percentage points lower than the OECD average. Nevertheless, average efficiency has improved since 1998. This trend has been driven by the construction of new, efficient thermal power plants along with the closure of small and inefficient power plants. Meanwhile, the rate of transmission and distribution losses in the Chinese grid is about 6% of the distributed volumes, which is below the world average of 9%. Considering the fact that those losses recorded 7.5% in 1990, they have declined slightly over time. Following the announcement of 20% reduction in energy intensity target in 11th FYP, the Chinese government developed a series of policies and measures, including government reorganization, to support the realization of that goal. See Figure 2.50.

FIGURE 2.50: a) EFFICIENCY OF POWER GENERATION AND THERMAL POWER PLANTS, CHINA, 1990-2009
b) ELECTRICITY TRANSMISSION AND DISTRIBUTION LOSSES, CHINA, 1990-2009



Source: Enerdata, 2011

As a framework policy, the "Medium and Long Term Energy Conservation Plan" (implemented in 2004) set energy saving targets for the period of 11th FYP through 2010, and for the period from 2010 to 2020.

Although in 2008, Premier Wen Jiabao and the State Council warned that meeting its energy intensity and emission reduction goals “remained an arduous task”, China still successfully lowered its energy intensity per unit GDP by 19% over the 11th FYP period (2006-2010), slightly short of the stated 20% goal. According to the plan, by 2020, energy consumption per 10,000 Yuan GDP should be reduced to 1.54 tons of coal equivalent (tce; 27.7 MMBtu) with an average annual energy efficiency rate of 3% from 2003 to 2020. Efficiency of coal-fired power generation should be increased from 355 gce/kWh in 2010, to 320 gce/kWh in 2020 (Rommeney, 2008).

Over the 12th FYP period, China plans to reduce energy intensity per unit GDP by another 18%. China also has pledged to cut carbon intensity by 40-45% by 2020 from 2005 levels, which would help decrease environmental impact while demand for energy continues to rise. Meanwhile, the coal industry will undergo restructuring, which should lead to the closure of inefficient facilities and some small factories. According to the plan, consolidation of coal mining enterprises will continue, reducing the number from the current 11,000 to approximately 4,000 by 2015. This will be done by promoting mergers and acquisitions, and shutting down illegal users and producers. At the same time, power lines and smart-grid solutions will be developed to help conserve energy (NZTE, 2011).

Based on the 12th FYP, Chinese government will strictly enforce the system for assessing and examining energy savings of various investment projects. In addition, efforts will be made to implement conservation priorities and enforce regulation of both the supply and demand sides.

The Fukushima disaster has had a number of impacts on China’s nuclear safety protocol and policies; however, since the accident it has had little influence on overall Chinese energy policy, energy efficiency goals or programs in China. The government continues to promote its energy intensity reduction targets through institutional and technological reforms, but because current policy emphasizes expanding supply, conservation and efficiency have not been identified as tools to meet future energy demand.

2.3.2 Renewable Energy Trends and Policy

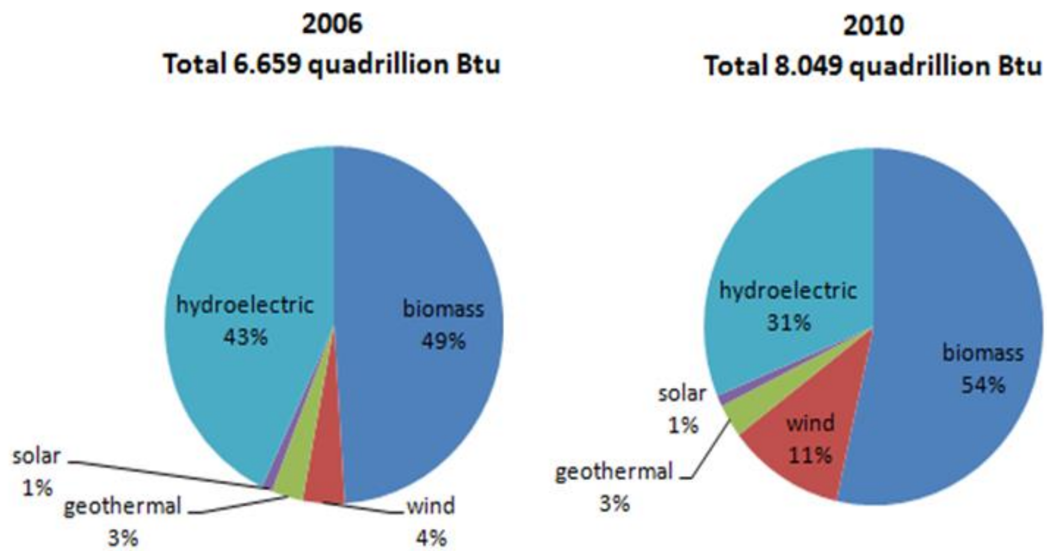
United States

In the U.S., renewable energy consumption has increased considerably in the last several years (Figure 2.51), growing about 6% from 2009 to 2010 while total energy consumption in the U.S. increased about 4% during the same period. Indeed, renewable sources supplied about 10% of electricity in 2010. Figure 2.50 summarizes renewable energy consumption by source for both 2006 and 2010. Overall, electricity generation from renewable energies increased 2% from 2009 to 2010.

Interestingly, ethanol consumption doubled from 2006 to 2010. This trend is expected to continue in the future as the Clean Air Act 2011 set the ethanol consumption target of 13.95 billion ethanol equivalent gallons compared with 13.19 billion gallons in 2010.

The renewable portfolio standard (RPS) has been the primary policy tool used to increase the renewable energy generation in the U.S. The RPS requires a certain percentage of qualifying utility generation to come from renewable energy. The percentage varies depending on a particular state’s policy. The RPS creates market demand for renewable energy sources, which incentivizes utilities or other independent agents to invest in and supply renewable energy. It also leads to improvements in the competitiveness and performance of renewable energy technology and in the electricity power market in the long-term. . As of 2009, 33 states and the District of Columbia have enacted RPS policies, with renewable energy mandates of between 4 - 30% of electrical generation. The benefits from RPS include improved energy security, new jobs, and reduced power price volatility.

FIGURE 2.51: RENEWABLE ENERGY CONSUMPTION BY SOURCE, U.S., 2006 AND 2010



Source: EIA, 2011c

The 2011 AEO projected that the renewable energy generation share (excluding hydropower) will increase to about 33% of the total electricity generation by 2035 due to state-level policies like the RPS as well as federal tax credits. The scenarios are summarized in Table 2.5 and figure 2.52 below. The scenario encompassing both tax credits for renewables and energy efficiency standards shows largest increase of renewable energy generation.

As shown in Table 2.5, in the EIA's AEO Reference case, renewable generation increases by 26% from 2005 to 2035. The growth in the No Sunset and Extended Policies cases account for 36 and 38% of the total generation growth, respectively. While the renewable energy proportion of the total electricity generation is 14% in the Reference case, it increases to 16% in the No Sunset case and the Extended Policies case.

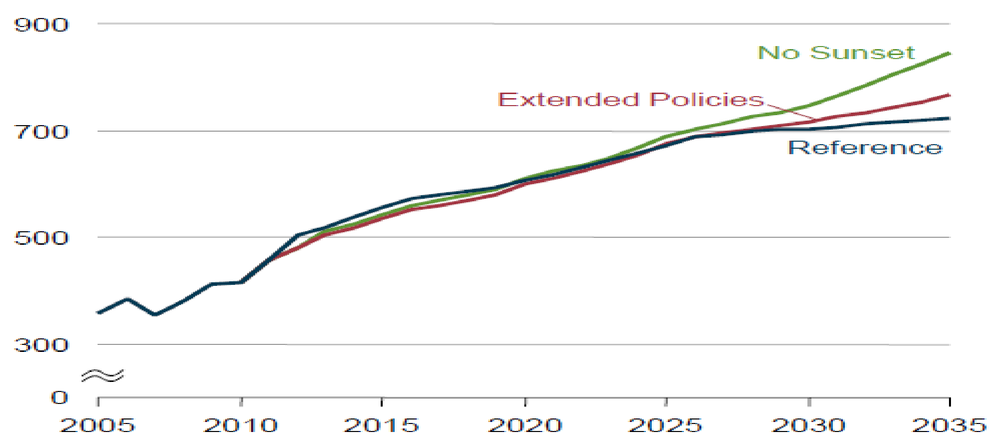
Overall it appears that there were no significant policy changes with reference to renewable energy measures after the Fukushima accident. For example, the wind production tax credit was renewed by the U.S. Congress. In the past, the Production Tax Credit (PTC) contributed in a period of strong growth from the wind-rich fields of the Midwest to the emerging manufacturing hubs in the Southeast.

TABLE 2.5: RENEWABLE ENERGY DEVELOPMENT SCENARIOS IN THE U.S.

Scenario	Description
Reference Case	Baseline economic growth (2.7 percent per year from 2009 through 2035), world oil price, and technology assumptions. World light, sweet crude oil prices rise to about $125 per barrel (2009 dollars) in 2035. Assumes RFS target to be met as soon as possible
No Sunset Case	Begins with the Reference case and assumes extension of all existing energy policies and legislation that contain sunset provisions, except those requiring additional funding (e.g., loan guarantee programs) and those that involve extensive regulatory analysis, such as CAFE improvements and periodic efficiency standard updates.
Extended Polices case	Begins with the No Sunset case but excludes extension of blender and other biofuel tax credits. Assumes expansion of the maximum industrial ITC and CHP credits and extension of the program. Includes assumptions of the "Expanded Standards and Codes case". Assumes new LDV CAFE standards (to 46 mpg by 2025) and tailpipe emissions proposal consistent with the CAFE 3% Growth case described below

Source: EIA, 2011b

FIGURE 2.52: U.S. RENEWABLE ELECTRICITY GENERATION IN THREE CASES, 2005-2035 (TWh)



Source: Leone, 2012

The conclusion is that overall renewable energy policy in the United States has not changed drastically as a result of the Fukushima crisis. The U.S. still maintains commitments to nuclear and other alternative energy sources in order to improve energy security and reduce GHG emissions, and no significant changes seem to have taken place to alter this policy (Siemens, 2012). While the federal government has failed to pass any significant policies over the past two years, such as a national clean energy standard, state policy has advanced in some circumstances. California continues to promote renewable energy technologies, with the city of Los Angeles passing a FIT in 2012 (Robbins, 2012). However, most policy changes following Fukushima are simply extension of policy trends that existed prior to the accident.

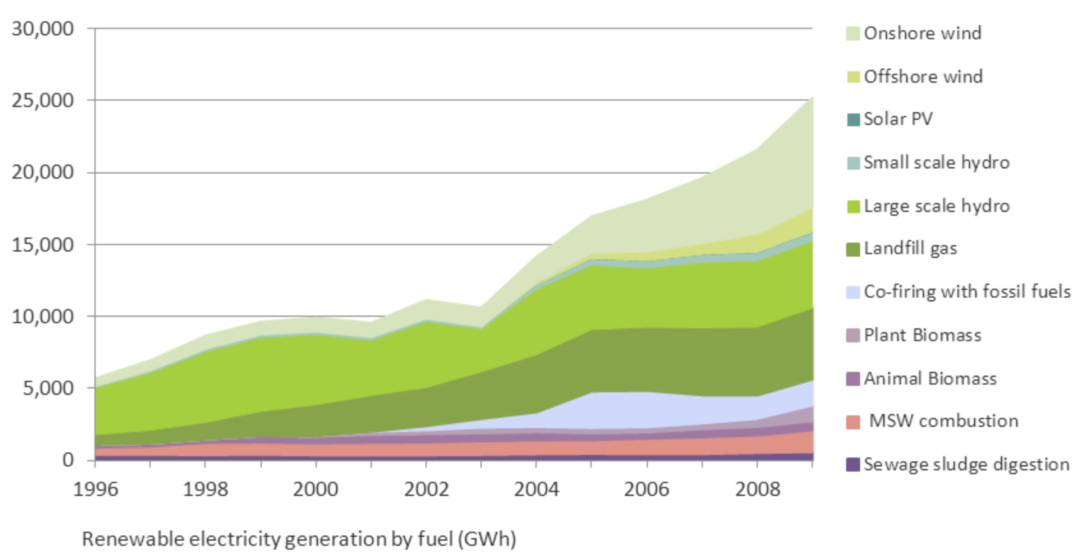
United Kingdom

The U.K. Department of Energy and Climate Change defines renewable electricity as electricity generated from onshore and offshore wind, solar PV, small scale hydro, large scale hydro, landfill gas, co-firing with fossil fuels, plant biomass, animal biomass, municipal solid waste combustion, and sewage sludge combustion. There has been a steady increase in the role of these renewables over the past decade. Over 9,900 GWh of renewable electricity was generated in 2000, equivalent to 2.93% of the total electricity generated. By 2009, this proportion had grown to 6.63% of the total electricity generated (25,182 GWh of renewable electricity).

Biomass makes a significant contribution to the renewable electricity generated in the U.K. As of 2009, 42.1% of the total renewable electricity generated was derived from biomass. Onshore wind was the second most important renewable electricity source. There was a staggering increase in the capacity of onshore wind generated electricity capacity between 2000 and 2009. Onshore electricity generated grew from 945 GWh in 2000 to 7,564 GWh in 2009, representing a 700% increase over the 10 year period. Offshore wind also increased significantly over the period. As of 2000, only 1 GWh of total electricity supplied was derived from this source. By 2009, 1,740 GWh of total electricity generated was derived from offshore wind. Electricity generated from solar PV also grew from 1 GWh in 2000 to 20 GWh in 2009.

Electricity generation from small scale hydro increased by 35.6% between the years 2000 and 2009. Large-scale hydro, however, continues to play an important role in U.K. electricity generation. Even though there has been no significant growth in electricity generated from large hydro, with slight reductions being realized in some cases over the observed period, 18.5% of total electricity supplied was generated from this source in 2009.

FIGURE 2.53: U.K. RENEWABLE ELECTRICITY GENERATION BY SOURCE, 1996-2009



Source: DECC – DUKES, 2011

The U.K. government has stated its commitment to increase the share of renewables in its energy mix as part of efforts to decarbonise the energy sector and secure security of supply. The Office for Renewable Energy Deployment of the U.K. Department for Energy and Climate Change (DECC) developed a Renewable Energy Roadmap in July, 2011 to steer the U.K. towards a low carbon path driven by renewables coupled with nuclear, carbon capture and storage and energy efficiency (DECC, 2011b). The Roadmap is intended to build on efforts already underway to promote the renewable energy sector through the development of 'financial support mechanisms for renewables, the Green Investment Bank to help companies secure investment in green infrastructure and efforts to encourage the development of new offshore wind manufacturing facilities at port sites (DECC, 2011b). The Roadmap is not only committed to the development of renewables for electricity but also to heat generation and transport.

The U.K. has set a target to meet 15% (234TWh) of its energy needs through renewable energy sources across the electricity, heat, and transport sectors by 2020. 90% of this is to be supplied by 8 core technologies. The individual contributions of the different technologies are projected as follows:

TABLE 2.6: U.K. PROJECTED CONTRIBUTIONS OF RENEWABLE TECHNOLOGIES, 2020

	Projected Range for 2020 (TWh)
Onshore wind	24-32
Offshore wind	33-58
Biomass Electricity	32-50
Marine	1
Biomass heat(non-domestic)	36-50
Air-source and ground-source heat pumps(non-domestic)	16-22
Renewable transport	Up to 48TWh
Others(including hydro, geothermal, solar and domestic heat)	14
Estimated 15% target	234

Source: DECC, 2011b

The remaining 10% of the 2020 target is to be met though technologies including hydropower, solar PV, and geothermal heat and power.

To meet the 15% target by 2020, renewable energy consumption is expected to increase at a rate of about 17% per annum. Across the different sectors, renewable electricity will be expected to grow at an annual rate of 15% per annum from the 2010 baseline of 28 TWh. Renewable heat will be expected to grow at over 19% per annum in order to realize an increase from 13 TWh to the projected 73 TWh by 2020 (DECC, 2011b). In support of these goals, the U.K. aims to deliver a total of up to 29 GW of operational capacity of renewable electricity by 2020. 22 GW of potential new capacity is being planned, has been approved, or is under construction. Combining this with the existing capacity, it is projected that about 29 GW of renewable electricity will be added to the grid by 2020 (DECC, 2011b).

About 4 GW of renewable electricity is expected to be connected by the end of 2012. Onshore wind will be the largest contributor to new generation, with 11 GW already in the pipeline. There is 6 GW of offshore wind in the pipeline and this capacity is expected to increase over time. In addition, 4.3 GW of biomass electricity is currently in the pipeline. The availability of sustainable feedstock for electricity generation given the competing demands for the use of biomass in heat, transportation and other non-energy sectors is expected to affect how much biomass electricity is actually brought online by 2020 (DECC, 2011b).

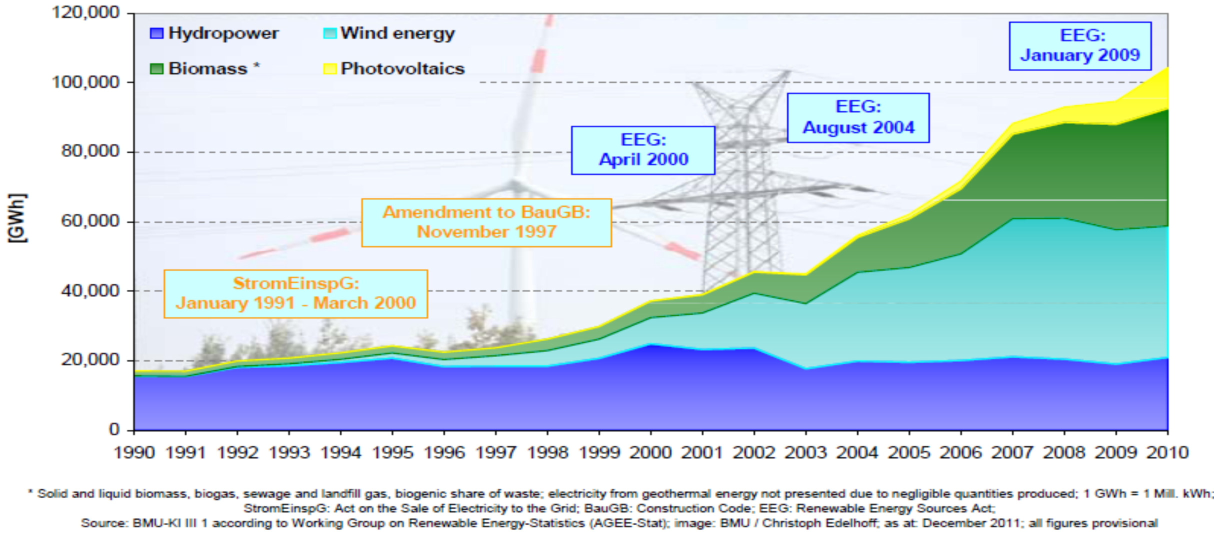
Various actions are being taken across the U.K. to meet the 15% by 2020 target. The Scottish government has introduced a target to produce 100% of its electricity from renewables by 2020. The Northern Ireland Executive has also set a target to produce 40% renewable electricity by 2020. The Government of Wales has also indicated the possibility of the region delivering twice as much renewable electricity as it currently delivers and the likelihood of generating 4 GW of this from marine energy.

An independent study by the U.K. Commission on Climate Change (CCC) has suggested that the U.K. has the capacity to obtain from 30-45% of its total energy consumption from renewables by 2030 if a commitment is made to do so. According to the CCC, the attainment of this ambitious target will require government action to remove current uncertainties in the renewables market and reduce costs. The U.K. Government is expected to address the recommendations of the CCC as part of the 4th carbon budget for the period 2023 – 2027 (DECC, 2011c).

Germany

The German government has made an effort to increase renewable energy to address energy security and climate change. Since 1991, Germany relied on its Renewable Energy Sources Act (EEG) to ensure that grid operators to obtain electricity from renewable sources. Biomass (including landfill gas) supplied about 9% of electricity in 2009. The solar energy share has expanded about 80 times since 1990 as especially EEG focused on increasing utilization of solar energy. The following figure shows the contribution of renewable energy into Germany’s electricity production for the period 1990-2010.

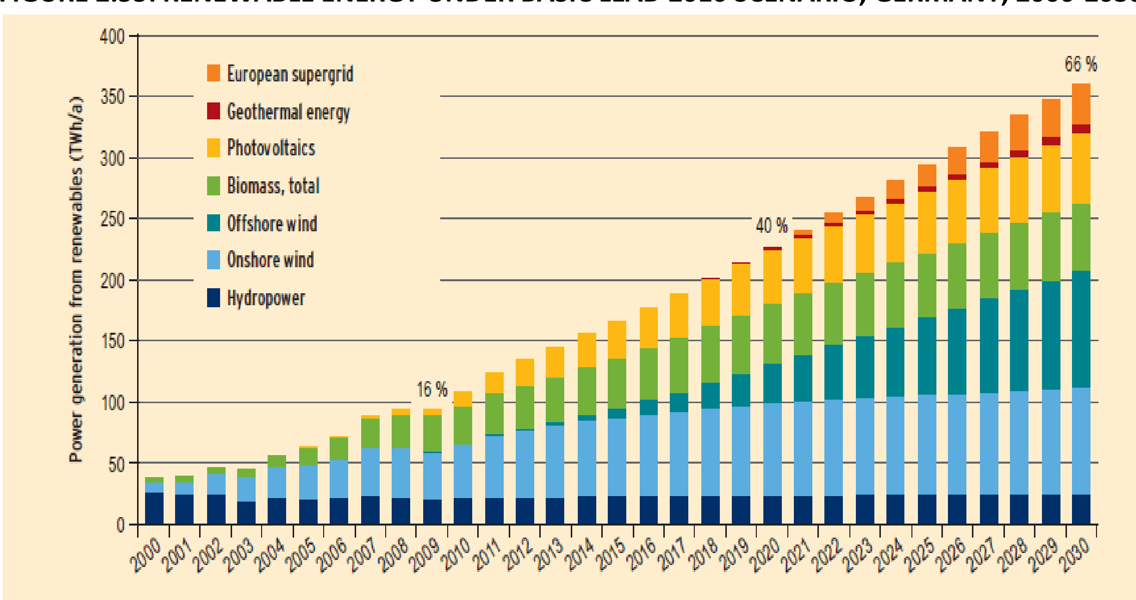
FIGURE 2.54: RENEWABLE ENERGY GENERATION IN GERMANY, 1990-2010



Source: BMU, 2012

The German government's Lead Study 2010 modelled an 85% reduction in carbon dioxide emissions by the year 2050, assuming a variety of life extensions for the country's fleet of nuclear reactors. The contribution of renewable energy under this basic scenario of the Lead 2010 Study is shown in Figure 2.54.

FIGURE 2.55: RENEWABLE ENERGY UNDER BASIC LEAD 2010 SCENARIO, GERMANY, 2000-2030



Source: BMU, 2011

The graph shows that the contribution of renewable energy reaches 66% of the total electricity generation in the year 2030. The Lead 2010 Study also included a scenario which models a power supply of 100% renewable energy by the year 2050, assuming a strong development of hydrogen energy as an energy storage medium. Table 2.7 below depicts the capacity of renewable energy to be installed annually to meet this 100% renewable power supply target. The modelling analysis shows that the share of renewable energy has to increase substantially after the year 2030 if the 100% renewable power goal for 2050 is to be met.

TABLE 2.7: ANNUAL INSTALLED RENEWABLE ENERGY CAPACITY IN 100% RENEWABLE SCENARIO, GERMANY

	POWER (MW_{el}/yr)							
	hydro	wind	PV	geotherm. power	power import	biomass power	biogenic waste power*)	total power MW_{el}/yr
2010	**35**	**2040**	**8500**	**4**		**373**	42	**10993**
2011	35	2020	6000	7		344	20	8426
2012	40	2060	4200	10		329	20	6658
2013	45	2110	3600	13		317	20	6105
2014	50	2238	3300	17		320	20	5944
2015	**55**	**2460**	**3050**	**22**	**0**	**288**	20	**5895**
2016	60	2694	2830	28	0	335	22	5969
2017	70	2940	2750	35	0	300	28	6123
2018	70	3232	2650	43	100	292	28	6415
2019	75	3900	2580	51	200	258	28	7091
2020	**74**	**4228**	**2540**	**62**	**280**	**165**	28	**7377**
2030	**100**	**4310**	**2783**	**85**	**635**	**465**	**0**	**8378**
2040	**104**	**4690**	**4258**	**130**	**1103**	**233**	**0**	**10518**
2050	**109**	**6883**	**4900**	**410**	**2120**	**460**	**0**	**14882**

Source: EWI, 2010

As was discussed earlier, the German government has announced a shift in its overall energy policy, with renewable energy becoming the central focus for future energy development. The government has set new renewable energy targets, proposing to increase the renewable energy production share from 20% to 35% by 2022. By 2050, 80% of energy will be from renewable energy sources. In support of renewable technology deployment, the government announced a grid infrastructure upgrade in May, 2012. Unfortunately, the systematic decline in German feed-in-tariff (FIT) rates may impact the adoption of renewable energy technologies.

France

On November 17, 2008, the Ministry of Ecology, Energy, Sustainable Development, and Land Planning of France released a series of policies designed to promote the use of renewable energy under the *Grenelle Environnement* framework discussed previously. The document, titled "Fifty measures for the development of renewable energies of high environmental quality," lays out the policies that will be used to reach the renewable energy targets and goals set out by the Grenelle (23% of gross final energy consumption by 2020 and 27% of gross final electricity consumption by 2020). The support mechanisms include feed-in-tariffs, tender schemes, and income tax credit schemes, (IEA, 2010a).

The most important policy for supporting renewable energy technologies are feed-in-tariffs (FIT) for electricity plants with capacity less than 12 MW. The tariffs are imposed on Electricité de France (EDF) and the system is funded through a public benefit charge added to all electricity bills. Under the new Grenelle law, purchase obligations and feed-in-tariffs will also benefit local authorities (Article 88). The current feed-in-tariff structure and prices are listed in the table below.

TABLE 2.8: FRENCH NATIONAL FEED-IN TARIFFS FOR RENEWABLE ELECTRICITY, 2009

National Feed-in Tariffs for Renewable Electricity*, 2009

	Decree date	Contract length	Feed-in tariffs (in eurocents/kWh)
Hydropower	1 March 2007	20 years	6.07, plus 0.5 to 2.5 bonus for small hydropower (<12 MW) plus bonus of 0 to 1.68 for production regularity in winter time.
Wind power	10 July 2006	15 years - onshore	Onshore: 8.2 if installed in "zone développement éolien" for the first ten years, then 2.8 to 8.2 for the next five years, depending on site.
		20 years - offshore	Offshore: 13 for the first ten years, then 3 to 13 for the next ten years, depending on site.
Geothermal	10 July 2006	15 years	12 in metropolitan France, plus a bonus of 0 to 3 for increased energy efficiency. 10 in overseas departments, plus a bonus of 0 to 3 for increased energy efficiency.
PV solar power	10 July 2006	20 years	Non-digressive base tariff of 30, plus 25 bonus in metropolitan France if building-integrated **. In Corsica and overseas departments 40, plus 15 bonus if building-integrated. Specific tariff of 45 for professional buildings if integrated, even when installed capacity is more than 12 MW.
Biogas and methane	10 July 2006	15 years	7.5 to 9, plus 0 to 3 energy efficiency bonus plus 2 methane bonus.
Solid biomass	16 April 2002	15 years	4.9, plus 0 to 1.2 energy efficiency bonus.
Methane gas	16 April 2002	15 years	4.6, plus 0 to 1.2 energy efficiency bonus.
Geothermal	13 March 2002	15 years	7.62, plus 0 to 0.3 energy efficiency bonus.
PV solar power	13 March 2002	20 years	15.25 in continental France and 30.5 in Corsica and overseas departments.
Animal waste	13 March 2002	15 years	4.5 to 5, plus 0 to 0.3 energy efficiency bonus.
Landfill biogas	3 October 2001	15 years	4.5 to 5.72 according to capacity, plus 0 to 0.3 energy efficiency bonus.
Municipal solid waste	2 October 2001	15 years	4.5 to 5, plus 0 to 0.3 energy efficiency bonus.
Co-generation	31 July 2001	12 years	6.1 to 9.15 depending on gas price, length of service and capacity.
Hydropower	25 June 2001	20 years	5.49 to 6.1 according to capacity, plus 0 to 1.52 bonus for production regularity in winter time.
Wind power	8 June 2001	15 years	8.38 for the first five years, then 3.05 tot 8.38 for the next ten years, depending on site.

*Applies only to facilities equal or less than 12 MW (exception: PV solar on professional buildings).
**Tariffs indexed on both prices and costs of work in industry. Feed-in tariff 2008 was EURc 31.19/kWh and EURc 57.19/kWh in case of building-integration.

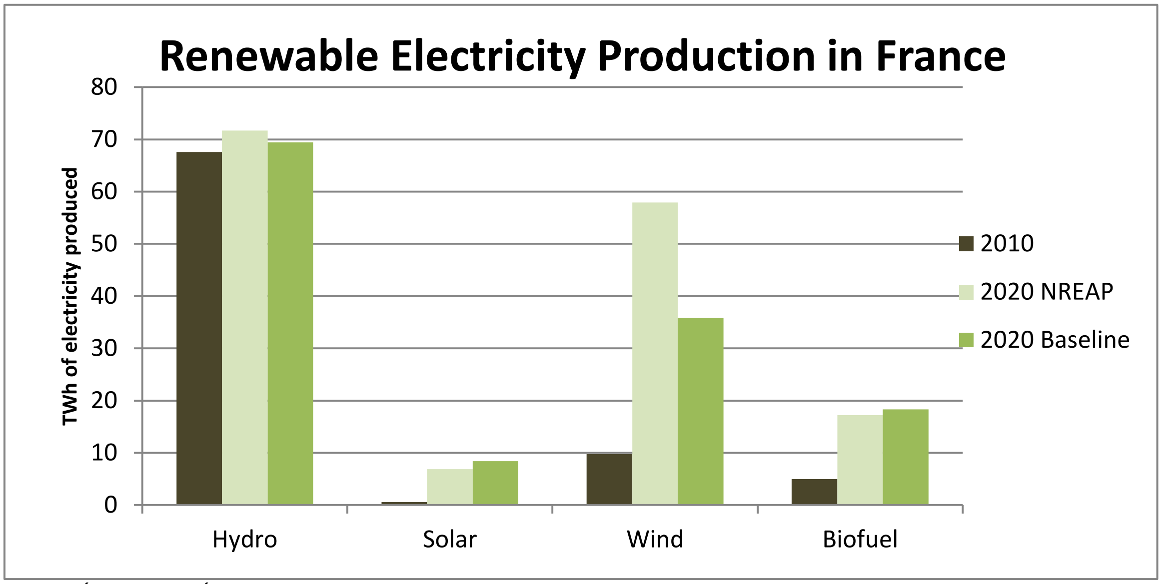
Source: IEA, 2010a

France is attempting to develop large-scale investments in renewable energy by initiating calls for tender (i.e. bids on renewable energy projects). The initial 2004 tenders were for 200 MW of solid biomass, 50 MW of biogas, 500 MW of offshore wind, and two separate 500 MW tenders for onshore wind. In 2008, additional tenders went out for PV - the French government hoped to have a PV plant, with capacities varying between 5 and 20 MW and adding up to 300 MW total by 2011. As of July 30, 2011, there was a total capacity of 216.9 MW of installations with output between 5 and 20 MW. Moreover, calls for tenders were launched for renewable heating systems which aim to increase renewable heat from 2.0 Mtoe in 2006 to 7.5 Mtoe in 2020.

Consistent with the 20-20-20 European Directive, France is aiming for a renewable energy target of 23% in gross final energy consumption by 2020, up from a level of 9.6% achieved in 2005 (MEESDP, 2009). In the electricity sector alone, a target of 27% of gross final electricity consumption produced from renewable energies is targeted for 2020 (MEESDP, 2009).

The increase between the 2010 production levels and the target levels for 2020 (set by the NREAP) are presented in the figure below. The figures shows that the share of solar, wind, and biofuels in the electricity mix is expected to rise significantly over the 10 year period from 2010 to 2020. Note that the 2020 NREAP scenario is taken from the pre-Fukushima National Renewable Energy Action Plan (MEESDP, 2009), and the 2020 Baseline scenario is taken from the post-Fukushima RTÉ General Adequacy Report (RTÉ, 2011b) described in the next section.

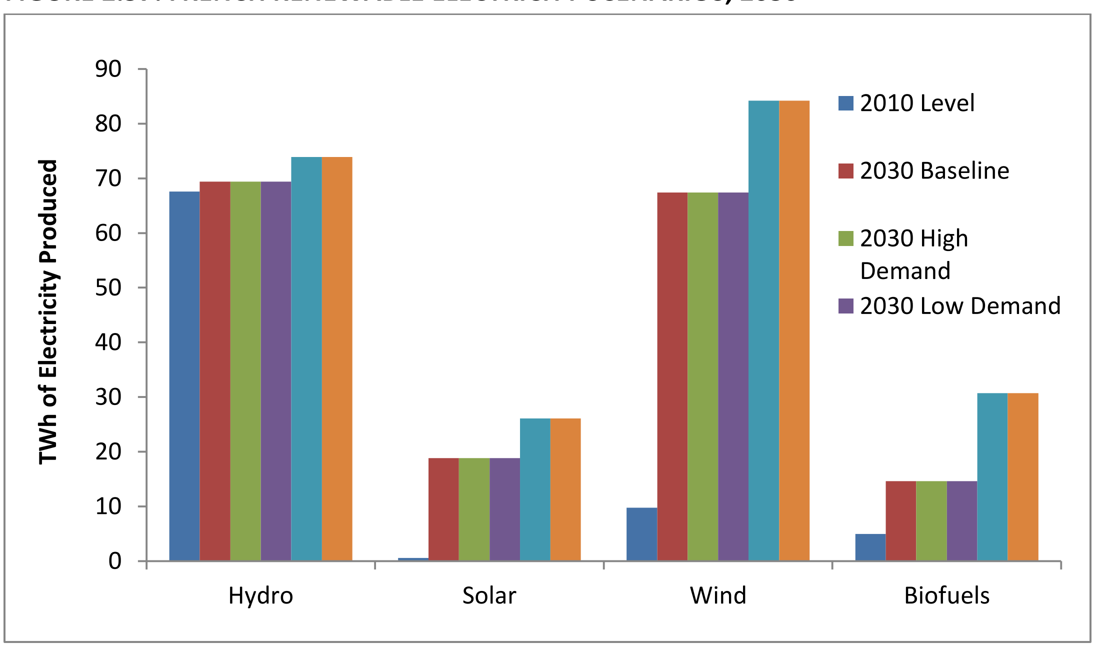
FIGURE 2.56: RENEWABLE ELECTRICITY PRODUCTION IN FRANCE, 2010 & 2020



Source: RTÉ, 2011a; RTÉ 2011b

In 2011, the French RTE released their annual "General Adequacy Report" on the supply-demand balance of the electricity system in both the near and long term. The report accounts for the German government's decision to abandon their nuclear program by 2022 - it represents an up-to-date reference scenario as well as several current alternative scenarios. The 2010-2030 "Baseline" scenario in this report foresees minimal additional capacity in nuclear, coal, CCGT, and hydroelectric generation and continuous increases in renewable thermal, wind, and PV capacity (RTÉ 2011b). In the "Low Nuclear" scenario, the renewable energy targets are kept constant from the "High RES" scenario.

FIGURE 2.57: FRENCH RENEWABLE ELECTRICITY SCENARIOS, 2030



Source: RTÉ, 2011a; RTÉ 2011b

On November 8th, 2011, the Union Française de l'Électricité (the French electricity industry association and lobby group made of up the main electricity players like EDF, GDF, RTE, and E-ON) released a series of 2030 electricity scenarios for France (UFÉ, 2011). The table and figure below show the installed capacity of each renewable generation technology under the three different scenarios. In the UFÉ report, no figures were given for the actual amount of energy produced.

TABLE 2.9: INSTALLED RENEWABLE GENERATION CAPACITY SCENARIOS, FRANCE, 2030

Generation Technology (GW installed capacity)	70% scenario	50% scenario	20% scenario
Hydro	29	29	29
Onshore Wind	22	25	30
Offshore Wind	6	10	15
Solar	10	15	18
Biomass	3	4	5
Renewable Total	70	83	97

Source: UFÉ, 2011

These data indicate that wind and solar programs continue to progress. New Renewable Energy development emphasis by the Hollande government is possible. With President Hollande planning to slash French reliance on nuclear power by 25% by 2025, there could be a forced switch of billions of euros to fund investment in French renewable and energy efficiency schemes (Webb, 2012).

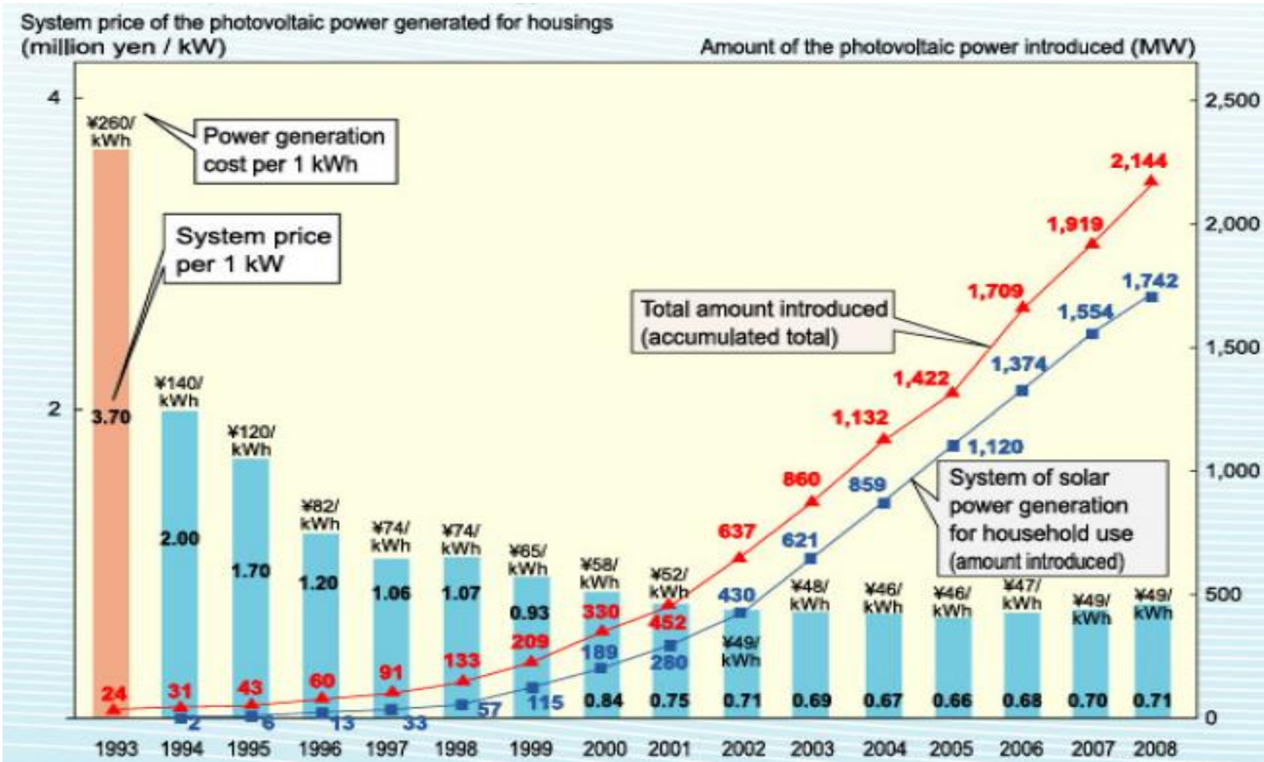
Japan

At the end of 2009, the share of electricity from renewables (excluding large hydropower) in Japan was just 2.2% of electricity generated; if large hydropower were included, the share would have reached 10% (REN21, 2011).

Japan's main measures to support renewable energy have been subsidies and initial investment in R&D. In addition, an RPS was initiated in 2003; however, its effectiveness was limited because the target was not very aggressive (1.35% by 2010) and the target periods were short (maximum 8 years). The original FIT for PV was suspended in 2005, causing Japan to lose its position as global leader in PV capacity. The FIT was subsequently reinstated by the government to bolster market growth (JREPP, 2011). At the end of 2010, Japan was the fourth largest country in terms of PV capacity, with 3.6 GW. In terms of annual addition of PV in 2010, Japan was ranked fourth, after Germany, Italy, and the Czech Republic.

The FIT was expanded to other renewables on July 1, 2012. "The Act on Purchase of Renewable Energy Sourced Electricity by Electric Utility" required utility operators to purchase electricity generators from renewable sources including solar PV, wind power, hydraulic power (below 30MW), geothermal and biomass at a fixed price over a period. The costs of feed-in-tariffs will be passed on to customers. However, the customers who were significantly damaged by the Great East Japan Earthquake were exempted from the surcharge for a period from July 1, 2012 to March 31, 2013 (METI, 2011).

FIGURE 2.58: PV POWER AND COST IN JAPAN, 1993-2008

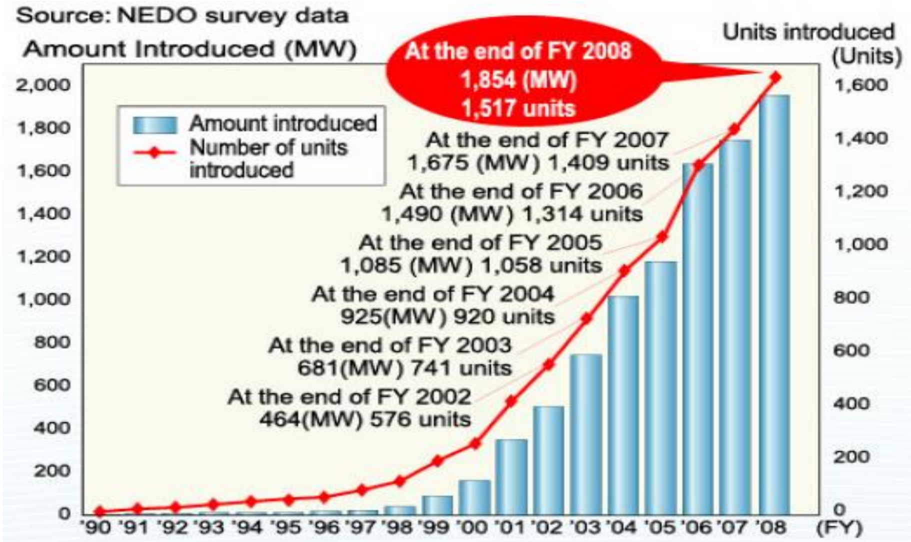


Source: Agency for Natural Resources and Energy, 2010

Since the 2008 G8 Summit, the Japanese government has recognized the importance of renewables and changed its attitude, restarting subsidies for initial installments in renewables in 2009. Beginning in November 2009, a FIT limited to residential was implemented (JREPP, 2010). Under this program, utilities are required to purchase surplus solar electricity for 10 years at a fixed rate of JPY48/kWh (US$0.48)—almost twice as high as the market price of the electricity—for residential PV systems below 10kW. Non-residential and residential installations above 10kW will receive JPY25/kWh (METI, 2011). Thanks to the FIT for PV, PV installations in 2010 doubled from 480 MW in 2008 (REN21, 2011).

Beginning with the first installed wind turbines in 1980, wind power has increased incrementally over the past three decades, reaching 1,845 MW in 2008 and 2 GW as of 2010 (JREPP, 2010; REN21, 2011). (See Figure 2.59 below.) Recently, large-scale wind farms continue to be constructed in Hokkaido, Tohoku and Kyusu where the wind conditions are desirable (Agency for Natural Resources and Energy, 2010).

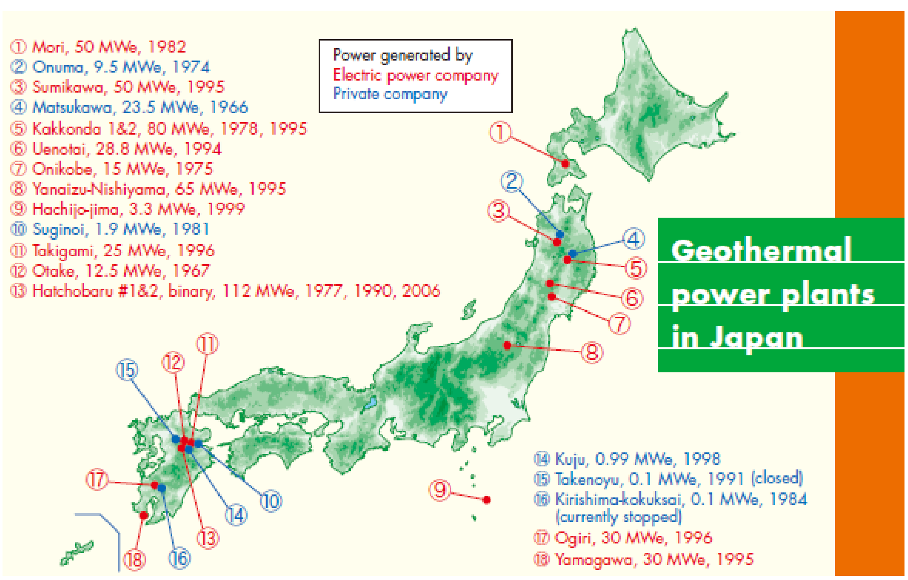
FIGURE 2.59: WIND POWER DEVELOPMENT IN JAPAN, 1990-2008



Source: Agency for Natural Resources and Energy, 2010

Japanese investment in geothermal power plants began in the 1960s. Due to oil price shocks of the 1970s, the government recognized the necessity to diversify energy sources, initiating the Sunshine Project to promote alternative energy deployment. As a result, geothermal power plants were actively constructed (The Geothermal Research Society of Japan, 2010). By the end of 2010, Japan ranked eighth in geothermal capacity with 0.5 GW (REN21, 2011). Thanks to 120 active volcanoes across Japan, the estimated potential of geothermal power generation is as large as 20,000 MW . However, only twenty-one electric geothermal plants are in operation with a total capacity of 538 MW, as shown in the figure below (The Geothermal Research Society of Japan, 2010).

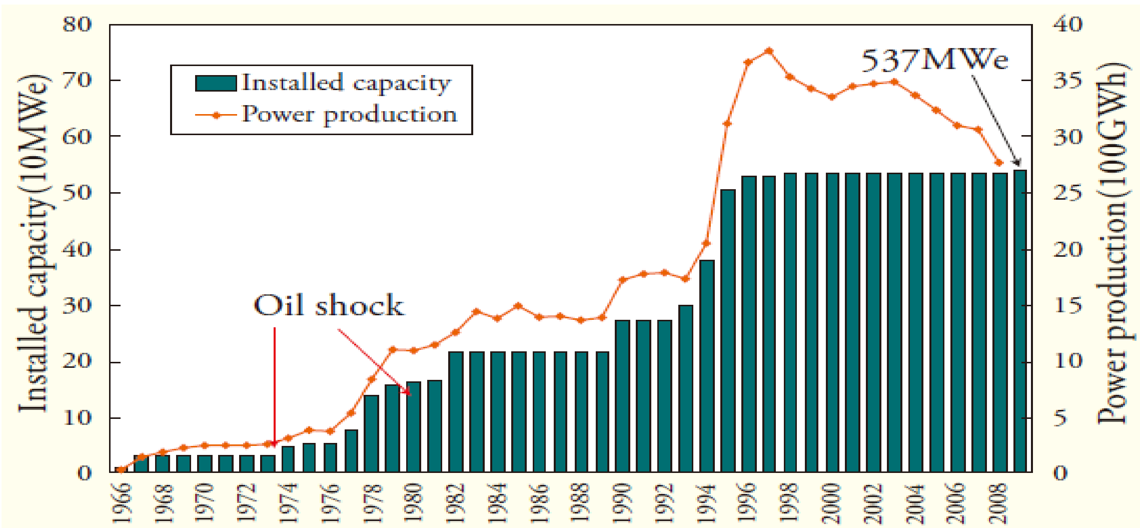
FIGURE 2.60: GEOTHERMAL POWER PLANTS IN JAPAN



Source: The Geothermal Research Society of Japan, 2010

Since 1999, the development of geothermal power slowed due to switch from conventional energy sources to nuclear. In addition, geothermal power has been neglected even in renewable energy policies. That is now changing. Parts of geothermal power generation are supported through the RPS (Agency for Natural Resources and Energy, 2010). From 2012 on, it will be supported by the FIT. Thus, in recent years, geothermal power generation has once again begun drawing attention due to the huge resource potential and growth of domestic industry (The Geothermal Research Society of Japan, 2010).

FIGURE 2.61: CAPACITY AND POWER PRODUCTION OF GEOTHERMAL POWER PLANTS IN JAPAN



Source: The Geothermal Research Society of Japan, 2010

Small hydropower (smaller than 10,000kW) capacity is relatively small, 3,225 MW (1,198 plants), accounting for only 6.6% of the total hydropower capacity in Japan. It is even smaller when compared to the total electricity generated, less than 1%. The growth rate of small hydropower capacity has decreased: only 127 plants (166 MW) were constructed after 1990 (JREPP, 2010). Similar to geothermal power, small hydropower is subject to the RPS and then it will be supported by the FIT.

Energy Scenarios Suggestions Towards Zero Carbon Society (WWF, 2011) will be used in this report to analyse the future for Japanese renewables. The study estimates the electricity mix up to 2050, and includes a scenario incorporating a nuclear moratorium and a zero carbon society. Under that scenario, the PV potential in Japan has been estimated at 101 GW for single-family houses and 106 GW for multi-family residential dwellings. Another 150 GW of PV could be installed at public buildings, facilities, and etc. Installments of 53.1 GW for single-family houses and 22.1 GW for multi-family residential dwellings can be achieved by 2030. As all the potentials are added, 357 GW of PV can be installed by 2050 (WWF, 2011).

According to WWF estimates, the electricity generated from wind in 2030 could reach 34 TWh; in addition 64 TWh of electricity generated from PV will be used for fuels for EV and etc. (see the below table). According to the estimation of the WWF, the electricity generated from geothermal in 2030 is 45 TWh (see the below table) the growth rate of geothermal is fast as much as that of PV or that of wind.

According to the estimation of the WWF, the electricity generated from hydropower (which includes large hydro as well) in 2030 is 97 TWh; this estimation is bigger than the Energy Supply and Demand Subcommittee of the Advisory Committee for Natural Resources and Energy's estimation (88.9 TWh) (see the below table).

TABLE 2.10: HISTORICAL AND ESTIMATED RENEWABLE GENERATION MIX SCENARIOS FOR JAPAN, 2010-2030/2050

Electricity generated (TWh)	Historical Data		Zero Carbon Emissions & Nuclear Moratorium				Maximum Introduction	
	2000	2010	2020	2030	2040	2050	2020	2030
Geothermal	3.3	2.7	24	45	70	87	3.4	7.5
Biomass	15.2	21.8	23	32	42	49	57.5	90.7
PV	0.3	2.8	68	151	219	253		
Wind	0.1	3.8	34	76	109	127		
PV (Fuel)*	N/A	N/A	20	128	214	270	N/A	N/A
Wind (Fuel)*			10	64	107	135		

Source: IEA, 2010; WWF, 2011; Energy Supply and Demand Subcommittee of the Advisory Committee for Natural Resources and Energy, 2009

A new FIT scheme went into effect in July, 2012. The purpose of this program was to increase renewable energy capacity by 2.5 GW (13%) by 2013. The law made it mandatory for utilities to purchase electricity generated from five different renewable energy resources at a fixed price for a pre-decided length of time. The FIT costs more than the cost of producing renewable energy and helps cover the cost of setting up production and distribution systems, and thereby decreasing the risks of investing in new renewable energy facilities (Johnston, 2012).

As discussed above, the Energy and Environment Council acknowledged the need to shift to clean energy sources (renewable energy and energy conservation) and secure green growth (through the promotion of green investment and innovation). The Council targets increasing the share of renewable energy to over 25-30% in 2030. Furthermore, renewable energy will play a much more crucial role in Japan's revised energy policy, particularly geothermal and wind power, as the nation seeks to replace planned nuclear capacity and reduce its current level of dependence on nuclear power.

China

Historically, China has not placed great emphasis on developing renewable energy over conventional energy sources, but in the past decade this trend has shifted as the government has sought to promote energy security through diversification. Thus, China has launched massive projects to develop large-scale hydropower resources, and more recently has also sought to capture its vast wind resource as well. Wind is the second leading renewable source for power generation in China. China is the world's fifth largest wind producer, generating 25 TWh in 2009, growing 100% from 2008. China's installed wind capacity in 2010 was 16 GW, and has roughly doubled capacity each year since 2005 (Qiao, 2012). However, the lack of transmission infrastructure has left a significant amount of capacity underutilized. The country plans to install up to 200 GW of capacity by 2020 (REEGLE, 2012a).

China has also sought to expand its market presence in renewable energy technologies. Despite very low deployment of solar PV technology domestically, China has become the global leader in PV manufacturing. It has also been a global leader in wind manufacturing, although unlike PV, China has more aggressively developed its wind resources. Nonetheless, as it builds a large renewable technology industry, China will be more capable of tapping into domestic renewable energy sources to supply its ballooning energy demand in the future.

Chinese renewable energy policy, as in the United States and other major energy consuming nations, has not significantly changed as a result of Fukushima. Nor has its renewable energy policy changed appreciably. China is still committed to nuclear plants, and also growing shares of wind and hydroelectric generation capacity. Furthermore, China will continue to pursue targets of increasing shares of renewable energy and reducing carbon emissions, enacted prior to the accident in Japan in the Five Year Plan for 2011-2015 (Siemens, 2012). The rapid expansion in use of renewable energy sources is expected to increase. Capacity development targets for 2015 drawn up in 2011 are increased substantially. PV energy capacity would increase from 3.1 GW in 2011 to 15 GW in 2015. Wind energy capacity would also continue to increase in China, from 17.6 GW in 2011 to 100 GW by 2015.

2.3.3 Conclusion

The Fukushima accident created a significant degree of policy turmoil in several nations, most notably Germany and Japan; however, in many others, while nuclear policies or nuclear safety regimes changed, energy efficiency and renewable energy policies remained largely unchanged as a direct result of the crisis. Both energy efficiency and renewable energy continue to develop and expand in each nation as a result of policies trends that were implemented prior to and will continue to play a role following the accident. This is especially true in the United States, where federal initiatives have largely failed over the past two years while state programs have flourished, and in China, where economic growth continues to drive short-term energy policy despite several programs that have expanded renewable energy deployment (primarily wind) or energy efficiency initiatives rapidly.

As noted, however, Germany and Japan have both announced plans to incorporate a much larger share of renewable energy and energy efficiency into their future policies and energy mix scenarios. Germany has committed itself to a “radical” shift towards renewable energy, aiming to increase the renewable generation share to upwards of 30% in the next two decades and to 80% by 2050. Coupled with European Union-wide energy efficiency targets of 20% by 2020 to which Germany is also committed, the nation’s renewable energy and energy efficiency policy have a much different outlook than they did prior to the accident. Similarly, in Japan, recent policy releases indicate that both energy efficiency and renewable energy will play a much larger role as Japan seeks substitutes for the nuclear capacity it had planned to install over the next several decades. Apart from its historical and likely future success in improving its energy efficiency, Japan has also indicated that wind, geothermal, and even solar PV will boost its renewable energy share significantly. The ability of these two nations to realize their new renewable and energy efficiency targets will be a major litmus test for the world at large as nations wrestle with feasible mechanisms to ensure sustainable energy policy and economic growth.

PART 3. IMPLICATIONS FOR KOREAN ENERGY POLICY

3.1 Introduction

The previous analysis looked at the experiences of six major energy-consuming nations with large or growing shares of nuclear power in their electricity mix profiles. Through this analysis an understanding of the impacts of the Fukushima nuclear disaster is gained, as well as of other factors that drive or influence short- and long-term energy policy decisions in industrial nations. This report now turns to the specific experiences of Korea prior to and following Fukushima Dai-ichi. The research explores trends in Korean energy and electricity policy, generation mix, and projections with a focus on the similarities and differences in trends and policy decisions between Korea and the other countries in this report.

Part 3 is organized as follows. It begins with a review of Korea's energy sector and policy in section 3.2. The section will first explore Korea's government, industry, and civil society response to the Fukushima accident. Next, it will explore the implications of the accident on Korea's long-term nuclear, energy, and electricity status and policies. This includes a review of Korea's current energy mix profile, the structure of its power sector, and recent policy initiatives that shape its energy choices. This section also will include a review of Korea's energy efficiency and renewable energy sectors, status, and policies, as was done for the other nations in Chapter 2.

Section 3.3 moves on to explore the future course of Korea's electricity mix in response to different policy paths. This section then conducts a scenario analysis of the Korean energy projections out to 2030 through projection of three different scenarios: a business-as-usual scenario, an energy efficiency scenario, and a renewable energy/low carbon scenario. The section also compares the long-term cost implications for Korea of the three scenarios. Finally, section 3.4 reviews current Korean agreements and initiatives to implement and support energy efficiency and renewable energy technologies. It considers multilateral, bilateral, and regional agreements and pacts, and it also suggests potential areas in which Korea can enhance its activity and support for these technologies. The chapter concludes with several policy recommendations for Korea based on the review of its current policies and the results of the scenario analysis conducted for this report.

3.2 Korean Energy Policy Profile

3.2.1 Initial Response to the Fukushima Disaster

The accident in Japan catalyzed a flurry of responses throughout Korea. Having recently committed to new nuclear power as the dominant source of power on the peninsula in the most recent national energy policy, the geographical proximity and implications of the disaster at the Fukushima Daiichi plant forced various sectors in Korea to respond rather aggressively. The government initiated investigations of the accident and Korean regulations which resulted in a number of overhauls later in the year. The Korean nuclear industry, under the lead of the Korean Hydro and Nuclear Power Co. (KHNP), also organized an independent response to address safety concerns and reduce risk through reviews and enhanced self-policing measures. The media acted as an intermediary between the government and

Korean civilian and other groups, playing an integral part in communicating information in response to the government's "open dialogue" approach.

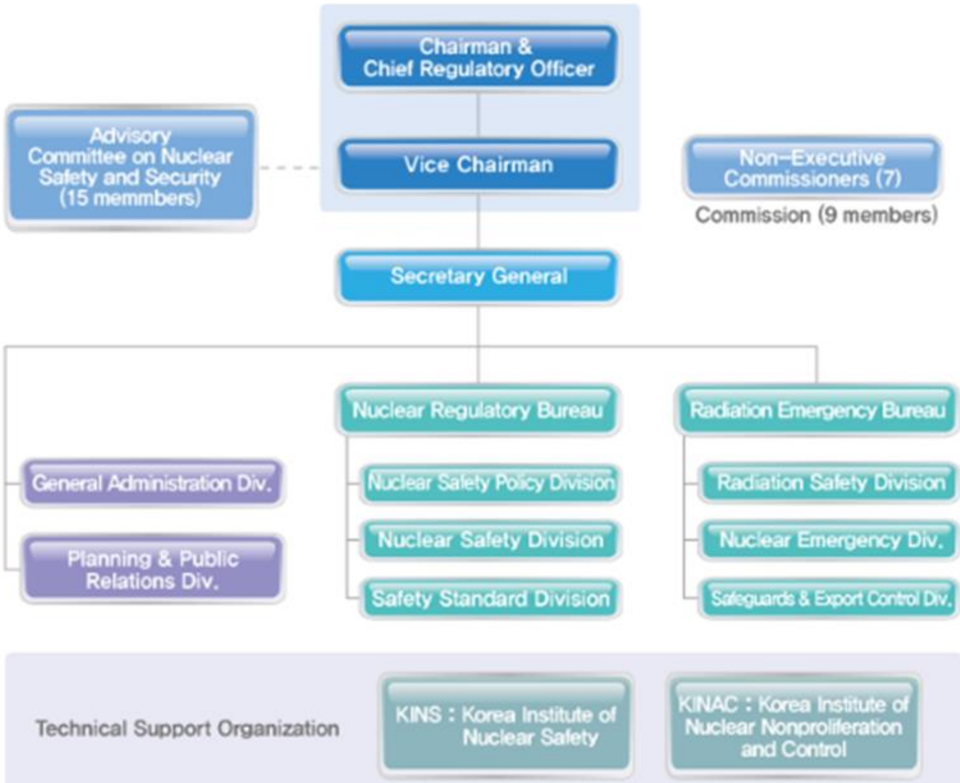
Immediately following the Fukushima incident, KHNP conducted an assessment of each operational site from March 16-18, 2011, followed by a special safety review of all plants (with special attention to Kori-1) led by the Korean Ministry of Education, Science & Technology (MEST) from March 23 to May 3, 2011. After the internal examination, an International Atomic Energy Agency (IAEA) Integrated Regulatory Review Service assessed the overall safety of South Korean nuclear plant operation in July, 2011.

Results from these inspections verified the safety of Korean nuclear power plants for expected maximum earthquake and tsunami contingencies (based on up-to-date research and investigation). However, in order to cope with the worst case events, 50 short- and long-term improvements were identified to augment safety (Lee, 2012a). In addition, 10 supplementary measures were derived from recommendations made by international institute reports and actual improvements made in overseas nuclear power plants after the Fukushima crisis (KINS, 2012). Hence, the government approved implementation of a total of 60 short- and long-term plans, including: fortification of the coastal barrier at the Kori site near Busan; provision of vehicles with portable diesel generators at each site; prevention of emergency battery power failure due to flooding; installation of watertight doors at major buildings; water-proofing pumps; installation of passive hydrogen gas-removal systems; and installation of exhaust and decompression equipment. In total, the approved measures require an investment of approximately US$1 billion over five years (WNA, 2012c).

Further reviews of the nuclear industry and political regime in Korea led to a number of changes throughout the summer and fall. The recommendations produced by these reviews culminated with the launch of the new Nuclear Safety and Security Commission (NSSC) on October 26, 2011. The NSSC is a new independent ministry-level government agency which serves as a regulatory body for nuclear safety concerns, reporting directly to the president. The creation of the NSSC deserves attention since it enabled the separation of nuclear regulatory duty from the MEST for the first time. Previously, promotion and regulation of the nuclear energy was managed by the same ministry (MEST). As of October 2011, the Korean Institute of Nuclear Safety (KINS), formerly the expert safety regulator under MEST, and the Korea Institute of Nuclear Non-proliferation and Control (KINAC) became technical support organizations under the NSSC, while the role of MEST was restricted to R&D support of nuclear power.

This regulatory reform was preceded by changes in the legal framework of the nuclear industry in Korea. The "Act on Establishing & Operating NSSC" was created, and the government separated the "Nuclear Safety Act" from the "Atomic Energy Act," which it renamed the "Promotion of Atomic Energy Utilization Act." The above laws defined the NSSC's regulatory authority over licensing, inspection, enforcement, incident and emergency response, non-proliferation and safeguards, export/import control, and physical protection. It is expected that the commission will lead efforts to strengthen global nuclear safety regimes based on independence, expertise and transparency.

FIGURE 3.1: ORGANIZATIONAL CHART OF THE KOREAN NUCLEAR SAFETY AND SECURITY COMMISSION



Source: Nuclear Safety and Security Commission (NSSC)

On several occasions, President Lee Myungbak has declared that Korea will continue with its current energy policy despite the Fukushima mishap (Lee, 2012a). According to his announcement, importance of nuclear energy would not be underestimated in order to balance supply and demand of electricity, to cope with the limitations of renewable energy, and to deal with climate change challenges. Thus, it appears that the Fukushima incident in 2011 has a negligible impact on Korea's overall nuclear power development path (Lee, 2011).

Meanwhile, at the industry level, KHNP officially established the Nuclear Safety Council (NSC) on October 19, 2011 (KHNP, 2011). NSC is a permanent council of CEOs organized to pursue cooperation and solutions for nuclear safety issues. Fourteen institutes and companies comprise the council, which controls the operation, design, manufacturing, construction and maintenance of nuclear power plants, including KEPCO E&C, Doosan Heavy Industries, and Hyundai Heavy Industries. This council is expected to revitalize discussions on nuclear safety issues by sharing expertise and building a close network among the participants.

Many Korean media groups and organizations maintained keen interest following the nuclear accident in Japan (OECD-NEA, 2011). Not only was interest high about the event in Japan, but special concern was also paid to health implications for the Korean public. Government officials arranged numerous press releases and interview forums to attain and distribute relevant information regarding the disaster. Among many civil groups and civilians, serious concerns rose in Korea because of geological closeness to

Japan. Phone line and website traffic spiked as many civilians sought answers about the disaster's implications for Korea and the safety of Korean nuclear plants (OECD-NEA, 2011).

Japan's nuclear accident raised concern for safety of nuclear power in Korea. Although many experts argued that, unlike reactors in Fukushima, nuclear reactors in Korea were designed with excellent safety features, some civil groups and environmental NGOs opposed the continuation of nuclear reactors (Park, 2011). These groups raised questions about the safety, environmental impacts, and economic feasibility of nuclear power. In addition, they urged the Korean government to re-examine nuclear projects, and to invest in more sustainable technologies such as renewable energy systems. The Korean government made it clear that they would enhance the safety regulations of nuclear power generations after finishing the review of Japan's accident (Moon, 2011).

To counter civilian opposition and mistrust of government assessments, the independent Korean Institute of Nuclear Safety (KINS) led most of the civilian and media response efforts (OECD-NEA, 2011). This included establishing an emergency response center staffed by phone line operators and posting information about the disaster on its website. Furthermore, KINS conducted numerous monitoring activities across the country to measure radiation and provided updates on and results of Korean nuclear safety and risk assessments. The Institute also provided the media access to nuclear experts and officials in order to disseminate vital information and maintain a strong link between government efforts to respond to the crisis and civilian concern regarding the accident. In contrast to the Japanese government's controversial decisions regarding public safety and provision of information, the Korean government's policy of "openness" resulted in much less public panic and moderated civilians' concerns about the safety of nuclear power (KINS, 2012).

The Korean government responded aggressively in response to the accident in Japan to protect against the threat from its geographic proximity and to moderate strong public or industry reactions against nuclear power. Its response initiated a series of short-term and long-term safety assessments culminating in the issuance of 50 recommendations and an overhaul of the regulatory regime. The Korean nuclear industry, led by KHNP, also sought to improve self-regulatory measures and reduce barriers to cooperation and collaboration on design, operation, maintenance and safety issues. This resulted in a new industry-led organization to achieve the aforementioned aims. Korean civilian groups and media, though displaying some opposition and concern regarding the accident and its implications for nuclear safety, did not overwhelmingly rise against nuclear power. A major reason for this lack of any immediate response was the public relations campaign led by KINS to monitor radiation, share information, and report the results of nuclear safety assessments across Korea (OECD-NEA, 2011).

However, in 2013 it was discovered that safety reports for four reactors near the Korean capital, Seoul, had been faked (Park and Lee, 2013). Components with falsified safety certificates had been used, possibly compromising the safety of the entire region. Those reactors were taken off-line in May. Despite that action, distrust of nuclear power is growing, with 63% of respondents to a recent poll indicating that they felt that Korea's nuclear reactors were unsafe.

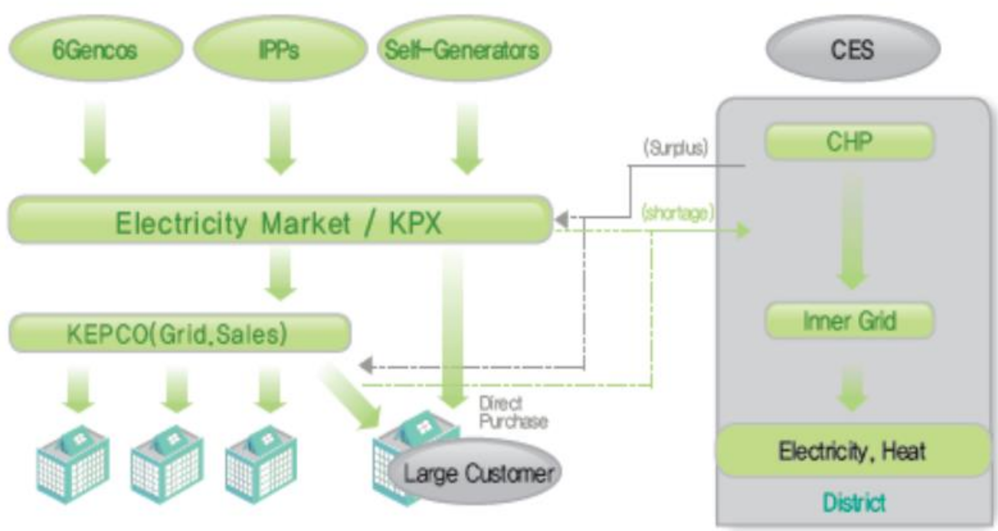
3.2.2 Nuclear Policy Prior to and Following Fukushima

To review the impacts of Fukushima on long-term nuclear policy in Korea, it is important to first understand the development of the nuclear power industry in Korea. This section begins with a review of the structure of the Korean power sector, followed by a short history of nuclear power in Korea. Finally, a look at the most recent energy plan established in 2008 and the implications for nuclear power in future energy plans as a result of the accident will be discussed. Since the accident, the government has indicated that it remains committed to nuclear power as a major source of energy for the future, but Fukushima may yet alter the role of nuclear energy in the country's new energy plan, which will be delivered in 2013.

Power Sector Structure

The electric power industry in Korea has made remarkable progress since 1887 when electricity was first supplied in the country. In 1961 the Korean government established the Korea Electric Company (KECO) as a state-run monopoly electric utility, subsuming three independent private regional electric suppliers. The goal of the restructuring was to improve the reliability of electricity supply. That year the nation initiated an ambitious industrialization plan that depended on reliable access to energy, especially electricity. KECO successfully met rapidly rising electricity demand throughout the early phase of Korea's industrialization. It was during this period that nuclear power generation was first introduced to Korea. In 1982, KECO was restructured as the Korea Electric Power Corporation (KEPCO) in order to improve the existing governance regime with respect to competition and regulatory structure.

FIGURE 3.2: ELECTRICITY MARKET STRUCTURE IN KOREA



Source: Korea Power Exchange, 2010

Since those initial restructuring efforts, the government has sought to improve efficiency and the regulation of the electricity industry by promoting competition among generation companies through greater participation of private generation assets and improved operation systems. In the following decades, the Korean government reorganized the electricity industry to increase efficiency of electricity supply and benefits for customers through enhanced competition. In 1999, the government introduced "The Basic Plan for the Restructuring of the Electric Power Industry" which included the gradual introduction of competition through three steps, as presented in "Plans for Privatization and Management Planning" (Lee and Ahn, 2006).

Based on this roadmap, in 2001 KEPCO was divided into five fossil fuel power subsidiaries and one subsidiary producing hydro and nuclear power. KEPCO's six subsidiary companies now account for 87% of the electricity capacity and 94% of the gross generation. KEPCO is also responsible for power transmission and distribution (T&D) facilities and customer management. Other subsidiary companies include KEPCO Engineering & Construction Company for power plant design and maintenance, and KEPCO NF for nuclear fuel supply. The Electricity Regulation Commission under the Ministry of Knowledge Economy (MKE) oversees regulation of the electricity industry. Also under the MKE, the Korea Power Exchange (KPX) manages and regulates all domestic electricity supply markets (EPIC, 2011).

Like many other countries, Korea has reorganized and privatized the electricity sector. More recently, a call for a re-examination of the electricity industry organization has arisen out of concern for supply reliability and safety. As a result, the reform plan of electricity supply structure has been suspended. The electricity industry's structural transition has continued without any clear guideline (EPIC, 2011).

In 2010, the Korean government released "The Measures for Improvement of the Electricity Industry Structure" to enhance competition and efficiency in the electricity industry. According to the government's release, six subsidiary companies including Korea Hydro & Nuclear Power are to be market-oriented public enterprises to promote competition among generation companies and to strengthen management responsibility. The management evaluation of KEPCO reports directly to the Ministry of Strategy and Finance which oversees public enterprises. Included in the Measures were business cooperation guidelines that guarantee autonomous industry management.

Nuclear Policy in Korea Prior to Fukushima

Korea, like Japan, depends heavily on imported fuel sources to power its dynamic economy. Thus, nuclear power has historically played an ever increasing role in supplying a growing base load power, due to its low cost of generation, large-scale capacity, and benefits to national energy security. Confronted with environmental, economic, and security challenges of the coming decades, Korea recently planned aggressive nuclear expansion. This was most apparent in the 2008 energy plan released by the government, which targeted a 59% generation share for nuclear in the future (Lee, 2012a). Furthermore, the Korean nuclear industry also established itself as a major technological exporter in the global nuclear market (*Asia News Monitor*, 2012; *The Korea Herald Online,* 2012; Hwang, 2009).

The Korean nuclear industry began in 1978. Since that time, Korea has become one of the elite nuclear nations in the world, currently operating its existing plants at the highest average capacity factor in the world. In order to reduce its carbon emissions and improve its security of supply through diversification, Korean authorities deemed nuclear energy a vital technology for future energy policy. As such, new nuclear capacity became the central crux for the power sector in President Lee's energy policy, issued in

2008. Furthermore, the government saw exports of nuclear technology as a key route to economic prosperity and job creation for domestic industry. Thus, prior to the Fukushima disaster, Korea followed Japan on the path of growing nuclear dependence as the key to addressing global environmental, energy, and economic challenges.

According to a report by KHNP electricity generation from nuclear power has increased more than 67 times since the commission of the first nuclear power plant in 1978. As of 2011, nuclear power accounted for 22% of installed capacity and 31% of total electricity generation (WNA, 2012c). In terms of electricity generation, nuclear power is the second largest contributor after coal, which accounts for 40.3% of total power supply. Due to the rising importance of nuclear power in the Korean economy, the government projects that the share of nuclear as a share of generation will grow steadily through 2024, based on the 2010 "The Fifth Basic Plan for Electric Power Supply & Demand" (MKE, 2010a). The existing and planned nuclear power plants are mapped in the figure below.

FIGURE 3.3: NUCLEAR POWER PLANTS IN KOREA, 2012

Source: Korea Hydro & Nuclear Power Co., 2012

Currently, the Korea Hydro & Nuclear Power Co. (KHNP) operates four nuclear power stations in Korea, with 21 individual reactors: 17 Pressurized Water Reactors (PWR) and four Pressurized Heavy Water Reactors (PHWR). These 21 commercial nuclear power plants generate 154.7 TWh of electricity, with total generation capacity of 18.7 GW. According to the latest National Energy Basic Plan (NEBP), issued in 2008, 19 additional reactors are scheduled to be completed by 2030, with the goal of generating as much as 59% of the energy supply from nuclear sources.

As can be seen from the figure above, four nuclear power stations are located at Kori, Wolsong, Yonggwang and Ulchin. Among the four, Kori power station's Unit 1 reactor was the first to be built and began commercial operation in 1978. Meanwhile, seven additional units are under construction at Kori, Wolsong and Ulchin and six units are scheduled for Kori by the end of 2019 and Ulchin by June, 2021. All additional units will be PWR-type reactors.

Korea also entered the global nuclear market in an effort to export Korean reactor designs and technology to foreign markets. Korea has promoted the exports as a method of promoting domestic industry and employment. Thus, the government has intended nuclear power technology to contribute to economic development and expansion. Korean firms competed on contract bids in the Middle East, winning rights to construction for a training reactor in Jordan and four commercial reactors in the United Arab Emirates in 2009. The latter contract came as a surprise as Korean companies outbid French nuclear behemoth AREVA. The Korean government continues to seek partnerships and opportunities to export nuclear power abroad, including in South Africa, Turkey, and India.

Nuclear Policy Following Fukushima

The most important changes in Korea following the Fukushima crisis addressed flaws in the regulatory regime, strengthened operational safety, and improved emergency response protocol (OECD-NEA, 2011). The initial response phase to the accident resulted ultimately in the formation of a new, independent regulatory agency, effectively removing oversight authority from MEST. This agency, the Nuclear Safety and Security Commission (NSSC), will be responsible for implementing and monitoring compliance with stricter safety and emergency response standards as Korea pursues aggressive nuclear development plans. Numerous recommendations and additional safety measures are in the process of being implemented as well. However, a long-term shift from nuclear power, as seen in Germany and is expected for Japan, is not yet apparent. Rather, the government has reaffirmed support for nuclear development repeatedly since the accident.

Despite the severity of the accident in Japan, Korea has not significantly shifted away from its commitment to nuclear power, nor does it plan to reduce its growing dependence solely based on the implications of the disaster for the nuclear industry. Rather, officials on several occasions have reaffirmed the importance of nuclear power to Korea. Among the most vivid examples of this continuing support is a speech given by Korean President Lee to the UN in September of 2011. Several quotes from that speech highlight the justification for Korea's nuclear commitment (Lee, 2012a: 15):

- "I do not think that Fukushima accident should be cause to renounce nuclear energy; on the contrary, this is a moment to seek ways to promote the safe use of nuclear energy based on scientific evidence."
- "The use of nuclear energy is inevitable as there still remain technical and economic limits for alternative energy…"
- "We will actively utilize nuclear energy in accordance with our 'low carbon, green growth policy."

Korea has had a stellar record in terms of nuclear safety and operation, and therefore Korean officials are confident in Korea's ability to both prevent accidents but also minimize damages that may occur should an incident arise. Furthermore, Korea requires large amounts of secure, cheap energy to meet existing goals and targets for the coming decades in line with established policy. Not only does it deem nuclear power as a necessary component to maintaining economic growth under such policy guidelines, but officials also believe more sustainable alternatives such as wind or solar lack the technological and economic maturity to replace large portions of current power capacity. Also indicative of Korea's future commitment to nuclear, officials continue to pursue negotiations with foreign governments to export nuclear technology. Therefore, there seems to be little indication or possibility of a drastic shift in Korea's long-term nuclear policy in the near future.

Despite few changes in long-term nuclear development plans, the regulatory landscape shifted drastically with the formation of the NSSC. Independent organizations such as the Nuclear Safety Council will also become important actors as the industry tries to adapt to safety concerns following Fukushima. Many of those concerns can already be seen in current efforts to improve safety and emergency response systems. As mentioned, 50 recommendations to improve safety and operation of existing and proposed nuclear sites resulted from government investigations and assessments. Among those recommendations, four improvements had already been implemented by the end of 2011. First, KHNP improved the firefighting plan by eliminating barriers to cooperation between fire crews located on and off site at each nuclear facility. Also, officials increased training time for severe accidents from 8 hours every 2 years, to 10 hours per year. Third, the radiation emergency plan was amended to cope with simultaneous natural disasters at multiple units. Lastly, quality standards for equipment and replacements became more rigorous to reduce risks from defective components.

Based on scenario analyses of the severity of the events, several response strategies have been developed and implementation of these new strategies was under way in 2012. To cope with the event of large scale earthquakes and tsunamis (the first stage), the government has introduced plans to ensure safe shutdown of nuclear reactors. Such plans include raising the height of the seawall at Kori plant to that of other sites (10 m), installing an automatic seismic trip system, and installing waterproof gates and waterproof drain pumps. These improvements should be completed by 2014.

To respond to the event of flooding of nuclear power plants (the second stage of the new strategies), improvements are being made to secure electric power sources vital for reactor cooling. This includes additional redundancies for backup of spent fuel pool cooling equipment, availability of a vehicle with a mobile generator, and fortification of wall barriers for outdoor tanks. These tasks will be completed by 2014.

In the event of severe accidents (the third stage), building reinforced containment buildings and securing cooling equipment against malfunction are priorities. Thus, the government took several measures to achieve these goals, such as installation of passive hydrogen removal equipment, addition of filtered vent facilities in the containment building, and addition of conduits for injecting emergency cooling water to the nuclear reactor from external sources. Completion of these three tasks is expected by 2015.

Finally, in response to radiation release emergency events (the last stage), priority was given to strengthening emergency response capabilities. This is possible through provision of additional radiation protection equipment for residents near the site and procurement of additional emergency equipment in preparation for a prolonged emergency event. Both tasks were to be finished in 2012. Meanwhile, practical drill scenarios for earthquake and coastal flooding will be finalized in 2012 to test the efficacy of the radiation emergency training system.

In sum, these ongoing improvements will be completed according to the established implementation plan by 2015, in addition to four improvements which were made in 2011. However, additional steps will be taken based on various international institute reports, such as those from IAEA, WANO (World Association of Nuclear Operators) and INPO (Institute of Nuclear Power Operations), and foreign national reports that reflect lessons learned from the Fukushima crisis (KINS, 2012). In order to implement the remaining measures, the government allocated US$1 billion for investment in 2012.

On April 13, 2012, the MKE released a comprehensive nuclear power revision plan (Nuclear Street.com, 2012). Announcement of this plan begins a process of overhaul of nuclear power plants in order to prevent serious accidents and restore public confidence. The four-pronged plan proposed safety package calls for tests, greater transparency in operations, higher performance standards for workers and contractors, and open communication with residents and private groups. The plan includes safety reviews of the nine reactors that have exceed 20 years of operation. The MKE will form the task force to carry out the plan and also identify and incorporate independent monitoring regimes involving civic groups and civilian experts to enhance transparency.

Under these circumstances, some groups have pushed for revision of the First National Energy Basic Plan (NEBP) (covering the period 2008 to 2030), which went into effect in September of 2008. In addition to pressure from various civic groups who oppose the expansion of nuclear power plants embodied in the current NEBP, the impact of new variables and circumstances following the Fukushima accident was also considered by government officials (Choi, 2012). Since the NEBP has to be updated every five years to reflect relevant changes, it is likely that re-examination and the follow-up changes will take place by the end of 2013. Several groups such as the Korea Energy Economics Institute (KEEI) have already begun work on the new plan.

In sum, Korea has been a nuclear nation since 1978. The development of nuclear power and the structure of the Korean nuclear industry are a result of economic and electricity policies enacted by the government since the 1960s. However, in the past few years nuclear power has become the centerpiece of a national energy, economic, and environmental policy known as "low carbon, green growth." Not only would aggressive development of new nuclear capacity help Korea achieve its future economic and environmental goals, Korean companies exporting nuclear technology abroad also intend to establish a dynamic new industry that promotes domestic growth and employment. Although the Fukushima disaster led to several significant changes to the Korean regulatory regime and safety protocols, it failed to drastically influence Korean officials or civilians to reject its commitment to nuclear power. Thus, nuclear is expected to continue to grow in importance in the Korean power sector and economy.

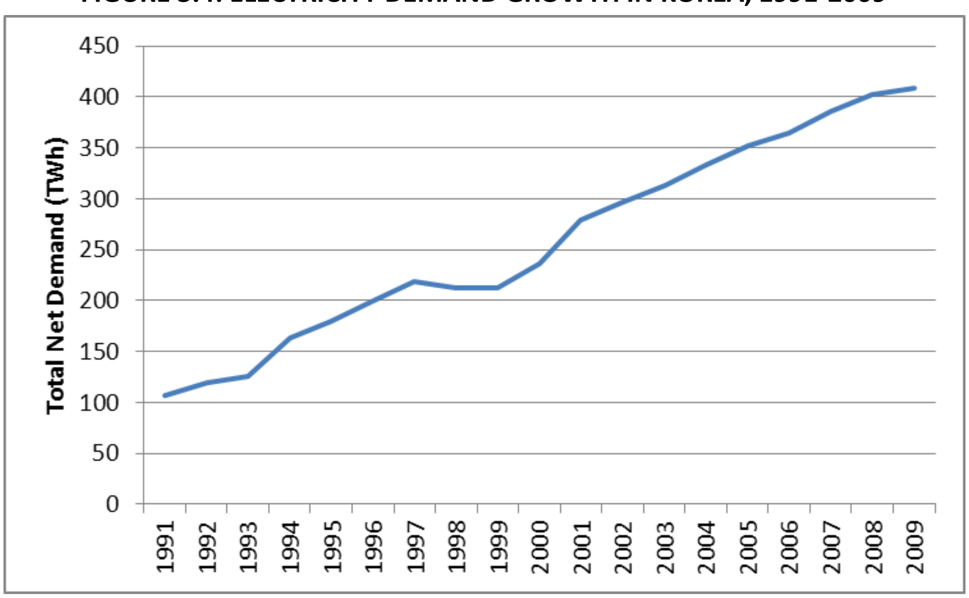
3.2.3 Energy and Electricity Mix Profile and Changes

The focus on nuclear power directly results from current challenges Korea faces in terms of meeting its long-term energy demand. In this section, the historical Korean supply, demand and price trends will be discussed in order to understand the implications of energy supply in Korea in the future. This will lead to a review of Korean electricity and market policy to identify the historical programs and future targets the government has enacted to overcome the challenges it currently faces in the energy sector. Finally, an assessment of historical and projected generation mix scenarios will illustrate the future energy landscape in Korea as the nation seeks to maintain economic development and reduce dependence on scarce or dirty sources of energy. Due to its unique geographical circumstances, the options open to Korea are limited. Not only does the nation lack significant domestic reserves of fossil energy, but it also isn't ideally situated for easy import of fuel or cheap exploitation of renewable energy resources. The government is reluctant to fully embrace renewable energy technologies; however, due to the supply and market volatility associated with fossil fuels, the Korean peninsula will have to surmount substantial obstacles in developing practical alternatives.

Energy Demand, Supply, and Price Trends

Korean energy demand has steadily grown since the 1970s as a result of policies that accelerated economic development rapidly over the decades that followed. In the 1990s, total electricity demand grew at an average rate of 10% per year; however, after the financial crisis in 1998, electricity demand showed absolute decline for the first time. Following recovery from that crisis, electricity demand growth has returned, but at a slower rate than throughout the 1990s. Between 2000 and 2009, the growth rate averaged 7% per year. The figure below depicts the growth in demand from 1991 to 2009.

FIGURE 3.4: ELECTRICITY DEMAND GROWTH IN KOREA, 1991-2009



Source: EIA, 2012d

Sector-level data shows that industry has been the largest source of demand growth, driving much of Korea's economic development since the 1980s. However, in more recent years the commercial/public and residential sectors have experienced rising demand. In 2009, industry comprised 49% of net power demand, while the commercial and residential sectors accounted for 34% and 14%, respectively (IEA, 2011a). Transportation, fishing, and agriculture each accounted for negligible shares of demand. Power sector self-use and losses represented 7% and 4% of gross consumption, respectively. Over this period, electricity demand also represented a majority in the growth in total energy consumption; however, coal and natural gas consumption have also increased in Korea. Between 2000 and 2010, coal consumption has grown substantially, reaching 2.969 quads in 2010 at an average annual growth rate of 9% (EIA, 2012d). Natural gas consumption has also increased dramatically at an average annual rate of 13% over the past decade, reaching 1.7 quads of demand in 2010. Total primary energy demand in 2010 exceeded 10 quads.

In order to meet rapidly rising demand, Korea has had to invest heavily to develop new sources of supply. The power sector has grown considerably as a result. Between 1990 and 2009 installed capacity more than quadrupled with over 80 GW by 2010 (EIA, 2012h). By far, fossil fuel-powered generation capacity comprised the largest source of capacity growth, increasing 410% in that period to over 56 GW. As mentioned, nuclear capacity also increased dramatically over the past two decades, growing from 7.6 GW in 1991 to over 18 GW last year. Hydropower and RES have grown at a much slower rate, however, with modest capacity installations in 2010. Thus, in response to strong demand, large volumes of new generation capacity have come online.

In terms of supply of primary energy sources, however, Korea suffers from many of the same problems as Japan. It has extremely limited reserves of fossil energy such as coal, petroleum and natural gas. Therefore, a majority of Korea's fossil fuel demand has been met by growing volumes of imports. Currently, Korea imports virtually 100% of its coal and natural gas. Much of the natural gas is imported as LNG, exposing Korea to the volatility in both gas and oil markets due to Asia's LNG markets that index prices to petroleum. The high dependence on imported fuels thus plays a critical role in Korean energy and electricity policy formation.

Despite market efforts to privatize generation assets and deregulate whole-sale markets, the price of electricity in Korea has also risen steadily since the introduction of the Korean Power Exchange (KPX) in 2001. Initially, marginal system prices remained low, between 47.32 and 50.48 KRW/kWh (US$0.044-$0.048/kWh); but, in 2004, prices began to rise drastically. They reached a high of 122.63 KRW (US$0.116)/kWh in 2008, before falling to 105.04 KRW (US$0.10)/kWh in 2009 (KPX, 2012a). This represented a period during which electricity prices rose 143% in only five years, indicating that despite increasing in installed capacity radically over the past two decades, supply has not adequately adjusted to meet demand, and that it has suffered from more widespread volatility in global energy markets.

In January of 2010, the peak electricity price reached a record high of 335.17 KRW (US$0.312)/kWh (KPX, 2012b). The average electricity price was 117.77 KRW (US$0.11)/kWh in 2010, which increased about 12% from 2009 (KPX, 2012a). The average unit price per year in the settlement through KPX increased 4.8% because of high fuel price and increasing electricity demand. The increased price is due to increasing electricity demand (+9.3%) which came from increasing demand for cooling and from business recovery. The increased demand was a factor in the blackout of September, 2011, during which nearly two million households lost power for over thirty minutes (Kim, 2012).

Energy Policy

The year 2008 marked a shift in the long-term course of Korean energy policy with the implementation of several key policy objectives. Of the greatest importance was the introduction of the "low carbon, green growth" strategy. This included three main pillars to address energy and environmental goals in Korea. The first was a mid- and long-term strategy for energy demand and supply to achieve green growth targets. The second pillar addressed energy security, energy efficiency, and environmentally-friendly policies. The final pillar instituted the "Vision Five" strategy for green growth in Korea's energy sector as explained below.

The mid- to long-term energy policy in Korea will emphasize green options to limit the growth in demand. This will especially focus on improvements in energy efficiency. Korea expects to develop and deploy advanced technologies that will help it achieve a long-term efficiency improvement target of 47% by 2030. To promote supply side options, policymakers will pursue an energy-mix strategy that enhances energy security by offsetting a declining share of oil and coal inputs with nuclear and renewable sources. This approach will emphasize economic and environmental feasibility to ensure it adheres to the principles of Korea's "green growth" strategy.

Energy security and energy efficiency will both play an important role in achieving these medium- and long-term policy objectives. Among the key shifts in energy security policy, Korea will pursue greater self-sufficiency in energy supply by developing overseas and foreign resources as a means of securing secure access to energy inputs. This endeavor to secure a foreign resource supply chain will be pursued in tandem with the energy efficiency targets mentioned above. To further the deployment of energy efficiency, Korea will also invest in R&D for green, clean technologies. In addition, the country also plans to promote renewable energy as a new growth option.

The final pillar of the new energy policy direction in Korea, "Vision Five," sets five ultimate policy objectives to encourage the "low carbon, green growth" strategy. This pillar includes the following five targets:

- Enhance energy independence through increasing self-sufficiency and renewable energy deployment,
- Transform the economy into a low energy consumption society by lowering energy intensity,
- Create an oil-free society by reducing oil dependency,
- Encourage widespread prosperity through enhanced energy accessibility by low-income groups, and
- Encourage economic growth and job creating through support for green technology markets.

These policy pillars are central to Korea's new policy direction. They emphasize not only energy security and economic growth, but also the focus on establishing new green energy paths that reduce energy consumption and carbon emissions. The green growth strategy also has implications for Korea's electricity policy and sector, which is discussed next.

Electricity Policy

Officially, the Korean electricity market was deregulated in 2001. Due to market volatility, initial deregulatory policies were suspended in 2004. Since the suspension of the reform plan, KPX has utilized a Cost-Based Pool (CBP) model to determine costs among competitive generation assets (Kim, 2012). CBP applies whole-sale prices to determine the market price. Over 420 companies participated in the market in late 2010, and installed capacity grew to 77.4 GW representing a 5.5% increase above 2009.

Among the key flaws of this market system is the pricing mechanism. Whole-sale and retail supply prices are not determined by supply and demand of electricity, which leads to market distortions in the price and distribution of resources. This then leads to a situation in which a lack of incentives to invest in base-load generation assets compounds resource misallocation. Since 2007, KPX has attempted to improve market mechanisms to address these problems; however, due to the limited efficacy of market-based fixes, several problems persist such as rigid electricity prices due to supply-only cost considerations, lack of consumer choice, and price volatility resulting from instant, spot-price-induced demand fluctuations (KEEI, 2008).

MKE released "The 5th Basic Plan of Long-Term Electricity Supply & Demand (2010-2024)" in 2010 (MKE, 2010a). According to this plan, the average annual growth rate of electricity demand will be 1.9%, which will reach 551 TWh by 2024, up from 423 TWh in 2010, which is less than the KPX projections. During the summer, the peak demand will be 95.04 GW in 2024. In order to respond to these demand increases, the government will invest about KRW 49 trillion (US$46 billion) in power plants. New capacity installations will include 14 new nuclear reactors in addition to coal and LNG plants and the contribution of nuclear power plants will be 32% compared with 25% in 2010. By 2024, increased reliance on nuclear power will shift consumption from high-carbon sources like coal to low-carbon alternatives (MKE, 2010a). The table below indicates planned capacity additions as a result of the 5th Basic Plan.

TABLE 3.1: PLANNED CAPACITY ADDITIONS, 2010-2024

	Nuclear	Bituminous	LNG	Oil	Hydro	Total
the 4th plan ('08-'22)	15,200(no.12)	9,480(no.12)	10,730 (no.17)	77(no.1)	840(no.3)	36,327
the 5th plan ('10-'24)	18,200(no.14)	12,090(no.15)	12,236(no.19)	-	800(no.2)	43,326

Source: The Center for Energy Politics, 2009

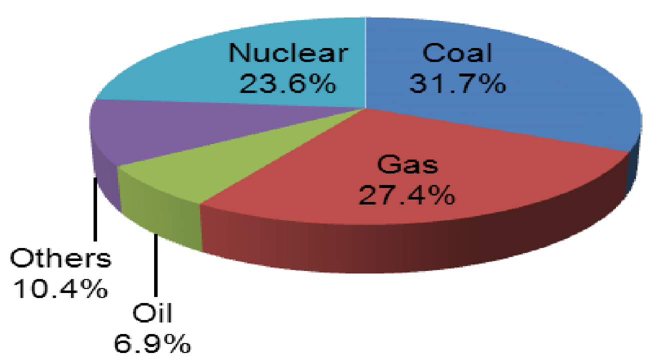
Despite significant attempts to restructure the power sector and deregulate electricity markets, policy seems to have failed to keep up with growing demand. Emphasis remains on augmenting supply; furthermore, KEPCO continues to control a dominant share of the generation and T&D market limiting competition and pressure to reduce prices. Only recently have energy efficiency, demand-side management, and alternative energy options seriously entered policy considerations and analysis. Those will be discussed in section 3.2.4 below.

Historical and Projected Electricity Generation Mix Scenarios

With the release of energy and electricity plans in 2008 and 2010, the Korean government set a new policy direction that began to change the energy landscape. Previous policies that focused overwhelmingly on economic growth resulted in a heavy reliance on imported fossil fuel-based generation capacity; policy focus has now shifted to account for energy security and environmental impacts along with growth. Therefore, a changing generation mix profile in Korea will manifest the influence of those additional goals. It is useful to consider how new policies will impact government projections at different points in time over the next two decades. Considerations of alternative scenarios will indicate how a change in policy focus may alter government projections. Altogether, these projections illustrate the government's perceptions of the viable energy policy options it faces for the future.

The current electricity generation mix shows the heavy influence of the economic-growth drive policy on the power sector. Large-scale, cheap sources of energy, primarily coal, dominate the share of capacity and generation. The situation has led Korea to depend heavily on foreign imports, exposing the country to global market volatility. It also results in Korea producing among the highest carbon emissions in the world (10.4 tonnes per capita in 2008). The figure below depicts Korea's supply mix, with coal and natural gas accounting for nearly 60% of all generation capacity in 2011.

FIGURE 3.5: INSTALLED CAPACITY AND ELECTRICITY GENERATION MIX IN 2011



Source: KPX, 2007a *Others include hydroelectric and renewables.

Improving energy security and reducing greenhouse gas emissions became two of the top priorities for Korea in the First NBEP of 2008. In order to address long-term energy challenges, the government committed heavily to increasing its nuclear capacity; thus, nuclear has already increased in many government projections to a 59% generation share in 2030. Furthermore, the new plan focuses on improving energy efficiency, reducing energy intensity, and developing more renewable and efficient energy technologies such as wind turbines and fuel cells. A more in depth of assessment of policies supporting energy efficiency and renewable energy will be explored in the next section.

The following tables depict changing installation and generation shares from 2009 to 2024. Despite growing in absolute capacity, both coal and natural gas will decline in absolute terms and in their share of all capacity. In contrast, the proportion of nuclear power capacity and gross energy generation will increase to 31.9% and 48.5%, respectively, by 2024. Also, the renewable energy generation share will increase to 8.9% by 2024. Growth in nuclear and renewable energy generation will allow Korea to reduce some of its dependence on imported fossil fuels.

TABLE 3.2: CURRENT AND PROJECTED INSTALLED CAPACITY (MW, %), 2009-2024

	Nuclear	Bituminous	Anthracite	LNG	Oil	Hydro	Renewables	Group	Total
2009	17,716	23,080	1,125	17,850	5,368	3,900	1,891	1,255	72,185
	24.54%	31.97%	0.56%	24.73%	7.44%	5.40%	2.62%	1.72%	100.00%
2010	18,716	23,080	1,125	19,422	5,372	3,900	2,127	1,674	75,416
	24.82%	30.60%	1.49%	25.75%	7.12%	5.17%	2.82%	2.22%	100.00%
2011	19,716	23,080	1,125	20,122	5,384	4,700	2,531	2,299	78,957
	24.97%	29.23%	1.42%	25.48%	6.82%	5.95%	3.21%	2.91%	100%
2015	24,516	29,820	1,125	23,517	4,108	4,700	4,183	4,314	96,283
	25.46$	30.97%	1.17%	24.42%	4.27%	4.88%	4.34%	4.48%	100%
2020	31,516	30,820	1,125	23,517	4,108	4,700	6,653	4,846	107,285
	29.38%	28.73%	1.05%	21.92%	3.83%	4.38%	6.20%	4.52%	100%
2024	35,916	30,320	1,125	23,517	4,108	4,700	8,061	4,846	112,593
	31.9%	26.93%	1.00%	20.89%	3.65%	4.17%	7.16%	4.30%	100%

Source: KPX, 2007b

TABLE 3.3: GROSS GENERATION BY SOURCE (GWH, %), 2010-2024

	Nuclear	Coal	LNG	Oil	Hydro	Renewables	Total
2010	144,856	193,476	100,690	14,693	2,084	5,949	461,747
	31.4%	41.9%	21.8%	3.2%	0.5%	1.3%	100%
2011	157,008	196,332	98,038	19,334	1,399	8,629	480,740
	32.7%	40.8%	20.4%	4.0%	0.3%	1.8%	100%
2015	201,089	220,886	89,891	6,795	2,551	20,009	541,221
	37.2%	40.8%	16.6%	1.3%	0.5%	3.7%	100%
2020	259,378	217,454	62,081	3,039	6,256	40,648	588,856
	44.0%	36.9%	10.5%	0.5%	1.1%	6.9%	100%
2024	295,399	188,411	59,201	2,912	8,202	54,467	608,591
	48.5%	31.0%	9.7%	0.5%	1.3%	8.9%	100%

Source: KPX, 2007a

In the wake of the Fukushima accident, the government has not yet announced any significant shifts in policy or energy mix projections. However, it is very likely that any future energy plan may reflect a diminishing role for nuclear power, creating more room for alternative technologies to grow. Policies may also reveal a shift away from large-scale supply expansion goals towards more flexible programs promoting energy efficiency, competition, and demand-side management to control growing energy demand. Until the new plan is released, however, evidence indicates that projections will continue to resemble those provided prior to the Fukushima accident.

3.2.4 Energy Efficiency and Renewable Energy Policy Changes

Historically, energy efficiency and renewable energy policy has lagged in Korea due to overwhelming emphasis on economic growth. Recent policy shifts outlined in new energy plans incorporate more aggressive tools to promote efficiency and alternative technologies, and build a new domestic "green" market. Generally, this plan is referred to as the "low carbon, green growth" policy. This policy aims for a larger share for renewable electricity generation as part of the national generation mix, and plans for implementation have been under way since 2008. Although the Fukushima accident did not significantly alter the outlook or role for renewables and energy efficiency in Korea, several changes in 2011 and 2012 reaffirm their growing importance as energy sources; ultimately, however, the accident at Fukushima may even improve the prospects for renewable and efficiency technology deployment as Korea may seek to replace some of its nuclear power with alternatives.

Energy Efficiency

As mentioned, due to its principal focus on economic growth, the Korean government has not historically promoted energy efficiency. Furthermore, much of the country's economic development depended on energy-intense industries. Not surprisingly, Korea boasts one of the least energy efficient economies of all OECD nations. Prior to 2000, Korea experienced increasing energy intensity, as the amount of total energy consumption in the country grew faster than GDP. In 2003, this trend began to reverse itself as final energy consumption fell below GDP. However, as of 2008, Korea remained one of the most energy intense economies in the OECD despite the recent downward trend in final intensity.

The first important government plan to enhance energy efficiency in Korea was the General Energy Conservation and Efficiency Improvement Plan of 2004. This plan set energy intensity improvement targets of 8.6% between 2004 and 2007, saving up to 17.6 million tons of oil-equivalent (Mtoe). Contrasted with the expected 3.7 % business-as-usual energy intensity development, this was seen as a considerable improvement. Improvements in the industrial sector represent the largest source of savings from this plan. Even so, many of the targets left Korea above the IEA member nation energy intensity average.

With the introduction of the "low carbon, green growth" policy in 2008, the government revised its energy intensity targets to increase the rate of decoupling more aggressively than in the 2004 plan. The new policy aimed to reduce energy intensity by 42% by 2030, with energy savings of 42 Mtoe through efficiency. Furthermore, the policy attempted to promote low carbon industry and enhance technological cooperation among businesses to reduce their energy use. The government is still in the process of implementing many of these measures, and of the country has already witnessed a decrease in energy intensity over the past decade; however, Korea continues to depend on many energy-intense industries and therefore must continue to promote efficiency to reach levels of efficient energy use comparable to many other OECD or IEA member nations.

The power of energy efficiency and policy to aggressively develop efficient technologies remains potent after the Fukushima accident. In November of 2011, the Ministry of Knowledge Economy announced a new investment plan to promote green energy technology. As part of this investment plan, a 12% below BAU energy efficiency target was identified (MKE, 2011a). The potential of such opportunities will be explored in the following section. Regardless, as the government prepares to release its new energy plan in 2013, energy efficiency will undoubtedly play an increasingly important role in policy.

Renewable Energy

As with energy efficiency, renewable energy policy has been limited in Korea. Despite sufficient potential to support a strong market in renewables, deployment has been limited for many years. Thus, by 2011, total installed capacity of renewable energy technologies was only 2.5 GWp, accounting for 3.2% of all domestic capacity. In terms of electricity generation share, however, renewables perform even worse: in 2011, they only accounted for 1.8% of total generation. On the other hand, renewable energy development has begun to exhibit large rates of growth in Korea as the result of several recent policy programs.

In 2006, the Korean government implemented a feed-in tariff (FIT) for solar PV (REEGLE, 2012b). The FIT offered subsidies at two levels, one for installations below and a second for those above 30 kWp. The solar FIT continued until 2008 when it was reduced due to extremely high rates of growth in PV installations. The ultimately goal of the first FIT program was to install over 1 GW of solar PV by 2012. A FIT to develop wind was also established, resulting in 379.3 MW by the end of 2010; however, the FIT incentives failed to support a more aggressive deployment.

In 2008, Korea's First National Energy Basic Plan expanded its goals for renewable energy development. The energy plan also sought to establish a new green industrial base in the country to develop and manufacture renewable energy technologies and systems for the global market. The policy aimed to achieve 11% of national energy consumption from renewable energy by 2030, a key tenet of the "low carbon, green growth" ideal of the new plan. Unfortunately, degression of the solar FIT and the ineffective wind FIT, coupled with the global economic downturn, meant that the momentum of domestic renewable energy markets slowed towards the end of 2008 into 2009.

In 2010, Korea planned to abandon the FIT altogether, opting instead for a renewable portfolio standard (RPS) to promote greater renewable energy development (REEGLE, 2012b). By 2012, the RPS had officially replaced the FIT (Choudhury, 2011). The goals of the RPS are to generate 4% of all electricity from renewable energy by 2015, rising to 10% by 2022. In addition, new incentives for technologies such as wind and solar, primarily the use of renewable energy certificates (REC), will help the government realize many of the ambitious targets outlined in the RPS. Wind power is expected to grow dramatically under the plan, generating up to 70% of all renewable energy by 2022 with over 15 GW installed by that time. Much of the new wind installations will most likely be offshore, utilizing Korea's substantial coastal wind resources. Solar PV will also grow, although at a slower rate than wind. As part of the RPS quota, the solar PV requirement will be 120 MW in the first year (2012) and rise to 200 MW by 2022.

Other renewable technologies will also benefit as a result of the new, ambitious energy plan. The government offers a 5% tax credit on all renewable technologies, and up to 60% of capital costs as subsidies to local or regional governments that pursue renewable energy projects. In addition, significant government and private investments have been pledged for green energy technology research and development, which will total US$31billion by 2020 (Han, 2011).

Among the technologies that may see a significant boon are biomass fuels, tidal power, and fuel cells. The use of biomass grew significantly between 2006 and 2009, and represents the largest source of renewable energy generation, excluding large-scale hydropower (REEGLE, 2012b). A new biomass cogeneration plant, the nation's first, was expected to begin supplying energy before the end of 2012. Due to its extensive coastline, Korea is also exploring tidal power. In 2011, the Lake Sihwa generation facility was completed, becoming the world's largest tidal generation plant at 254 MW. Finally, the Korean government and many Korean corporations have announced plans to pursue development, commercialization, and aggressive deployment of fuel cells (Vincent, 2010). In line with this policy aim, Korea has already built several of the world's largest fuel cell parks, and numerous contracts exist that will advance fuel cell technology and create investments for new installations.

Both energy efficiency and renewable energy will play a major role in Korea's energy sector in the future. Prior to 2004, policy measures to promote renewables and efficiency were uncommon, but with several shifts in policy over the past decade Korea has begun to expand both considerably. Not only has national energy intensity decreased, but new installations of PV and wind capacity have risen. After several initial policy mechanisms failed to realize sufficiently strong development, the years 2008 and 2010 both marked periods of revision and reform. This culminated with the implementation of a new RPS scheme in 2012, which seeks to increase the renewable generation share from 1.8% to 10% by 2022 (REEGLE, 2012b). Whether Korea can achieve its most ambitious targets is unclear; however, in the wake of the Fukushima accident, the importance of developing alternative energy technologies became self-evident, and the new energy plan in 2013 will most likely reflect this in the form of more aggressive development of energy efficiency and renewable energy.

3.2.5 Conclusion

The Fukushima disaster had important consequences for Korea. The government responded aggressively, initiating a series of investigations and programs that resulted in a complete overhaul of its regulatory institutions and safety protocol. The approach alleviated the fears of much of the Korean populace, and industry's commitment to comply with stricter safety standards ensured the improvement of nuclear power operation and management. However, despite these strong overtures to safety, the Korean government remains committed to developing nuclear power as a means of overcoming several of its most daunting energy challenges, including energy security and climate change concerns. Whether Fukushima will lead to a long-term reduction in nuclear or merely to a shift in the extent of its dependence on it should become apparent once the Korean government releases its next energy plan.

Nuclear power expected to gain importance in Korea over the next two decades, according to Korean government projections. This is indicative of a history of Korean energy development focused on expanding large-scale, centralized supply to meet rising demand and power strong economic growth. Due to the challenges of growing demand, but also new concerns over energy security and environmental impact, it is no surprise that nuclear technology has become the center piece of Korean energy policy. On the other hand, though historically receiving little policy support, energy efficiency and renewable energy technologies are exhibiting their great potential in helping Korea solve its energy challenges. In the past decade, new policies have resulted in strong development of efficiency and renewable energy, none of which is more important than the “low carbon, green growth” ideals of the First National Energy Basic Plan of 2008. Regardless of the future role of nuclear, it is likely that the next energy plan will indicate the growing potential of energy efficiency and renewable energy in achieving Korea’s energy goals.

3.3 Energy Efficiency and Renewable Energy Development and Policy

3.3.1 Electricity Demand Projection

Over the past 30 years electricity generation[3] in Korea has experienced a significant increase from 37 TWh in 1980 to 451 TWh in 2009 (IEA, 2011a). Likewise, electricity consumption has increased from 33 TWh in 1980 to 415 TWh in 2009. The difference between electricity generation and total consumption can be attributed to electricity used by power plants for self-consumption and to transmission and distribution (T&D) losses. For the last 10 years, the difference between electricity generation and consumption was, on average, 8% (see Table 3.4).

[3] Electricity generation (gross supply) is defined here as gross production minus the amount of electricity produced in pumped storage plants.

TABLE 3.4: ELECTRICITY GENERATION AND CONSUMPTION IN KOREA, 2000-2009

Year	Gross Production TWh	Pumped storage use TWh	Gross Supply TWh	Own use by Power Plants TWh	T&D Losses TWh	Total Consumption TWh	Difference *
2000	291.1	2.1	289.0	12.4	12.5	264.1	8.6%
2001	283.3	2.4	280.9	12.7	12.1	256.1	8.8%
2002	332.4	3.2	329.2	14.6	13.9	300.7	8.7%
2003	346.9	2.2	344.7	15.5	11.0	318.2	7.7%
2004	368.2	2.0	366.2	15.4	12.8	338.0	7.7%
2005	389.4	2.0	387.4	16.6	13.7	357.1	7.8%
2006	404.0	2.3	401.7	15.8	14.6	371.3	7.6%
2007	427.3	1.8	425.5	16.9	15.3	393.3	7.6%
2008	446.4	3.2	443.2	17.8	16.1	409.3	7.6%
2009	454.5	3.7	450.8	19.5	16.8	414.5	8.1%
							8.0%

Sources: IEA, 2010b; IEA, 2005 * Represents difference between Total Consumption and Gross Supply

According to the Ministry of Knowledge Economy's (MKE, 2010a) "5th Electricity Demand and Supply Basic Plan," electricity consumption under the reference (BAU) scenario will increase from 425 TWh in 2010 to 654 TWh in 2024 (the latest projected year by MKE). Consumption for2025 through 2030 can be assessed using a linear extrapolation of MKE data for 2010 - 2024. Based on that linear projection, electricity consumption for 2030 was estimated at 759 TWh. After accounting for differences between electricity generation and total consumption, which arises due to electricity consumption by power plants and T&D losses, required electricity generation values were derived. The resulting values are presented in Figure 3.6. This approach leads to a projection of the electricity supply required to meet forecasted demand of 819 TWh in 2030.

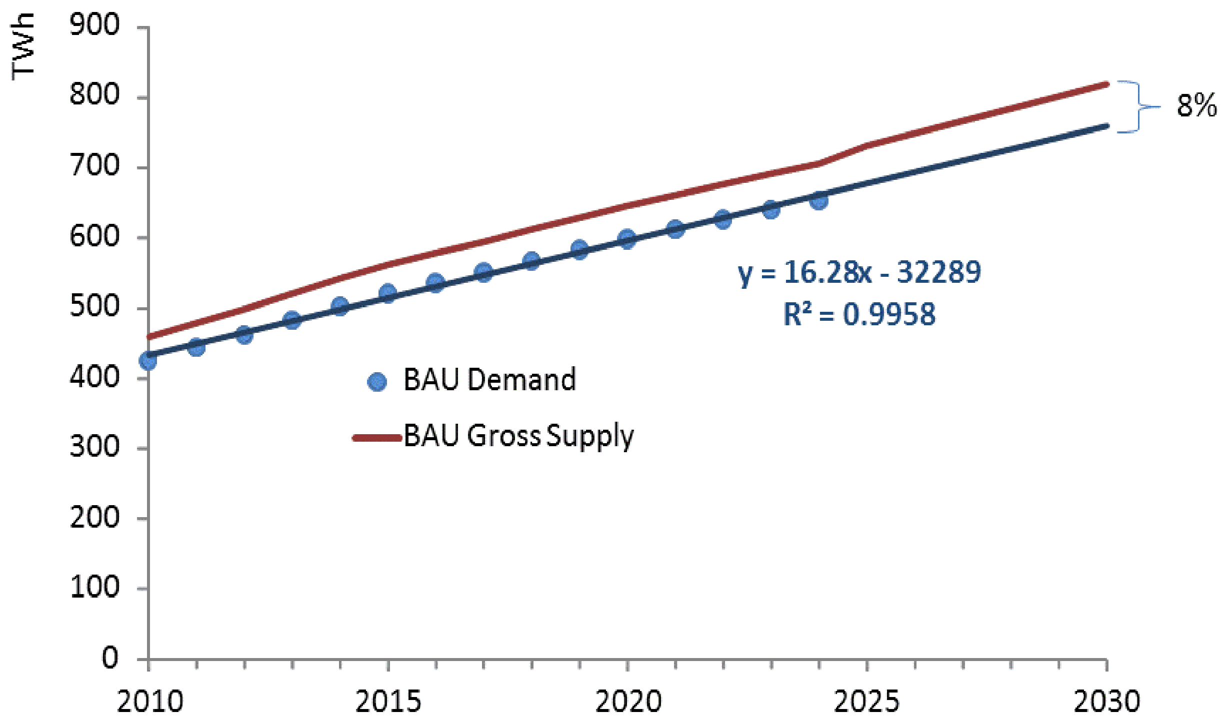
3.3.2 Electricity Supply under Business as Usual (BAU) Scenario

To meet projected electricity demand under the business-as-usual (BAU) scenario, detailed power plant construction schedules proposed in the 5th Basic Plan were reviewed. The following sections provide detailed description of the assumptions used to build the BAU scenario for each power source.

Capacity Projection for Nuclear Power

Since the oil supply shocks of the 1970s, the Korean government has diversified its national energy mix to reduce dependence on oil. One of the major strategies in decreasing foreign oil imports was to promote nuclear power. For the last 40 years nuclear power capacity has significantly increased and by the end of July, 2012, the nuclear capacity, with 23 reactors in total, reached 20.7 GW and provided one-third of Korea's electricity (WNA, 2012c). According to recent government announcements, Korea will add 17 more nuclear units by 2030, reaching 40 in total. This then forms the basis for the BAU nuclear scenario.

FIGURE 3.6: ELECTRICITY SUPPLY AND DEMAND PROJECTIONS UNDER BAU



As shown in Figure 3.6 above, by 2030, nuclear power will comprise 41% of the total generation capacity and will contribute 59% of total electricity generation (WNA, 2012c). To carry out a scenario analysis for nuclear, the construction schedule outlined in the 5th Basic Plan (MKE, 2010a) was utilized. The plan listed each proposed nuclear power unit by the operation start date and nameplate capacity for the years 2011 through 2023. Most of the new nuclear power units under the construction plan are designated as 1,400 MW capacity Advanced Power Reactor-1400 (APR-1400) reactors (see Table 3.5). The last 2 reactors listed under the 5th plan are 1,500 MW capacity designs. Since the last reactors are expected to have higher capacities, it was assumed that all reactors built after 2023 will have 1,500 MW capacities.

The 5th Basic Plan does not schedule any current reactors for retirement. To account for retirement, we assume an average lifespan of nuclear plants to be 50 years. This might be a relatively generous assumption compared to other studies, which list the lifetime of a typical nuclear plant to be 30-40 years (IAEA, 2012). For power generation projections it was assumed that nuclear power plants will operate at 90% capacity factor, which is typical for the nuclear power plants in Korea. [4]

[4] 90% is also a conservative assumption. The capacity factor for nuclear power in 2009 was 95% (IEA, 2011c).

TABLE 3.5: NUCLEAR CAPACITY ADDITIONS AND RETIREMENT UNDER BAU

Year	Month	Name	New Capacity Additions, MW	Capacity Retired, MW	Status
2010	12	Singori #1	1000		Started operation on February 2011
2011	12	Singori #2	1000		Started operation on June 2012
2012	3	Sinwolsung #1	1000		Started operation on June 2012
2013	1	Sinwolsung #2	1000		Under construction (99.34% completed as of June 2012)
2013	9	Singori #3	1400		Under construction (91.08% completed as of June 2012)
2014	9	Singori #4	1400		
2016	6	Sinwoljin #1	1400		Under construction (30.76% completed as of June 2012
2017	6	Sinwoljin #2	1400		
2018	6	Singori #5	1400		Preparing for construction
2019	6	Singori #6	1400		
2020	6	Sinwoljin #3	1400		Preparing for construction
2021	6	Sinwoljin #4	1400		
2022	6	Singori #7	1500		
2023	6	Singori #8	1500		
2024	6		1500		
2025	6		1500		
2026	6		1500		
2027	6		1500		
2028	4	Kori #1		587	
2028	6		1500		
2029	6		1500		

Source: MKE, 2010a

Capacity Projection for Coal Power

Over the years the share of coal power in the total electricity supply in Korea has increased. In 1980 coal provided only 7% of electricity generation, but in 1990 the share of coal power rose to 17%. In 2000 the share of coal was 38%, and by 2010 coal accounted for more than 40% of Korea's electricity generation (IEA, 2011d). However, the future role of coal power plants will likely be constrained as Korea seeks to adhere to its climate change commitments.

For the BAU scenario analysis it was assumed that new coal power plants would come online according to the schedule outlined in the 5th Basic Plan. The plan lists 15 new coal units that will come online between 2014 and 2017, and no coal-fired plant is scheduled to be constructed after 2017 (see Table 3.6). For the analysis it is assumed that coal power plant will be retired after 40 years of operation, and that coal plants will operate at 90% capacity factor, typical for base load power generators in Korea.

TABLE 3.6: COAL CAPACITY ADDITIONS

Year	Month	Name	New Capacity Additions, MW
2014	6	Youngheng #5	870
2014	12	Youngheng #6	870
2014	12	Donghae #1	500
2015	12	Samchuk #1	1000
2015	12	Samchuk #2	1000
2015	12	Dangjin #9	1000
2015	4	Donghae #2	500
2015	6	Dongbu Green #1	500
2015	6	Dongbu Green #2	500
2015	11	Yeosu #1	350
2016	6	Dangjin #10	1000
2016	6	Sinboryeong #1	1000
2016	6	Taean #9	1000
2016	12	Taean #10	1000
2017	6	Sinboryeong #2	1000

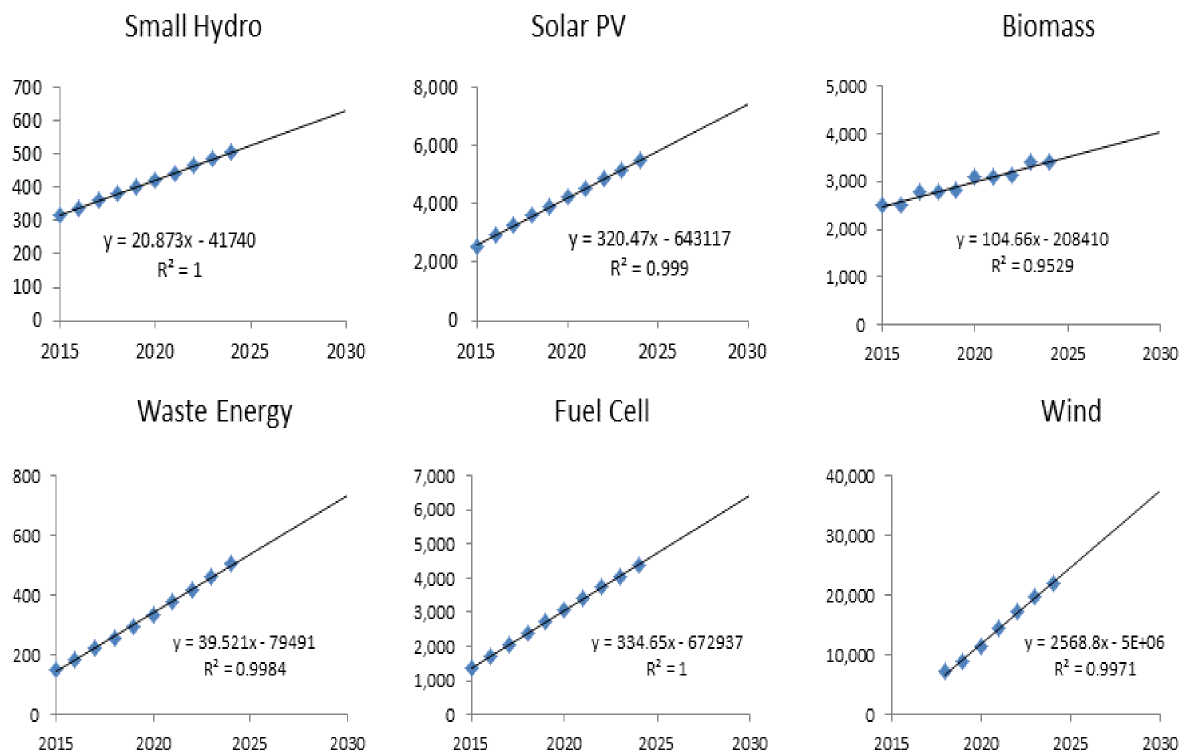
Source: MKE, 2010a

Capacity Projection for Renewable and New Power Generation

The 5th Basic Plan provides a detailed schedule for power production from different renewable energy and new energy sources. However, as in the case of nuclear and coal power, MKE (2010a) projections only covered the period from 2010 through 2024. In most cases electricity production from these sources can be linearly extrapolated (small hydro, solar, and wind); however, in some cases (i.e., ocean energy, by-product gas, and normal hydro) technologies reach their targeted potential earlier and they are kept at the same level afterwards. The 2025-2030 generation projections for these two sets of technologies are conducted under different assumptions.

For ocean energy, normal hydro, and for other new energies including by-product gas and integrated gasification combined cycle/clean coal technology (IGCC/CCT) we followed the 5th Basic Plan assumptions. The Plan assumed that electricity generation from these sources would not be increased beyond the following years: 2018 for ocean energy, 2014 for by-product gas, 2020 for IGCC/CCT, and 2011 for hydro. For the other set of technologies – small hydro, solar PV, biomass, waste energy, full cell, wind and geothermal – the linear regression provides relatively high R-square values (see Figure 3.7). From the applied linear fit, annual growth of power generation for each energy source can be easily calculated. For example, Figure 3.7 shows that, based on 5th Basic Plan data, from 2015 through 2024 electricity generated from small hydro will increase by about 21 GWh per annum. We assume this trend will continue beyond 2024, and by 2030 small hydro will provide 631 GWh. The same method was applied for each other technology.

FIGURE 3.7: PROJECTED RENEWABLE AND OTHER NEW ENERGY SUPPLY UNDER BAU (GWh)



The projected values for each technology are presented in Table 3.7. Based on this analysis under the BAU scenario, the total expected renewable energy generation in 2030 is projected at 59 TWh (including normal hydro) and an additional 16 TWh is expected to come from new energy sources.

Other Generation Sources

Previous sections dealt with power generation projections from nuclear, coal, renewable and other new energy sources. Typically in an electricity generation system, coal and nuclear power plants provide base load generation. Renewables and new energy technologies, depending on technology, can serve both peak as well as base load generation (e.g., pump hydro can be used for peak generation, while biomass and geothermal energy are typically used for base load). However, most renewables such as wind, solar PV, small hydro and ocean are intermittent and need to be dispatched in real time. The remaining power generation, oil and natural gas, typically serve intermediary and peak load demand.

The 5th Basic Plan does not schedule any new oil power plant additions. However, it assumes retirement of four oil plants (Yeosu, Namjeju, Yeongnam and Woolsan) with 1,240 MW combined capacity. Based on this schedule, assuming a 40% capacity factor, power generation from oil power plants was calculated.[5]

[5] 40% is close to the historically observed capacity factor for oil plants in Korea. For example, in 2009 the capacity factor for oil generation in Korea was 41% (IEA, 2011c).

TABLE 3.7: RENEWABLE AND OTHER NEW ENERGY SUPPLY UNDER BAU SCENARIO (TWh)

	Renewable Energy						**Other New Energy**				**Normal Hydro**	**Total RE**	**Total Other NE**	**Total**
	Small Hydro	Wind	Ocean	Solar	Bio	Geo-thermal	Waste Energy	By-prod. gas	Fuel Cell	IGCC/ CCT				
2010	0.2	0.8	0.0	0.7	0.5	0.0	0.1	0.5	0.2	0.0	3.1	2.1	0.7	5.9
2011	0.2	1.4	0.5	0.9	0.5	0.0	0.1	1.4	0.4	0.0	3.2	3.6	1.9	8.6
2012	0.3	3.0	0.5	1.2	0.8	0.0	0.1	1.4	0.6	0.0	3.2	5.8	2.1	11.1
2013	0.3	4.4	0.5	1.7	2.2	0.0	0.1	2.3	0.8	0.0	3.2	9.1	3.2	15.5
2014	0.3	5.1	0.6	2.1	2.5	0.0	0.1	2.7	1.1	0.0	3.2	10.6	3.8	17.6
2015	0.3	5.6	0.6	2.6	2.5	0.0	0.2	2.7	1.4	1.1	3.2	11.6	5.3	20.0
2016	0.3	6.0	1.6	3.0	2.5	0.0	0.2	2.7	1.7	2.1	3.2	13.3	6.7	23.2
2017	0.4	6.2	4.0	3.3	2.8	0.0	0.2	2.7	2.1	3.2	3.2	16.7	8.1	28.0
2018	0.4	7.2	5.7	3.6	2.8	0.0	0.3	2.7	2.4	4.2	3.2	19.7	9.5	32.4
2019	0.4	9.0	5.7	3.9	2.8	0.0	0.3	2.7	2.7	5.3	3.2	21.9	10.9	36.1
2020	0.4	11.5	5.7	4.3	3.1	0.1	0.3	2.7	3.1	6.3	3.2	25.1	12.4	40.6
2021	0.4	14.4	5.7	4.6	3.1	0.1	0.4	2.7	3.4	6.3	3.2	28.3	12.8	44.3
2022	0.5	17.3	5.7	4.9	3.1	0.1	0.4	2.7	3.7	6.3	3.2	31.6	13.1	47.9
2023	0.5	19.9	5.7	5.2	3.4	0.2	0.5	2.7	4.1	6.3	3.2	34.8	13.5	51.5
2024	0.5	22.0	5.7	5.5	3.4	0.2	0.5	2.7	4.4	6.3	3.2	37.4	13.9	54.5
2025	0.5	24.8	5.7	5.8	3.5	0.3	0.5	2.7	4.7	6.3	3.2	40.6	14.3	58.1
2026	0.5	27.3	5.7	6.1	3.6	0.3	0.6	2.7	5.1	6.3	3.2	43.7	14.6	61.5
2027	0.6	29.9	5.7	6.5	3.7	0.3	0.6	2.7	5.4	6.3	3.2	46.7	15.0	64.9
2028	0.6	32.5	5.7	6.8	3.8	0.4	0.7	2.7	5.7	6.3	3.2	49.8	15.4	68.3
2029	0.6	35.0	5.7	7.1	3.9	0.4	0.7	2.7	6.1	6.3	3.2	52.8	15.7	71.8
2030	0.6	37.6	5.7	7.4	4.1	0.5	0.7	2.7	6.4	6.3	3.2	55.9	16.1	75.2

Sources: For 2010-2024 values data is from MKE, 2010a; Numbers for 2025-2030 are projected

The other important source of power generation in Korea is natural gas. Over the last 20 years the natural gas share in power production has increased from 9% to 20%. Natural gas power plants typically operate as peak or intermediate generators and they play a vital role in balancing power supply. In our analysis we assume that existing and new (see Table 3.8) natural gas power plants, combined with other generation sources, will provide enough power to meet energy generation needs in Korea. Therefore, natural gas generation will fill the difference between total annual power demand and generation from other sources. To meet total power generation needs, capacity factors of natural gas power plants will vary from year to year. Under the BAU scenario, the capacity factor for natural gas generation varies from 26% to 67%, and the average value for the 2010-2030 forecasting period was calculated at 43%.

TABLE 3.8: NATURAL GAS CAPACITY ADDITIONS

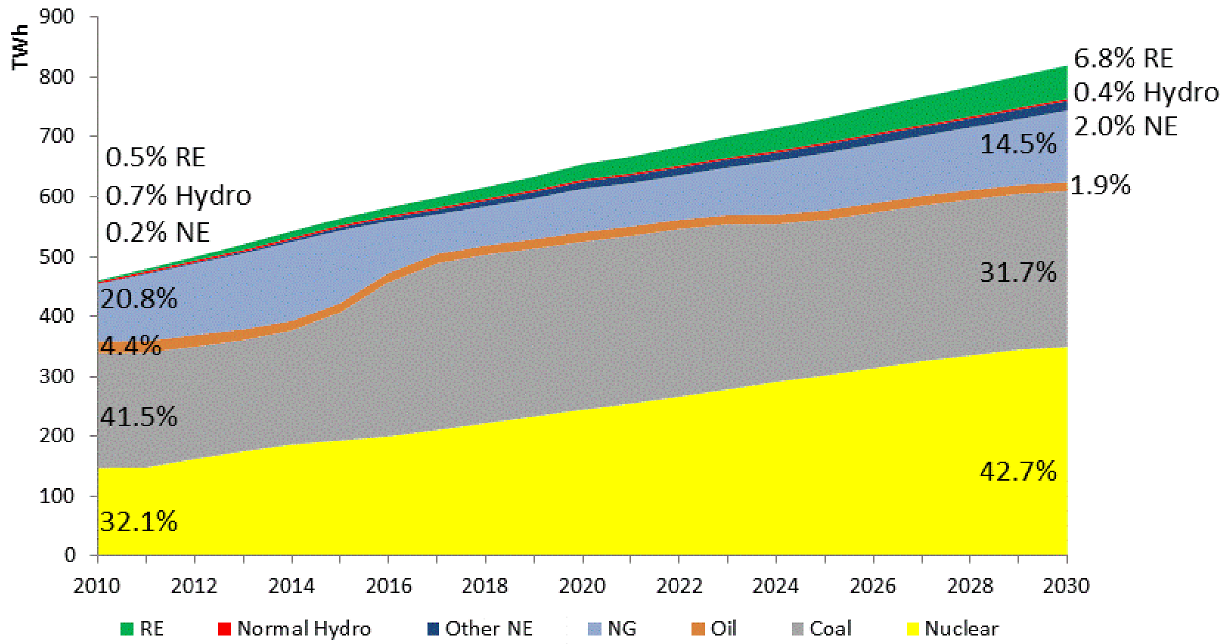
Year	Month	Name	New Capacity Additions, MW	Retirement, MW
2010	10	Youngwol	385	
2011	2	POSCOPower #5	575	
2011	6	POSCOPower #6	575	
2011	9	Boryeong #4		450
2012	12	Incheon #3	450	
2012	12	Oseong	833	
2013	1	Jeju GT #3		55
2013	10	Boryeong #3		450
2013	12	Pocheon #1	750	
2013	12	Bugok #3	500	
2013	12	Andong	400	
2014	3	Ansan #1	750	
2014	5	Jangheung	800	
2014	6	Munsan	800	
2014	8	POSCOPower #1		450
2014	9	Pocheon #2	750	
2014	10	Chuncheon	500	
2014	12	Seoul thermal #4,5		388
2014	12	Seoul CC #1, 2	1000	
2014	12	Dongduchen #1, 2	1500	
2015	1	POSCOPower #2		450
2015	2	POSCOPower #7	600	
2015	8	POSCOPower #8	600	
2021	1	Honam thermal #1,2		500

Source: MKE, 2010a

Electricity Supply Mix under BAU Scenario

Combining the power generation forecasts for the different energy sources covered in the previous sections resulted in the total power generation mix for 2010 through 2030. Figure 3.8 presents the resulting projections. Under the BAU scenario, the share of electricity from new and renewable energy (including normal hydropower) will increase from 1.4% in 2010 to 9.2% in 2030. The share of nuclear power will be increased from 32.1% in 2010 to 42.7% in 2030. Thus, under the BAU, despite significant growth, renewables and new energy will contribute only quarter of what nuclear power will provide in 2030. At the same time, the share of fossil fuel-fired electricity will decline from 66.7% in 2010 to 48.2% by 2030.

FIGURE 3.8: ELECTRICITY SUPPLY MIX UNDER THE BAU SCENARIO

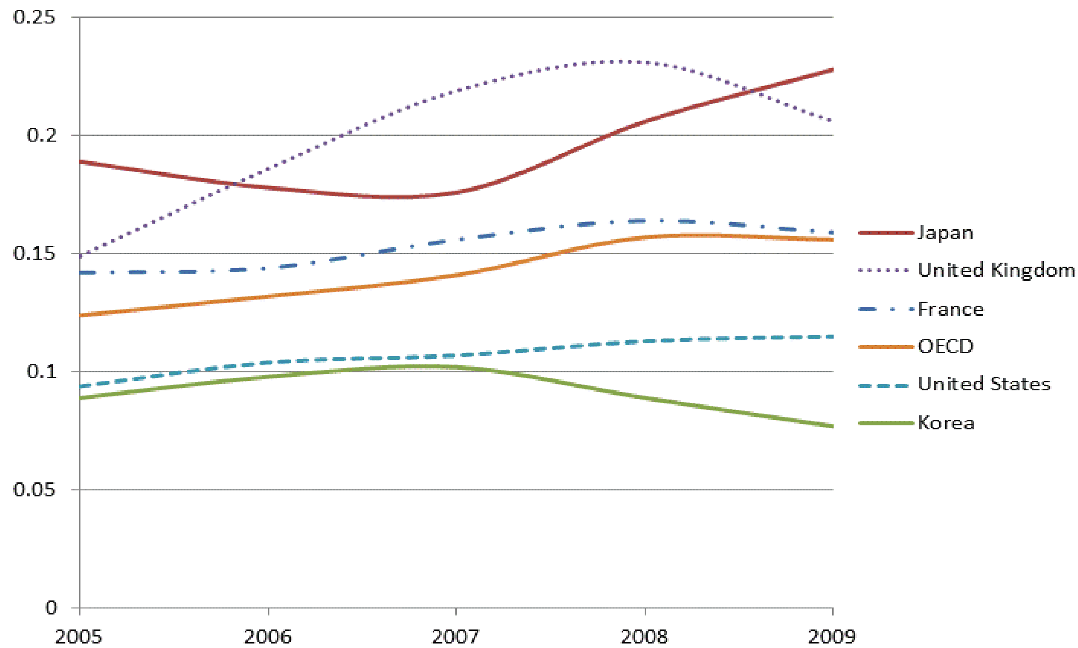


3.3.3 Electricity Supply under Alternative Scenarios

The 5th Basic Plan provides an alternative – the Target scenario – in addition to the Reference scenario used to calculate the BAU. The Target scenario assumes strengthening demand side management (DSM) compared to the BAU and rationalizing electricity rate structures (MKE, 2010a). DSM and efficiency improvement measures mentioned in the plan include utilization of high efficiency appliances and machinery, using standby power, and improvements in commercial and industrial building energy management systems. Rationalization of the electricity rate structure includes the gradual transition to a rate structure that more accurately reflects supply costs for industrial, commercial and residential customers and introduction of more flexible pricing systems such as real-time pricing.

Currently, electricity prices in Korea are the lowest among the OECD countries. In 2009, households in OECD countries paid an average US$0.156 per kWh, while Koreans paid only US$0.077 per kWh. Electricity prices are much higher in Japan and United Kingdom, where households pay over US$0.2 per kWh (see Figure 3.9). Likewise, industrial customers in Korea paid the lowest rate in the OECD, US$0.058 versus the US$0.104 per kWh OECD average (IEA, 2011a).

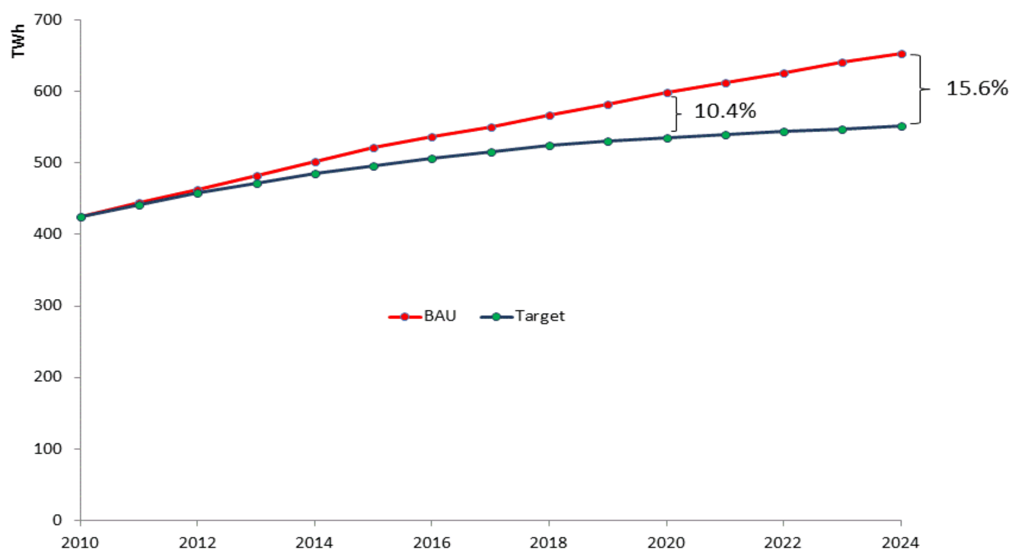
FIGURE 3.9: ELECTRICITY PRICES FOR HOUSEHOLDS IN OECD COUNTRIES ($/kWh)



Source: IEA, 2011a

Korea's low prices for electricity reflect current political and economic circumstances, and, unfortunately, the Korean electricity industry does not fully recover its costs for electricity generation (Kim, 2012). Improved pricing structures combined with DSM programs can help to reduce energy consumption. This is reflected in the Target scenario presented in the 5th Basic Plan. Comparison of the Target scenario with the BAU shows that by 2020 the Target scenario requires 10.4% less energy than the BAU and by 2024 electricity demand is 15.6% less than in the BAU (see Figure 3.10).

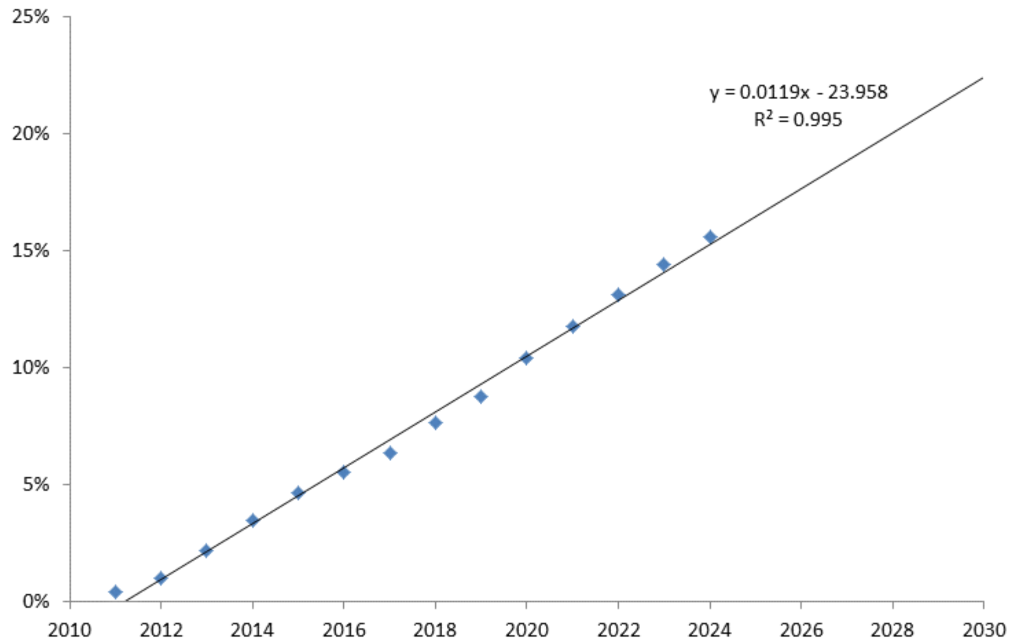
FIGURE 3.10: ELECTRICITY DEMAND PROJECTIONS UNDER BAU AND TARGET SCENARIOS



Source: MKE, 2010a

In the 5th Basic Plan, as in the case of the BAU scenario, energy demand under the Target scenario is presented only for 2010 through 2024. To project energy efficiency improvements after 2024, energy savings under the Target scenario (the difference between Target scenario consumption and BAU consumption) was plotted against the projected BAU Consumption (see Figure 3.11). Extrapolating energy savings against BAU consumption yields 22.4% savings in 2030.

FIGURE 3.11: ENERGY SAVINGS IN TARGET SCENARIO AGAINST BAU CONSUMPTION

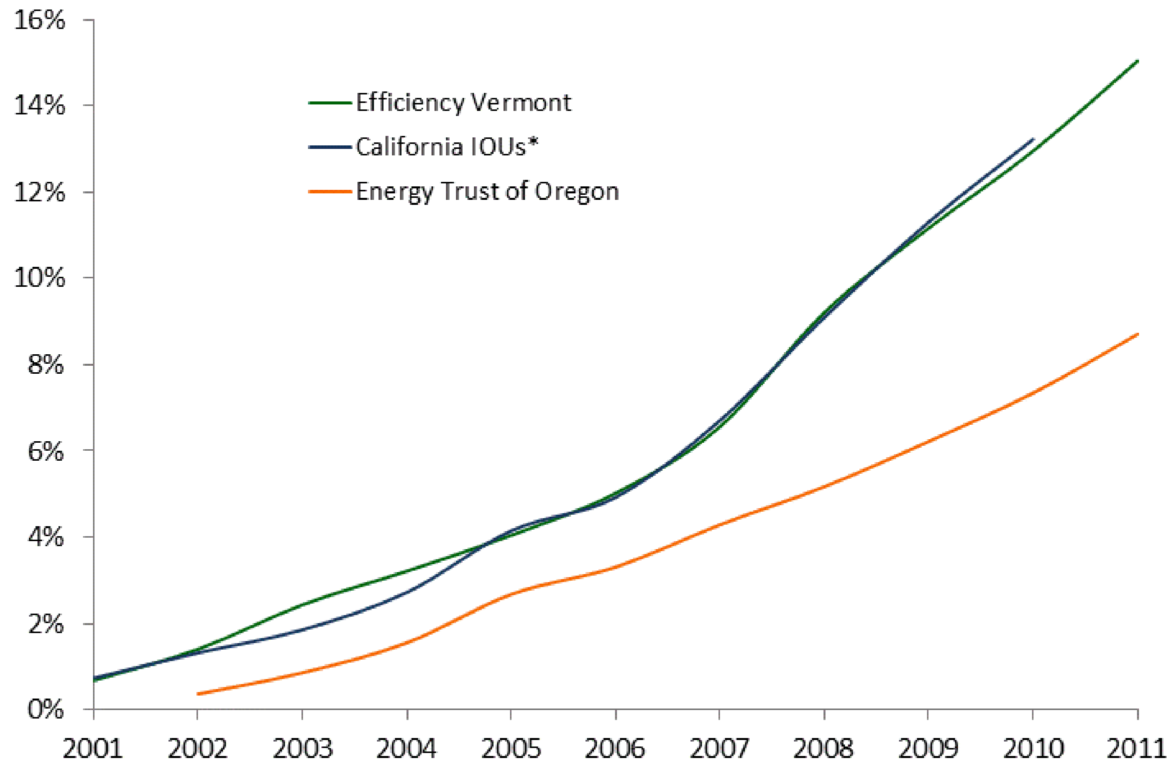


Source: MKE, 2010a

At first, 22.4% efficiency savings against the BAU might appear high; however, considering that this value includes not only efficiency savings through DSM programs but also energy demand reductions due to pricing structure reforms, it might even be considered to be conservative. For example, in the United States the leading electricity service companies and utilities show that significant energy efficiency savings can be achieved. Efficiency Vermont and California's largest utilities, Pacific Gas & Electric Co. and Southern California Edison Co. which represent two third of the state's electricity sales, reached cumulative savings of 13%-15% over 10 years. In the same timeframe Energy Trust of Oregon reached 9% cumulative savings (see Figure 3.12). These savings are only through DSM measures and do not reflect additional potential savings that might have occurred due to electricity price changes (e.g., due to customer behavioral changes and energy conservation).

In terms of efficiency improvement potential, a previous study conducted by the Center for Energy and Environmental Policy estimated that through specific efficiency measures Korea could save 22% of energy demand by 2020 under its Major Policy Commitment Strategy scenario (Byrne *et al.*, 2004). Yet again, the study demonstrates that significant potential exists for energy efficiency improvements in Korea.

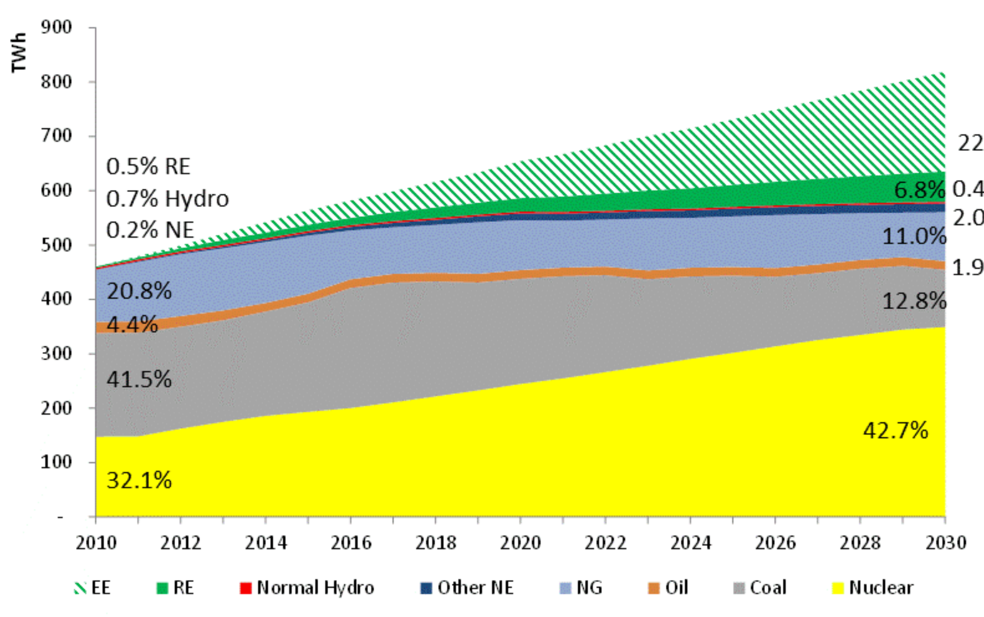
FIGURE 3.12: CUMULATIVE ENERGY EFFICIENCY SAVINGS IN LEADING U.S. STATES



Sources: Efficiency Vermont, 2003-2011 Reports; Energy Trust of Oregon, 2003-2011; IEA, 2001-2010
*Based on the two largest Californian investor owned utilities (IOUs): Pacific Gas & Electric Co and Southern California Edison Co.

Energy efficiency improvements and demand reductions allow for a change in the power supply mix. Assuming energy savings for 2010-2024 will follow the Target scenario outlined in the 5th Basic Plan and that after 2024 the savings trajectory will continue till 2030, alternative scenarios can be developed. Figure 3.13 depicts one of the possible scenarios, under which no new coal power plants will come online after 2015 and life time of existing coal plants will be 25 years instead of 40 years as assumed under the BAU scenario. Under this scenario, nuclear, oil, renewable energy and new energy will provide the same amount of energy as under the BAU and the share of coal will shrink from 32% to 13%, if energy efficiency is counted, or 17% against adjusted demand. Natural gas will also be reduced from 14% to 11% if energy efficiency is counted, or 14% against reduced demand. Under this scenario the amount of nuclear will remain the same, but its share against lower demand will increase to 55% in 2030. Significant reductions in coal power generation will have noticeable impacts on CO_2 emissions, and therefore this scenario is referred to as the Low Carbon scenario (LCS).

FIGURE 3.13: ELECTRICITY SUPPLY MIX UNDER THE LOW CARBON SCENARIO (LCS)



To estimate CO_2 reductions under the LCS, emission factors for fossil fuel power generators in Korea were analyzed. According to IEA data for Korea (2011d; 2010b), for the past 10 years emission factors for coal power plants fluctuated from 0.890 to 0.978 tons per MWh with a mean of 0.933. Likewise, emission factors for natural gas plants fluctuated from 0.325 to 0.353 tons per MWh with a mean of 0.342 over the same period (see Table 3.9). Using the mean values, CO_2 emissions under the BAU and the LCS were calculated. The results are presented in Table 3.10. Under the LCS, carbon emissions in 2020 will be a quarter less than under the BAU, and in 2030 CO_2 emissions will be less than half compared to BAU. Such levels of emission reductions would achieve recent government emissions targets (MOE, 2011).

TABLE 3.9: CO_2 EMISSIONS FROM POWER PLANTS IN KOREA (kg/kWh or tons/MWh)

	Coal	Oil	NG
2000	0.891	0.482	0.336
2001	0.944	0.484	0.353
2002	0.890	0.410	0.338
2003	0.943	0.400	0.325
2004	0.987	0.404	0.347
2005	0.971	0.420	0.343
2006	0.980	0.415	0.349
2007	0.902	0.407	0.351
2008	0.896	0.344	0.343
2009	0.921	0.412	0.339
Mean	**0.933**	**0.418**	**0.342**

Source: IEA 2011b, 2010c

TABLE 3.10: SCENARIO CO_2 EMISSIONS FROM POWER PLANTS IN KOREA (Million Metric Tons)

	BAU	**LCS**	**Less than BAU**
2010	**219.23**	**219.23**	**0.0%**
2011	224.67	223.98	0.3%
2012	223.55	221.93	0.7%
2013	224.22	220.95	1.5%
2014	229.83	223.92	2.6%
2015	**247.27**	**231.12**	**6.5%**
2016	275.68	243.46	11.7%
2017	288.43	241.52	16.3%
2018	291.18	233.97	19.6%
2019	291.73	224.20	23.1%
2020	**293.01**	**218.72**	**25.4%**
2021	292.33	211.47	27.7%
2022	292.71	202.47	30.8%
2023	290.78	187.96	35.4%
2024	283.17	179.45	36.6%
2025	**281.68**	**170.96**	**39.3%**
2026	282.48	159.56	43.5%
2027	283.28	153.07	46.0%
2028	285.39	149.86	47.5%
2029	286.46	144.18	49.7%
2030	**289.63**	**135.46**	**53.2%**

As can be seen from the LCS analysis, energy efficiency improvements can reduce the need for conventional power generation. Likewise, increasing the renewable energy supply can lead to similar results. Under the BAU scenario, renewable and new energy sources combined will provide 6.2% of electricity supply in 2020, and 9.2% in 2030. Based on the recent study by Byrne et al.(2011), the share of renewables can be much higher in Korea. According to the study, by 2020 wind energy can provide 10.87% of electricity, solar PV can generate 2%, biomass 1.03%, and geothermal energy 0.02%. To project further deployment of renewable energy in Korea, a new technology diffusion model was constructed.

Technology diffusion has often been described by a logistic growth model (an S-shaped curve). Logistic growth models have proven to be accurate tools for forecasting a wide range of phenomena, including solar PV diffusion (see Byrne and Kurdgelashvili, 2011). Typically, new technologies grow exponentially during the early phase of their deployment because of the broadening scope of their application and expanding access to new users and markets. In the long-term technological diffusion is confined by some limit, such as the size of the potential market or the technical potential of an available resource. The maximum limit is also referred to as the "ultimate target" (Byrne and Kurdgelashvili, 2011; Byrne *et al*., 2005; Fisher and Pry, 1971; OECD, 2003). For renewable energy the ultimate target is represented by the maximum share of a specific renewable energy technology in the electricity supply.

To identify the ultimate targets for key renewable energy technologies for the purposes of this analysis, four studies were reviewed: 1) Greenpeace's Energy [R]evolution (2010); 2) the European Commission's World Energy Technology Outlook (2006); 3) WWF's Energy Report (2011); and 4) IEA's Energy Technology Perspectives (2010). The Greenpeace, European Commission, and IEA studies contain multiple scenarios, as outlined below.

Greenpeace (2010) presented two alternative scenarios: the energy [r]evolution scenario and the advanced energy [r]evolution scenario. The energy [r]evolution scenario has been developed based on two goals: 1) reduce energy related CO_2 emissions by 50% against 1990 level by 2050, and 2) the global phasing out of nuclear power. To achieve these goals, Greenpeace explored energy efficiency and renewable energy deployment potentials. The advanced energy [r]evolution scenario takes a stricter position on stabilizing the CO_2 content in the atmosphere. Under this scenario, by 2050 energy related CO_2 emissions should be 83% below 1990 levels, and it assumes earlier retirement of coal power plants (20 years against the more typical 40 years). Both scenarios assume a high share of wind and solar in electricity supply (28% to 29% for wind, 19% to 24% for solar CSP, and 15% to 18% for solar PV).

The European Commission's (EC) Carbon Constraint Case (CCC) describes a future with a CO_2 concentration below 550 ppm by 2050, based on advanced and new energy technology deployment such as distributed electricity production, low emission vehicles, carbon capture and storage, low energy buildings, etc. According to the CCC, wind will contribute 12.2% to the total electricity generated, followed by biomass and solar. The EC study also has a second scenario referred to as the H_2 Case. This scenario is derived from CCC and assumes technological breakthroughs that lead to higher utilization of hydrogen (mainly in transportation). Compared to other scenarios reviewed, the EC scenarios are more conservative in terms of the share of renewables in the utlimate total electricity supply (see Table 3.11).

IEA (2010a) refers to its alternative energy scenario as the Blue Map scenario. By 2050, the Blue Map scenario targets a 50% reduction (compared to 2000 levels) of energy related CO_2 emissions through successful introduction of low-carbon technologies such as carbon capture and storage (CCS), renewables, nuclear power and energy efficiency. To achieve this target the Blue Map scenario assumes lower energy demand (13% less than BAU) through energy efficiency improvements and a higher level of renewable energy in the electricity mix (48% vs. 22% in BAU).

In addition to the original Blue Map scenario, IEA also developed four additional scenario variations including the Blue no CCS, Blue hi NUC, Blue hi REN, and Blue 3% scenarios (detailed further in Table 3.11). The variants of the blue map scenario share the same goal of limiting global temperature rise to 2~3°C by 2050. The Blue no CCS scenario assumes CCS will not be employed while renewables, providing 54% of electricity, will play a bigger role. The Blue hi NUC scenario assumes higher utilization of nuclear power, under which nuclear capacity will reach 2,000 GW by 2050: this is 800 GW higher than in the original Blue Map scenario. Under the Blue hi REN scenario renewables provide 75% of the global electricity supply in 2050. Under this scenario coal and nuclear play lesser roles compared to the original Blue Map scenario (2% vs. 13% for coal and 12% vs. 24% for nuclear). The Blue 3% scenario uses a 3% social discount rate rather than the more typical 8-14% market rates used in the original scenario. Under this scenario renewables provide a higher share than under the Blue Map scenario (57% vs. 48%).

The WWF scenario, developed by energy consultancy Ecofys, is the most aggressive in its target to provide 100% of world energy supply from renewable energy sources by 2050. Unlike other studies, Ecofys provides only one scenario. The resulting renewable energy share to electricity production is as follows: Solar PV will account for 29.0% of total electricity generation followed by wind at 25.1% and solar CSP at 16.9%, with the remaining 29.0% from biomass, hydro, geothermal and ocean energy.

TABLE 3.11: LONG-TERM TARGETS FOR RENEWABLE ENERGY DEPLOYMENT

Renewables	Greenpeace (2010)		EC (2006)		WWF (2011)	IEA (2010)					Median
	GP-ER	GP-adv ER	CCC	H_2-case	Ecofys	Blue	Blue no CCS	Blue hi NUC	Blue hi REN	Blue 3%	
Solar PV	14.6%	18.1%	4.0%	3.6%	29.0%	6.2%	7.2%	5.0%	12.3%	9.1%	8.1%
Solar SCP	18.8%	23.8%	0.0%	0.0%	16.9%	6.2%	7.2%	5.0%	12.3%	9.1%	8.1%
Wind	27.0%	28.6%	12.7%	11.8%	25.1%	12.2%	14.5%	9.6%	21.8%	14.9%	14.7%
Biomass	2.3%	1.5%	4.6%	4.5%	12.7%	6.1%	7.0%	5.6%	7.0%	5.7%	5.6%
Geothermal	3.2%	7.8%	0.0%	0.0%	3.8%	2.5%	2.6%	2.3%	3.7%	2.7%	2.7%
Hydro	16.1%	13.5%	8.9%	8.7%	11.7%	14.3%	14.5%	14.0%	16.0%	14.1%	14.0%
Ocean	2.2%	5.1%	0.0%	0.0%	0.7%	0.3%	0.7%	0.2%	1.5%	1.0%	0.7%
Total	84.2%	98.6%	30.2%	28.7%	100.0%	47.9%	53.6%	41.6%	74.6%	56.6%	54.0%

Sources: (European Commission, 2006; Greenpeace, 2010; IEA, 2010b; WWF, 2011)

Table 3.11 lists seven renewable energy sources including concentrating solar power (CSP), which requires high levels of solar irradiation. Because Korea lacks sufficient solar resources CSP was not considered in our scenarios. Hydropower is already a mature technology and it was assumed that its deployment in Korea would follow the same path as outlined in the BAU scenario. In the case of ocean energy, the median value obtained from Table 3.11 is 0.7%. This value is lower than under the BAU scenario, which assumes around 1% of electricity coming from ocean energy. Therefore, the logistic model was not used for CSP, hydro and ocean energy projections.

In the case of the other four renewable energy sources (solar PV, wind, biomass and geothermal) it was assumed that Korea would achieve a similar level of renewable development as the rest of the world. To set the ultimate target for the selected renewable energy sources, the median values presented in Table 3.11 were used. The obtained ultimate targets are used in the logistic model to fix the maximum level of renewable energy share in Korea's electricity supply. To build logistic curve trajectories it was assumed that Korea would achieve 2020 targets developed in a previous study (see Byrne *et al.*, 2011). Based on these assumptions, diffusion models for each of the renewable energy sources were constructed (see Figure 3.14).

FIGURE 3.14: RENEWABLE ENERGY TARGETS UNDER ALTERNATIVE SCENARIO, 2010-2030

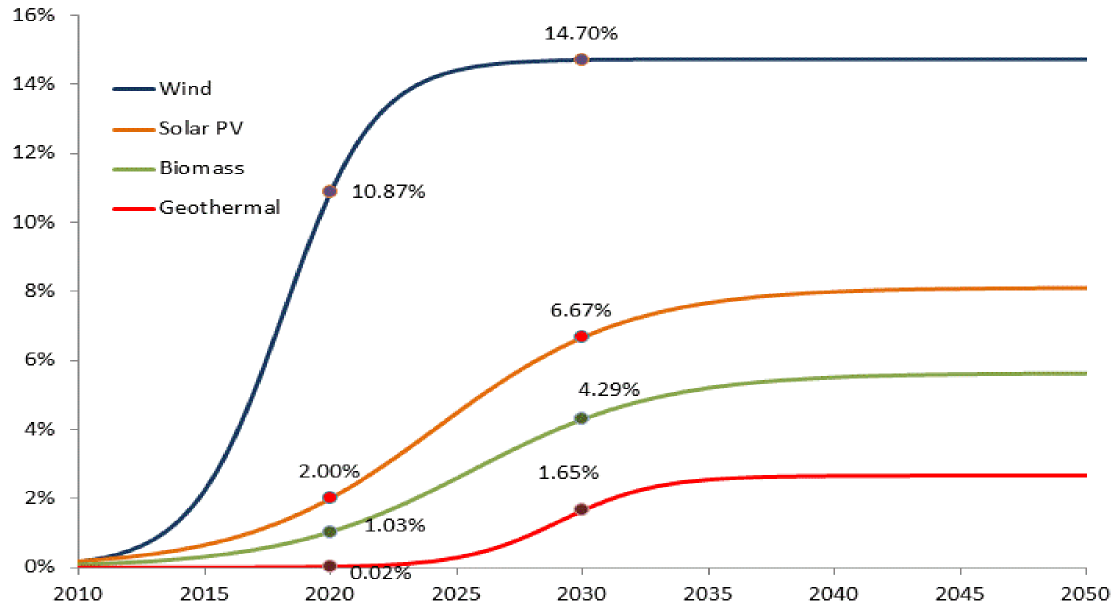


TABLE 3.12 RENEWABLE AND OTHER NEW ENERGY SUPPLY UNDER ALTERNATIVE SCENARIO (TWh)

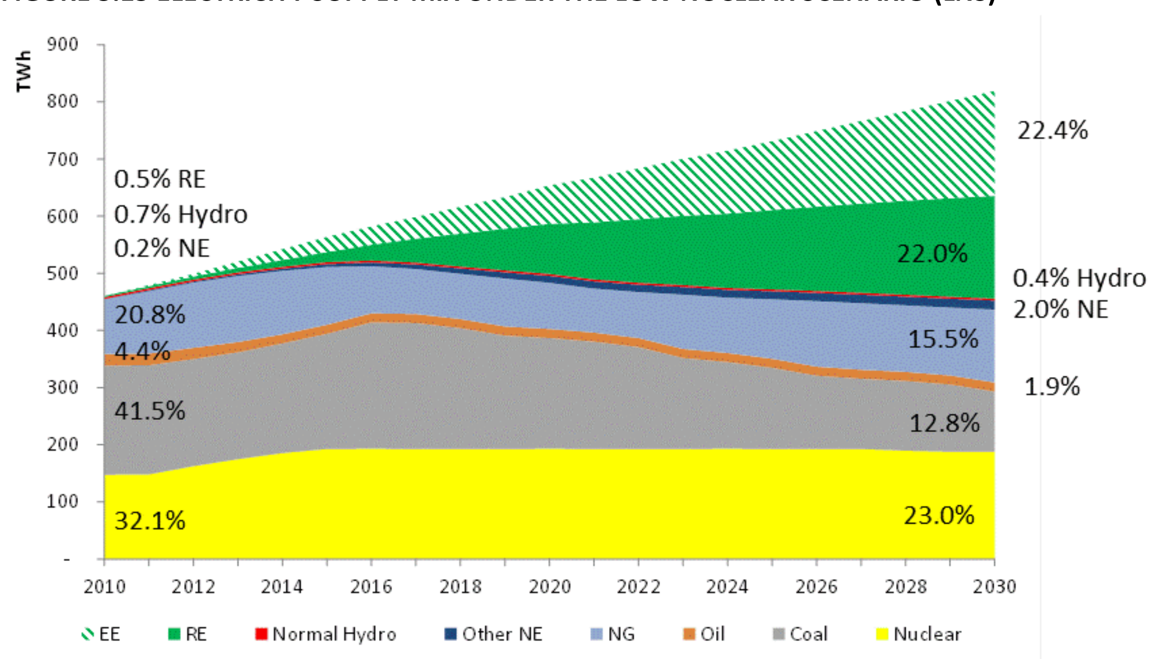
	Renewable Energy						Other New Energy				Normal Hydro	Total RE	Total Other NE	Total
	Small Hydro	Wind	Ocean	Solar	Bio	Geo-thermal	Waste Energy	By-prod. gas	Fuel Cell	IGCC/ CCT				
2010	0.2	0.8	0.0	0.8	0.4	0.0	0.1	0.5	0.2	0.0	3.1	2.2	0.7	6.0
2011	0.2	1.4	0.5	1.1	0.5	0.0	0.1	1.4	0.4	0.0	3.2	3.7	1.9	8.8
2012	0.3	2.4	0.5	1.5	0.7	0.0	0.1	1.4	0.6	0.0	3.2	5.4	2.1	10.7
2013	0.3	4.2	0.5	2.0	1.0	0.0	0.1	2.3	0.8	0.0	3.2	8.0	3.2	14.3
2014	0.3	7.2	0.6	2.7	1.3	0.0	0.1	2.7	1.1	0.0	3.2	12.0	3.8	19.0
2015	0.3	12.0	0.6	3.5	1.7	0.0	0.2	2.7	1.4	1.1	3.2	18.1	5.3	26.5
2016	0.3	19.2	1.6	4.6	2.2	0.0	0.2	2.7	1.7	2.1	3.2	27.9	6.7	37.7
2017	0.4	28.9	4.0	5.9	2.9	0.0	0.2	2.7	2.1	3.2	3.2	42.1	8.1	53.4
2018	0.4	40.5	5.7	7.5	3.7	0.0	0.3	2.7	2.4	4.2	3.2	57.9	9.5	70.6
2019	0.4	52.7	5.7	9.4	4.8	0.1	0.3	2.7	2.7	5.3	3.2	73.1	10.9	87.2
2020	0.4	63.8	5.7	11.7	6.1	0.1	0.3	2.7	3.1	6.3	3.2	87.8	12.4	103.4
2021	0.4	72.1	5.7	14.3	7.5	0.2	0.4	2.7	3.4	6.3	3.2	100.3	12.8	116.2
2022	0.5	78.4	5.7	17.2	9.3	0.4	0.4	2.7	3.7	6.3	3.2	111.4	13.1	127.8
2023	0.5	82.9	5.7	20.5	11.3	0.7	0.5	2.7	4.1	6.3	3.2	121.4	13.5	138.1
2024	0.5	85.7	5.7	23.8	13.4	1.1	0.5	2.7	4.4	6.3	3.2	130.2	13.9	147.3

2025	0.5	88.0	5.7	27.3	15.8	1.7	0.5	2.7	4.7	6.3	3.2	139.1	14.3	156.6
2026	0.5	89.7	5.7	30.8	18.3	2.8	0.6	2.7	5.1	6.3	3.2	147.8	14.6	165.6
2027	0.6	90.9	5.7	34.1	20.7	4.2	0.6	2.7	5.4	6.3	3.2	156.3	15.0	174.5
2028	0.6	91.9	5.7	37.2	23.1	6.1	0.7	2.7	5.7	6.3	3.2	164.6	15.4	183.2
2029	0.6	92.8	5.7	40.0	25.3	8.3	0.7	2.7	6.1	6.3	3.2	172.6	15.7	191.6
2030	0.6	93.5	5.7	42.4	27.3	10.5	0.7	2.7	6.4	6.3	3.2	180.0	16.1	199.3

Under the alternative scenario renewables can play a much more significant role than in other cases. Under this scenario, electricity generation from renewables would more than triple from 56 GWh (under BAU) to 180 GWh. Annual generation projections for each renewable energy source are provided in Table 3.12 above.

Increased supply of renewables combined with energy efficiency strategies will allow Korea to decrease not only CO_2 emissions but also the need for new nuclear power capacity. Some of the nuclear power units listed in the Basic Plan (See Table 3.5) are already online (Singori #1 and #2, and Sinwolsung #1), and some are nearly completed (Sinwosung #2, Singori #3 and #4). The alternative scenario assumes these units will be operational according to the schedule outlined in the Basic Plan. At the same time, energy efficiency and increased renewable supply obviates the need for the remaining nuclear units listed in the plan. Under the Low Nuclear scenario (LNS) it was assumed that no nuclear units would come online after 2015. Based on these assumption,the share of nuclear power will be 23% without demand adjustment and 30% against lower demand (see Figure 3.15).

FIGURE 3.15 ELECTRICITY SUPPLY MIX UNDER THE LOW NUCLEAR SCENARIO (LNS)



3.3.4 Estimation of Costs under Different Scenarios

Investment Costs

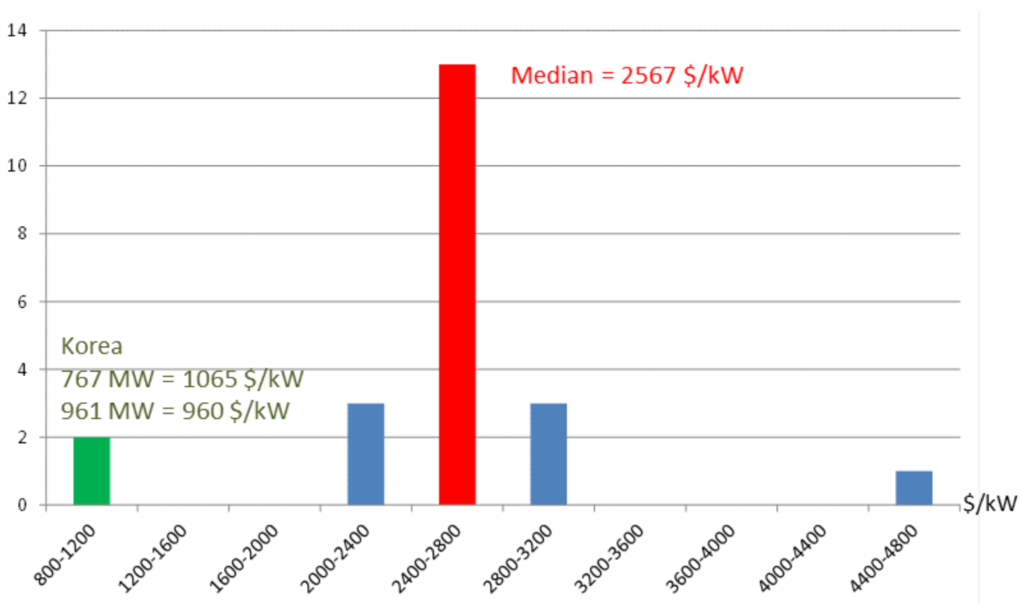
In the three scenarios presented, the BAU scenario assumed power plant construction schedule would follow the 5th Basic Plan, the LCS assumed no coal power plants would come on-line after 2015, and the LNS assumed that both coal and nuclear units scheduled after 2015 would not come on-line. To estimate the investment cost under these scenarios a data set from an IEA study (2010c) was analyzed.

Coal

The investment cost data listed by IEA (2010c) include pre-construction, construction (engineering, procurement and construction), and contingency costs, plus interest accrued during construction. The investment cost spread for coal power plants is shown in Figure 3.16. From the data it is clear that for the majority of OECD countries the investment costs for coal power plants range from US$2,000 to US$3,200 per kW. However, the reported costs for Korea are around $1,000 per kW, which is less than half of the median value of $2,567 per kW.

Using the construction schedule outlined in the 5th Basic Plan, the investment cost outlook for coal power plants was determined (see Table 3.13). The end cost projections apply Korean turnkey prices, while high end values use the OECD median. In the former case, it is assumed that all coal power units with nameplate capacity exceeding 1,000 MW will cost US$960 per kW and those below 1,000 MW will be US$1,065 per kW.   Cumulative investment costs under the BAU range from U$12 billion to US$31 billion. The LCS and LNS have the same construction schedule for coal power plants, and investment costs for these scenarios range from US$7 billion to US$18 billion.

FIGURE 3.16: INVESTMENT COSTS FOR COAL POWER PLANTS IN KOREA AND OECD



Source: IEA, 2010c

* Investment Costs include pre-construction, construction (engineering, procurement and construction), contingency costs, and interest during construction (at 10% discount rate)

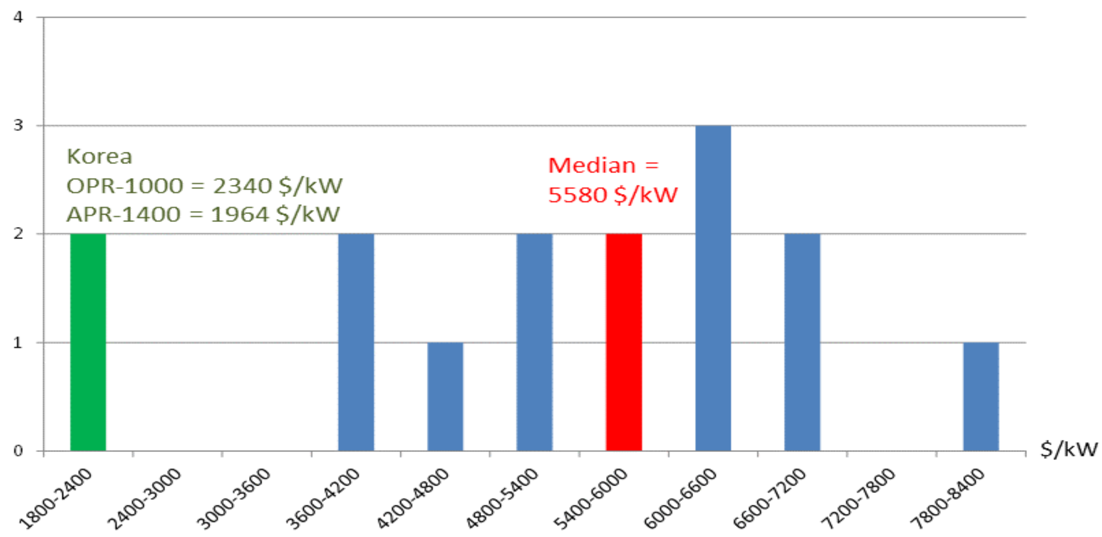
Nuclear

Nuclear investment costs in the IEA (2010c) data set also generate a wide range of cost projections. Again, Korean turnkey costs represent the low end while OECD median costs are the high end (see Figure 3.17). Most new nuclear power plants have costs between US$3,600 and US$7,200 per kW. The cost of Korean nuclear plants is around $2,000 per kW, much lower than median value of $5,580 for OECD countries.

TABLE 3.13: INVESTMENT COST OUTLOOK FOR COAL POWER IN KOREA

	Plant name	MW	Cost, $/kW* (Korean)	Cost, $/kW** (OECD)	Million $* (Korean)	Million $** (OECD)
2014	Youngheng #5	870	1065	2567	927	2,233
2014	Youngheng #6	870	1065	2567	927	2,233
2014	Donghae #1	500	1065	2567	533	1,284
2015	Samchuk #1	1000	960	2567	960	2,567
2015	Samchuk #2	1000	960	2567	960	2,567
2015	Dangjin #9	1000	960	2567	960	2,567
2015	Donghae #2	500	1065	2567	533	1,284
2015	Dongbu Green #1	500	1065	2567	533	1,284
2015	Dongbu Green #2	500	1065	2567	533	1,284
2015	Yeosu #1	350	1065	2567	373	898
2016	Dangjin #10	1000	960	2567	960	2,567
2016	Sinboryeong #1	1000	960	2567	960	2,567
2016	Taean #9	1000	960	2567	960	2,567
2016	Taean #10	1000	960	2567	960	2,567
2017	Sinboryeong #2	1000	960	2567	960	2,567
Total LCS&LNS					7,236	18,200
Total BAU					12,036	31,035

FIGURE 3.17: INVESTMENT COSTS FOR NUCLEAR POWER PLANTS IN KOREA AND OECD



Source: IEA, 2010c

*Investment Costs include pre-construction, construction (engineering, procurement and construction), contingency costs, and interest during construction (at 10% discount rate)

For the BAU and LCS scenarios it was assumed that between 2011 and 2023 capacity additions would follow the 5th Basic Plan and for 2024 through 2030 an additional 6 reactors (9 GW) would come online. Following the same methodology as applied for coal, costs were estimated using Korean as well as median OECD values. For the Korean case it was assumed that nuclear 1,000 MW units would cost $2,340 per kW, while larger reactors (1,400 and 1,500 MW) would cost $1,964 per kW. Based on these assumptions cumulative investment costs under the BAU and LCS scenarios were estimated at US$53 billion. Applying the median value of $5,580 the cumulative cost is US$146 billion. Under the LNS only those nuclear plants that have been completed or are under construction will come online (recall Table 3.5). It is assumed that plants which are scheduled to be commissioned after 2015 are eliminated. Using the Korean and median cost values, the cumulative investment cost under the LNS was estimated to be between US$12.5 billion to US$32 billion.

TABLE 3.14: INVESTMENT COST OUTLOOK FOR NUCLEAR POWER IN KOREA

	Plant name	MW	Cost, $/kW* (Korean)	Cost, $/kW** (OECD)	Million $* (Korean)	Million $** (OECD)
2011	Singori #2	1000	2340	5580	2,340	5,580
2012	Sinwolsung #1	1000	2340	5580	2,340	5,580
2013	Sinwolsung #2	1000	2340	5580	2,340	5,580
2013	Singori #3	1400	1964	5580	2,750	7,812
2014	Singori #4	1400	1964	5580	2,750	7,812
2016	Sinwoljin #1	1400	1964	5580	2,750	7,812
2017	Sinwoljin #2	1400	1964	5580	2,750	7,812
2018	Singori #5	1400	1964	5580	2,750	7,812
2019	Singori #6	1400	1964	5580	2,750	7,812

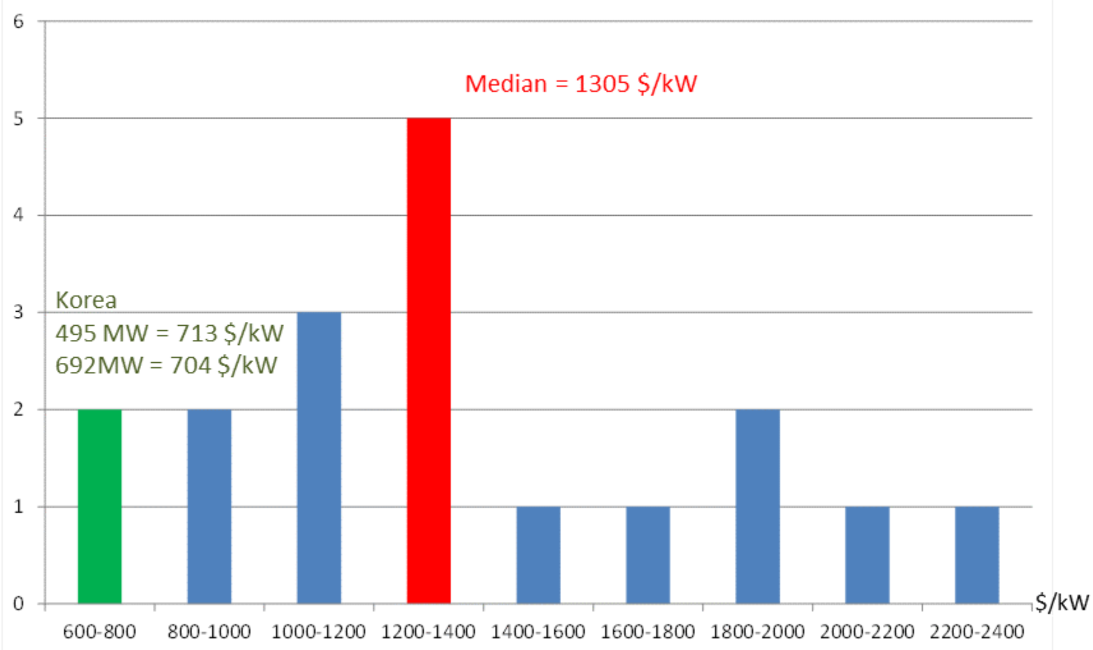
2020	Sinwoljin #3	1400	1964	5580	2,750	7,812
2021	Sinwoljin #4	1400	1964	5580	2,750	7,812
2022	Singori #7	1500	1964	5580	2,946	8,370
2023	Singori #8	1500	1964	5580	2,946	8,370
2024		1500	1964	5580	2,946	8,370
2025		1500	1964	5580	2,946	8,370
2026		1500	1964	5580	2,946	8,370
2027		1500	1964	5580	2,946	8,370
2028		1500	1964	5580	2,946	8,370
2029		1500	1964	5580	2,946	8,370
2030						
Total LNS					12,519	32,364
Total BAU&LCS					52,585	146,196

* Based on Korean Data from IEA 2010a ** Based on Median value from IEA, 2010a

Natural Gas

Under all three scenarios it was assumed that natural gas plants would follow the 5th Basic Plan schedule (Table 3.15). Cumulative investment costs for natural gas were estimated using the same method as for coal and nuclear. From the IEA (2010c) data set, the median cost of natural gas power plants is US$1,305 per kW. This is nearly two times higher than what is listed for Korea (US$700 per kW) (see Figure 3.18). Based on this schedule, cumulative investment costs for natural gas plants were estimated between US$8 billion to US$15 billion. The former assumes Korean values of $713 per kW for plants under 700 MW, and $704 per kW above 700 MW, and the latter uses a median OECD value for natural gas plants.

FIGURE 3.18: INVESTMENT COSTS FOR NATURAL GAS POWER PLANTS IN KOREA AND OECD



Source: IEA, 2010c

* Investment Costs include pre-construction, construction (engineering, procurement and construction), contingency costs, and interest during construction (at 10% discount rate)

TABLE 3.15: INVESTMENT COST OUTLOOK FOR NATURAL GAS POWER IN KOREA

	Plant name	MW	Cost, $/kW* (Korean)	Cost, $/kW** (OECD)	Million $* (Korean)	Million $** (OECD)
2011	POSCOPower #5	575	713	1305	410	750
2011	POSCOPower #6	575	713	1305	410	750
2012	Incheon #3	450	713	1305	321	587
2012	Oseong	833	704	1305	586	1087
2013	Pocheon #1	750	704	1305	528	979
2013	Bugok #3	500	713	1305	357	653
2013	Andong	400	713	1305	285	522
2014	Ansan #1	750	704	1305	528	979
2014	Jangheung	800	704	1305	563	1044
2014	Munsan	800	704	1305	563	1044
2014	Pocheon #2	750	704	1305	528	979
2014	Chuncheon	500	713	1305	357	653
2014	Seoul CC #1, 2	1000	704	1305	704	1305
2014	Dongduchen #1, 2	1500	704	1305	1056	1958
2015	POSCOPower #7	600	704	1305	422	783
2015	POSCOPower #8	600	704	1305	422	783
Total					8,041	14,855

Efficiency and Renewable Energy Scenarios

Compared to the BAU scenario, the LCS assumes lower electricity demand. As was discussed above, the lower demand is achieved through demand side measures as well as through rationalizing electricity rate structures. However, in order to estimate initial investment costs for energy efficiency it was assumed that all savings would come from energy efficiency measures. The difference between electricity demand under the BAU and LCS scenarios is equal to cumulative energy efficiency savings. Based on this data, annual efficiency savings and required annual additions were estimated (see Table 3.16). The cost of the initial investments needed to achieve this level of efficiency savings was estimated assuming a rate of $178 per MWh saved. This rate was derived from the ACEEE (2009) study, which shows that the typical levelized cost of efficiency savings is $25 per MWh. Using a 10% discount rate and an average efficiency measure life of 13 years, the initial cost corresponding to this levelized cost was calculated. Using this method, the initial investment cost was estimated to be US$30 billion.

The BAU and LCS have the same assumptions regarding renewable energy sources, but the LNS assumes a much higher role for renewables (see Tables 3.7 and 3.12). To estimate the cumulative investment costs for renewable energy sources, IEA (2010a) cost projections for different renewable and other energy sources were applied (see Table 3.17). Assuming gradually declining costs, the investment cost outlook presented in Figure 3.19 was derived. Using this outlook, the cumulative investment costs required for the BAU/LCS and LNS scenarios were calculated. The results are presented in Table 3.18. Under the LNS with a more aggressive development of solar, wind, geothermal and biomass, cumulative investments would be US$102 billion more than under the BAU or LCS. However, these cumulative costs are offset by lower investments needed for nuclear power, which is US$40 billion if using Korean values or US$114 billion if using the OECD median. The LNS would also reduce operation and maintenance (O&M) costs for nuclear power.

TABLE 3.16: INVESTMENT COSTS FOR ENERGY EFFICIENCY

	BAU, GWh	LCS, GWh	EE Savings, GWh	Savings Additions, GWh	Investment Cost, Million $
2010	425,413	425,413	0	0	$0
2011	443,787	441,926	1,861	1,861	$330
2012	462,092	457,570	4,522	2,661	$473
2013	482,401	471,996	10,405	5,883	$1,045
2014	502,614	485,051	17,563	7,158	$1,271
2015	520,842	496,590	24,252	6,689	$1,188
2016	536,092	506,482	29,610	5,358	$951
2017	550,527	515,591	34,936	5,326	$946
2018	567,175	523,867	43,308	8,372	$1,487

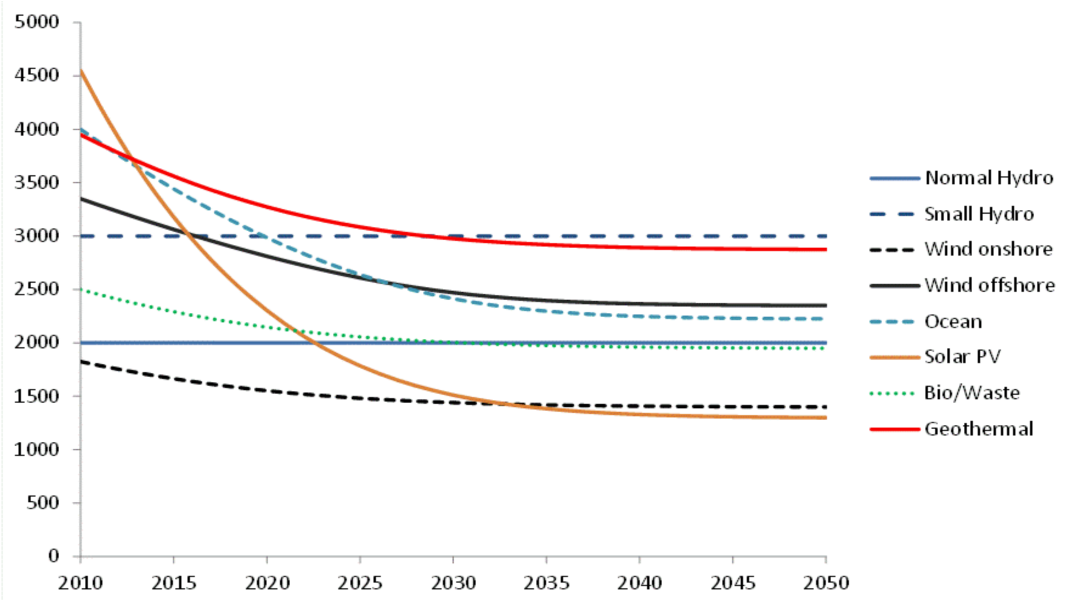
2019	582,461	531,261	51,200	7,892	$1,401
2020	598,221	535,779	62,442	11,242	$1,996
2021	612,289	540,078	72,211	9,769	$1,735
2022	626,427	544,153	82,274	10,063	$1,787
2023	640,297	547,997	92,300	10,026	$1,780
2024	653,541	551,606	101,935	9,635	$1,711
2025	677,184	565,711	111,473	9,538	$1,694
2026	693,463	571,050	122,413	10,941	$1,943
2027	709,743	576,002	133,741	11,328	$2,012
2028	726,023	580,565	145,458	11,716	$2,081
2029	742,303	584,741	157,562	12,104	$2,149
2030	758,583	588,529	170,054	12,492	$2,218
Total				170,054	$30,199

TABLE 3.17: INVESTMENT COSTS FOR RENEWABLE AND OTHER NEW ENERGY

	Investment Cost, $/kW		O&M Cost, $/kW/yr	
	2010	2050	2010	2050
Large hydro	2000	2000	40	40
Small hydro	3000	3000	60	60
Wind onshore	1450-2200	1200-1600	51	39
Wind offshore	3000-3700	2100-2600	96	68
Ocean	3000-5000	2000-2450	120	66
Solar PV	3500-5600	1000-1600	50	13
Biomass steam turbine	2500	1950	111	90
Geothermal	2400-5500	2150-3600	220	136
Fuel Cell	5000-11000	3000-4300	2.1-6.5	2-6
IGCC/CCT	2400-3200	1850-2450	72-96	56-74

Source: IEA, 2010b

FIGURE 3.19: INVESTMENT COST OUTLOOK FOR RENEWABLE ENERGY SOURCES ($/Kw)



Calculated based on IEA data. 2010b

TABLE 3.18: CUMULATIVE INVESTMENT COSTS FOR RENEWABLE AND OTHER NEW ENERGY

	BAU and LCS, Million $	LNC Million $
Normal Hydro	120	120
Small Hydro	680	680
Wind*	28,119	73,632
Ocean	10,007	10,007
Solar PV	18,339	64,854
Bio/Waste	1,072	7,544
Geothermal	182	4,029
Fuel Cell	5,355	5355
IGCC/CCT	2,300	2300
By-product gas	803	803
Total Costs	66,976	169,324

* For wind energy it is assumed that 60% would come from on-shore projects and 40% from off-shore

In addition to the initial investment costs, the three scenarios also differ on annual O&M costs. The LCS and LNS provide opportunities to reduce fuel and O&M costs for coal power plants compared to the

BAU. The LNS can save annual expenditures for nuclear power as well, but annual O&M costs for renewables are higher compared to the LCS. To estimate the difference in O&M and fuel costs for these three scenarios, IEA (2010c) median values for nuclear, coal and natural gas plants were used (see Table 3.19).

TABLE 3.19: O&M AND FUEL COST SAVINGS UNDER ALTERNATIVE SCENARIOS

$/MWh	Nuclear	Coal	NG
Fuel Costs	9.33	18.82	60.86
O&M Costs	14.74	6.02	4.38
Total Variable Costs	24.07	24.84	65.23

Source: IEA. 2010c

Under the LCS, energy efficiency measures during the 20 year forecast period will avoid 1,587 TWh of electricity. Nearly all of these savings come from reduced generation in coal power plants, and a very small portion (1 TWh) from natural gas. Cumulative O&M and fuel cost savings under the LCS compared to BAU were calculated to be US$40 billion. The higher renewable share of the electricity mix under the LNS compared to LNS and BAU allows for the elimination of most new nuclear capacity. As a result, 1,282 TWh of nuclear electricity can be displaced over 20 years. However, this scenario also requires a slight increase in natural gas generation (80 TWh) and thus reduces savings. In total, through O&M and fuel savings, the LNS saves US$65 billion resulting from diminished conventional power generation (see Table 3.20).

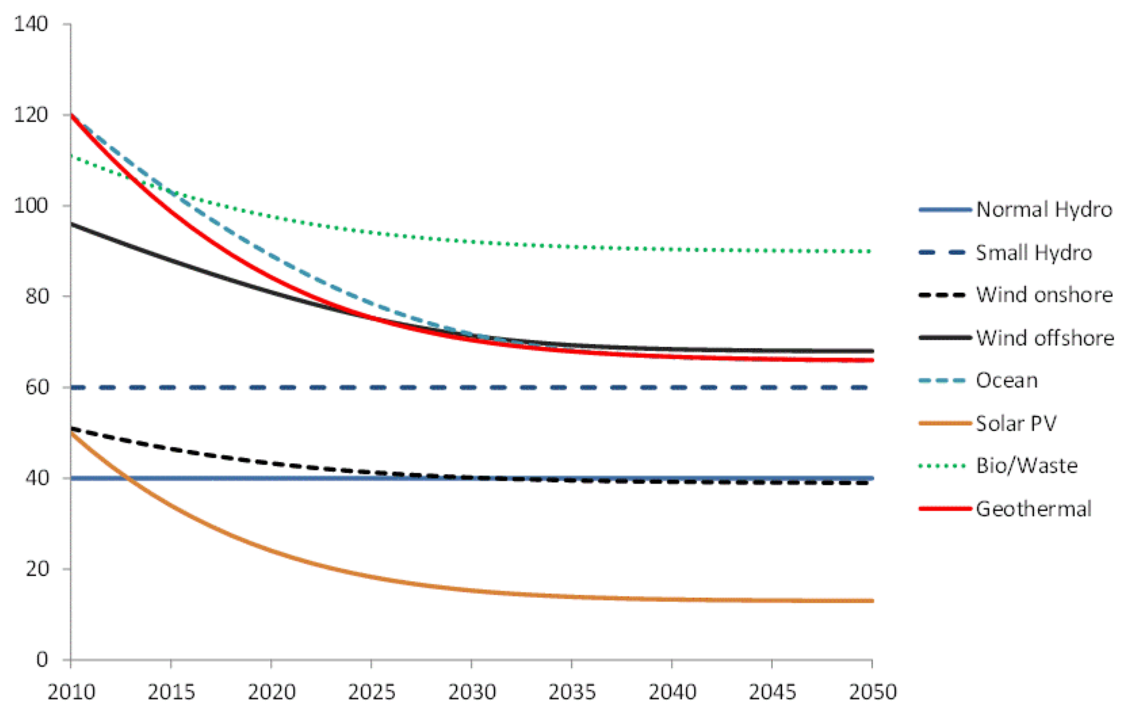
TABLE 3.20: CUMULATIVE O&M COST SAVINGS UNDER LCS AND LNS

	TWh Displaced				Million $ Saved			
	Δ Nuclear	Δ Coal	Δ NG	Δ Total	Δ Nuclear	Δ Coal	Δ NG	Δ Total
LCS vs. BAU	0	1,586	1	1,587	0	39,392	95	39,488
LNS vs. BAU	1,282	1,586	-80	2,788	30,867	39,392	-5,237	65,022

The LNS assumes a higher level of renewable energy supply compared to the BAU and LCS. Therefore, it is expected that the LNS scenario would have higher associated O&M costs for renewables. To estimate these values for different renewable energy sources, the data in Table 3.17 was used. These date together with the assumption of O&M cost reductions for these technologies lead to, the O&M cost outlook presented in Figure 3.20 below.

Using the O&M cost outlook for renewable energy sources below as well as projected renewable generation under the LNS and BAU scenarios, cumulative O&M costs were calculated. Based on these calculations the LNS would need US$22 billion more than the BAU or LCS for the projected period for O&M (see Table 3.21). Note that the cost profile for both the LCS and BAU scenarios is the same.

FIGURE 3.20: ANNUAL O&M COSTS FOR RENEWABLE ENERGY SOURCES ($/kW/year)



Calculated based on data from IEA, 2010b

TABLE 3.21 CUMULATIVE O&M COSTS FOR RENEWABLE ENERGY UNDER THREE SCENARIOS

	BAU and LCS, Million $	LNS, Million $	Δ LNS vs BAU, Million $
Normal Hydro	1,272	1,272	-
Small Hydro	259	259	-
Wind	6,786	23,339	16,553
Ocean	3,653	3,653	-
Solar PV	1,558	4,955	3,397
Bio/Waste	759	2,495	1,735
Geothermal	28	333	305
Fuel Cell	28	28	-
IGCC/CCT	875	875	-
	14,315	36,305	21,990

Table 3.22 provides a summary comparison of the three scenarios. Investment costs for conventional power plants are reported for both Korean as well as OECD median values. Based on the analysis presented above, under the LCS total cumulative investment costs, including energy efficiency and renewable energy, will be by US$17-25 billion higher than under the BAU. Likewise, investment costs under the LNS will be US$6-88 billion higher than under the BAU. Lower numbers are linked to higher power plant costs savings if median OECD values are used. Although initial investment costs for the LCS

and LNS are higher than the BAU, O&M and fuel savings lower the cumulative costs of these scenarios. In the case of the LCS, total savings compared to the BAU ranges from US$14 billion-$22 billion. The results of the LNS costs could potentially exceed the BAU by US$45 billion or be lower by US$38 billion, depending on whether Korean or OECD median values are used to calculate investment costs.

TABLE 3.22: SUMMARY OF COST COMPARISON FOR THREE SCENARIOS (million US $s)

	BAU		**LCS**		**LNS**	
Basis of Investment Cost Values	Korean	Median	Korean	Median	Korean	Median
Coal	12,036	31,035	7,236	18,200	7,236	18,200
Nuclear	52,585	146,196	52,585	146,196	12,519	32,364
NG	8,041	14,855	8,041	14,855	8,041	14,855
EE	-		30,199		30,199	
Renewables & NE	66,976		66,976		169,324	
Total Investment Costs	**139,638**	**259,062**	**165,037**	**276,426**	**227,319**	**264,942**
Δ Investment Costs Compared to BAU scenario	**-**	**-**	**25,399**	**17,364**	**87,681**	**5,880**
O&M and Fuel Cost Savings Compared to BAU	-		-39,488		-65,022	
Additional O&M Costs for Renewables Compared to BAU	-		-		21,990	
Δ Total Costs Compared to BAU Scenario	**-**	**-**	**-14,089**	**-22,124**	**44,649**	**-37,152**

3.3.5 Conclusion

Korea continues to pursue a policy of nuclear development with a limited growth outlook for renewable energy. Even energy efficiency targets set by the government in recent policies are conservative compared to the potential savings identified in several studies. Nonetheless, Korea has identified nuclear as the principal form of energy to replace fossil fuel-based electricity generation over the next two decades. This was depicted as the BAU scenario projected in this chapter.

Alternatives to Korea's current energy path do exist. The analysis in this chapter has identified two potential scenarios, a low carbon and a low nuclear scenario. The former projects energy supply under a more aggressive energy efficiency program than is pursued in the BAU. A low carbon pathway can meet up to 22.4% of projected demand through improved efficiency, demand side management schemes, and "rationalization" of electricity pricing structures. By doing so, some of Korea's fossil fuel-based generation could be eliminated from the future energy mix, helping the country realize its carbon emissions reductions targets by 2030.

The low nuclear scenario expanded upon the low carbon pathway by applying both an enhanced energy efficiency policy with a more aggressive policy to develop Korea's renewable and alternative energy sources. This assumes standard development of renewable energy technologies with limited potential in Korea such as hydro, ocean or tidal power, and by-product gas. A logistic growth model was applied to estimate the potential share of wind, solar PV, biomass, and geothermal energy. If these resources are fully developed, the nuclear power share could be limited to 23% of projected demand in 2030 in addition to reducing coal generation to a 14% share.

Finally, the analysis in this chapter explored the economic impacts associated with each scenario. It found that both the LCS and the LNS require higher initial investments compared to the BAU; however, the LCS produces significant savings compared to the BAU regardless of whether Korean or OECD median turnkey costs are applied. The LNS produces vaguer results, with overall costs projected as being either higher or lower than the BAU depending on whether Korean or OECD values are used largely due to the increased investment and O&M costs associated with renewable energy technology.

3.4 International Cooperation Initiatives in Korea

The broad energy security risks for South Korea involve a widening gap between the amount of fossil fuel imports and indigenous fossil fuel reserves, environmental externalities due to fossil fuel use, the constrained ability of local energy industries to adapt to volatile deregulated energy markets, and political challenges that potentially constrain regional investments inn energy infrastructure and trade. Addressing such types of risk requires international cooperation to expand energy efficiency, renewable energy and clean energy technology in Korea.

The nuclear accident in Fukushima clearly highlighted the need for Korea to account for both traditional energy security concerns that result from increasing reliance on imported fuels and the vulnerability to severe energy shortages that would follow any sudden reduction in domestic power production. With the temporary and/or permanent closure of many nuclear reactors in Japan, the country needed to replace lost power, and Tokyo had little choice but to increase fossil fuel consumption to meet power demand. This strategy has negatively affected the economy of Japan due to the rising cost of fossil fuels. Furthermore, and in relation with the environmental sustainability dimension of energy security, Japan's extra consumption of fossil fuels has significantly increased its greenhouse gas emissions and has affected the country's ability to meet its commitments to the Kyoto targets. Overall, the energy security risks faced by Japan due to the accident in Fukushima reveal the importance for Korean policymakers of considering the cost and benefits of strengthening the reliability of domestic energy sources and the extent to which the country needs to have in place domestic energy response measures (Vivoda, 2012).

This section will present international initiatives and partnerships for energy cooperation in which Korea participates and will conclude with policy recommendations seeking to strengthen energy security in the country. The next section presents international initiatives and partnerships for energy cooperation in which Korea is already actively participating. The final sections will explore recommendations to improve Korea's participation in international initiatives and enhance international, regional, and domestic energy security through clean or efficient energy technologies and renewable and alternative energy programs.

3.4.1 International Initiatives and Partnerships

APEC Energy Working Group (EWG)

As a member nation of Asia-Pacific Economic Cooperation (APEC), Korea cooperates with 21 Pacific Rim countries to promote energy security and efficiency. The 21 member nations of APEC represent more than one third (2.6 billion people) of the global population. They also account for 60% of global GDP and approximately 47% of world trade. Therefore, the importance of cooperation on energy security, energy efficiency and renewably energy in the region cannot be overstated.

The Energy Working Group (EWG) of APEC was launched in 1990 in an effort to promote regional economic development by maximizing the energy sector's contribution while limiting environmental degradation from the use of fossil fuels. In response to the call by economic leaders "for appropriate measures to promote stability in the mutual interests of consumers and producers" (APEC, 2000: 1), the EWG recommended an Energy Security Initiative (APEC Energy Working Group, 2004).

The Energy Security initiative includes short-term and long-term cooperative actions to achieve energy security in the Asia-Pacific region. The highlighted issues in the initiative are as follows: the monthly oil data initiative to promote monthly oil data sharing; sea land security; real-time emergency information sharing; oil supply emergency response information; and, non-petroleum and long-term concerns. The long-term programs in the initiative recommend related expert groups to work closely on energy efficiency and promote greater use of non-petroleum energy sources.

The four expert groups designed to support EWG are the Expert Groups on Clean Fossil Energy (EGCFE), Efficiency and Conservation (EGEEC), Energy Data and Analysis (EGEDA) and New & Renewable Energy Technologies (EGNRET). Of these, Korea is working most closely with the EGNRET. The EGNRET projects include developing policy recommendations, conducting renewable resources assessments, encouraging information exchange, promoting commercialization of renewable energy technologies, identifying and mobilizing finance sources, and promoting technology cooperation. Since 1993, Korea has been participating in EGNRET meetings regularly and engaging in energy cooperation through efforts such as provision of new and renewable energy policy information.

Another APEC initiative is the Energy Smart Communities Initiative (ESCI), launched in 2010. The ESCI seeks to promote energy security, reduce greenhouse gas emissions, enhance sustainable economic growth, expand employment opportunities, and achieve energy intensity targets. The four key pillars of the initiative are Smart Transport, Smart Buildings, Smart Grid, and Smart Jobs and Consumers.

Korea has been involved in the Smart Buildings project, which aims to establish a building materials testing and rating center that will provide data so that consumers and businesses can be confident in purchasing energy-efficient building components from any APEC region. Korea also participates in the Cool Roof Demonstrations project to document cost savings from roofs in a range of building types and climates. The results will be used to promote cost-effective use of cool roofs in buildings throughout the APEC region.

As part of the Smart Grid pillar, Korea participates in the Interoperability Survey and Road Map project to support efficient energy use and greater penetration of intermittent renewable power sources. Korea also will lead an effort to build and operate a Smart Grid Test Bed Network. At the 37th meeting of the EGNRET on August 22-26, 2011, Korea agreed to support and be a co-sponsoring economy of the two Russian projects, “Piloting Smart/micro Grid Projects for Insular and Remote Localities in APEC Economies” and “Prospects for Marine Current Energy Generation in APEC Region.” These projects aim to explore marine energy opportunities and integrate smart grid and micro-grid technologies to maximize economic and environmental benefits, respectively (MERF, 2011).

The Clean Energy Ministerial Initiative of the International Energy Agency

There are a number of other initiatives on international energy cooperation in which the Republic of Korea participates. This section describes these initiatives, particularly those organized by the International Energy Agency (IEA), maps their primary functions in relation to Korea, and highlights cases where Korea collaborates with the U.S., Japan, and China.

Following the Fukushima nuclear accident in 2011, IEA published the *Clean Energy Progress Report: IEA input to the Clean Energy Ministerial*, a document that develops recommendations as input for the discussions that took place among member countries’ ministers in the second Clean Energy Ministerial (CEM) in Abu Dhabi in 2011 (IEA, 2011f). The Clean Energy Ministerial provides an international forum for sharing information and knowledge, and for forming commitments to action on clean energy development. The forum, comprised of 23 key governments including Korea, sets ambitious goals for the global development of clean energy technologies. The CEM promotes various actions in collaboration with existing international initiatives on technology deployment, such as the International Low-Carbon Technology Platform or the European Union Strategic Energy Technology Plan. The main recommendations to the ministers are summarized as follows (IEA, 2011f):

- Use the CEM meeting as a vehicle for the commitment of governments and the private sector to launch financial mechanisms, targeted policies and/or procurement provisions in favor of clean energy technologies.
- Work closely with IEA to collect and share data on technology deployment, implementation of programs, and investments in clean energy research, development and deployment.
- Conduct analysis to identify the most promising products and technologies for common standards and map the existing initiatives on the harmonization of technologies for specific technology fields.
- Mobilize the participation of the private sector on best example practices for research, development & deployment, and innovation for clean energy technologies.

Regarding key factors that should be addressed in the development of the global clean energy technology plan, CEM suggests that governments should increase the public funding available for energy technology innovation. In addition, special emphasis should be placed on the exploitation of the large untapped potential currently available for energy efficiency improvements in all sectors of the economy. For example, targeted policy interventions should be developed for energy efficiency practices that would sustain efficiency improvements. Apart from energy efficiency, governments should continue to improve policy innovations for renewable energy, for example by removing non-financial barriers or creating attractive and transparent frameworks for investment. An energy initiative that should receive particular attention within the next 10 years is the market diffusion of electric vehicles. Finally, governments should develop integrated systems for clean energy technologies, a goal which calls for energy interventions in the energy grid infrastructure of urban areas. Smart grids should be scaled up through the development of large scale energy systems and system-wide energy infrastructure renovation in order to support the integration of energy supply and demand with the transport sector (IEA, 2011f).

As highlighted above, the CEM initiative aims to bring large scale development and implementation of clean energy technology. A mechanism which the CEM recommends as necessary to deliver this policy goal is the development of public-private partnerships. To set this process in motion, CEM has been conducting roundtable forums which bring together energy ministers, government officials, business leaders, and experts from NGOs. The main themes of the dialogue involve policies for the global development of renewable energy, technology innovation and business strategies for energy efficiency, clean energy development in cities, and regulatory provisions to speed-up utility scale energy efficiency interventions (CEM, 2011a). CEM also collaborates with other initiatives for international energy cooperation: For example, in conjunction with the International Renewable Energy Agency (IRENA), CEM has developed a consistent prototype of Global Atlas under the Multilateral Solar and Wind Working Group initiative (CEM, 2011b).

In order to provide a more specific idea of the type of initiatives in which Korea participates in the Clean Energy Ministerial, the following table presents the initiatives split by participant country:

TABLE 3.23: COUNTRY PARTICIPATION IN CLEAN ENERGY MINISTERIAL INITIATIVES, 2012

Participation in Clean Energy Ministerial Initiatives

January 2012

	Australia	Brazil	Canada	China	Denmark	European Commission	Finland	France	Germany	India	Indonesia	Italy	Japan	Korea	Mexico	Norway	Russia	South Africa	Spain	Sweden	United Arab Emirates	United Kingdom	United States
APPLIANCES (SEAD)	●	●	●			●		●	●	●			●	●	●		●	●		●	●	●	●
BIOENERGY		●			●							●								●			
BUILDINGS AND INDUSTRY (GSEP)	●		●		●	●	●	●		●			●	●	●		●	●		●			●
CARBON CAPTURE (CCUS)	●		●	●				●	●				●	●	●	●		●			●	●	●
CLEAN ENERGY POLICY	●							●		●		●	●		●			●		●	●		●
ELECTRIC VEHICLES (EVI)				●	●		●	●	●	●			●					●	●	●		●	●
ENERGY ACCESS (SLED)												●											●
HYDROPOWER		●						●							●	●							●
SMART GRID (ISGAN)	●		●	●		●	●	●	●	●		●	●	●	●	●	●		●	●		●	●
SOLAR AND WIND	●	●			●	●		●	●				●	●	●	●		●	●		●	●	●
WOMEN IN CLEAN ENERGY (C3E)	●				●										●	●		●		●	●	●	●

Non-CEM governments, nongovernmental organizations, and private businesses also participate in selected initiatives.

Source: CEM, 2012c

The Global Superior Energy Performance Partnership of the CEM

At its first meeting in July, 2010, CEM launched the Global Superior Energy Performance Partnership (GSEP) which aims to reduce global energy use in industrial and commercial buildings through improvements in energy efficiency. The use of public-private partnerships is a main mechanism that targets cooperation for selected technologies or interventions in individual energy-intensive sectors. The Energy Management Certification Group of GSEP is responsible for sharing best practices among countries, developing national programs, and ensuring harmonization across national policies (IPEEC, 2011). The countries of Korea, the U.S., and Japan participate in GSEP (CEM, 2011d).

Asia-Pacific Partnership (APP) on Clean Development and Climate

Representatives from Australia, Canada, China, India, Japan, Korea and the U.S. worked together from 2006 through 2011 as part of the Asia-Pacific Partnership (APP). The partnership aimed to expand investment and trade in cleaner energy technologies, goods and services, as well as to promote best practical technologies in its partner countries. There were nine public sector task forces in total, all focused on improving energy efficiency and promoting renewable energy: aluminium, building and appliances, cement, cleaner fossil energy, coal mining, power generation and transmission, renewable energy and distributed generation, and steel. Korea participated in many of the projects within the partnership. Several of the most prominent projects are those: exploring construction of super high efficiency solar light station in critical scale; verifying the commercialization of the proton-exchange membrane fuel cell (PEMFC) for power generation; researching bioenergy for environmentally sustainable energy and water; advancing the APP mega solar light project; supplying China with CHP systems using coke gas and; building renewable energy hubs in the rural districts of China and India.

Renewable Energy and Energy Efficiency Partnership (REEEP)

The Renewable Energy & Energy Efficiency Partnership is a non-profit agency established in 2002. Its aim is to catalyze markets for renewable energy and energy efficiency. Currently, REEEP involves 400 partners. Apart from 45 governments, the agency consists of private companies, international organizations and individuals. Key activities of REEEP cover the following aspects (REEEP, 2012): 1) Initiate and fund projects, which establish a favorable regulatory framework and provide financial and business support in partner countries; 2) Develop policy-maker networks through initiatives such as the Energy Efficiency Coalition (EEC), the Sustainable Energy Regulation Network (SERN) and Renewable Energy and International Law (REIL); and 3) Build capacity and increase learning of sustainable energy growth though publications, websites and events. Even though the partnership focuses heavily on emerging economies and developing nations, numerous governments of developed countries also participate including Australia, Canada, Germany, Italy, the Netherlands, Norway, the U.S. and South Korea through the Korean Ministry of Commerce, Industry & Energy.

International Renewable Energy Agency (IRENA)

Launched in 2009, IRENA does not have a long history, but as of January 2012, it had 155 member states including the EU, 86 of which have ratified its statute. As an intergovernmental organization dedicated specifically to renewable energy development, IRENA shows an unprecedented level of engagement not only from governments but also from non-governmental organizations and the private sector. Korea is the second largest country in IRENA to provide Official Development Assistance. Also, Korea hosted the second regional workshop in cooperation with IRENA in Seoul in October of 2010 – the first was held in the United Arab Emirates (IRENA, 2011). The workshop was dedicated to helping people understand the situation of renewable energy deployment and policy landscape of the Asia-Pacific region, identifying difficulties of promoting renewable energies, and exploring measures to overcome them.

ASEAN+3 Energy Meeting

Since 1997, 10 member nations (Philippines, Indonesia, Malaysia, Singapore, Thailand, Myanmar, Cambodia, Laos, Vietnam and Brunei) of the Association of Southeast Asian Nations (ASEAN) and three non-ASEAN nations, Korea, China and Japan, have formed a forum, ASEAN Plus Three (ASEAN+3) to discuss various issues regarding regional politics, economics, and security.

In October 2004, the first ASEAN+3 New and Renewable Energy forum was held in Seoul (MKE, 2010b). During the forum, the member nations' representatives discussed each nation's new and renewable energy status and opportunities for multilateral cooperation. In March, 2008, the 4th ASEAN+3 New and Renewable Energy Forum was held in Seoul. The participating nations exchanged views on national trends and discussed opportunities for joint research and technology cooperation into bioenergy resources. The 8th ASEAN+3 Ministers on Energy meeting was held in Brunei Darussalam in September, 2011. During that meeting the ministers agreed to develop initiatives to promote renewable energy, energy efficiency and conservation through greater involvement of the private sector and relevant institutions. Additionally, initiatives relating to smart grid technologies and demand side energy management efforts to reduce energy intensity in the transportation sector were discussed.

3.4.2 Bilateral Energy Cooperation

Korea-China energy cooperation

Existing Korea-China Energy Cooperation

An important area for strategic cooperation between Korea and China has been regarding petroleum reserves. For example, in 2006, Korea had an oil storage capacity surplus of 43 million barrels; at the same time, China was exploring the creation of an emergency oil stockpile at that time. Since joint oil stockpiling would be beneficial to the stabilization of both oil price and oil supply in the region, the Chinaoil and Korea National Oil Corporation (KNOC) renewed their joint contract for oil stockpiling in September of that 2006 (Oh, 2007)d.

The nuclear power industry is another realm in which both China and Korea have benefitted from cooperation. China's plans to construct more nuclear reactors have provided several opportunities for Korean companies. Korea Doosan Heavy Industries & Construction provided key reactor parts for reactors to be built in Haiyang and Sanmen, China (Park, 2007). Furthermore, government leaders of China and South Korea have reaffirmed the importance of nuclear energy, and agreed to increase their cooperation on nuclear safety and disaster preparedness after the Fukushima nuclear accidents in Japan.

In terms of renewable energy, the Korea Electric Power Corporation participated in the Wuzhi thermal power plant construction in China's Henan province and the Saihanpo wind power plant in Neimenggu, in 2006 (Oh, 2007). In addition, in January, 2012, Korean president Lee Myung-bak visited Chinese chairman Hu Jintao in Beijing. In a joint press communiqué they revealed intentions to strengthen cooperation on renewable energy and energy efficiency, and to develop common industrial standards and certification. Recently, various energy forums have been held or planned in order to explore further opportunities for energy cooperation between these two countries. For example, the third China-Korea Green Economic Cooperation Forum was held in April of 2011 in Wuxi, China (JEShine, 2012). The forum attracted more than 300 energy experts from industry, academia and government covering topics including solar, wind, water treatment technologies, batteries, oil, and natural gas. For China and Korea, a focus of strategic cooperation is the PV industry. The Chinese PV industry, though a global leader in production, is limited by its lack of advanced technology, particularly in silicon extraction. The Korean company OCI, a global giant in silicon refining, suggested that China and Korea open their PV markets in order to form a competitive, large scale, high-tech PV industry, thus lowering cost and increasing market penetration substantially.

Prospects for energy cooperation between Korea and China

The cooperation and collaboration between Korea and China on energy issues has great potential in the future. Based on the complementary situation in energy resources, especially solar, geothermal and wind, it is expected that cooperation between the two countries will be strengthened and enhanced on a larger scale and deeper level. Focus could be placed on the following aspects: strategic planning through increased communication and dialogue regarding climate change and policy measures at the highest governmental levels; and the establishment of new institutional frameworks such as treaties and charters (Han, 2008). At lower governmental levels, communication and collaboration between related industries, enterprises, research institutes, or even university labs should be facilitated in areas related to advanced power generation, power transmission, renewable energy exploration and utilization. Public and private partnership should be developed in order to reflect private sector's opinions and ideas at government level. In one example, Cho and Katz estimate that US$7.5 billion dollars is required for infrastructure development in Northeast Asia in the following 15 or 20 years (Doh, 2003). However, there is a financing gap at around US$5.0 billion a year. To fill the gap, a new institutional arrangement – a sub-regional development bank – could provide an effective option.

Korean-Japan energy cooperation

Between 1986 and 1997 Korea and Japan held 11 meetings for working-level officials to discuss energy cooperation. The officials discussed structural reform in energy industry, energy supply and demand prospects, cooperation in energy technology, and other energy related topics. The meetings came to halt for few years, then resumed in March, 2004 (MKE, 2010c). The November 2005 Korea-Japan Joint Seminar on New and Renewable Energy in Seoul, the November 2006 joint seminar for wind power generation in Seoul, the joint seminar for hydrogen fuel cells in Chiba, Japan, and the October 2008 joint seminar on wind energy in Seoul reflect the renewed dedication to cooperation and discussion between Korea and Japan.

In 2011, at the 16th meeting for Korea-Japan energy cooperation held by the Ministry of Knowledge Economy (MKE), Korea shared its vision to implement the Renewable Portfolio Standard (RPS) in 2012. Korea shared its vision to implement the 2012 Renewable Portfolio Standard (RPS), and its plan to generate 11% of the nation's electricity supply from new and renewable sources by 2030. Similarly, Japan showed progress made in its recently launched nationwide energy conservation campaign – implemented to prevent summer power shortages (MKE, 2011).

Korean-U.S. energy cooperation

Energy cooperation between the Republic of Korea and the U.S. is quite strong and close incorporating many multilateral initiatives, such as the Major Economies Forum, Clean Energy Ministerial, the Asia Pacific Economic Cooperation Forum, the International Energy Agency the Korea-led Global Green Growth Institute. In October 2011, Korea and the U.S. signed a new agreement to further strengthen cooperation. The newly established U.S.-Korea Clean Energy Technology Partnership clearly states that the two countries will cooperate on clean energy research of energy efficiency, renewable energy, smart grid technology, green transportation, carbon capture and storage, and energy storage system (DOE, 2011).

In terms of nuclear energy programs, due to political concerns, cooperation between Korea and the U.S. is very subtle. Under Section 123 of the U.S. Atomic Energy Act of 1954, Korea must obtain U.S. consent for any reprocessing or enrichment activities related to nuclear materials or technology supplied by the U.S (Holt, 2013). According to the agreement signed in 1973, Korea is banned from reprocessing spent fuel to prevent weapons proliferation (von Hippel, 2010). However, with the pact scheduled to expire in 2014 and Korea's storage capacity for spent fuel approaching its limit in 2016, Korean officials are calling for a change of the reprocessing restrictions in order to allow pyro-processing technology. Legislation to authorize the two-year extension to the agreement was introduced into the U.S. House of Representatives in June of 2013. While U.S. involvement in the development of domestic nuclear plants in Korea may be small, it will be involved as Korea ramps up the export of its nuclear technology since U.S.-made components and U.S. engineering have been incorporated into that technology. In this and other arenas, U.S-Korea cooperation on nuclear technology will continue.

3.4.3 Supportive Institutional Frameworks for Regional Energy Security

Broad policy recommendations from literature

Since enhanced international energy cooperation in the region would require large amounts of capital and funding for joint projects for which the requisite institutional frameworks and financial mechanisms particularly for this objective need to be created or improved. For example, a new financial institution in the form of a regional bank could be founded to provide the level of funding required for the materialization of inter-regional energy infrastructure. In addition to funding provisions, the institutional and regulatory frameworks for energy projects should be developed that will be supportive and conducive of implementing joint projects at the regional level. Regional cooperation on renewable energy and energy efficient technologies can be pursued through initiatives such as country to country grants, sharing of technical expertise, joint ventures for the manufacturing of energy efficiency and renewable energy devices, greenhouse gas emissions trading arrangements or co-funding of research projects for the joint development of key energy technologies. This would involve fostering of public-private partnerships as well as the development of competitive market structures that would eliminate structural barriers to international capital flows for energy projects in the region.

These types of institutional and financial reforms need to be based on a clear vision for energy cooperation that is shared by high level governmental officials and agencies of the region (Doh, 2003). One policy goal of such regional cooperation should be the exploitation of regional economies of scale in order to develop larger production capacity of more efficient technologies in the near future (Hippel *et al*., 2012a). Other goals are discussed in the sections that follow.

Strengthened regional electricity infrastructure

Strengthening the energy infrastructure of the region is a key component in fostering regional energy security through renewable energy development. This would involve increasing the interconnection between the electricity grids of the countries in the region. A number of different schemes have been proposed for the region including a transmission 'ring' which will surround the Sea of Japan/Korea East Sea. In certain cases, seasonal differences between peak electricity loads across countries of the region might constitute a viable market for electricity trading. For example, electricity demand in the Republic of Korea's grid peaks in summer while the Democratic People's Republic of Korea (DPRK) demand is highest in winter (von Hippel *et al*., 2012b). However, studies suggest that the potential seasonal south-north power export might be limited. Key aspects that need to be taken into consideration for grid interconnections in the region to facilitate regional renewable electricity flows include (Hippel *et al*., 2012b):

- A full monetary cost and benefit analysis of the project. For example, this would include the cost of the transmission line. It is estimated that a line that crosses the Russian Far East area to Korea passing through DPRK would cost on the level of $0.5 to $1 billion.
- The seasonal availability of electricity for exchange between the countries of the region.
- Environmental impacts of transmission lines, plants siting and operations.
- Institutional and pricing arrangements. The establishment of a widely accepted multi-lateral institution to administer the operation of the region's transmission link.

The realization of regional large infrastructure project to promote renewable electricity trade and flows would depend on a number of factors. First, the availability and stability of finance as typically electricity infrastructure projects require investments in the order of billions of dollars. This would require collaboration between large public and private organizations. Strong and solid financial banking would be necessary since the projects would transverse a number of countries, a factor which raises project development costs. Second, the project planning and operation should be transparent between countries. For example, data should be freely accessible. Third, electricity pricing within the regional system must be transparent and stable. This can be a challenging task since the electricity will pass through several countries and that passage will need to be supported by a variety of agencies and companies. Fourth, project regulations, technical, environmental, and administrative, need to be agreed upon between the countries in advance. Fifth, local social and economic impacts associated with regional energy infrastructure projects need to be minimized while net benefits such as energy security, economic efficiency or economic development should be fostered across countries (Hippel *et al*., 2012b).

3.4.4 Conclusion

Korea has been involved in a number of initiatives to promote energy efficiency, renewable energy, and energy security in the Asian geopolitical sphere. It has also participated in a number of bilateral agreements with key energy-consuming nations such as China, the U.S. and Japan. Following the Fukushima disaster, these partnerships will play an important role in Korean energy policy, especially due to the potential for renewable energy and energy efficiency technology sharing and market development. It is important to note, however, that despite Korea's current level of involvement in various organizations, initiatives, and partnerships, significant opportunities to augment its level of cooperation and activity exist. Among these opportunities, investment in and expansion of regional energy and electricity infrastructure may be among several recommendations that will help Korea overcome its energy challenges in the future.

3.5 Recommendations for Korean Policy

As Korea forms the 2nd National Energy Basic Plan, set to be released in 2013, it must consider the implications of the various energy choices and paths it faces. The previous energy plan emphasized growth in nuclear power that would replace coal as the dominant energy source, helping to reduce carbon emissions in line with its "low carbon, green growth" policy, and also enhanced energy security through diversification of its energy resource base. The Fukushima disaster has forced Korean policy makers to reconsider the targets of the previous plan. Based on the work conducted in this report, several recommendations regarding energy mix options and future international or regional cooperation initiatives can be suggested that will both inform and enhance Korean energy policy formation. This chapter reviews the factors and recommendations that have the greatest implications for policy in the future.

3.5.1 Key Factors and Trends following Fukushima

Although recent decisions and the continuing construction and approval of nuclear reactors indicate no significant shifts in long-term nuclear and energy policy, several key factors shaping the policy and technology landscape may ultimately alter the prospects for Korea's energy outlook as well. Of those factors, three portend to impact decisions on nuclear power more than any others. They are the shift in the global nuclear industry following Fukushima, the rising global influence of cheap natural gas, and the growing prospects for alternative energy technologies and energy efficiency. As discussed in the first two parts of this report, Fukushima created varied responses and a wide range of policy impacts in the six countries examined. Several, such as the U.K., the U.S., and China seemed to exhibit particularly muted impacts of the accident. Approved and ongoing projects progressed with only minor delays due to the Japanese crisis, suggesting these nations' commitments to new nuclear power remains steadfast. However, the full implications of the accident, particularly in terms of influence on cost projections, have yet to be accounted for. Already, financing for major new units in the U.K. has disappeared, and construction timelines on new U.S. reactors have been extended in the face of new safety and regulatory hurdles (Bonner, 2012; Nuclear Street, 2012a).

The drastic changes in Germany's and Japan's, and a potential shift in France's polices have already been documented, but the consequences for policy and markets haven't yet fully surfaced. Germany, as noted, has adopted the most radical shift in that it will decommission all its reactors by 2022, and, more importantly, its major utilities, such as E.ON and RWE, and nuclear technology leader Siemens have all made moves towards full or partial exit from the nuclear market. These decisions have already created substantial upheaval in the nuclear industry, most notably in the loss of financing for the U.K.'s Project Horizon. Despite the rejection of a full-scale phase out with the election of Prime Minister Noda in 2011, Japan faces a vastly altered outlook for its nuclear share for the future, falling from a target of nearly 50% to potentially much less. Finally, with the election of François Hollande in May of 2012, France faces a declining nuclear presence for the first time in four decades, and the difficulties encountered by AREVA and EDF in building a new generation of reactors will have far-reaching implications for the nuclear market in Europe and abroad (Webb, 2012). Critically for Korea, although interest remains, many nations seeking to import nuclear technology have cause for concern due to safety and economic considerations in the time since the Fukushima accident.

The vast supply of natural gas and its versatility as a substitute for oil have both led to the growing deployment of gas-fired technologies in numerous sectors, especially the power sector. The exploitation of new reserves in Russia and unconventional gas resources in the United States will play a major role in the energy mix discussion over the next decades. Both sources of gas require significant infrastructure investments for transport, but as the prospects to move more natural gas into Korea near realization, it is important to consider the potential consequences (Lee, 2012b). First, imported Russian and U.S. gas may improve energy diversity and security in Korea, a key goal of energy policy. Second, and more importantly, Russian and particularly U.S. gas may lead to price reductions due to convergence of spot and oil-indexed prices. With access to cheap gas, large-scale nuclear power investments may become less attractive due to the ability to dispatch gas turbines at capacities and along timelines that match the incremental rise in demand.

The final factor that may impact Korean is the steady decline in costs of renewable energy technologies and, especially, energy efficiency investments. Already, the Korean government has aimed to promote renewable energy, especially wind, through implementation of a new renewable portfolio standard. Furthermore, a 42% reduction in energy intensity is targeted for the future, and about a 25% improvement against BAU is deemed feasible. However, rates of deployment of efficiency technology and renewable energy have been limited to date. As demand-side programs receive greater attention and the levelized costs of efficiency and alternative energy investments improve in competitiveness, the large-scale installations, long lead times, and huge capital cost outlays of nuclear power become less attractive. As Korea reevaluates its current energy policy in light of Fukushima, energy efficiency and renewable energy will be increasingly feasible and attractive alternatives to growing nuclear dependence.

3.5.2 Recommendations for Korean Energy Policy and Cooperation

In light of these trends, and as a result of the work conducted in this report, several recommendations can be made. The first few recommendations are intended to inform future Korean energy policy directly, based on analysis of the energy scenarios generated for this report. The lists of recommendations that follow are formed as means to improve domestic, regional, and international efforts to promote renewable energy and energy efficiency. Together, these recommendations have the potential to enhance energy policy and security significantly.

Recommendations

The BAU scenario generated for this report suggests numerous opportunities to invest in alternative options, and thereby achieve many of Korea's energy goals. The first and most viable option depends on the development of energy efficiency. The first alternative scenario presented above, labelled the "low carbon" scenario, demonstrated an efficiency improvement of 22.4% compared to the BAU. Not only is this target feasible by Korean standards, but it is also relatively conservative compared to assessments of the full potential of efficiency upgrades in the country. Energy efficiency replaces significant shares of coal, which helps Korea meet its stated emissions reductions targets by 2030, and the pursuit of efficiency investments rather than investment in electrical generation plants also provides significant flexibility to adjust future energy mix options to changing circumstances. Furthermore, energy efficiency can result in savings of between $14-22 billion by 2030.

The second scenario, the "low nuclear scenario," assessed the impact of enhanced deployment of renewable and other energy technologies. As the scenario analysis made clear, renewable energy development can achieve a 22% share of generation (including energy efficiency in the mix), boosting both energy diversity and security. By significantly increasing renewable energy development, Korea may realize further savings in terms of lifetime costs. Ultimately, savings would depend on the investment and O&M costs of new nuclear installations, but the potential exists. Therefore, to truly promote enhanced energy security and a robust "low carbon, green growth" policy, the Korean government should enact measures to ensure development of energy efficiency initiatives and to promote enhanced deployment of renewable energy technologies. This approach offers both environmental and economic benefits.

Several specific policy goals result from this analysis. First and foremost, enhancing energy efficiency can result in significant energy savings and contribute to meeting future demand; therefore, Korean policy should continue to support and even expand deployment of energy efficient technologies, systems, and processes. A review of specific policy measures can be found in the JISEEF I report in 2004. More recently, the American Council for an Energy-Efficient Economy (Vaidyanathan *et al.,* 2013) released a report identifying key barriers and specific supportive policies that can enhance energy efficiency. Some of these policy tools that can enhance Korea's existing efficiency targets and mechanisms are listed below:

- Labelling schemes, such as the *Energy Star* program in the U.S., improve information and awareness of energy efficiency in consumer appliances and other technologies.
- Regulatory standards and codes can be enhanced to promote energy efficiency.
    - Open interconnection standards to ease access by combined heat-and-power (CHP) assets,
    - Use output-based emissions standards in setting air pollution or other regulations, which measures pollution per energy output rather than fuel input,
    - Reform utility regulations to encourage efficiency investments, which may require allowing cost recovery or stakeholder incentives to overcome structural barriers.
- Emissions fees address externalities related to greenhouse gas (GHG) emissions.
- "Feebates" can be used to reward purchases of best practice equipment with rebates while taxing purchases of inefficient equipment. Revenues can then fund additional rebates.
- Government building energy standards revisions and efficiency upgrades are vital for reducing energy consumption and waste in public buildings.

The results of the scenario analysis indicate that renewable energy potential in Korea is also significant, but the costs associated with renewable energy technologies are higher than those for energy efficiency. Thus, policy plays a vital role in supporting renewable energy deployment, particularly in the short term.

Korea has recently moved from a feed-in tariff system (FIT) in support of renewable electricity generating capacity to a renewable portfolio standard (RPS) and renewable energy credit (REC) market resembling several state programs in the United States. An important consideration is controlling the supply of RECs on the market. A rapid scale-up in supply can flood REC markets and depress prices, as has happened in New Jersey solar REC market[6] (Wang, 2012).

Another important consideration that arose from the scenario analysis is the influence of carbon emissions prices. Although not factored directly into the investment cost comparison, the analysis did consider additional potential savings in the face of a price on carbon. With a price levied on carbon price, renewable energy technologies and energy efficiency increase in cost competitiveness compared to fossil fuel generation capacity (although nuclear is comparable in its savings on carbon fees). The implication of this result is that effectively pricing carbon emissions will incentivize further investment in energy efficiency and renewable energy. Korea has recently committed to carbon emissions reductions as part of its 'low carbon, green growth' strategy. It should seek to implement a carbon market and carbon pricing in order to realize both its own carbon emissions goals along with enhancing both efficiency and renewable energy targets.

Recommendations to Enhance Regional and International Cooperation Initiatives

As described in the previous chapter, Korea has committed to various initiatives in cooperation with regional groups such as APEC, and through bilateral agreements. Many of these initiatives are meant to enhance regional energy security, promote energy alternatives, and ensure development of a 21st century infrastructure throughout Asia and the world. Realization of domestic energy goals and targets are more feasible through such commitments and initiatives, and so the government should seek opportunities to improve their current involvement. Therefore, to support this effort, a number of recommendations have been compiled. Below is a summary list of these recommendations, extracted from reviewed literature and categorized according to the broad themes of energy technology transfer, energy infrastructure, energy efficiency and renewable energy. Note that some recommendations are generic in nature and apply to more than one theme.

Energy Technology Transfer

- Intra- and inter-regional cooperation through capacity building and dialogue (Doh, 2003). Participation of Korea Doosan Heavy Industries & Construction in one of the nuclear plant construction is such a case.
- Increase the public funding for energy technology innovation (IEA, 2011).
- Mobilize the participation of the private sector on best example practices for energy innovation (IEA, 2011).
- Procurement provisions that favor clean energy technologies (IEA, 2011).

[6] Some insight on managing low REC prices can be learned from the January policy brief of the Delaware Sustainable Energy Utility on the Foundation for Renewable Energy and Environment (FREE, 2013).

- Identification of the most promising products and technologies for common standards (IEA, 2011).

Energy Infrastructure

- Increasing interconnection of the regional energy infrastructure to raise efficiency, and add flexibility and stability in the energy supply system of the region (Doh, 2003).
- Interconnection of the electricity systems of the countries of the region in order to exploit differences in demand load structures of countries, and to have access to extra back-up electrical support in case of emergency (Doh, 2003).
- Energy interventions in the energy grid infrastructure of urban areas (IEA, 2011).
- Development of smart grids (CEM, 2012).
- Regional investments on energy infrastructure to foster political support and ameliorate energy project risks. For example, cooperative construction of natural gas pipelines in the Northeast Asia area (Doh, 2003).
- Long-term joint investment in a common oil reserve to contribute to a secure balance between oil supply and demand throughout the region (Doh, 2003).

Energy Efficiency

- Intra- and interregional cooperation through capacity building and dialogue (Doh, 2003).
- Public-private partnerships to deliver targeted energy technology programs (IPEEC, 2011).
- Participation in CEM Clean Energy Policy initiative (CEM, 2012).

Renewable Energy

- Intra- and inter-regional cooperation through capacity building and dialogue (Doh, 2003).
- Public-private partnerships to deliver targeted energy technology programs (IPEEC, 2011).
- Participation in the Bioenergy CEM initiative (CEM, 2012).
- Participation in the Hydropower CEM initiative (CEM, 2012).
- Participation in the Electric Vehicle CEM initiative (CEM, 2012).
- Participation in the Clean Energy Policy CEM initiative (CEM, 2012).

Fostering Regional Renewable Energy Development

Areas of possible cooperation for the commercialization and diffusion of renewable energy technologies in the South East Asia (SEA) region include information sharing through continued engagement in APEC, ASEAN, G20 and the Asia-Pacific Partnership on Clean Development and Climate (AP6) in area of renewable energy; joint work with multilateral organisations such as the Asian Development Bank and World Bank; and engagement with the International Organisation for Standardization regarding product development, installation and maintenance of renewable energy systems. Specific strategies for cooperation in the area of new renewable energy technology development could involve (Curtotti and Drysdale, 2006):

- Resource mapping of the renewable energy potential in the SEA region by developing a database of reliable regional data on renewable energy resources. These data will help the region to identify the potential for renewable energy development, as well as areas of mutual interests between individual SEA member economies.

- Increasing the skill base for renewable energy technology development in individual SEA economies through exchange of information on technology development. This would involve, for example, establishing forums of dialogue, consultation workshops, training courses, and exchange of visits of technical experts on renewable energy.

- Establishing regulatory provisions to protect intellectual property rights for renewable technology development and technology transfer through cooperation.

- Forming partnerships can be formed between SEA economies, to fund demonstration projects in areas of new renewable energy technology of complementary interest. Demonstration projects support the commercialisation of new technologies, and joint work between regional economies will share the risk and lower the cost of undertaking these projects.

- Promoting standardization of renewable energy technology can be promoted by establishing an institution that reviews standards for renewable energy technology in the region such as product development, operation and maintenance. This could include engaging with the International Organization for Standardization and with local standards boards.

- Enhancing regional trade in manufactured components of renewable energy systems can facilitate their commercialization and diffusion as many of these systems incorporate advanced manufactured components. Market provisions to facilitate trade arrangements between SEA economies for these components will increase the prospects for developing renewable energy technology components in the region.

- Fostering competitive markets by reducing energy subsidies in order to create a "level playing field" for the diffusion of new energy technologies.

- Facilitating power trade and regional complementarities in electricity supply and demand through the regionalization of the electricity grid. This requires for cooperation in establishing standardized quality levels and specifications for the integration of electricity from new renewable energy generators into the regional grid.

Fostering Regional Energy Efficiency Development

Specific strategies to initiate cooperation in the area of energy efficiency include (Curtotti *et al.*, 2006):

- Promotion of standards and labels to improve energy efficiency. A number of initiatives already exist within the region, which can be used to facilitate cooperation among SEA economies, such as:

- Energy Standards Information System (ESIS)
- Renewable Energy and Energy Efficiency Partnership (REEEP)
- AP6 Power Generation and Transmission Task Force.

• Harmonisation of standards across SEA members to promote opportunities for scale economies in the manufacture and trade of appliances. Leveraging existing initiatives in the region will help to minimise the costs for this activity

• Accurate and detailed data on energy use, providing the important raw material for assessing the effectiveness of policy measures

• Facilitation of technology development and transfer. The identification and implementation of a small number of flagship projects timely can contribute to establishing a record of success for the regional countries and a reference point for future progress

• Exchange of information on energy efficiency policy and practice is evolving rapidly. Regional practitioners will benefit from access to the experience and expertise of others

3.5.3 Conclusion

Korea faces numerous challenges in meeting in improving its energy supply, meeting growing energy demand, and expanding or maintaining advanced infrastructure. The goal of this report was to explore similar challenges in other major energy-consuming nations, examine policy dynamics and considerations, and evaluate options to support Korean energy policy formation. In doing so, a number of insights were revealed that led to several recommendations. Several trends will play a growing role in influencing future energy policy in Korea, especially changing nuclear industry and market dynamics, growing access to cheap natural gas, and falling capital and levelized costs indicate the growing competitiveness and viability of renewable energy and energy efficiency. Each of these issues will likely factor into discussions and debate over the direction of the forthcoming 2nd National Energy Basic Plan.

Based on the implications of this report, several recommendations are made to enhance both Korea's energy policy and international cooperation. A significant share of coal and more limited expansion of nuclear can be achieved by 2030 through a stronger commitment to energy efficiency and renewable energy development. Energy efficiency, in particular, offers significant potential for low cost, high impact investment that generates substantial energy and economic savings by 2030. Therefore, Korea should do more to promote both efficiency and renewable energy deployment using a mix of policy and market mechanisms. In order to enhance these commitments, Korea should also seek to improve its cooperation on international initiatives in the areas of energy technology transfer, energy infrastructure development, energy efficiency, and renewable energy.

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