Analysis on Variation of Nuclear Energy Projections in Long-term Outlooks

Kei Shimogori* Yuhji Matsuo** Tomoko Ohira** Tomoko Murakami**

International organizations, private companies and some government agencies have provided their long-term outlooks not only on energy supply and demand but also on nuclear energy. This paper organizes the factors which have impacts on nuclear energy capacity projections in several long-term outlooks produced by four institutions. Those four outlooks denote the same tendency of variation of nuclear energy capacity projections. It could also be said that there are three factors which may have impacts on the projections: national or international policy trends especially on climate change issues, economics such as fossil fuel prices or macroeconomics, and accidents.

Keywords: Nuclear energy, Projections, Long-term outlook

1. Introduction

At present, various organizations including not only international organizations but also national government agencies, private companies and think tanks publish long-term outlooks on energy supply and demand. These long-term outlooks are frequently used as guideposts for national governments' policy decisions and private companies' business strategies. Nuclear power generation capacity projections in these outlooks are key data for considering the future nuclear energy market. Considering that nuclear power generation would become a key factor for examining future energy supply and demand with environmental problems taken into account, we assessed future nuclear energy capacity projections.

As indicated by an annual outlook published by the International Atomic Energy Agency (IAEA), nuclear energy capacity projections widely vary by year. Specifically, the IAEA revised nuclear energy capacity projections downward from 1981 to 2000, upward from 2001 to 2010 and downward from 2011.

It is important to sort out and analyze any common tendencies in and accuracies of different institutions' long-term projections as far as long-term projections are used for making decisions. This paper exhaustively collected and sorted out long-term projections of nuclear power generation capacity published by international and national institutions in the past and focused on extracting factors that have impacts on long-term projections.

* Researcher, Institute of Energy Economics, Japan, Inui Bldg. Kachidoki, 10th, 11th Floors, 13-1, Kachidoki 1-chome, Chuo-ku, Tokyo, 104-0054, Japan
** Senior economist, Institute of Energy Economics, Japan, Inui Bldg. Kachidoki, 10th, 11th Floors, 13-1, Kachidoki 1-chome, Chuo-ku, Tokyo, 104-0054, Japan

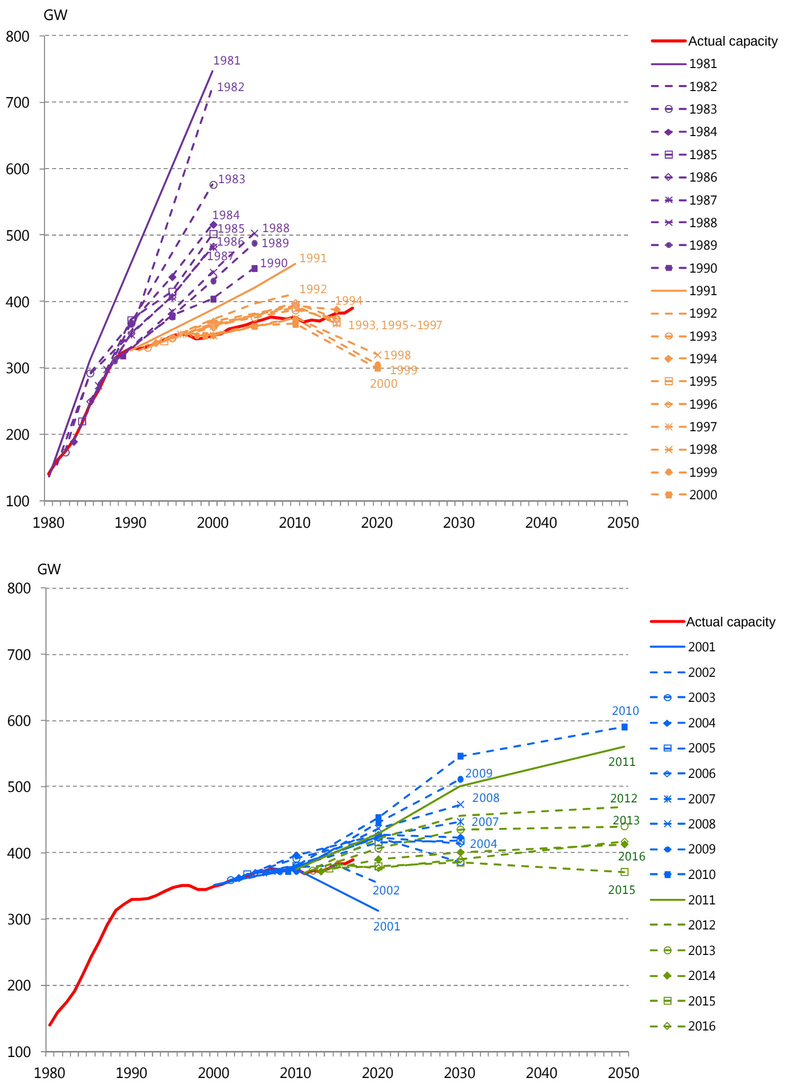

Figure 1 IAEA's long-term projections (global)

2. Methodology

This paper assessed four continuously published long-term outlooks: World Energy Outlook by the International Energy Agency (IEA), Energy, Electricity and Nuclear Power Estimates by the International Atomic Energy Agency (IAEA), International Energy Outlook by the Energy Information Administration of the U.S. Department of Energy (DOE) and Asia/World Energy Outlook by the Institute of Energy Economics, Japan (IEEJ). IEA outlooks from 1998 to 2016, IAEA estimates from 1981 to2017, DOE outlooks from 2006 to 2017 and IEEJ outlooks from 2004 to 2017 were collected and sorted out for comparing the four institutions' long-term projections of nuclear power generation capacity in gigawatts (GW). These organizations provide long-term projections on a region-by-region basis. Although definitions of regions differ by year and by institution, they are roughly comparable with small exceptions.

Here, each outlook is represented by i (i=1:IEA(Ref), i=2:IEA(NPS), …), a year for outlook publication by t, a projection year (2020, 2030, etc.) by t*, a projected nuclear power generation capacity in GW by C_{i,t,t^*}, and the set of projection years t^* in outlook i published in year t by $N_{i,t}$. A projection's change rate ($\Delta C_{i,t}$) is defined as shown by the following equation.

$$\Delta C_{i,t} = \frac{\sum_{t^* \in N_{i,t} \cap N_{i,t-1}} \frac{C_{i,t,t^*} - C_{i,t-1,t^*}}{C_{i,t-1,t^*}}}{\left| N_{i,t} \cap N_{i,t-1} \right|} \quad (1)$$

3. Results and discussion

3.1 Trends in long-term projections

The four institutions' long-term projections of global nuclear power generation capacity show the same trend.

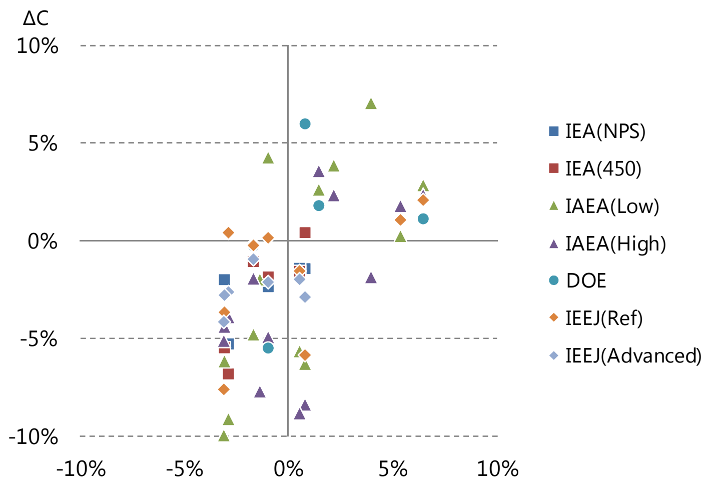

Figure 2 Correlation among long-term projection change rates of four institutions

Figure 2 shows change rates for the IEA reference scenario or Current Policies Scenario (abbreviated as CPS) on the horizontal scale and those for the other institutions on the vertical scale. While the R^2 value is around 0.36, a correlation analysis indicates the t value at 5.76 and the p value at 3.06×10^{-7}, representing a significant correlation.

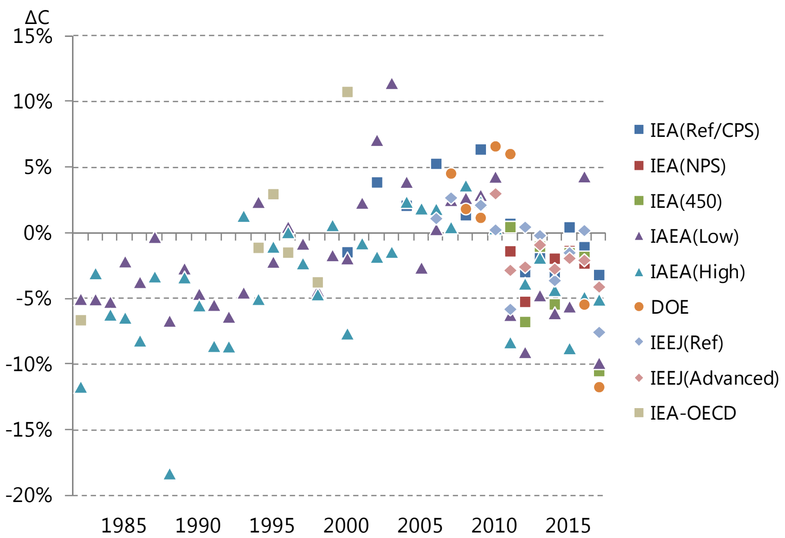

Figure 3 Trends in the change rates of long-term projections of global nuclear power generation capacity

Figure 3 indicates that long-term projections can be divided into three periods: the first period (until 2000), the second (2000-2010) and the third (from 2011). When we look at long-term projections region by region, we can find large variations in each period as described below.

The first period can be further divided into two: the 1-1 subperiod until 1990 and the 1-2 subperiod from 1991 to 2000. In the 1-1 and 1-2 subperiods, a characteristic tendency is seen in Eastern Europe (including the former Soviet Union) (Figure 4). The region saw economic confusion and stagnation from 1991 to 1999 due to the collapse of the Soviet Union in 1991. Projection revisions turned upward on an economic upturn around 2000, indicating a link between an economic slump and continuous downward revisions of projections in the 1-2 subperiod. In other regions in which economic growth continued in the first period, meanwhile, projections showed a gradual recovery toward 2000 while following a downtrend (negative ΔC) due to weak crude oil prices. In the 1-1 subperiod, the Chernobyl nuclear plant accident occurred in 1986. While having little impact on long-term nuclear energy capacity projections in the other regions, the accident could have contributed to downward revisions of projections for Eastern Europe.

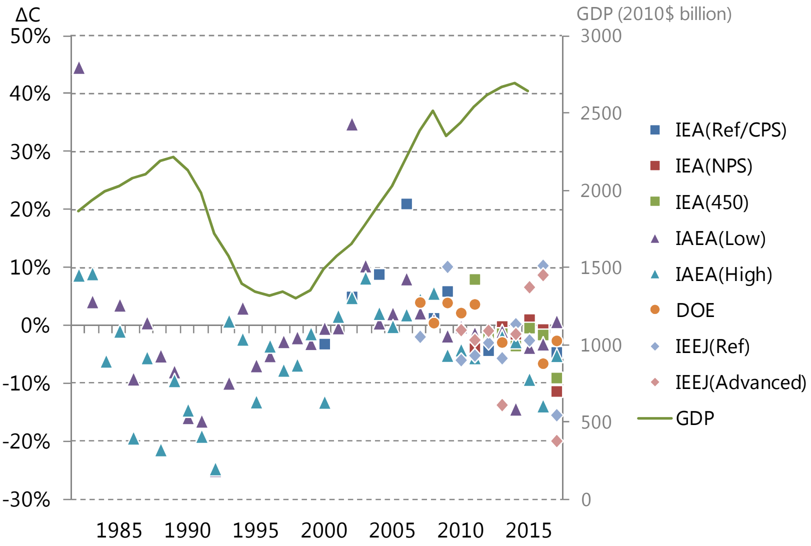

Figure 4 Trends in the change rates of long-term projections of nuclear power generation capacity for Eastern Europe

The second period can be divided into the 2-1 subperiod (2000-2005) and the 2-2 subperiod (2006-2010). The second period saw the so-called Nuclear Renaissance. Major national decisions on nuclear energy policy in the period included Finland's decision in 2002 to build Unit 3 of the Olkiluoto nuclear power plant, France's decision to construct Unit 3 of the Flamanville nuclear power station, the enactment of the U.S. Energy Policy Act of 2005, the United Kingdom's publication of a nuclear energy white paper and its policy support for nuclear power generation. Climate change countermeasures globally gained momentum as the Kyoto Protocol took effect in 2005 and the Intergovernmental Panel on Climate Change issued its fourth assessment report in 2007. In the second period, the four institutions tended to revise long-term nuclear energy capacity projections upward, reflecting national government policies and international trends involving greenhouse gas emission reduction. However, North America, unlike other regions, saw downward revisions triggered by natural gas price plunges in the 2-2 subperiod. While national policy trends prompted long-term projections to be revised upward during this period, economic factors such as prices of energy sources competing with nuclear energy also led to revisions of long-term projections.

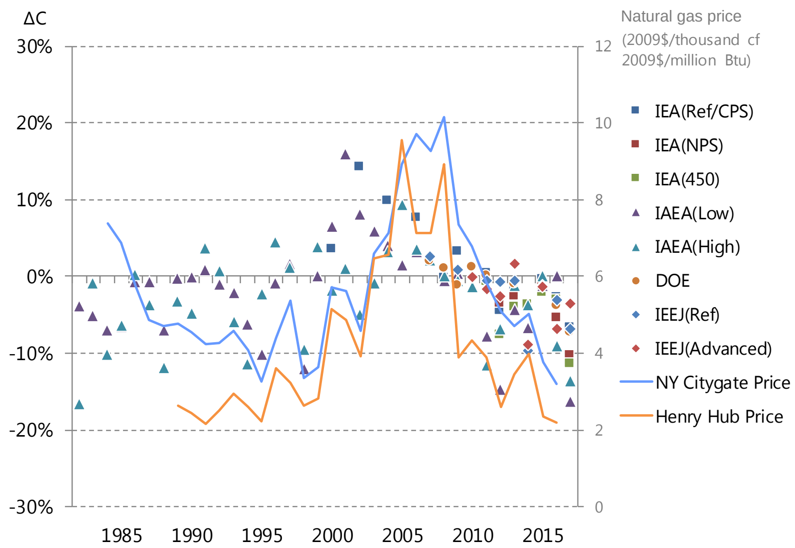

Figure 4 Trends in the change rates of long-term projections of nuclear power generation capacity for North America

The IEA also pointed out that national policy trends had impacts on nuclear power generation's roles during this period. "The increased determination to meet climate-change objectives could lead to a greater role for nuclear in the future energy mix," the IEA said in its WEO 2000. “Nuclear power – a proven technology for baseload electricity generation – could make a major contribution to reducing dependence on imported gas and curbing CO_2 emissions,” it said in its WEO 2006. The IEA WEOs from 2006 used global warming-related key words (including CO_2 emissions and lowering emissions) and energy security-related key words (including energy security, security of electricity supply and security of supply) for describing the characteristics or roles of nuclear power generation.

The third period has seen a downward revision trend from 2010 to 2011 and thereafter. These revisions could have reflected the 2011 Fukushima Daiichi nuclear power station accident. However, weak crude oil prices could have also contributed to the downward revisions. Given this, it can be pointed out that both the Fukushima accident and economics have had large impacts on long-term projections in the third period.

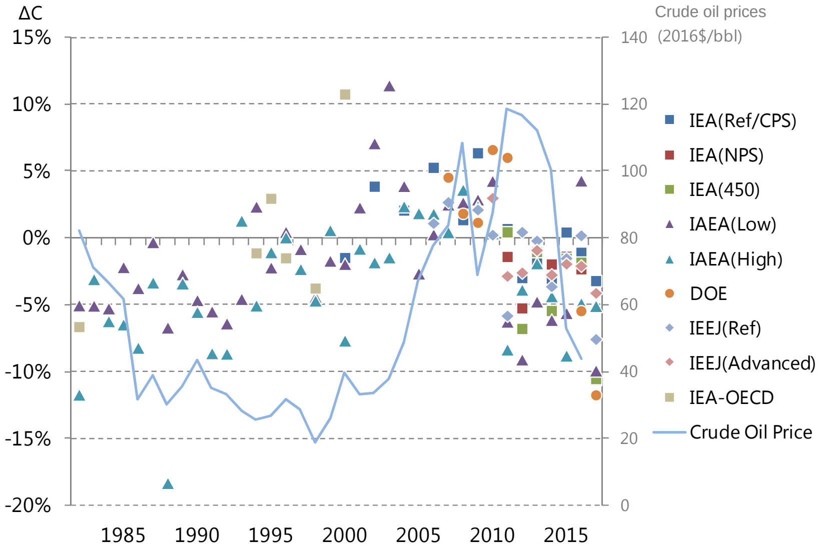

Figure 6 Trends in the change rates of long-term projections of global nuclear power generation capacity and crude oil price trends

Figure 7 shows the relationship between power demand and nuclear power generation projections. Here, long-term projections of global overall power generation are compared with those of nuclear power generation (Change rates for the four institutions’ nuclear power generation projections are plotted against that for IEA power generation projections).

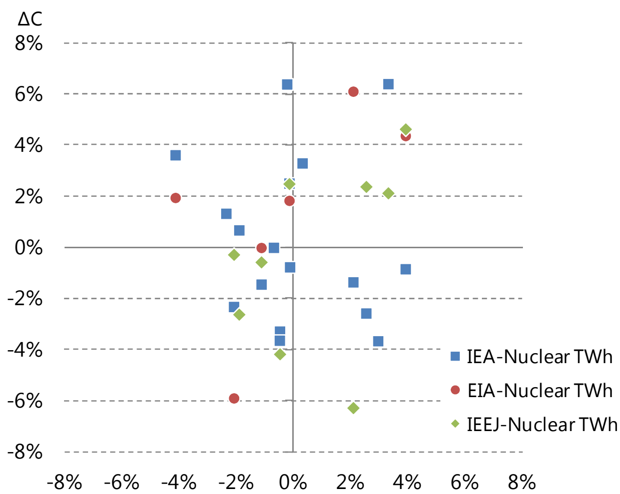

Figure 7 Trends in the change rates of long-term projections of global overall power generation and nuclear power generation

The R^2 value stands at 0.04, the t value determined through a correlation analysis at 1.09 and the p value at 0.285, indicating no significant correlation. This means that nuclear power generation has expanded through policies irrespective of power demand growth or slump.

3.2 Are long-term projections accurate?

In this section, we try to examine how close each institution's nuclear energy capacity projections were to actual results. Global projections for the second period (2-2 subperiod) were dominantly overestimating the nuclear power developments. Although projections in the IAEA's low nuclear scenario were the closest to actual results, the 1990 IAEA projection was an overestimation even after a downward revision as shown in Figure 3. Meanwhile, it is worthy of attention that long-term projections in the IEA reference scenario through 2008 were an underestimation.

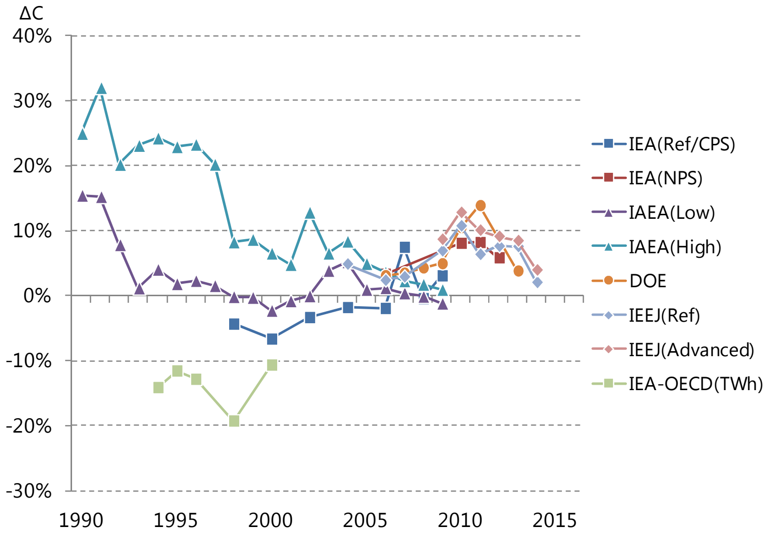

Figure 8 Change rates for gaps between projections and actual results for four institutions (global)

Gaps between projections and actual results by region indicate that projections for North America were an underestimation in the IAEA's low and high nuclear scenarios and the IEA's reference scenario between 1995 and 2004. Projections for Western Europe were also an underestimation in 1993 and in the 2000-2009 period. Even when long-term projections of global nuclear energy capacity were an overestimation, regional projections differed by institution.

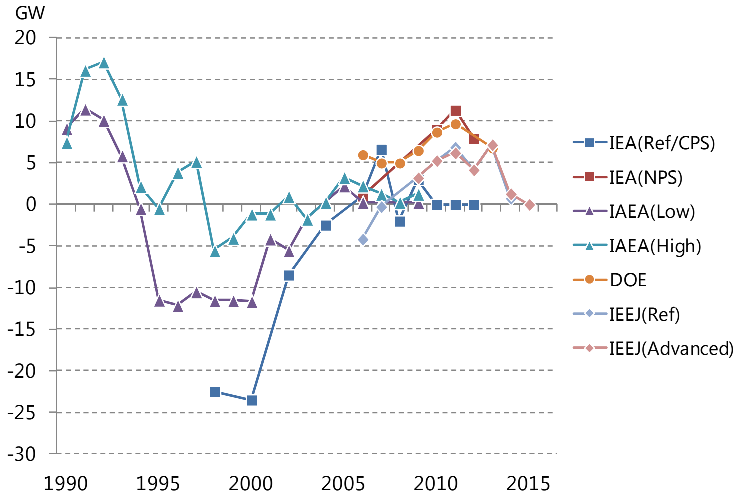

Figure 9 Gaps between projections and actual results for four institutions (North America)

4. Conclusion

As reviewed above, the four institutions' long-term projections of nuclear energy capacity followed the same trends, although with large regional variations. Table 1 shows various factors affecting nuclear capacity projections in each period.

Table 1 Factors affecting nuclear power generation capacity projections in three periods

1st period (-2000)		2nd period (2001-2010)		3rd period (2011-)
1-1 subperiod (-1990)	1-2 subperiod (-2000)	2-1 subperiod (-2005)	2-2 subperiod (-2010)	
Projections were revised downward ・Weak crude oil prices		Projections were revised upward ・Nuclear Renaissance		Projections were revised downward ・Crude oil price plunges ・Fukushima accident
1-1 subperiod: Sharp downward revisions for Eastern Europe ・USSR collapse ・Chernobyl accident		2-2 subperiod: Downward revisions only for North America ・Weak energy prices		

Factors that could have impacts on long-term projections include national and international policies, economics (macroeconomic and energy price changes which have impacts on the competitiveness of nuclear energy) and accidents. In Western Europe, particularly, renewable energy expansion through the feed-in tariff system and cost reductions could have reportedly exerted impacts on long-term nuclear energy capacity projections.

Among national and international policies, greenhouse gas emission reduction policies are destined to be enhanced globally, exerting upward revision pressure on long-term nuclear energy capacity projections.

As for economics, long-term projections of crude oil, natural gas and other energy prices are uncertain, while it is possible for these prices to remain slack over a long term. If nuclear energy can maintain its economic efficiency irrespective of prices of rival energy sources, long-term nuclear energy capacity projections may start an upward trend again. Achieving this will require nuclear power plant operators' efforts to cut operation and maintenance costs, government support for financing for nuclear power plant construction and regulators' further rationalization of various approval procedures and regulations.

Acknowledgements

This study was partly supported by the Environment Research and Technology Development Fund 2-1704 of the Environmental Restoration and Conservation Agency.

The authors would like to express their gratitude to Iris Marigold Operario for supporting data acquisition on the International Atomic Energy Agency's long-term outlooks.

References

1) International Energy Agency, World Energy Outlook, (1994-2017)
2) International Atomic Energy Agency, Energy, Electricity and Nuclear Power Estimates, (1981-2017)
3) U.S. Department of Energy, U.S. Energy Information Administration, International Energy Outlook, (2004-2017)
4) Institute of Energy Economics, Japan, Asia/World Energy Outlook (IEEJ Outlook), (2004-2017)