



CONSUMERS' ELECTRICITY CONSUMPTION BEHAVIOUR AND POWER UTILITIES' PREFERENCES

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ABSTRACT

The electricity market in Japan was liberalized in 2016. Consequently, consumers in Japan have options to choose preferred electricity retailers. Some electricity retailers specialize for environmentally friendly renewable energy (RE). RE is regarded as reliable and safe after the Great East Japan Earthquake in 2011. In addition, in the 5th Basic Energy Plan, the Japanese government attempts to raise RE for 22 to 24 % of all energy sources by 2030. However, supplies from RE destabilizes the grid operations. Nuclear power plays significant role in the smooth grid operations. The Japanese government regards nuclear power as one of the substantial energy sources due to Japan's energy policy. Japanese Power utilities also attempt to supply electricity from nuclear power plants. There are some benefits, economically and technologically. However, nuclear power has negative impacts on reliable and safe. In the Analytic Hierarchy Process (AHP) survey, the respondents put reliable and safe as the highest priority. Nuclear power is not acceptable to consumers. This implies gaps between demand and supply sides. This paper examines the preferences on both sides and clarifies the gaps. In addition, some possible solutions, e.g., distributed micro-grids and batteries, could be narrow the gaps.

Keywords: renewable energy, Japanese consumers preference, AHP, liberalization

Introduction

Several historical events have made for the past two decades in Japan's power sector. Firstly, climate change, caused by greenhouse gas emission (GHG,) raises the global average temperature. As a result, phenomenal weather, such as super typhoons and heatwaves, more frequently common in the world nowadays. International society is currently tackling climate change. In the Kyoto Protocol, which was implemented between 2008 and 2012, industrial countries, including Japan, were obliged to reduce GHG emissions. In 2016 the Paris Agreement came into effect to reduce GHG emissions for all countries. In particular, GHG emission drives from the consumption of fossil fuels, i.e., coal, oil, and natural gas. The power sector uses a large number of fossil fuels to generate electricity. It is inevitable to switch more environmentally friendly power sources from fossil fuels. One of the alternatives was nuclear power.

Secondly, liberalisation in the power sector is the world trend. Most power utilities are usually state-owned companies or monopolized. Inefficient management of these organizations leads to many deficits. Monopolized organizations also control the electricity market. In some countries, as a result, electricity tariffs are rather high. In other words, liberalization should bring many benefits to both the demand and the supply side. In Japan, liberalisation of the power sector was commenced in 2000. The electricity sector was completely liberalized in 2016. All consumers freely choose electricity retailers to purchase electricity. Accordingly, power utilities, which is monopoly regionally in Japan, are split into generation, transmission & distribution, and a retailer. The companies supply electricity from a conventional large scale of power plants, i.e., hydro, thermal and nuclear power plants. Fossil fuels are used for thermal plants. When more electricity is supplied, the environment is likely to be deteriorated. Hence, many consumers pay more attention to the environment than before. Nuclear power hardly emitted GHG and used to be considered clean and environmentally friendly energy.

However, most Japanese changed public acceptance for nuclear power after the Fukushima Nuclear Disaster in March 2011. (Tsujikawa et al. (2016) and Kim et al. (2013)) The 2011 Great East Japan Earthquake broke out on 11 March 2011, and huge tsunami struck Fukushima Dai-ichi Nuclear Power Plant. Radioactive substances were leaked due to the melt-down. Approximately 160,000 local residence needed to evacuate from the surrounding areas. Public acceptance for nuclear power in Japan has turned negative. Consequently, the Japanese government regards safety as one of the criteria for Japan's energy policy. To a larger extent, consumers decide priority from economic benefits, environment, and security when they choose an electricity retailer.

On the contrary, the Japanese government still shows a willingness to maintain 20 to 22 % of electricity supplies from nuclear power in the 5th Strategic Energy Plan disclosed in 2018. The government attempts to diversify power sources to secure energy security. Japan's electric power companies intend to supply electricity through nuclear power plants due to some advantages, such as generation costs and baseload generation. These points seem to imply different viewpoints from the government, electric power companies, and consumers. This paper focuses on the difference between the three parties. Reviews of relevant literature and secondary data will be made. Then consumers' preference will be examined through the Analytic Hierarchy Process (AHP). Finally, the paper attempts to clarify gaps and show an approach to narrow the gap.

Japan's Power Sector and Energy Policies

Japan was damaged physically due to heavy attacks by the Allies during the Second World War. Consequently, as Ohno (2006) mentioned, one-fourth of assets were destroyed after the Second World War. Japan needed to rebuild the country. The Japanese government stimulated its economy successfully. In the mid-1960s, Japan finally achieved the second-largest economy after the US in the world. Electricity is an indispensable good to develop its economy. This chapter describes the chronological change in both of the power sector and Japan's energy policies.

The transition for Japan's energy policies

The 5th Strategic Energy Plan adopts 3E+1S as Japan's current energy policy. 3E stands for energy security, economic efficiency and environmental sustainability and 1S stands for safety. This current energy policy is the result of changing circumstances for the power sector. Until the 1980s, 2E, energy security and economic efficiency, was significant. Then environmental sustainability was added in the 1990s. Finally, safety was added in the energy policy after the Fukushima Nuclear Disaster.

There are some potential areas to construct dams and hydro-power stations in Japan. There were many domestic coal mines. Until the mid-1960s, Japanese companies have mobilized this source to generate electricity. However, the rapid economic development in the 1960s required much more energy sources. Then, almost all oil has been imported from the Middle East. Thus, Japan's energy sector heavily relied on oil, but the first Oil Crisis in 1973 was destabilized in terms of energy supply from the Middle East. Oil prices also became higher at that time. The Japanese government promoted saving energy and energy diversification for economic development. Japan's Energy White Paper 2019 points out that the government introduced natural gas, coals, and nuclear for energy diversification. In particular, nuclear power has some advantages. Low-cost fuels, uranium, can be procured from various countries, such as Australia. Nuclear fuels can be used for a longer time. Hence, generation costs from nuclear power are much lower than other fossil fuels.

In the 1990s, climate change became an urgent global issue. The United Nation Framework Convention on Climate Change (UNFCCC), an international environmental treaty, was formed in 1994 after the Earth Summit in Rio de Janeiro. International society collectively has been tackling climate change. The reduction of GHG emissions is the main critical issue. Japan also obliged to decrease GHG emissions. Power sector plays essential roles in reducing because Approximately 40 % of CO₂ comes from the power sector. (METI 2018) The Japanese government ratified the Kyoto Protocol and the Paris Agreement, respectively. Japan set up its own target to reduce GHG emissions. The government committed to reducing by 26% of GHG emissions in Fiscal Year (FY) 2030, compared with the FY 2013 level. Then coal-fired and nuclear power were paid attention. Both powers are important as a baseload power source. However, coals emit much GHG, but nuclear power hardly emits GHG. The Japanese government planned to install many nuclear reactors.

However, the 2011 Great East Japan Earthquake broke out. The tsunami struck the Fukushima Dai-ichi Nuclear Plant. These lead to the Fukushima Nuclear Disaster. Over 160,000 local residents surrounding the areas were forced to evacuate. All nuclear reactors in Japan stopped operation. Forty-three thousand are still not allowed to return their own homes in the affected areas. In order to avoid this, safety becomes significant for Japanese. Kim et al. (2013) show the difference in public acceptance for nuclear power between before and after the earthquakes.

Public acceptance in Japan dropped by approximately 23 %. Thus, Japanese consumers' views on nuclear power are dangerous and not safe.

Instead of nuclear power, Renewable energy (RE) is safer and environmentally friendly than nuclear power and fossil fuels. In order to accelerate RE penetration in Japan, Feed-in-Tariff (FIT) was introduced in 2012. In Japan, liberalisation is also crucial for the power sector in Japan. Liberalisation was commenced for high-voltage consumers in 2000. Targets for liberalisation is wider and wider, and finally liberalisation was completed in 2016 for all consumers. Consumers can buy electricity from any electricity retailer. Parallely power utilities were unbundled, and new electricity retailers could sell electricity to any consumers.

Electric power companies and the influence of liberalisation in Japan

After the Second World War, many industries in Japan were rebuilt. The power sector was no exception. Nine (9) regional power utilities were established in 1951. These electric power companies own generation, transmission, and distribution lines and sell electricity to all consumers. Thus, local electric markets in 9 (nine) regions were monopolised. The Japanese government also set up a semi state-owned power company, Electric Power Development Company, which is specialized for generation, in 1952. Okinawa was handed over by the US government in 1972. The Okinawa Electric Power Company started operations in Okinawa. Prior to liberalisation, in other words, there were only 11 (eleven) power companies. Figure 1 shows ten (10) regional electric companies.

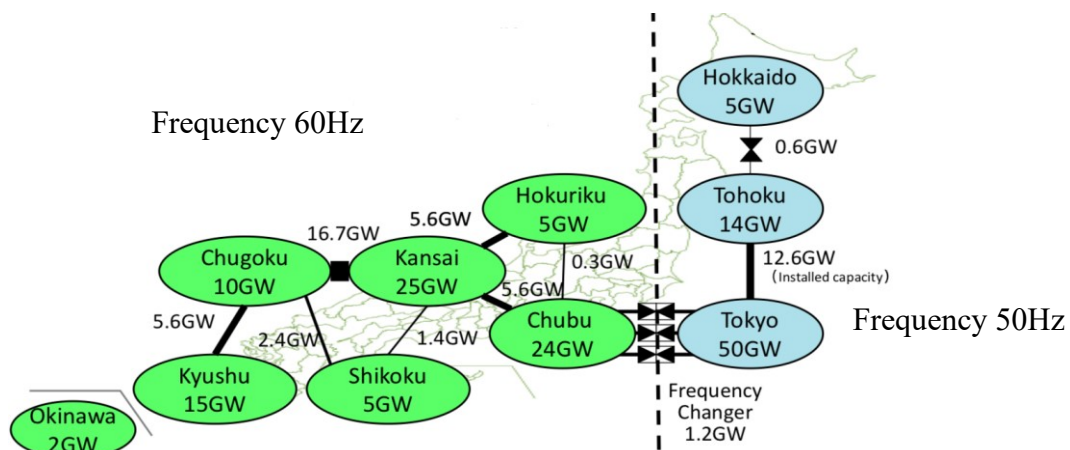


Figure 1. Regional Electric Companies in Japan

Source: Ministry of Economy, Trade and Industry (METI) (2018), Retrieved from <https://www.emsc.meti.go.jp/english/info/public/pdf/180122.pdf>

These electric companies will split into three (3) companies, i.e., generation, electricity retail, and transmission and distribution for legal unbundling in April 2020. Although the grid operation in a region is made under a single operator, retail and electricity generation are open to any party. According to the progress report on the liberalisation of electricity and gas retail in Japan disclosed by METI (2018a). The number of retailers is continuously increasing from 291 in April 2016. In December 2018, 543 electricity retailers were registered, but liberalisation seems not successful. This is because METI depicts that 11,7% of all households switched new retailers from the monopolised companies. Those who switched retailers, but the majority choose regional gas operators. Tokyo gas and Osaka gas, for instance, announced that the number of contracts with new customers is over 1.5 and 1 million households respectively. This switching number is a large proportion from all switching numbers, but liberalization

seems not to be accelerated. One-quarter of retailers do not have any customers. In Kansai, Tokyo, and Hokkaido, the market share for new retailers is high, but in the other areas, the market share for new retailers does not rise. These facts show the degree of liberalisation in the market.

Under the current situation, some retailers stress that electricity tariff is going down. Other retailers stress that electricity supply is specialized for environmentally friendly power sources, such as biomass and wind power.

Policy RE in Japan

The Japanese government has continuously promoted RE for two decades. To a large extent, RE raises Japan's energy security. (Duffield and Woodall (2011), Chen et al. (2014)) However, a disadvantage for RE is high generation costs. In the market, RE is not competitive compared with current conventional generations. In order to mitigate this difficulty, the Japanese government introduced regulation of a Renewable Portfolio Standard (RPS) in 2002 as a policy tool to boost RE penetration. Mid- and small-hydro, solar, wind, biomass and geothermal generation were targets for RPS. The regulation obliges electricity retailers to use more RE. Despite the fact that the Japanese government achieved the set-up goal to increase RE use by 2010, RE was not used widely in Japan. Ito (2015) states that "it remained uncertain whether the RPS itself effectively had worked to promote the strategic policy of renewal energy expansion more than that of "BAU (Business As Usual)" by the operators." This is because installing cost for RE is higher and RE, particular PV solar, is installed in European countries more than in Japan. The share of installed capacity for solar photovoltaic (PV) in Japan was declined in the 2000s. Feed-in-Tariff (FIT) successfully led to an increase in RE penetration in Europe.

After the 2011 Great East Japan Earthquake, the government attempted to accelerate RE penetration. Hence, FIT was adopted in 2012. Under the FIT scheme, a premium is added on market prices. RE power producers obtain the premium for a certain period based on the power purchase agreement. The premium will be allocated by a special fund, where consumers make some additional payment in electricity bills. To a larger extent, FIT stimulates investors to install RE facilities much more than before. As shown in Table 1, the amounts of power supply from respective RE sources has increased rapidly. Solar PV with more than 10kW has been rapidly increasing since 2012. Accordingly, consumers need to pay more to maintain the special fund year by year. The premium is reviewed for a certain period. In Japan, initially, 42 Japanese Yen was, for instance, set up for small-scale solar PV in 2012. FIT premium is decreasing by 24 Japanese Yen in 2019. For investors, it is harder and harder to construct RE facilities.

Approximately 10% of the total electricity in 2018 is from RE. This figure has been larger and larger since 2012, but under the circumstance that FIT premium is reducing, investment willingness for investors to RE could be smaller and smaller.

Consumers' priority and favorable power source

Most consumers do not change an electricity retailer to purchase. They do not enjoy benefits from liberalisation in the power sector. It is necessary to understand the reasons why not many consumers switch retailers and consumers' views of power sources. In this chapter, consumers' preferences will be clear through a survey. It is significant to clarify views of the demand side.

Table 1: Amounts of RE generation electricity under FIT

(Unit: 1000kWh)

Generation type	2012	2013	2014	2015	2016	Cumulative Amount
Solar PV (<10kW)	2,320,683	4,856,860	5,780,178	6,486,284	7,116,887	26,560,892
Solar PV (>10kW)	189,529	4,254,669	13,177,310	24,591,080	34,549,522	76,762,110
Wind generation	2,741,712	4,896,383	4,920,823	5,232,599	5,861,799	23,653,316
Hydro generation	120,074	935,526	1,072,772	1,476,329	2,007,873	5,612,574
Geothermal	1,235	5,709	6,081	58,811	76,202	148,038
Biomass	216,985	3,169,400	3,644,380	5,390,144	7,365,065	19,785,974
Total	5,590,218	18,118,547	28,601,544	43,235,247	56,977,348	152,522,904

Source: Agency for Natural Resources and Energy

Analytic Hierarchy Process (AHP) and its methodology

The Analytic Hierarchy Process (AHP), developed by Thomas L. Saaty, is one of multi-criteria decision-making methods. While decision-making processes are often subjective, the decision-making process in AHP will be understandable under a comprehensive and rational framework. AHP has a hierarchy structure, i.e., a goal, criteria and alternatives. Decision-makers decide the goal from alternatives based on the criteria.

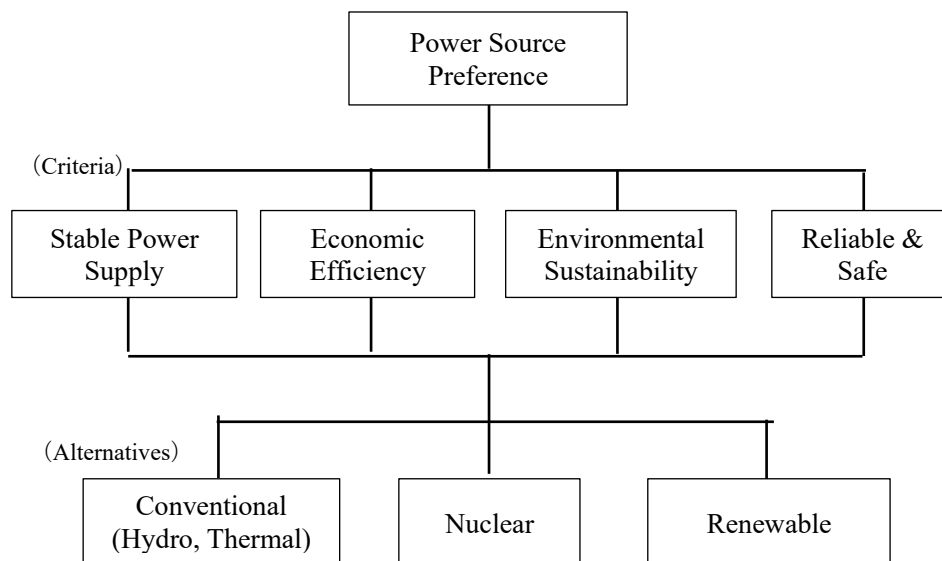


Figure 2. AHP structure

Figure 2 shows the AHP structure in this research. As the criteria, stable power supply, economic efficiency, environmental sustainability and safety are given based on Japan's 3E+1S policy. There are three alternatives to this research. As one of the alternatives, conventional power supply, i.e., large-scale hydropower and thermal power, arises. The second alternative is nuclear power, and the final alternative is RE. Based on these factors, the AHP structure for this research will be created in Figure 2. The questionnaire was designed accordingly.

Result

In May 2019, the questionnaire was distributed to 233 people, and the questionnaire was also distributed via the Internet. As a result of excluding omission of data entry and excluding those whose consistency (CI) exceeded 1.5, responses from 118 persons were obtained as the number of samples to be analysed. These data were analysed using AHP.

The survey results are shown in Figure 3 and Figure 4, respectively. Figure 3 describes that respondents were most concerned with an alternative of "reliable and safe" in the four (4) criteria. After reliable and safe, economic efficiency. Economic efficiency, stable supply and environmental sustainability are followed, but these three criteria are nearly half as reliable and safe. In other words, reliable and safe are the most important criterion, but the other criteria are not so significant as reliable and safe. The standard deviations for the three criteria are respectively 0.1073, 0.1094, and 0.0912. Variances for stable supply and economic efficiency are larger than for environmental sustainability. Views to environmental sustainability are not different, but consumers' views to stable supply and economic efficiency are various.

Figure 4 shows the breakdowns of the four criteria in respective alternatives and Figure 5 describes the proportion of the alternatives for the four criteria, respectively. In Figure 4, the top of the three-bar charts is renewable energy. In renewable energy, reliable and safety have the largest proportion in the criteria. In nuclear, reliable & safe is the smallest, but nuclear power has an advantage of economic efficiency. Generally, generation costs from nuclear and coal-fired are the lowest in all energy sources. In nuclear, environmental sustainability indicates 0.036. The respondents also consider that nuclear power is not applicable to environmental sustainability, but nuclear power does not emit GHG. At the same time, respondents could preoccupy the perception of the Fukushima Nuclear Disaster. This can make nuclear power environmentally bad. The respondents also regard conventional energy source as reliable and safe on the one hand. Conventional energy sources have a disadvantage in terms of economic efficiency. This could be a misperception. Through Figure 5, there are other misperceptions. For instance, renewable energy has an advantage in terms of stable supply, but powers from solar PV and wind power are not stable. Electricity through solar PV and wind power is fluctuating. When this power goes to transmission lines, fluctuate voltages affect the stability of grid operation. This is why the Kyushu Electric Power Company controlled intakes from solar power. To sum up, despite some misperceptions, the respondents consider that nuclear is not reliable or safe.

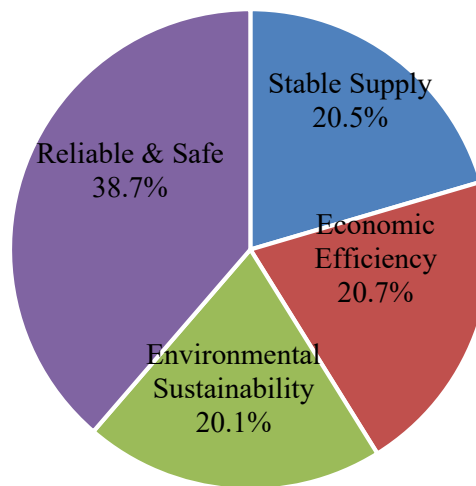


Figure 3. The result of the preferred criteria

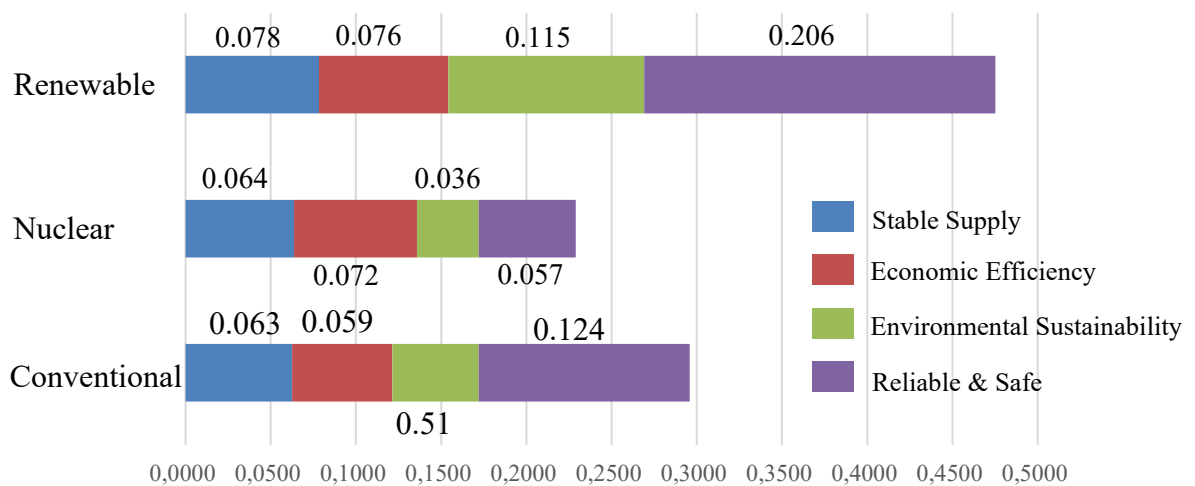


Figure 4. Breakdowns of the four (4) criteria in the three alternatives

Discussions

Through the literature reviews and the AHP survey, there are huge gaps between the demand and supply sides. In this chapter, the paper argues gaps in detail and consider possible solutions to narrow the gaps. At first, the Japanese government states that Japan's energy policy is 3E+1S. The government also completed liberalisation in the power sector as deregulation. Although ten (10) electric power companies had monopolised in the regional markets, any electricity retailers can commence their own business to sell electricity after liberalisation in 2016. The government also attempts to raise RE penetration. RE has a disadvantage of high generation cost. In order to mitigate it, FIT was introduced. It is beneficial for raising energy security and reduction of GHG emissions. From the viewpoint of the government to tackle climate change, nuclear power could be an alternative. In short, the government adopts comprehensive approaches. Nuclear is indispensable for Japan's energy mix policy. (Vivoda (2012), and Hong et al. (2013)) Respective electric power companies have the willingness to mobilize nuclear

facilities for sound management. After unbundling, an organization of transmission and distribution will be split. For the smooth grid operations, additional investments is needed to correspond fluctuate power supply. Batteries and generation to respond are, for instance, needed.

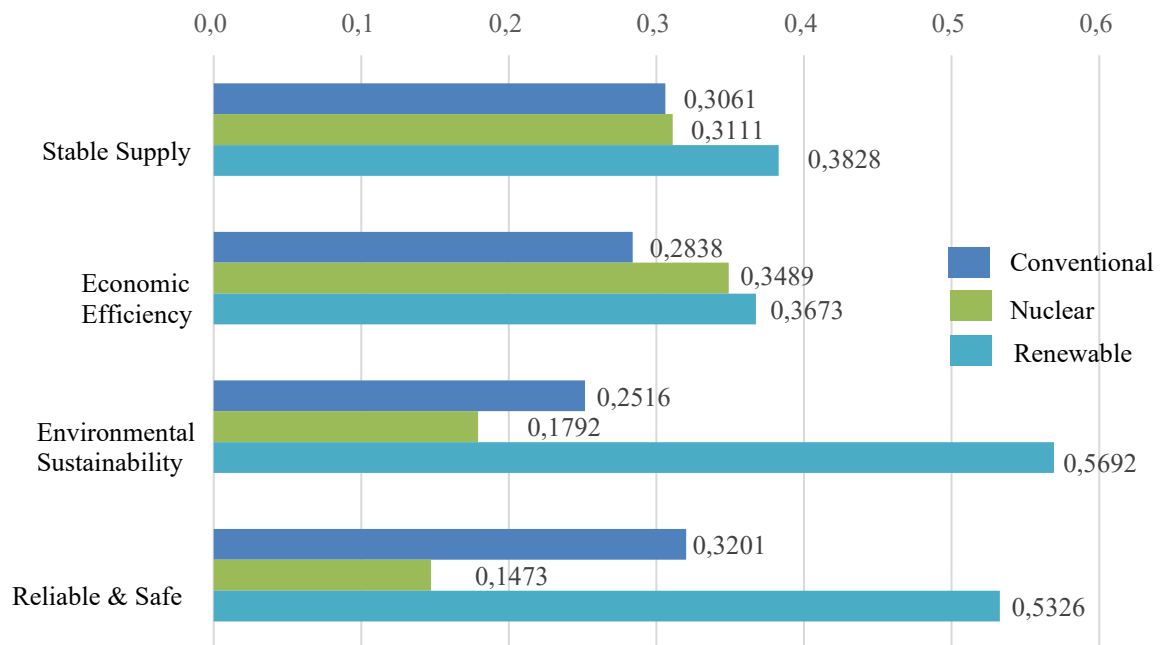


Figure 5. Proportion of the alternatives for the four criteria

Large scales of RE generations, e.g. mega solar power plants, are being constructed, because FIT was attractive to newly power producers. In order to install these facilities, large capital is required. Subsequently, these producers are generally large organisations, which own conventional generators and nuclear power plants. It is very difficult to distinguish RE in electricity from fossil fuels and uranium once electricity is sent to the grid. Hence, retailers except for certain specialised retailers for RE have difficulty in differentiation from RE. In particular, for retailers under monopolised electric power companies, it is difficult to show the breakdown, because output performance from respective power source has change second by second.

There are certain electricity retailers, such as community cooperatives, stress that power comes environmentally friendly RE sources. Their business areas do not cover broad areas in general. Consumers can choose an electricity retailer to buy electricity, but they have limited options due to a geological constrain. Many retailers also emphasise economic benefits. Electricity tariffs are likely to be discounted. Consumers can save some payments. As above-mentioned, only 11.7% switched retailers. Most consumers do not change retailers. Figure 5 shows major electricity retailers by sales quantity. The shares of TEPCO, former Tokyo Electric Power Company, and nine (9) electric power companies are still occupied largely in the electricity market shares. In Figure 6, eleven (11) are these companies out of sixteen (16) companies. Electricity from various sources is sent to the grids, which are operated by electric companies. It is very hard to distinguish environmentally friendly energy sources from nuclear power and fossil fuels.

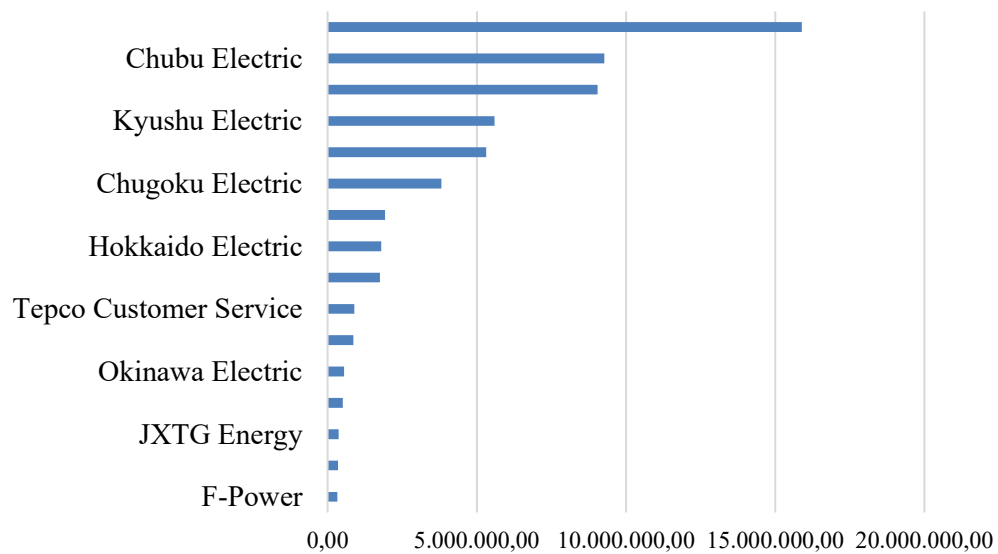


Figure 6. Main retailers' sales quantity for electricity as of May 2019
Source Energy Information Center

Consumers also install generation facilities, such as solar panels and windmills. Through the result of the survey, the majority do not accept nuclear power. RE is the most preferred energy source for consumers. However, not many consumers switched a new retailer from the electric power company. Hence, fossil fuels are still consumed. Consumers also receive benefits from FIT. It is not difficult to install solar PV and sell electricity. Table 1 shows approximately 12% of the total outputs from RE, a small number to generate electricity from small solar panels. Chapman et al. (2018) show statistical data for liberalization and solar roof-top PV installation and discuss the reason for the installation of RE. The largest motivation of individuals to install solar PV comes from economic benefits. The second largest comes from technological curiosity. Environment preference comes the third.

From the result of the AHP survey, environmental sustainability is not recognised as a significant criterion. Rather reliable and safe are much more important. From the viewpoint, RE is regarded as the most preferred energy source. The respondents also nuclear power is not reliable or safe. This is in accordance with public acceptance of nuclear power in the literature reviews. In terms of nuclear power generation, it is important to restart nuclear power plants for the government and electric power companies. However, the majority of the consumers do not accept it. Moreover, the grid operation technologically mixes up all energy sources. Consumers do not know what electricity is made from. In other words, it is hard for consumers to choose energy sources, such as RE, in the current system. Hence, the paradigm shift for energy preference is needed. One of the possible ideas could be distributed generations and distributed microgrids. (Faber et al. (2014)) Another possible solution is batteries, but these are advantages and disadvantages. It is necessary to examine these for the further study.

Chapman et al. also point out that economic incentives and curiosity are the two largest reason to install a roof-top solar PV system. After the two reasons, environmental concerns lead to the installation of solar PV. This is a different result from the AHP survey. In Japan, some

microgrids have already been operated. Further research is required to explore possible solutions to match consumers' preference and suppliers' activities.

Conclusion and further research

This paper examines consumers' preference through the AHP survey. The respondents' highest priority is reliable and safe. This is 1S from Japan's energy policy, i.e. 3E+1S. Through this criterion, nuclear power is not accepted. Nuclear power is not environmentally sustainable, as well as reliable or safe. The Fukushima Nuclear Disaster became a trigger to turn negative for nuclear power in public. Prior to the disaster, the government promoted the constructions of nuclear power plants, because nuclear power does not emit GHG. Nuclear power was an alternative to replace fossil fuels, a cause of climate change. It is dispensable to reduce GHG emission. Nuclear power as a significant baseload generation was the low-cost and environmentally friendly source, but nuclear gave a huge negative image in Fukushima.

Conventional generation is more reliable and safer than nuclear. The respondents pay attention to a criterion of reliable and safe. There are two types of energy source, the large scale of hydropower and fossil fuels. Fossil fuels are coals, oil and natural gas. Coals, as one of the fossil fuels also lots of emitting GHG, but coal-fired power plants are a low-cost baseload generation. Hence, coal-fired power plants give negative impacts on the environment. RE is paid more attention. The government also promotes RE generation. FIT was introduced in 2011. As a result, the total generation from RE has rapidly increased. FIT was a successful tool to promote RE, but consumers need to pay for a special fund to maintain the FIT scheme, Outputs of solar PV and windmills are fluctuating. This makes the grid operation unstable. Some electric power companies conduct cut off feeds from solar PV or windmills. RE is still a small portion of all energy sources, i.e. approximately 10% of all feeds to the grid.

Despite consumers' preference, consumers do not know what kind of energy sources are consumed. This is because all electricity is mixed up once electricity from all types of energy source is sent to the grid. Hence, consumers use electricity without consciousness of what energy sources are generated. This becomes a huge gap between the demand and supply side. Electricity was liberalised in 2016. Although consumers have a choice to consume electricity from any licensed electricity retailer, most consumers do not enjoy the benefits of liberalisation. Most still make a contract with the regionally monopolised electric power company. Possible solutions are to introduce distributed microgrids.

Consumers' preference is RE. The most significant behaviour is that consumers are conscious of RE as electricity sources for the use of energy. Distribute microgrid can improve current issues. This topic should be further research.

In addition, from the result of the AHP survey, there are some misperceptions to understand energy issues. Energy education is also significant to make a judgement to choose a better choice. Generation costs from coal-fired power plants are the lowest, but respondents consider the cost was not low. Takano et al. (2018) reported transitional difference before and after conducting energy education. Prior to energy education, more than half of the targets had negative opinions about nuclear power. After educating, the preference has changed. The number of negative opinions was decreasing. Issues of nuclear power are complicated. There are some solutions, but it is hard to make the best choice if consumers do not have sufficient knowledge. From this view, energy education plays significant roles in consuming electricity in an appropriate manner.

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