UTILITY OF THE FUTURE IN JAPAN

Utility 3.0

INTRODUCTION

5 megatrends (5Ds) will bring about changes to the Japanese power/energy business. These changes are inevitable and irreversible. Accenture and TEPCO have discussed this worldview in a book (published Sep 2017).

The 5Ds are:

1. Deregulation
2. Decentralization
3. Decarbonization
4. Digitalization
5. Depopulation

The first four are common trends in the world, especially in developed countries. Depopulation is the trend that Japan will likely face earlier than the rest of the world.

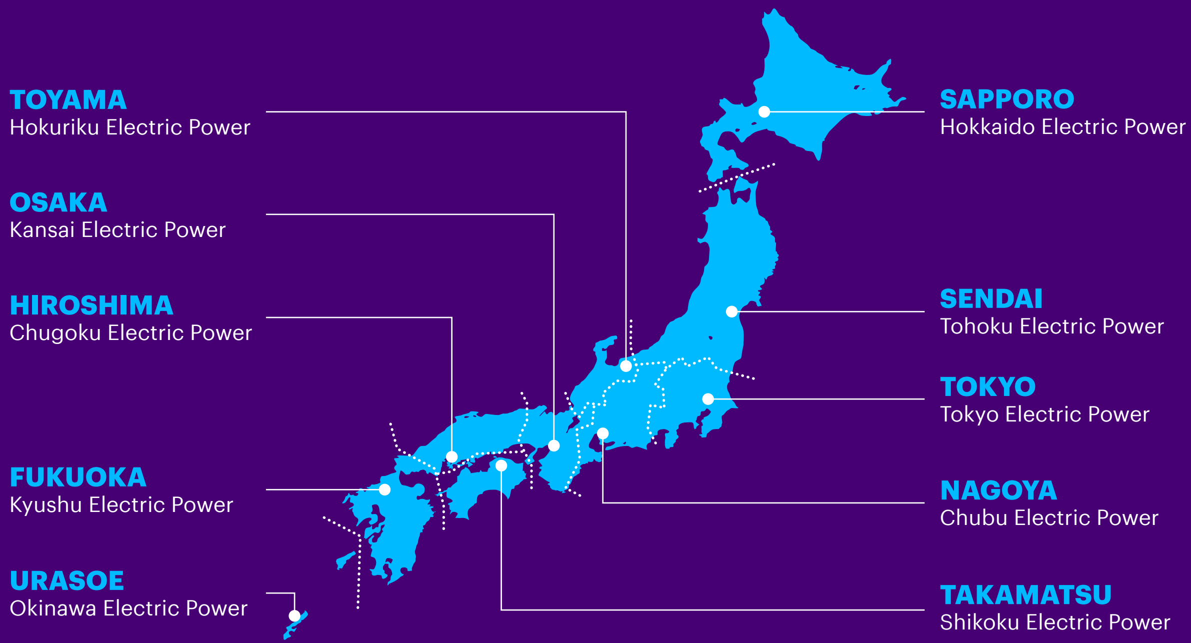
Box 1. Key Figures in TEPCO & Japan's Electricity Market

- Seen as kWh Sales volume,
- Japan's market is about a quarter of the size of the markets in the United States and Europe.
- Japan is the fourth largest market in the world, behind China, the United States, and India.
- TEPCO's share is around 30% of the market.

Table 1. Key Figures

NUMBER OF CUSTOMERS	
Japan	86 million
TEPCO	29 million
ANNUAL KWH SALES (FY 2016)	
Japan	927 TWh
TEPCO	247 TWh
USA	3,867 TWh
Europe	3,342 TWh

Figure 1. Ten Major Utilities in Japan



TRANSITION OF THE ELECTRICITY BUSINESS (UTILITYX.0)

The electricity business has existed for over a century. During that time, it transitioned from Utility 1.0 to Utility 2.0.

Utility 1.0 was the mainstream business model until about 20 years ago. It pursues the economies of scale via legal monopoly and has supported vigorous economic growth in many countries due to aggressive investment. Since smooth capital investment was required to catch up with the growing demand for electricity, it was a model that fit that era.

When the economy shifted to low growth, Utility 1.0 shifted to Utility 2.0. The facilities tend to be surplus under the legal monopoly, so switched to a model for efficiency based on market principles.

During Utility 1.0, the entire electrical power system was thought to be natural monopoly.

To allow for fair competition in the wholesale and retail electricity generation businesses during Utility 2.0, we unbundled the transmission and distribution businesses to ensure competitive neutrality. Japan is now at this stage.

Utility2.0 is not the final stage. Electricity businesses will shift to Utility 3.0 for 5Ds. During that process we will experience (1) Technology Shifts from centralized to decentralized systems and (2) New Integration to improve productivity and create new value.

With the shift to Utility 2.0, the vertically-integrated business was unbundled. Integration will occur again on the next stage.

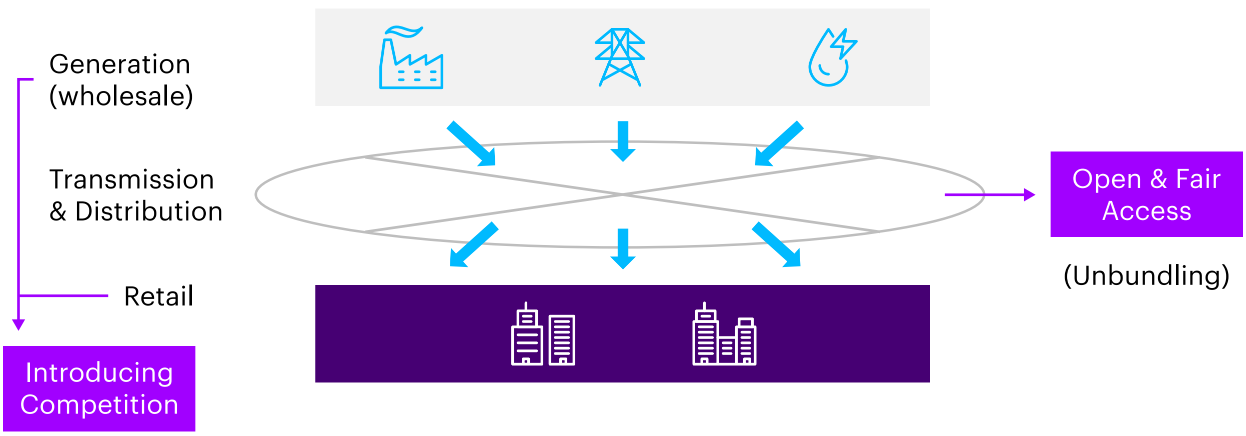
Figure 2. Shift from Utility1.0 to Utility2.0

UTILITY 1.0

- Strong demand for electricity growth & capital investment needs
- Legal monopoly & regulation secures abundant investment funds
- Economies of scale as an entire value chain

UTILITY 2.0

- Low growth economy, supply surplus
- Competition in a business that does not have a natural monopoly (generation/wholesale/retail)
- Aim for business streamlining, expect innovation



WHAT ARE 5DS?

Decentralization

Among the 5Ds, the impact of Decentralization will be great. It is assumed that exponential price disruptions will occur in distributed technologies, and that they will exponentially penetrate the market.

We will discuss photovoltaic (PV) and energy storage as distributed technologies. In this paper, Distributed Energy Resources (DER) = PV.

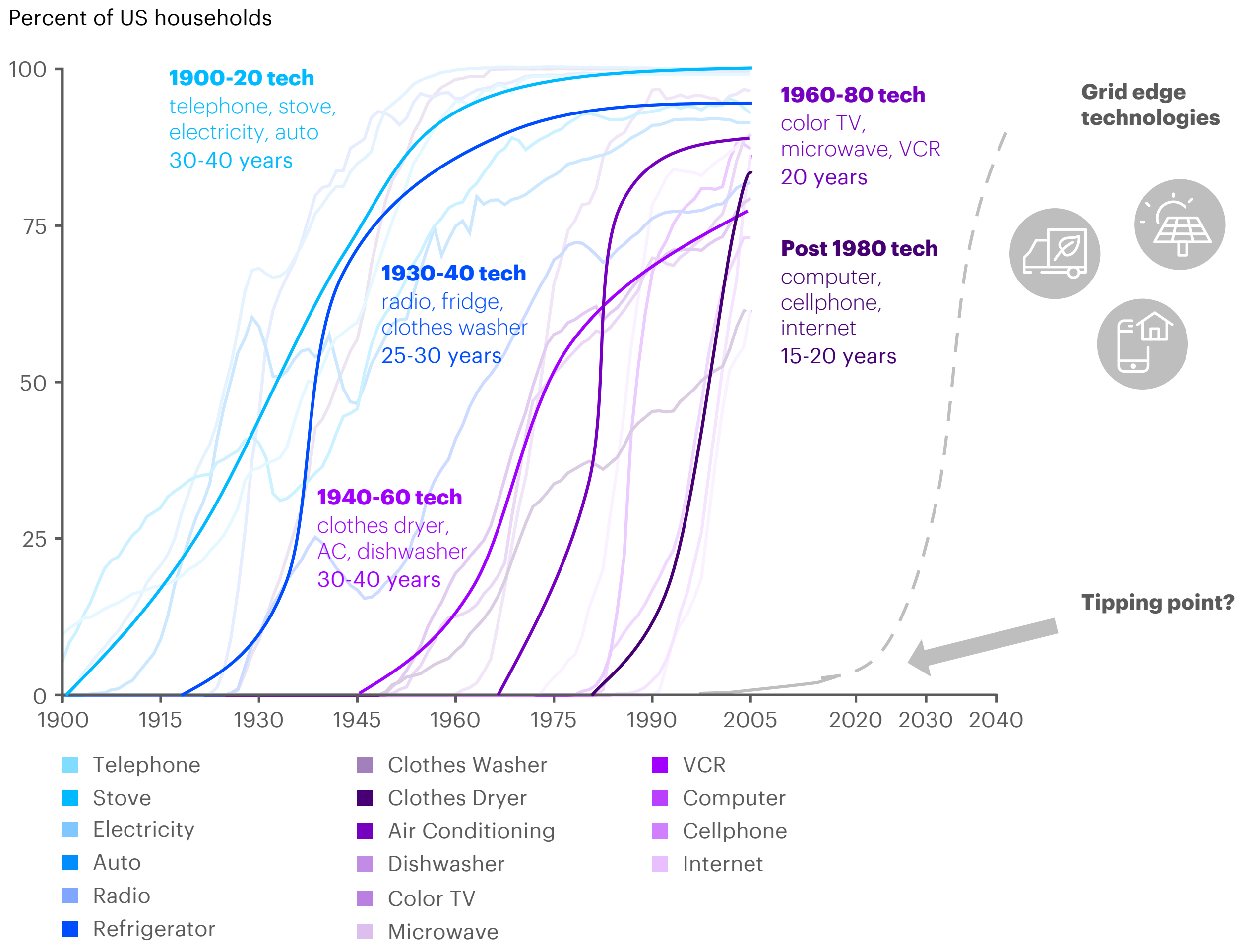
DERs are 1) CO_2 free, 2) zero marginal cost, and 3) not dispatchable. Not dispatchable means that “power generation is influenced by weather conditions and is difficult to control according to demand.”

Figure 3 is quoted from the World Economic Forum's report. In the past, various technologies have penetrated the market along the S-shaped curve shown in the figure.

PV and EV with energy storage are shown as the next technologies that will enter the market. The “tipping point” shown here will occur at some time before 2050. This will be a trigger that pushes the shift to Utility 3.0.

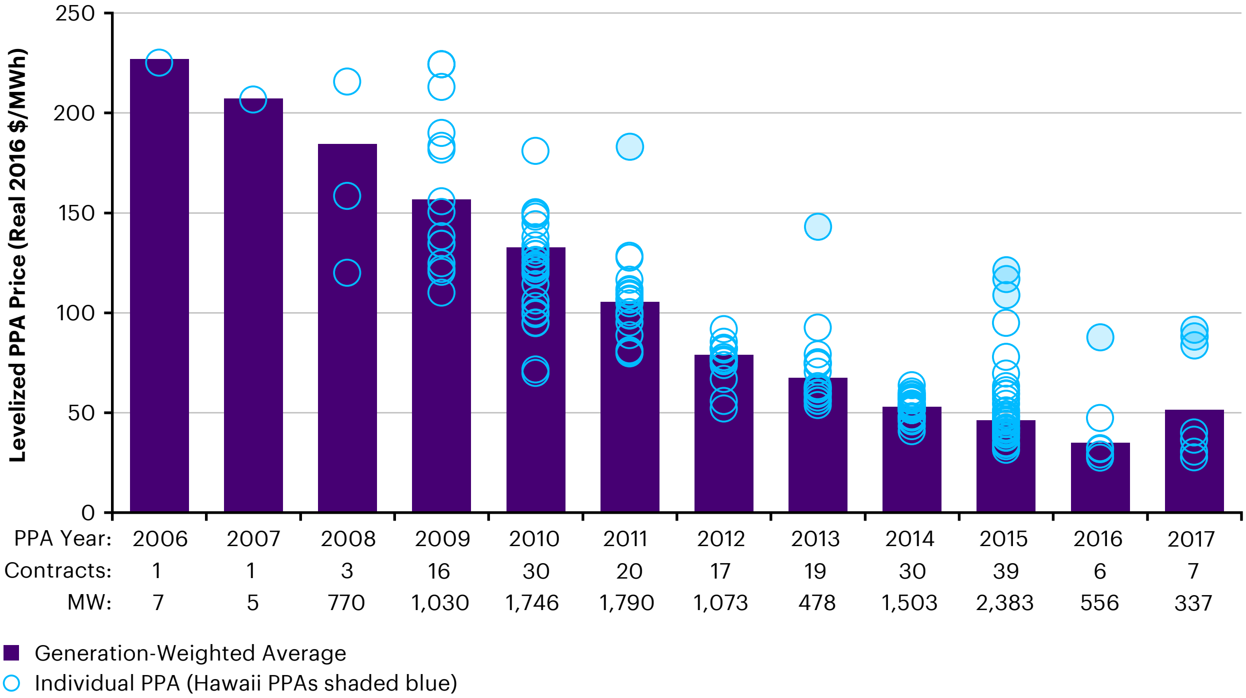
It seems that PV has already reached the tipping point in some countries (Figure 4 & Figure 5). Unfortunately, this has yet to occur in Japan.

Figure 3. Time for Technologies to reach 80% penetration



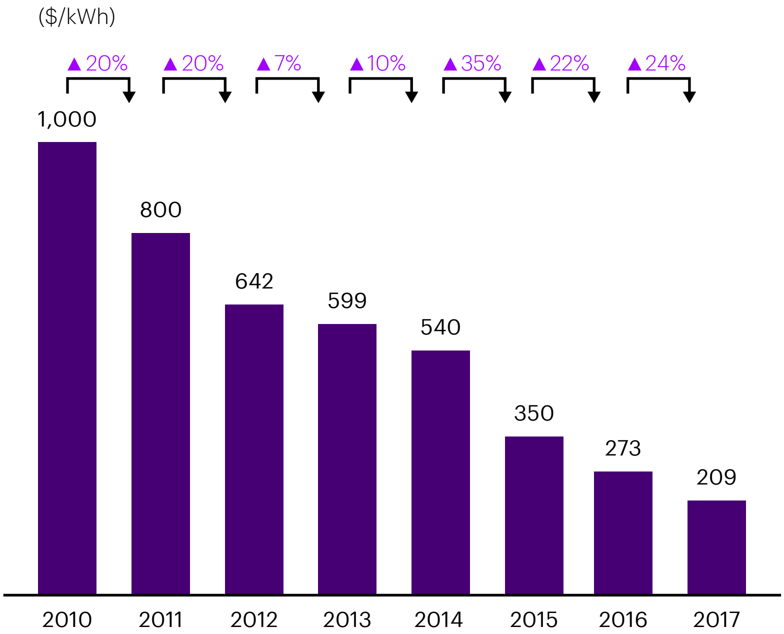
Source: WEF (2017)

Figure 4. Levelized PV PPA Prices by Contract Vintage in USA



Source: LBNL (2017)

Figure 5. Trends of battery pack price (volume weighted average)



Source: Bloomberg NEF (2017)

Decarbonization

Based on the Paris Agreement, some countries have set targets to significantly reduce greenhouse gas emissions by 2050 (e.g. 80% reduction). Decarbonization is an inevitable trend all over the world.

The Government of Japan also stated that, "as a long-term goal, we aim to reduce greenhouse gas emissions by 80% by 2050," in the Global Warming Countermeasure Plan (May 2016 Cabinet decision).

Deregulation

Deregulation has brought a shift from Utility 1.0 to Utility 2.0. Now, Decentralization is calling for changes in Deregulation. (IEA calls it "Re-powering markets.")

There are three kinds of values provided by the power plants: kWh, kW, and ΔkW. Conventional power plants were able to provide all three values. DER is zero marginal cost and is not dispatchable. This means that kWh can be supplied cheaply, but it cannot supply kW and ΔkW.

The current design of the power market does not assume massive market penetration of such power plants (DER).

Box 2. Three products provided by Power Plants (kWh / kW / ΔkW)

Currently, the electricity market is primarily a place to trade energy (kWh). This is natural because kWh is the final product of the electricity business.

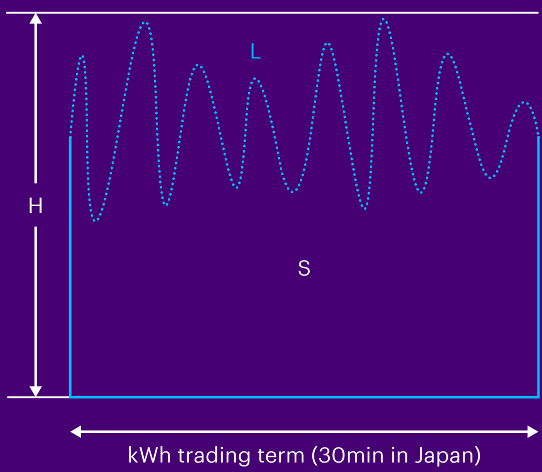
However, there are three values provided by power plants—

1. The value of electricity as energy. This is called kWh value. In Figure 6, it is indicated by the area S.
2. The value of the call option that can provide kWh according to demand. This is called kW value. In Figure 6, it is indicated by the height H.
3. The value of flexibility and the ability to maintain the quality of kWh (frequency, voltage, etc.). This is called ΔkW value or flexibility value. In Figure 6, it is indicated by the length L.

The values of (2) and (3) come from the following characteristics of electricity and are specific to the electric power system.

- "A strict balance between supply and demand is always required."
- "There is a tremendous social impact when the supply-demand balance collapses."

Figure 6. Three values provided by Power Plants



Digitalization

Digitalization is a trend seen in the entire economy, including the energy field. Many "things" loaded with sensors are connected to the Internet, and business is redefined through the interaction and convergence between the digital and physical world.

A business that provides "things" will transform into a business that provides value-added User Experiences (UX) by utilizing "connected things" as interfaces.

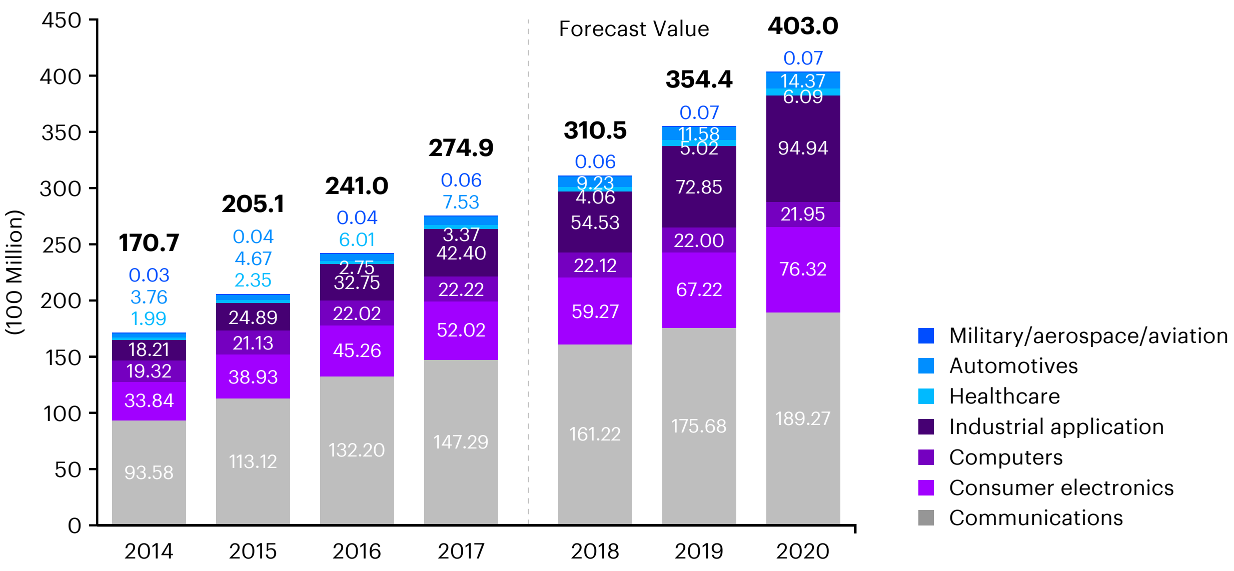
According to the IEA (2017), digitalization is primarily brought about by the following three factors.

- Increasing volumes of data thanks to the declining costs of sensors and data storage.
- Rapid progress in advanced analytics and computing capabilities.
- Greater connectivity with faster and cheaper data transmission.

Figure 8 shows the pricing trends of some key technologies.

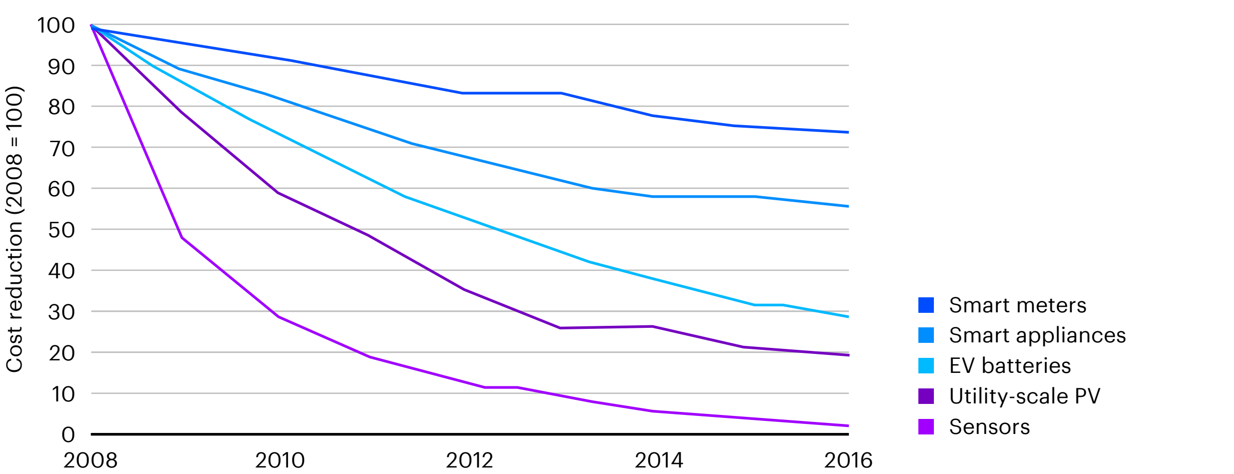
In just 8 years (2008 - 2016), prices for various technologies declined rapidly. The most significant cost reduction can be seen in sensors. This leads to enhanced connectivity and digitalization.

Figure 7. Trends of the number of IoT devices in the world



Source: MIC (2018)

Figure 8. Unit costs of key emerging electricity-based technologies



Source: IEA (2017)

Box 3. Michelin's Tire-as-a-service

Figure 9 shows Tire-as-a-service of Michelin, a major tire manufacturer. Michelin has transformed its business model from product-selling business to result-based service business. Michelin can offer valuable UX services that go beyond selling products by utilizing data obtained from tires with sensors attached.

Figure 9. Tire-as-a-service

Selling Tire

Leasing Tire
Billing according to mileage measured by sensor

Depopulation

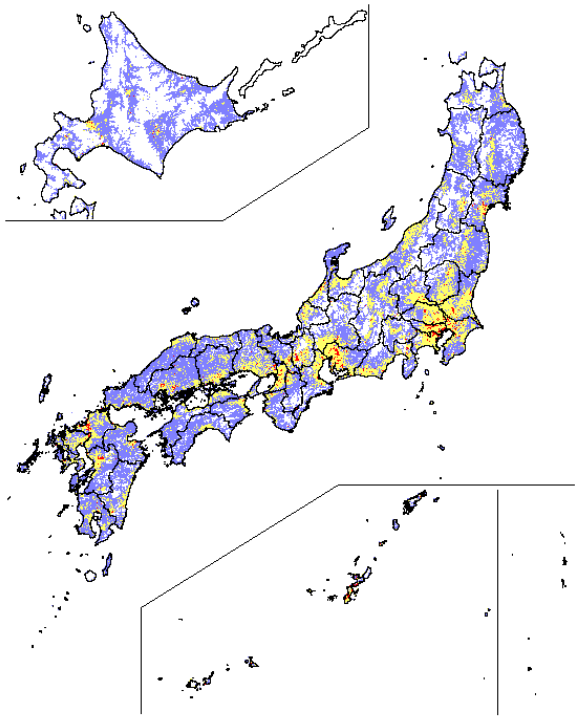
Japan is expected to face rapid Depopulation. It is almost inevitable unless the government accepts a large number of immigrants.

The total population of Japan from 2010 is predicted to decrease 20% by 2050. In addition, the population will be reduced to less than half in 60% of the country's living area, primarily in the countryside.

Infrastructure services will face sustainability challenges in Japan's countryside.

Transmission and Distribution,
Gas, Telecommunications, Logistics,
Public Transportation, Water Supply,
Roads/Bridges, Medical...

Figure 10. Population Projection



Note: the blue areas are where the population will be reduced to less than half.

Source: MLIT (2014)

WHAT DO THE 5DS BRING? WHAT WILL THEY PROMOTE?

Electrification/Decarbonization/ Abundant Energy

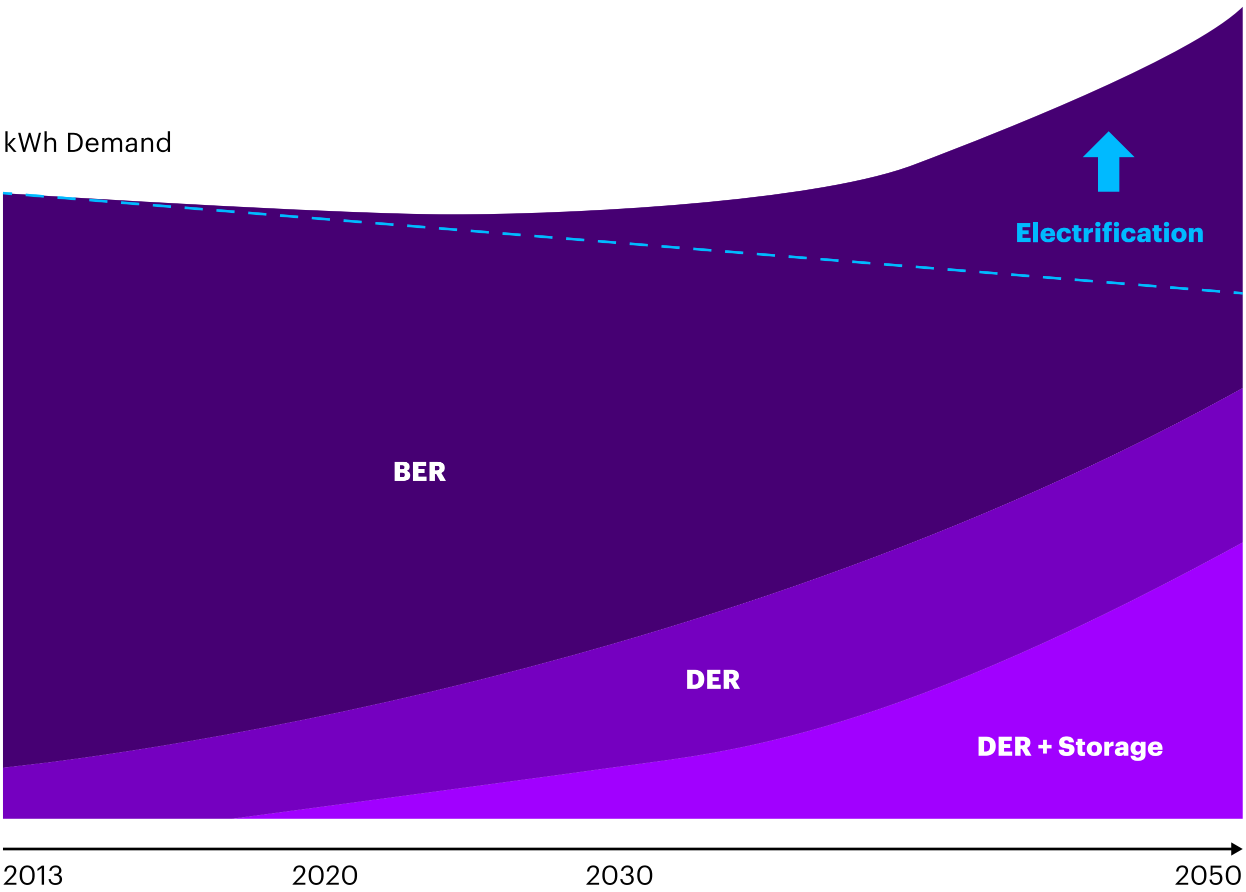
Exponential DER market penetration due to price destruction means that electricity will have a competitive advantage against other energy sources. Decentralization will inevitably promote Electrification.

Since DER is CO_2 free, the high carbon prices that Decarbonization brings will also promote Electrification. Decarbonization will progress alongside Electrification.

If price destruction similar to what occurred with semiconductors occurs in PV, the cost of kWh will shrink to almost zero. This may allow us to enjoy abundant energy for the first time in history.

Figure 11 expresses the above with a time-series transition. Without Electrification, demand for electricity will decrease with the population. But as Decentralization occurs, demand for electricity will increase due to advances in development.

Figure 11. Image of kWh Balance (-2050)



BER: Bulk Energy Resources (Conventional power plants including large thermal, nuclear, etc.)

Box 4. Potential of Decarbonization through Electrification

- The TEPCO Research Institute (TRI) made rough calculations concerning the potential of CO_2 reduction via Eletrification. They are promoting low-carbon energy resources (renewable, nuclear) on the supply side and Eletrification (e.g. from gasoline vehicles to EV) on the demand side. This optimization of the supply and demand sides brings a significant potential for CO_2 reduction.
- Figure 12a shows the final totals for energy and electricity consumption. The final energy consumption in 2013 is 12.0 Exa J (10^{18} Joule), and the ratio of electricity in final energy consumption is around 30% (see left graph).
- The middle graph shows the final energy consumption in 2050 in case the ratio of electricity does not change by 2050. We assumed that since the population will be reduced by 20%, the final energy consumption will be also reduced by 20%. The right graph promotes electrification from there. The demand for electricity increases, but since the electric appliances are energy efficient, the total final energy consumption will decrease.
- Figure 12b shows the corresponding CO_2 emissions. The generation mix is RES 55%, nuclear power 10%, and thermal power 35%. RES has adopted the maximum introduction case of the study by Ministry of Environment (MOE [2014]). Even in this case, RES cannot quantitatively cover the demand for electricity.
- If the Eletrification rate remains unchanged, CO_2 emissions will be half that of 2013. But if Eletrification is promoted, CO_2 emissions will be reduced by 72%.
- Conclusion: The combination of Decarbonization on the supply side and Eletrification on the demand side is important.

Potential of CO_2 Reduction by Eletrification

Figure 12a. Final energy consumption

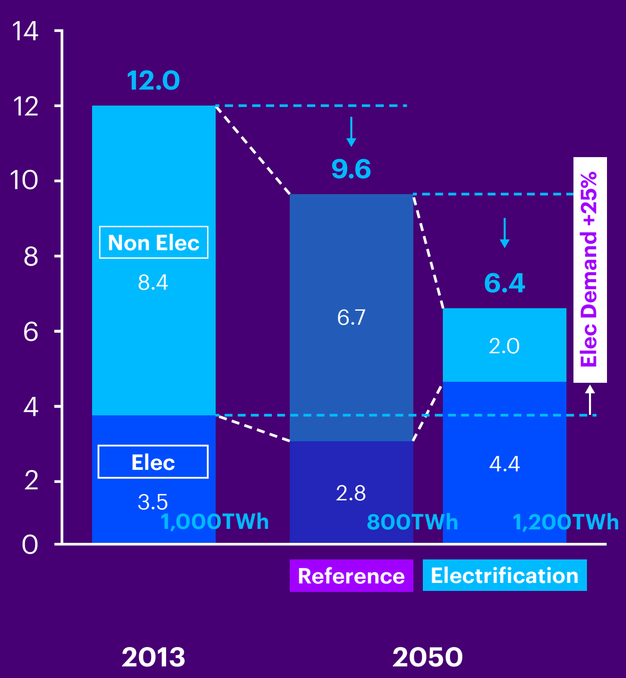
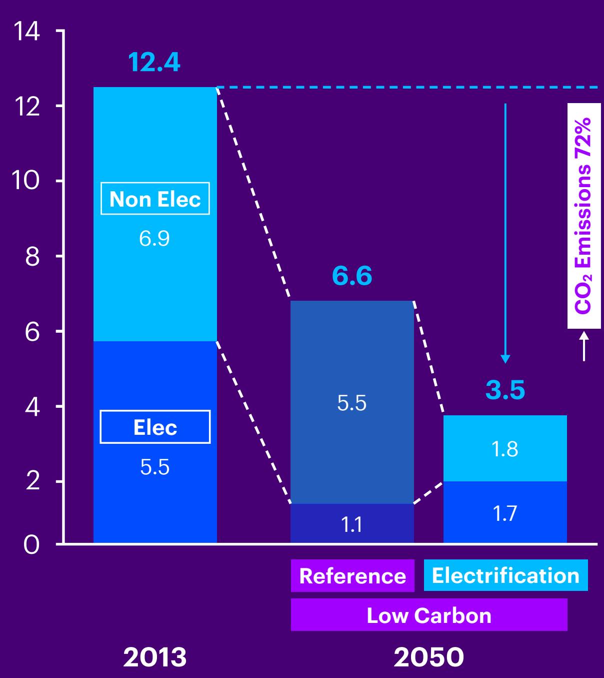


Figure 12b. CO_2 emissions



Box 5. What will abundant kWh and Energy Storage bring?

- ☐ Blockchain and digital tokens deliberately waste cheap storage to create something new and valuable.
- ☐ Over the past 50 years, the information revolution has been propelled by exponential advancwes in the cost, speed, and capacity of computing, communication, and memory/storage.
- ☐ Organizations have exploited these "big exponentials" in two ways. Incumbents compute more, communicate more, and store more data to run their businesses more efficiently. They create better and cheaper products and enable extensions to their current business models.
- ☐ But at some point, a resource becomes so cheap and abundant that wasting it to create something completely different makes economic sense.

Thinking Outside the Blocks (Boston Consulting Group (2017)

- Exponential market penetration of PV and EV will made kWh and energy storage cheap and abundant. Something completely different may be created by deliberately wasting cheap and abundant kWh and energy storage, such as in the information technology field.
- "Abundance" (Diamandis, Kotler (2012)) presents a similar vision.

Re-powering the Electricity Market (for a sustainable system)

DER has zero marginal cost and can cheaply supply kWh value, leading to abundant energy (kWh). But because it is not dispatchable, it cannot supply kW and ΔkW.

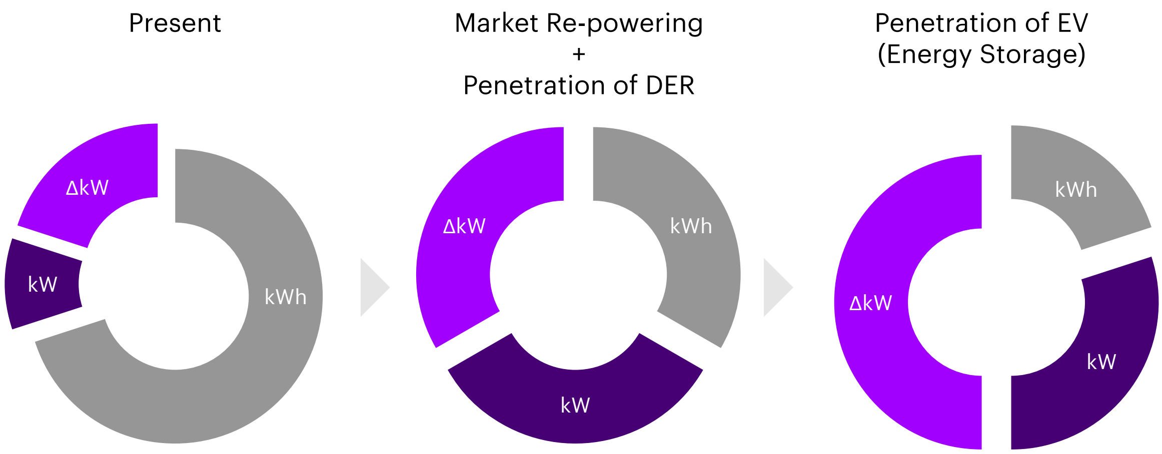
Therefore, it is necessary for resources other than DER to supply kW and ΔkW to maintain the stability of the power system.

Because the kWh value drops, the supply of kW and ΔkW cannot be maintained only in the kWh market. The electricity market must shift from kWh-centric to kW- and ΔkW-centric. (Re-powering the Market).

The sources of kW and ΔkW are:

- For the time being, BERs. They should be maintained as a source of scarce kW and ΔkW.
- Demand-side resources (DSRs) will enter the market in the medium- to long-term, especially if an idea to share energy storage of EV emerges. This could possibly mitigate the scarcity of kW and ΔkW.

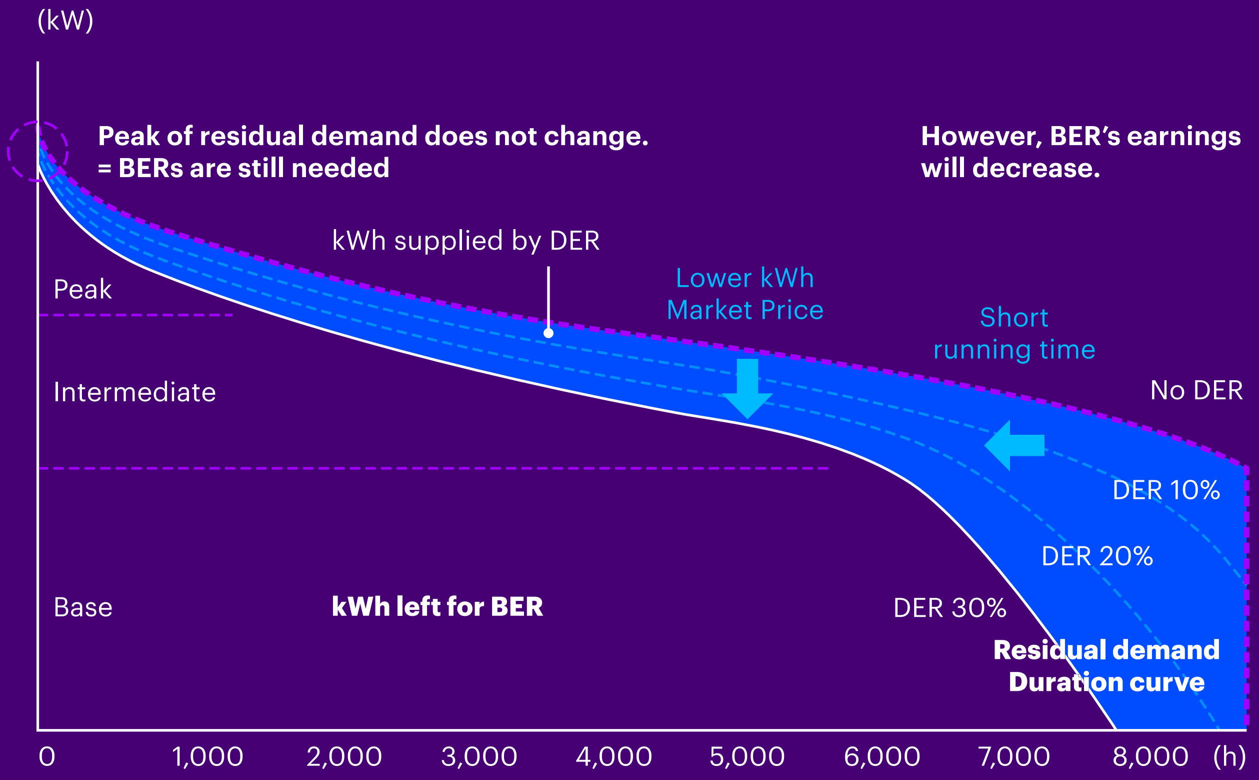
Figure 13. Transition of the Electricity Market



Box 6. The Impact of DER Penetration in the Electricity Market

- In Figure 14, the purple curve shows the load duration curve without DERs. The white curve shows the residual load duration curve supplied by the BERs when the DERs share is 30% of the demand for electricity.
- When comparing purple and white, the height of the curve does not change much. This indicates that the BERs will still be required as the main source of kW. BERs should be maintained after DER market penetration as a stable power supply.
- However, the changing shape of the duration curve from purple to white indicates that due to lower kWh market prices & shorter running times, BERs will be placed in a tough environment.

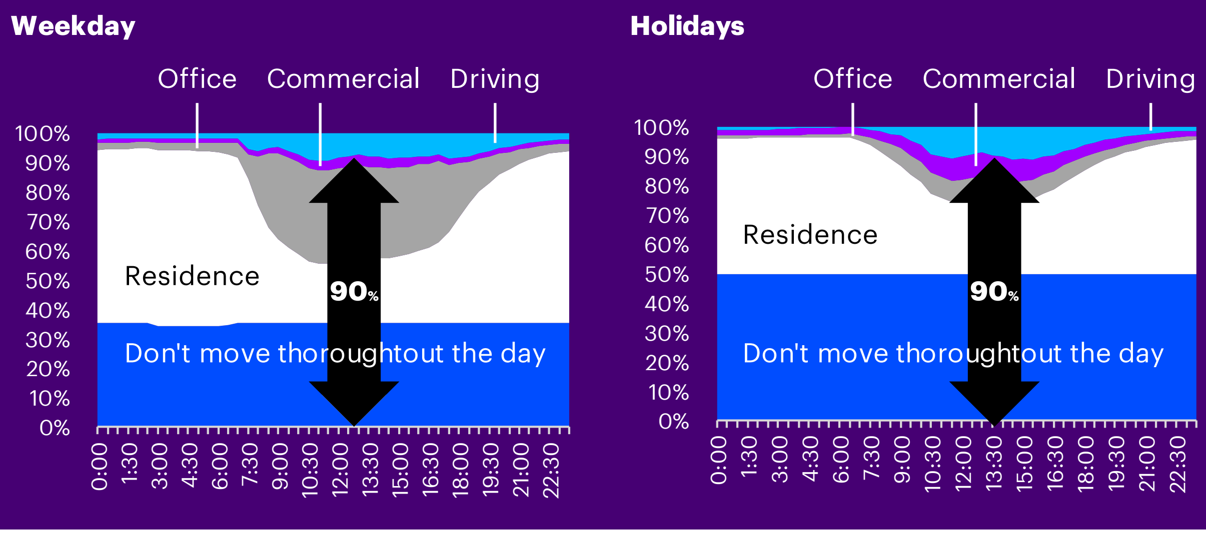
Figure 14. Impact of DER Penetration



Box 7. Sharing EVs & Energy Storage

Figure 15 shows that 90% of cars are currently parked. This indicates that the energy storage of parked cars will be in the idle state. There is a possibility that stored energy in parked EVs can be effectively shared and utilized as a source of kW & ΔkW.

Figure 15. Ninety percent of cars are stopped



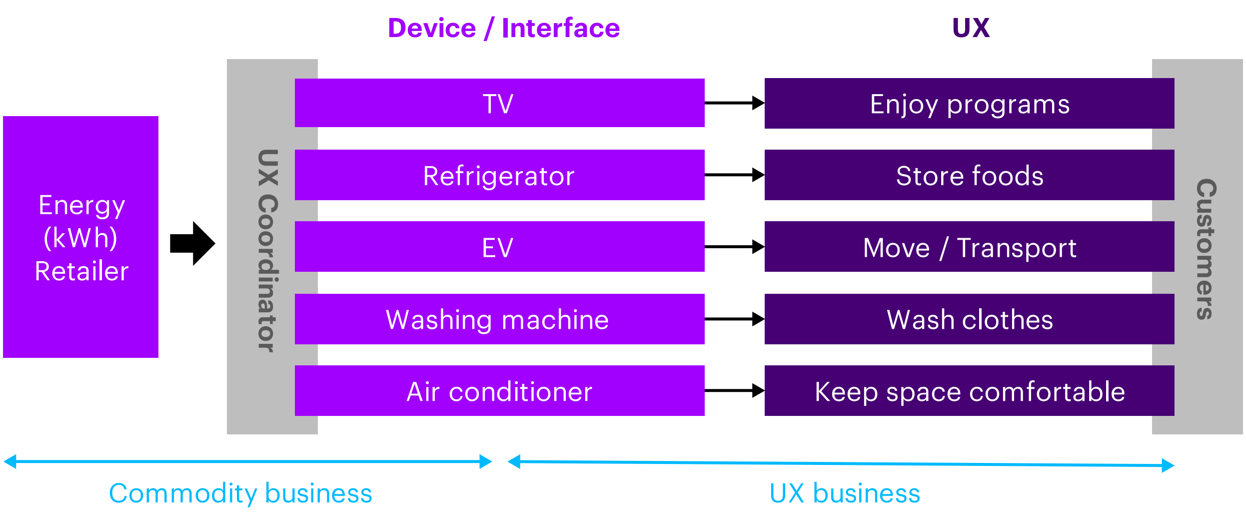
B2C Business: redefine business to UX & commodity supply

With Digitalization, a business that sells kWh shifts to a business that sells "UX" with electric devices as an interface.

Businesses selling kWh will survive as a B2B commodity supply to a UX coordinator.

Existing kWh businesses face the choice of entering the UX business or remaining a commodity supply. Under an abundant kWh situation, the commodity supply business will shrink.

Figure 16. Redefined B2C business



Transmission & Distribution (T&D) Business: facing sustainability challenge, move to New Integration

Due to 5Ds, the challenges faced by T&D infrastructure are as follows.

- Depopulation and Decentralization (kWh can be made at home) will lead to a decrease in kWh flowing through the T&D system, i.e. a decline in facility utilization.
- In addition, despite a very high fixed-cost ratio structure (not proportional to kWh), the recovery of T&D costs heavily depends on kWh-based billing. It is vulnerable to a decline in facility utilization.
- Decentralization calls for investment to increase the sophistication of the distribution network. In addition, facilities developed during periods of high economic growth will require renewal. Procuring the required funding will be a challenge.

The following approaches are necessary to deal with the challenges listed above.

- Rebalancing the T&D rate structure: This should be changed to a rate structure consistent with the cost structure. i.e. a shift to kW-based billing.
- Reducing facilities: We have so far made capital investments in line with the increasing demand for electricity, but the world has changed dramatically. We must promote facility reduction while effectively utilizing the flexible resources of the demand side.
- Advancement of facility maintenance: Utilize digital technology and use older facilities as long as possible.
- Integration with other infrastructure: Improve productivity and create new value through digital technology. (New Integration).

Box 8. TEPCO's initiatives aimed at New Integration.

TEPCO has begun initiatives targeting New Integration. TEPCO hopes to further cooperation with various stakeholders by sharing this vision.

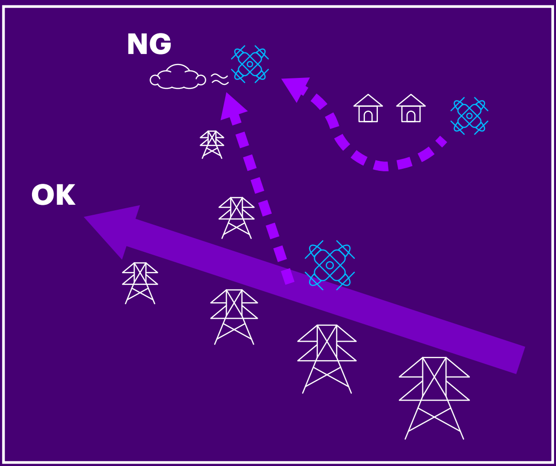
1. Joint investment company (TNX [cross]) with NTT

- NTT is Japan's largest telecommunications & telephone company. Although both NTT and TEPCO have substantial infrastructure in the Tokyo area, each company has independently developed and operated infrastructure.
- Our goal is to provide more efficient operations and new value through cooperation.

2. Drone Highway project

- This initiative is being promoted in cooperation with Zenrin (the largest map company in Japan) and Rakuten (an internet commerce company).
- This concept utilizes the Transmission/Distribution network as a safe flight path for drones, using idle spots at power transmission towers, substations, etc. as landmarks and charging ports.
- This extends the use cases of this infrastructure and allows drones to safely fly long distances.

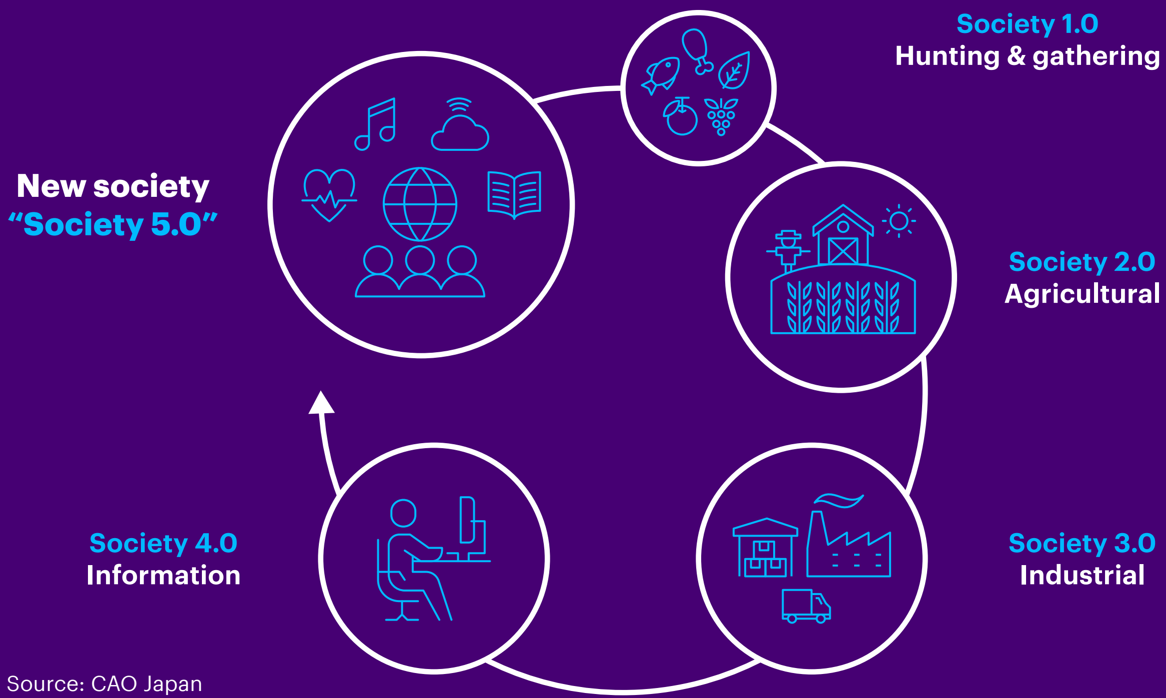
Figure 17. Drone Highway



Box 9. A Vision of the Government of Japan : Society 5.0

- The Government of Japan has proposed the concept of Society 5.0 in the 5th Science and Technology Basic Plan (Jan 2016 Cabinet decision) as the vision of our future society.
- It follows the hunter/gatherer society (Society 1.0), agricultural society (Society 2.0), industrial society (Society 3.0), and the information society (Society 4.0).
- It is defined as "A human-centered society that balances economic advancement with the resolution of social problems using a system that integrates cyberspace with physical space."
- The 5th Science and Technology Basic Plan stated;
  - Manufacturing initiatives around the world utilize networks and the Internet of Things (IoT). In Japan, the use of these networks will be extended to other fields to promote economic growth, the formation of a healthy and long living society, and for social transformation. It will allow the fruits of science and technology to enter many other fields and spheres, and will lead to enhanced business capabilities and higher-quality services.
  - We will share a vision of the future characterized by the sophisticated integration of cyberspace with physical space ("the real world"). We will refine this vision while pursuing the measures required to implement it under the concept of "Society 5.0."
  - We must "systemize" services and businesses, system advancement, and coordination between multiple systems. Therefore, we will promote the development of a common platform to achieve this goal (called the "Society 5.0 Service Platform") through collaboration between industry, academia, government, and the relevant government ministries.
- We expect that the "Society 5.0 Service Platform" will promote the New Integration. Paying attention to and cooperating with the initiative will be necessary.

Figure 18. Transition to Society 5.0



Source: CAO Japan

Figure 19. Society 5.0 Service Platform

Source: Cabinet Office (2016)

WHAT WILL UTILITY3.0 LOOK LIKE?

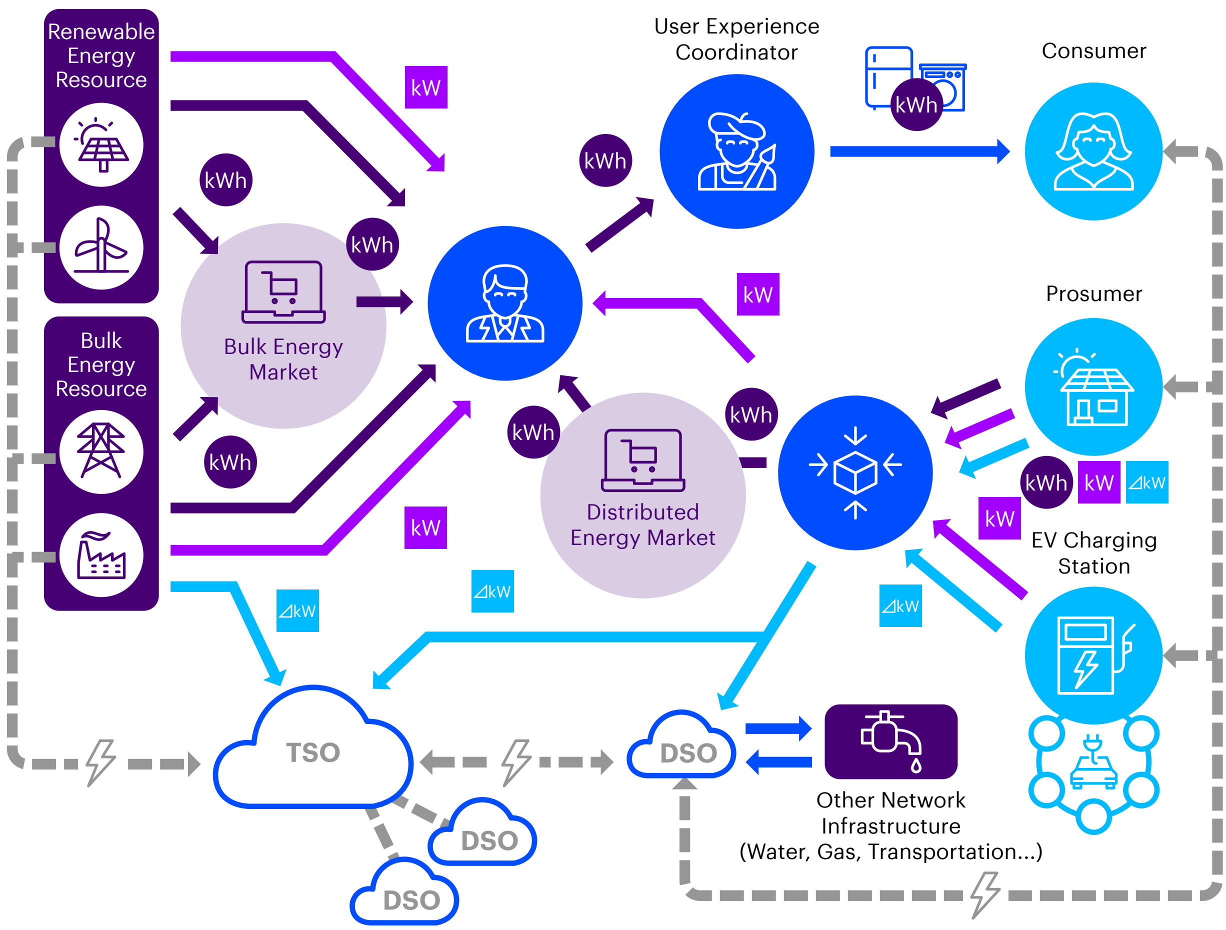
In Utility3.0, the vertically- and highly-integrated social system that is the electricity business will evolve into a new multi-layered social system.

Electric/gas retailers will transform from commodity suppliers into customer agents. While providing electrified and decentralized customers with new customer experiences as UX coordinators, they will create new business models integrating with other industries such as mobility and agriculture.

Three values will be traded independently in the power generation business. kWh will become greener with electrification and energy efficiency. The kW and ΔkW market will depend more on alternative resources such as energy storages and demand side resources.

The T&D business will evolve into new platforms based on social transformation. The Transmission business will evolve into a wide area grid that seamlessly handles nation/region-wide transactions, and the distribution business will evolve into an integrated local lifeline platform.

Figure 20. Image of Utility3.0 (Example)



About TEPCO

Tokyo Electric Power Company Holdings, Inc. (TEPCO) is Japan's largest power company group, holding three independent business entities: TEPCO Fuel & Power, Inc., TEPCO Power Grid, Inc., and TEPCO Energy Partner, Inc. As a group, it generates, distributes, and sells electricity and other types of energy principally to the Kanto metropolitan area, which includes Japan's two most populous cities, Tokyo and Yokohama. It has also developed overseas businesses in more than 70 countries. The TEPCO Group's 43,909 employees are committed to providing safe, reliable and sustainable energy and related services to enhance social welfare, as well as fulfilling the company's responsibilities to all stakeholders, especially the communities of Fukushima. (As of March 31, 2019)

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