Integrated Energy Network Concept in Japan

2017/5/16 @iiESI Workshop, London

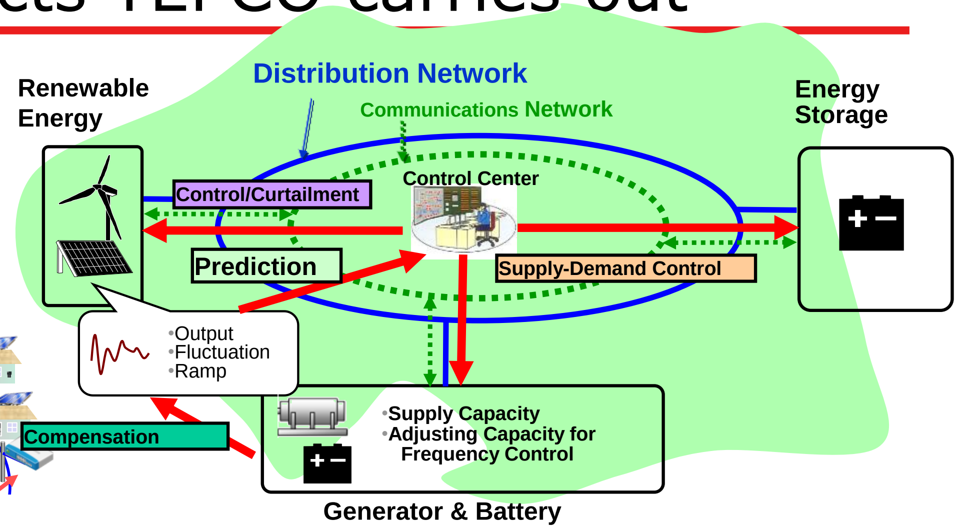
Naoki TODA
Chief Economist
TEPCO Research Institute (TRI)
toda.naoki@tepco.co.jp

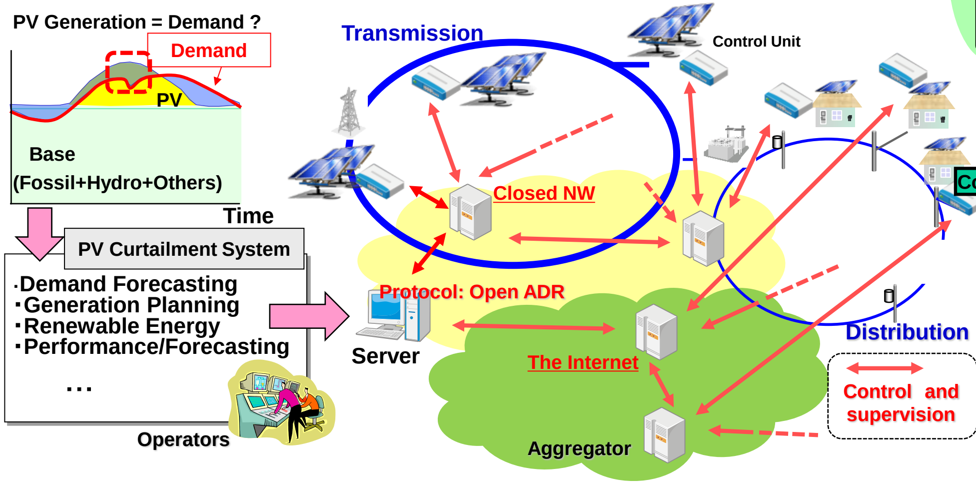
IEN Concept in Japan

- In Japan;
  - The Government has adopted the goal of reducing greenhouse gas emissions by 80% in 2050, and the realization of IEN can contribute to achieving that goal.
  - Several demonstration projects aiming to realize IEN are beginning.
- TEPCO Research Institute (TRI) ;
  - believes that the energy industry in Japan is facing the following 5 trends and challenges (5Ds) including De-carbonization.
  - is trying to draw a vision of the future of the energy industry looking to 2050, including IEN.
- This presentation, looking at 2050, will show;
  - What do 5 Ds bring to the energy industry?
  - Necessary reform of social system and market system.

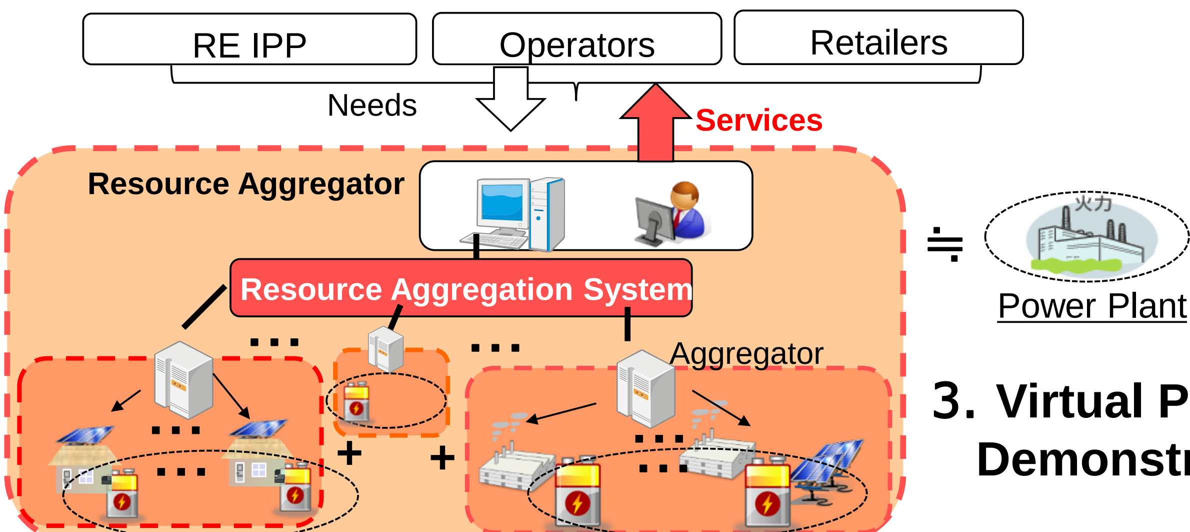
NEDO demonstration projects TEPCO carries out

1. Smart Grid in Niijima Island (2014-2018)





2. PV Curtailment Demonstration (2015-2018)



3. Virtual Power Plant (VPP) Demonstration (2016-)

Trends and Challenges facing Japan’s Energy industry

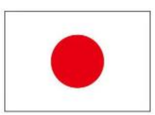
5Ds

Deregulation

Decentralization

De-carbonization

Digitalization

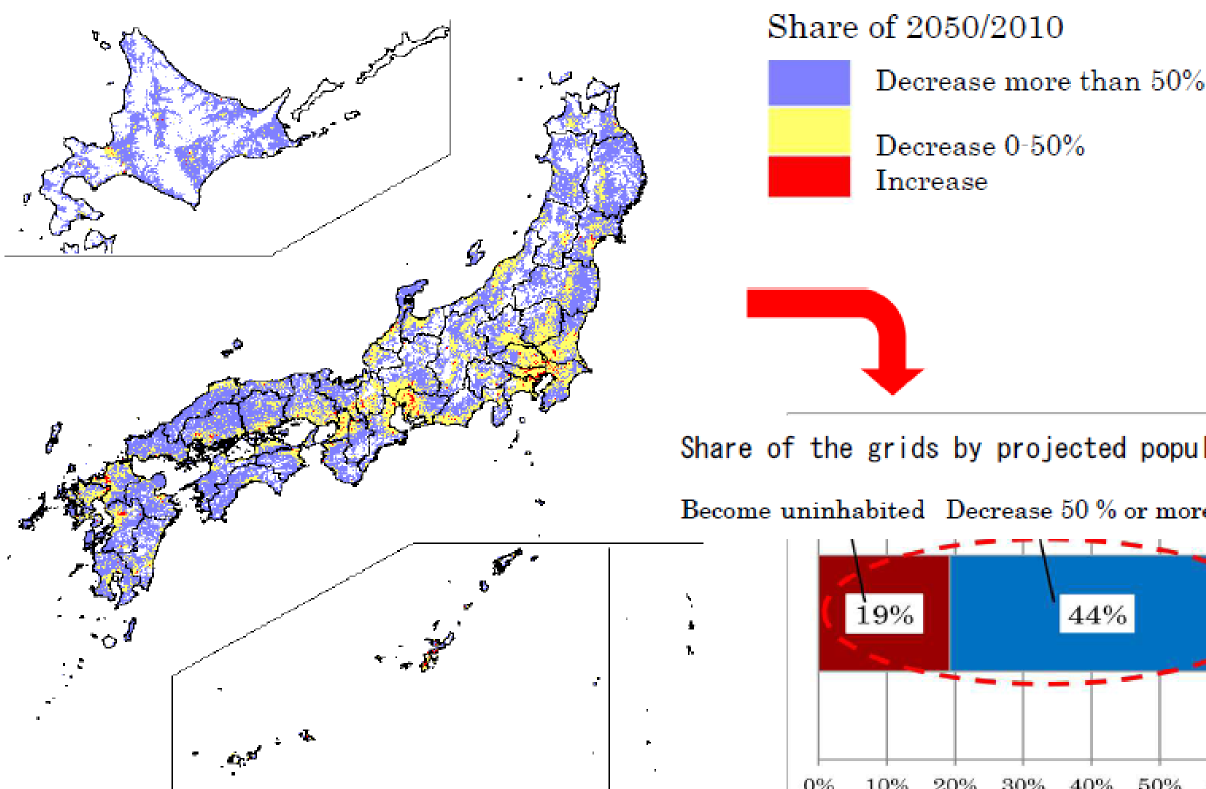


Depopulation

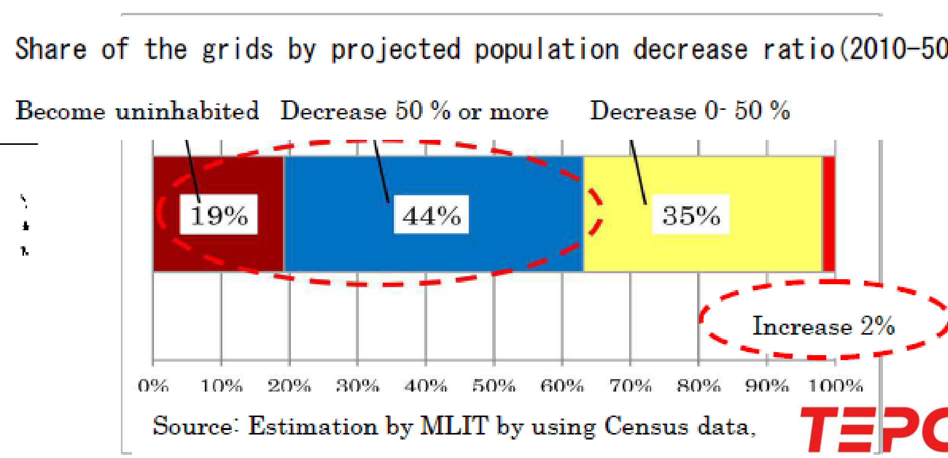
Depopulation

- In 2050 compared to 2010, more than 60% of the inhabited grid squares of 1 sq km will lose half or more population, and 20% of the grid squares will become non-inhabited.
- Every kind of infrastructure will face challenges of service sustainability.

[Population in 2050 compared to that of 2010]



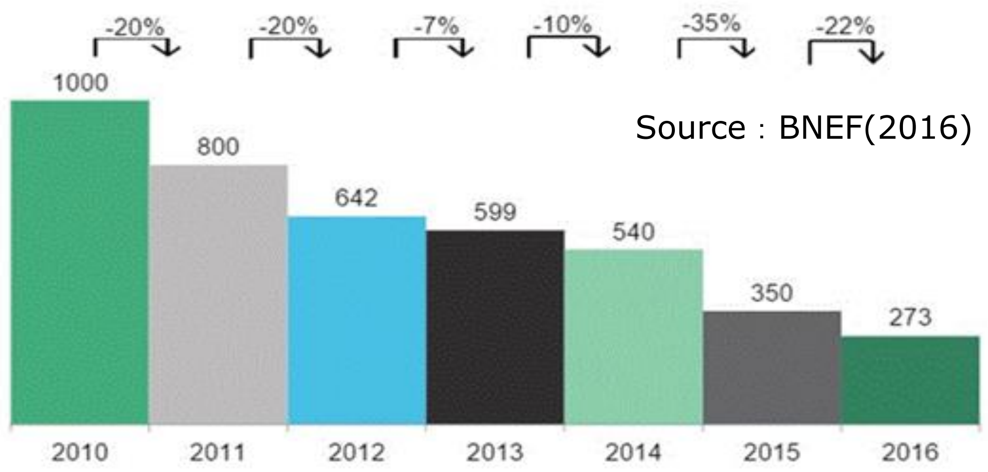
Source : MLIT(2014)



Decentralization

- Will DER including PVs & Storage scale on exponential curves?
- Can we realize abundant energy?

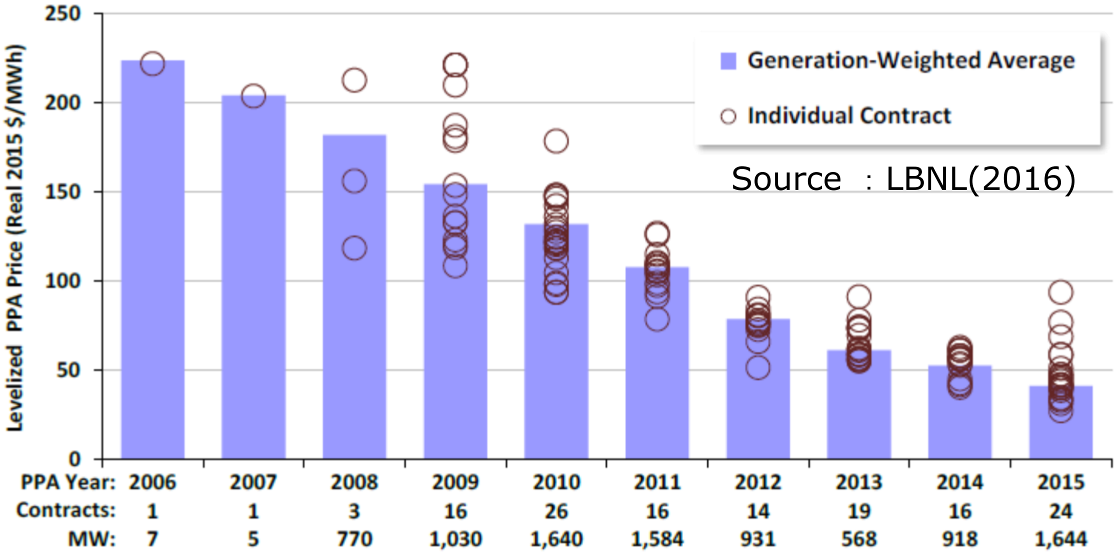
Figure 1: BNEF 2016 battery pack price survey results, 2010-2016 ($ per kWh)



Source：BNEF(2016)

If we want to achieve energy abundance, we need to choose technologies to scale – ideally, on exponential curves.
Solar fits all of these criteria.

Source ：Diamandis, Kotler(2012)



Source ：LBNL(2016)

Figure 20. Levelized PV PPA Prices by Contract Vintage[47]

TEPCO

Decentralization: SunShot's 2030 Goals (DOE)

- Published Nov. 2016
- Extended its goals to reduce the average unsubsidized LCOE of utility-scale PV to 3¢/kWh by 2030
- Targeted concurrent reductions for commercial and residential rooftop PV costs to 4¢/kWh and 5¢/kWh by 2030, respectively.

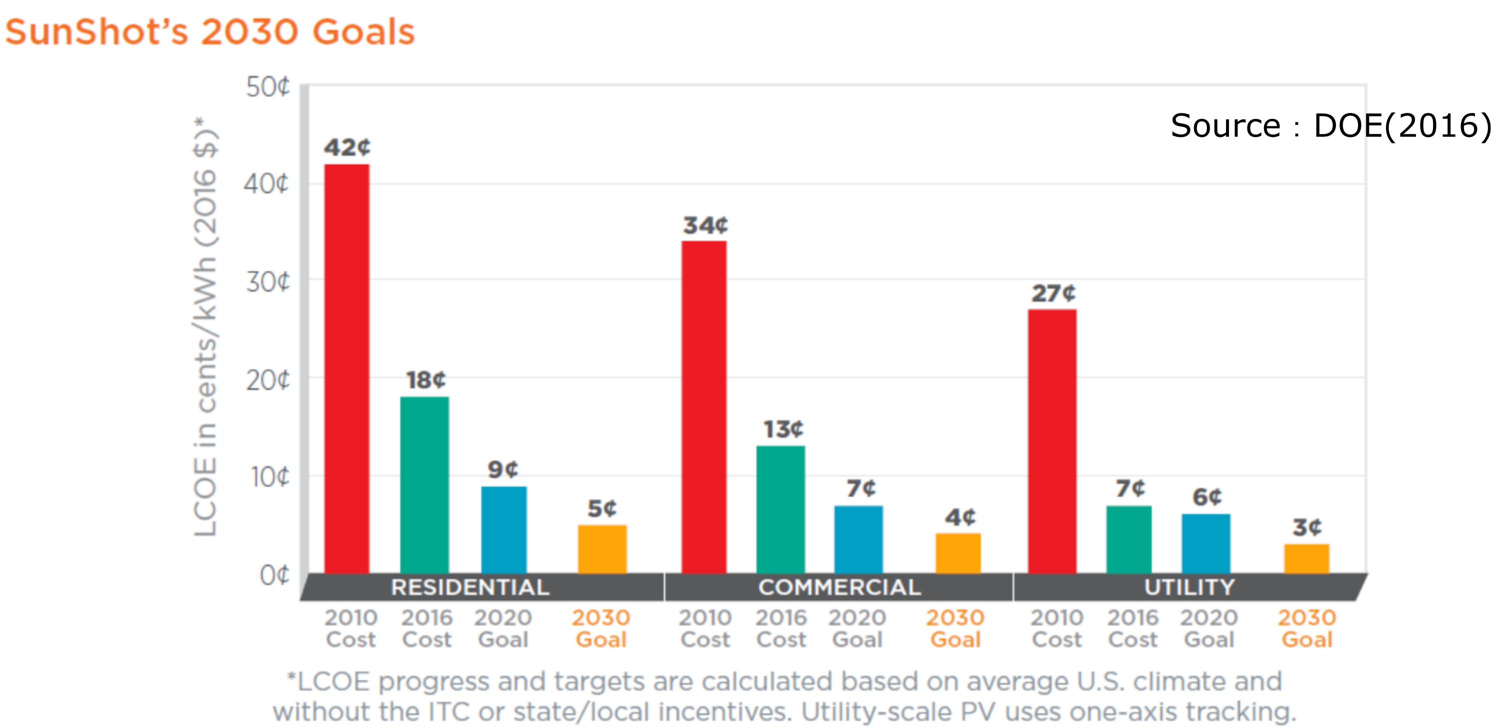
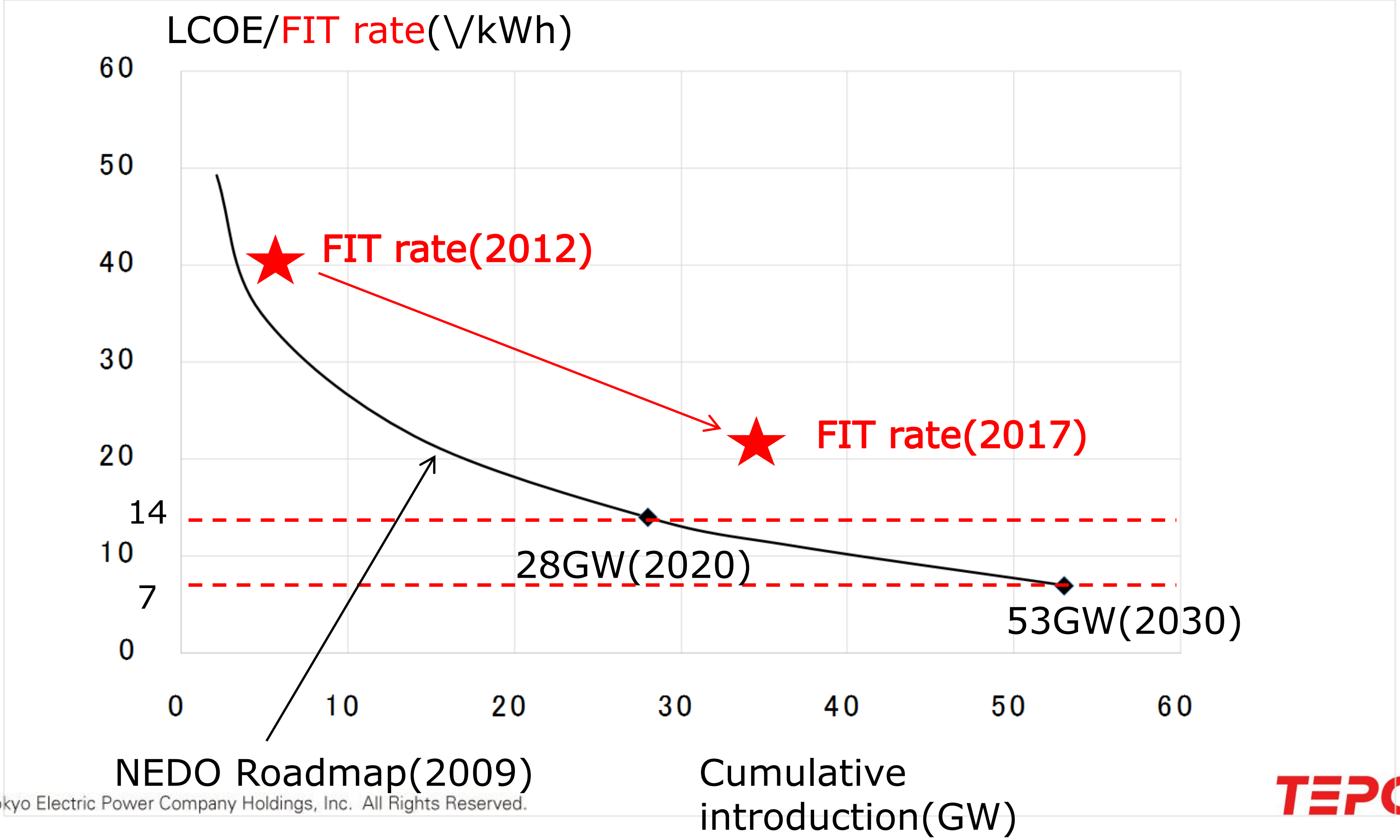


Figure 1. LCOE values and SunShot goals for the residential, commercial and utility-scale sectors.

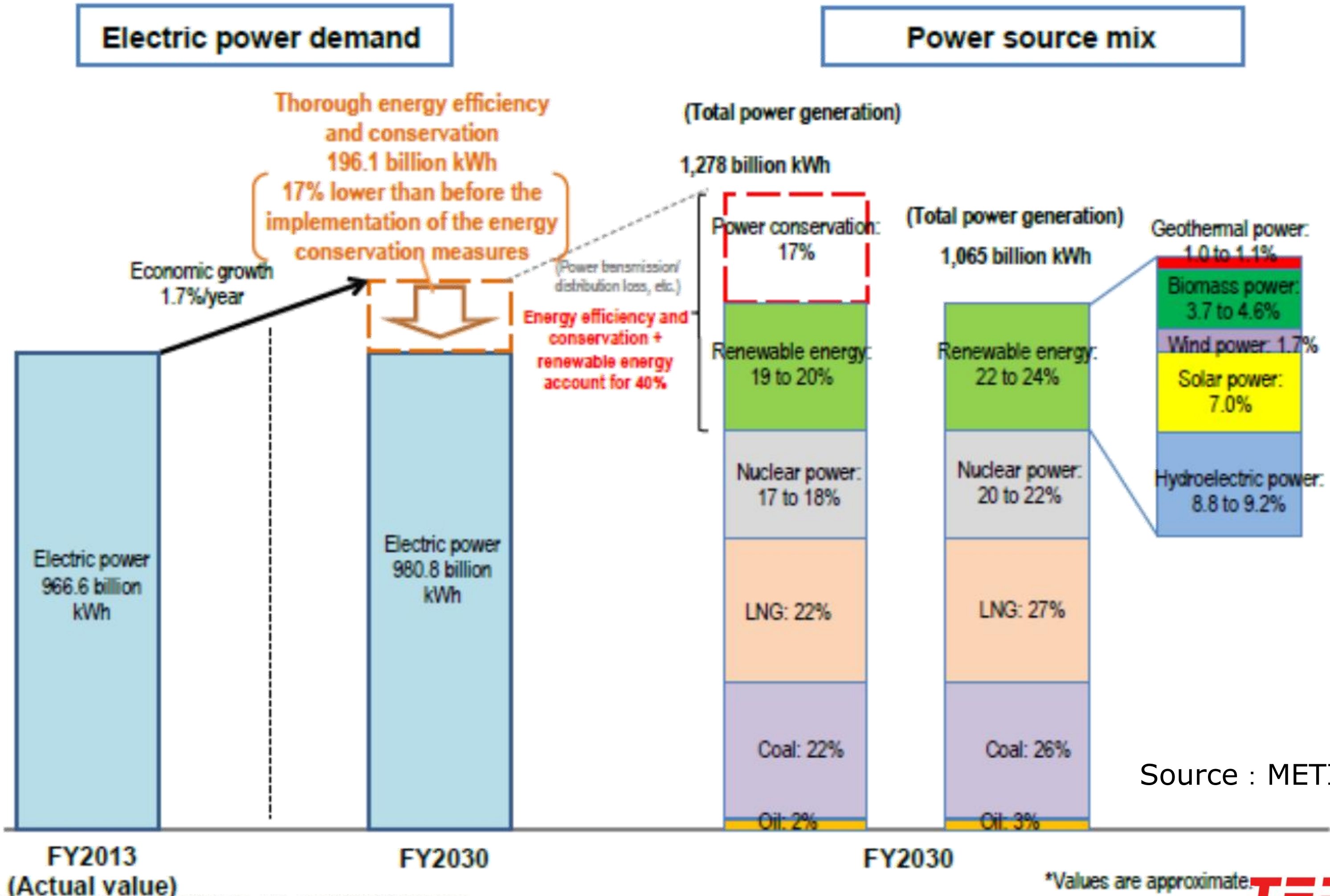
Decentralization: Japan’s Roadmap

- The goals of NEDO Roadmap were not achieved. LCOE of PV in Japan is more than twice higher than that of US & EU
- New goals are \14/kWh by 2020 and \7/kWh by 2030 for utility-scale PV.



Long-term Energy Supply & Demand Outlook (METI)

- VRE(Variable Renewable Energy; PV& Wind) : 8.7% in 2030
  - 8.7% is close to the VRE penetration rate of current Europe.

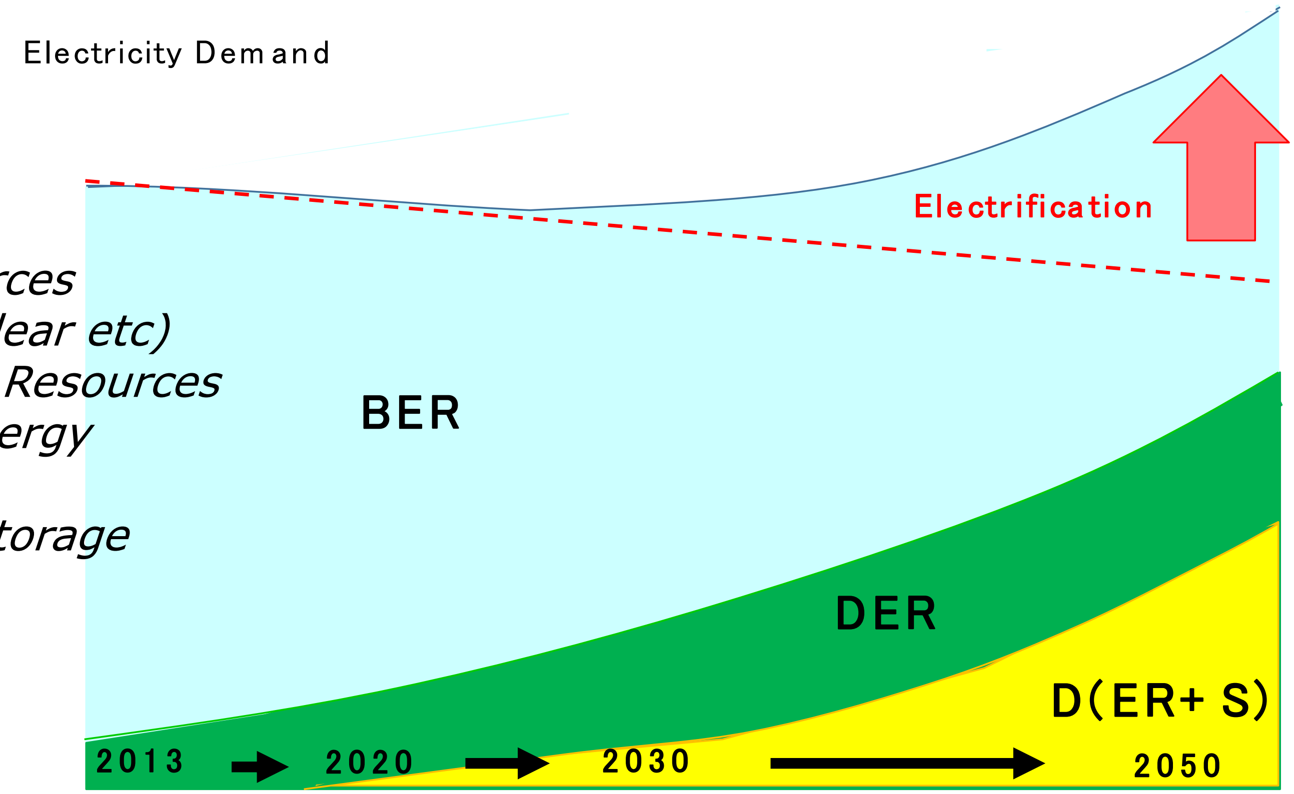


Source：METI(2015)

Decentralization + De-carbonization => Electrification

- If an exponential development occurs, DER & Storage will penetrate as a market choice irrespective of government outlook.
- "exponential development of DER & Storage"+"high carbon price" => Electrification (inevitable)
- BER market will shrink. But we will still need BER. What shall we do?

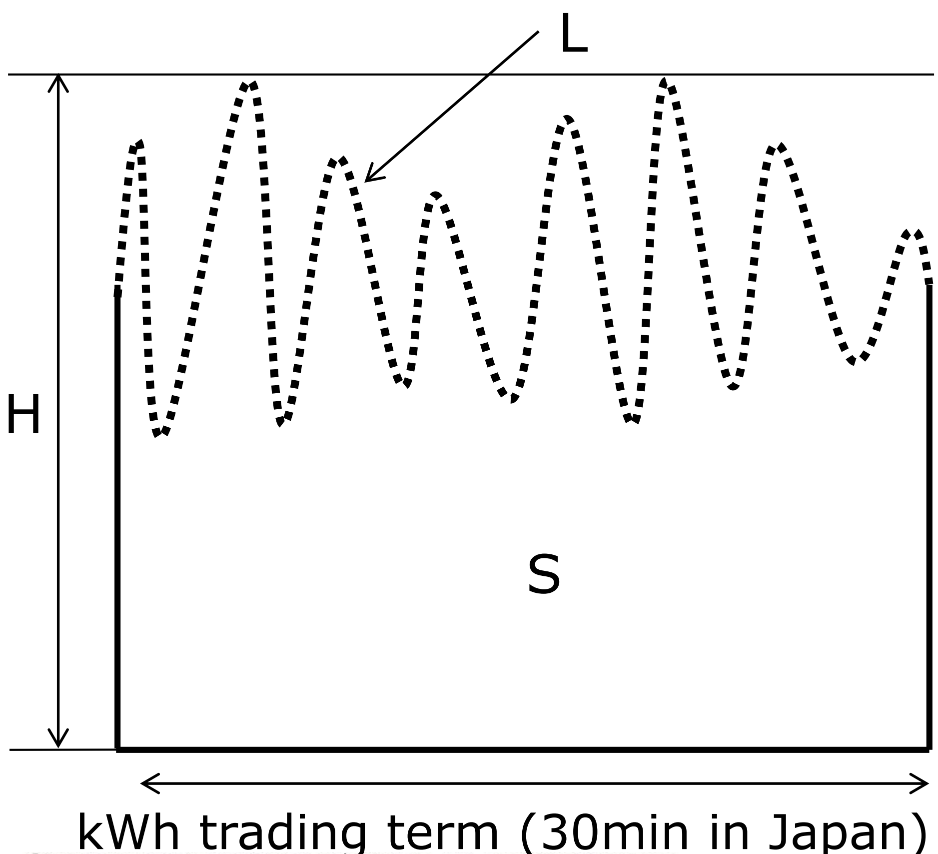
BER : Bulk Energy Resources (large thermal ,nuclear etc)
DER : Distributed Energy Resources
D(ER+S) : Distributed Energy Resource +Distributed Storage



TEPCO

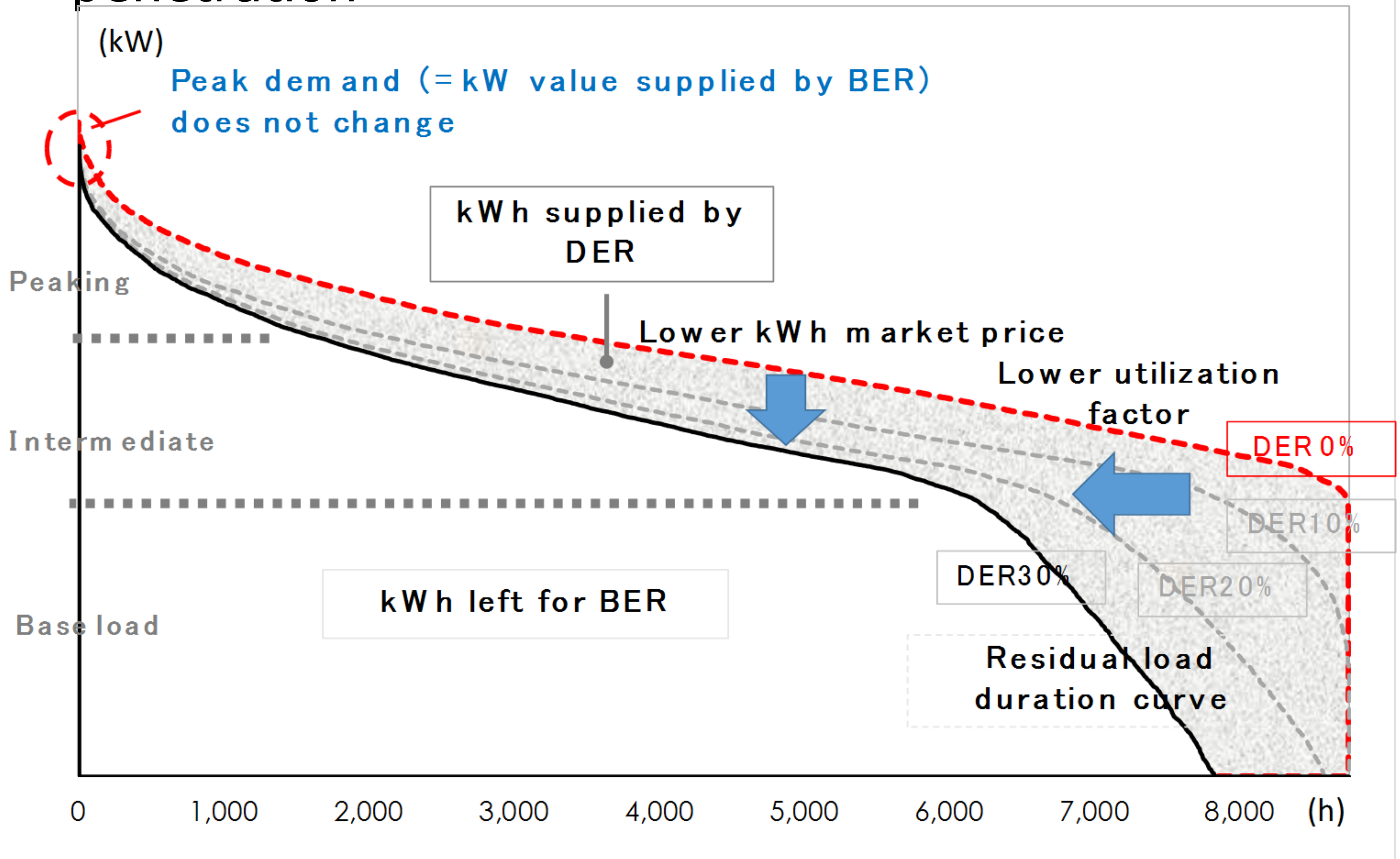
Three values provided by Generators

- Value of electricity as energy （kWh value：area S）
- Value of call option that can obtain kWh according to demand （kW value：height H ）
- Value of flexibility, value to maintain the quality of kWh (frequency, voltage, etc.) （⊿kW value：length L）



- kWh value：Value consumed by individual consumers
- kW value/⊿kW value：Value of power system's stability. public goods with non-excludability. Consumers have no incentive to pay for them. (Consumers can be free riders)

Changes in duration curve due to DER penetration



What changes in the duration curve tell

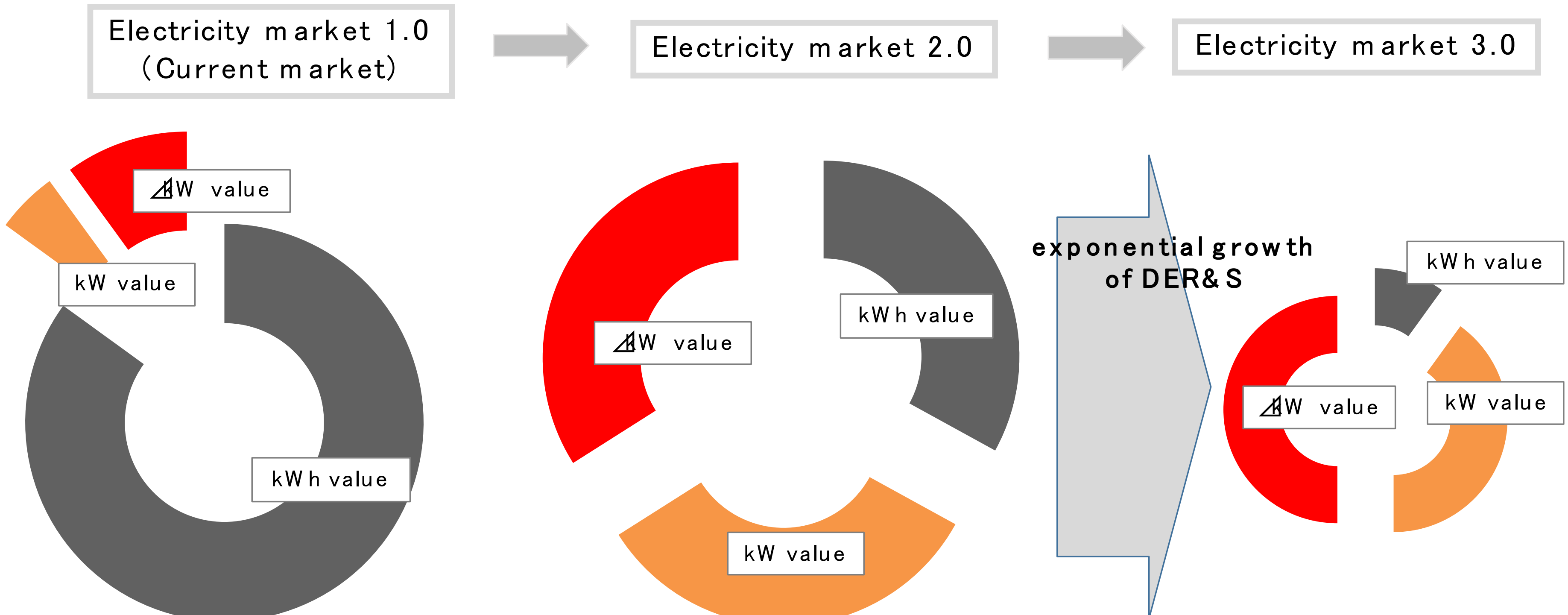
- DER
  - Able to supply only kWh value cheaply (zero marginal cost)
  - Unable to supply kW value nor ⊿kW value
  - High DER penetration=> kWh to be abundant, kW & ⊿kW to be scarce
  - Replace more kWh of BER during off-peak time => The goal of LCOE should be the marginal cost of base load power plants.
- BER
  - Continue to be the main source of kW value & ⊿kW value.
  - Due to lower kWh market price & lower utilization factor, BERs are placed in a tough environment.
- kWh market
  - Price will get close to zero.
  - kWh market price alone can not recover kW value & ⊿kW value

□ "Re-powering markets" is necessary to make kW value & ⊿kW value the main revenue source of BER.（Electricity market 2.0）

TEPCO

Stages of "Re-powering markets"

- The majority of the value traded in the electricity market will shift from the kWh value to the kW/⊿kW value.



- After exponential growth of DER&S;
  - kWh price will get closer to zero
  - Storage of EVs will emerge as a source of kW/⊿kW value and mitigate the scarcity of these values. (Electricity market 3.0)

TEPCO

The necessity of kW market (capacity mechanism)

- Capacity remuneration mechanisms should be able to be phased out once the (kWh) market itself delivers the appropriate investment incentives to ensure the adequacy of the system.

  In practice, the implemented model, while ensuring sufficient regulatory stability, should produce effects only as long as the underlying problem of generation adequacy requires an additional solution to complement well-functioning wholesale markets.

  (Eurelectric(2011))

- However, if De-carbonization and Decentralization progress;
  - the price of abundant kWh will get close to zero.
  - It is rather natural to create a new market with scarce kW value.

Advanced ⊿kW value market (ancillary service market)

- ⊿kW value market will evolve to evaluate the proven performance of excellent frequency control, with IoT technology.

Ex : pay for performance ※ Resource can include Generator, Storage or DR

When Q1＝Q2;

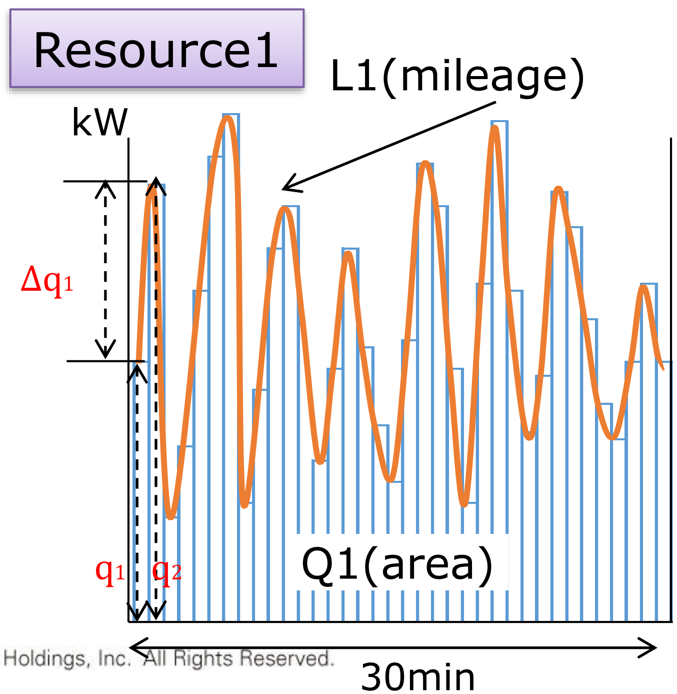
- ◻ Evaluating only kWh (Revenue＝@×Qm), revenue is "Resource1= Resource2", but Gen1 contributes more to power quality.
- ◻ Evaluating kWh & mileage (Revenue＝@×Qm＋@×Lm), revenue is "Resource1>Resource2" (∵ L1＞L2)

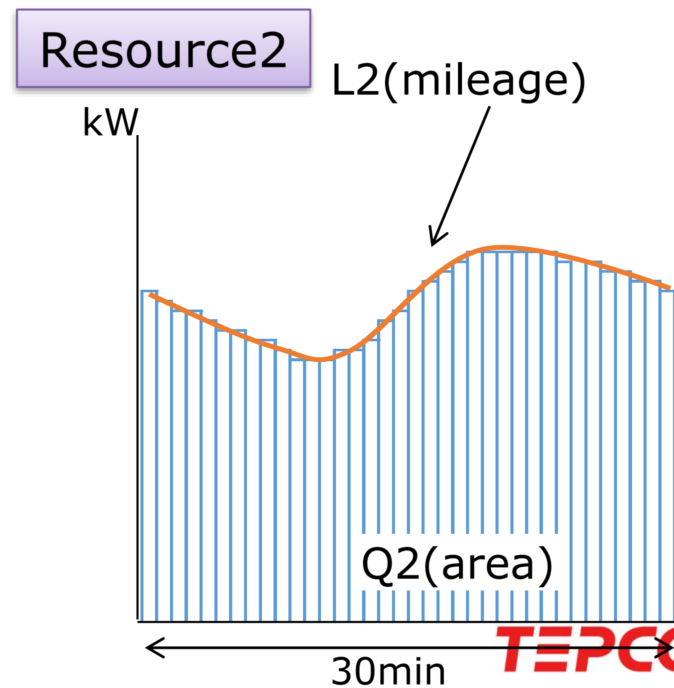
$$Q = \sum_{i=1}^{n} q_i$$

$$\Delta q_i = q_{i+1} - q_i$$

$$L = \sum_{i=1}^{n} |\Delta q_i|$$

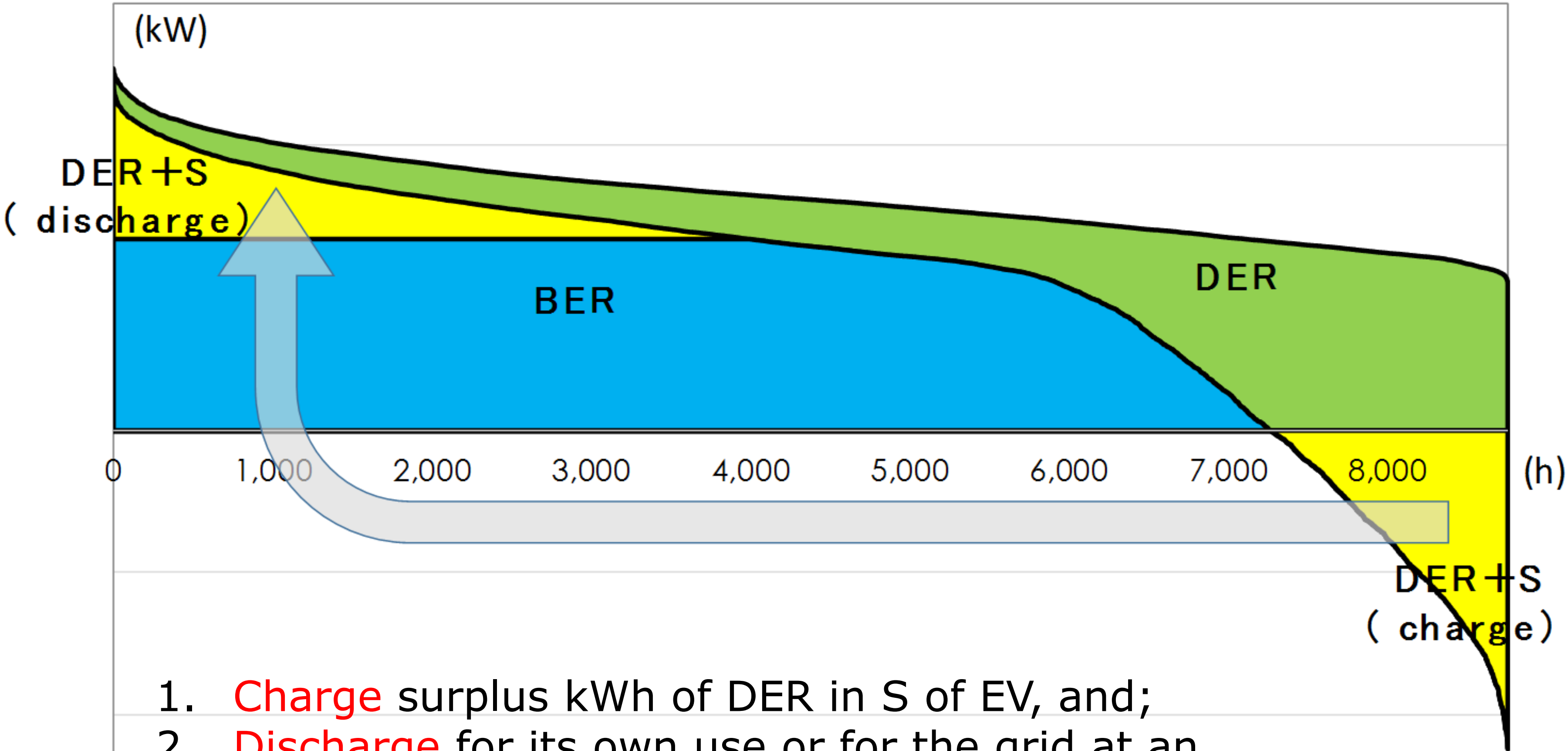
IoT will enable metering of higher granularity.





TEPCO

kW value provided by S of EVs



1. Charge surplus kWh of DER in S of EV, and;
2. Discharge for its own use or for the grid at an appropriate time.

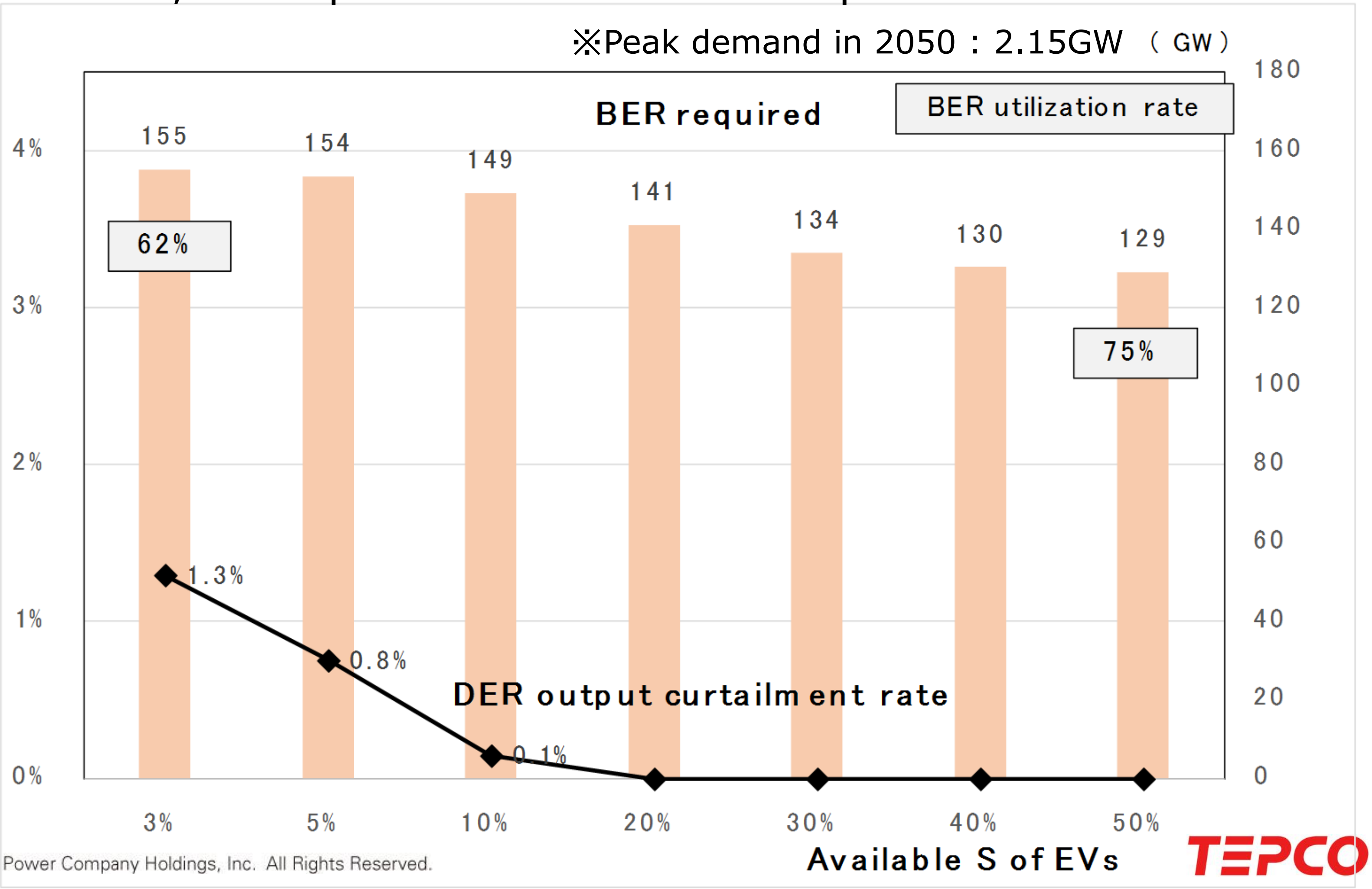
Rough simulation to utilize S of EVs (assumption)

- The kWh demand is to be 1,200 TWh in 2050. Distribute it to 8760 hours, using the demand pattern of 2013 and the standard load curve of EVs.
- DER penetration : PV 270GW Wind 70GW.
- Distribute kWh generated by PV to 8760 hours, according to the output pattern of 2013. Wind power is to be constant output at 25% utilization rate.
- Do not consider system constraints.
- Pumped hydroelectric energy storage : 27 GW × 7 hours.
- 40 million EVs nationwide, each has S of 60 kWh
- The output of BERs is constantly over 30 GW nationwide, which enables to clear the constraints of minimum output and constant reactor output.
- ⊿kW necessary for system stability is always secured.

=> Based on the above assumption, sensitivity analysis was performed to change the S capacity of EVs that TSO/DSO can freely utilize between 3% and 50%

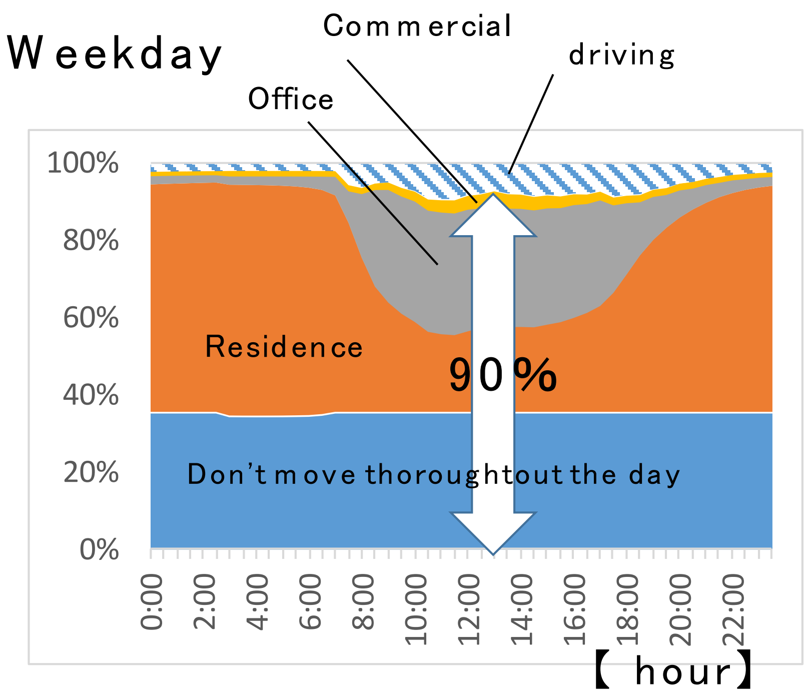
Rough simulation to utilize S of EVs (outcome)

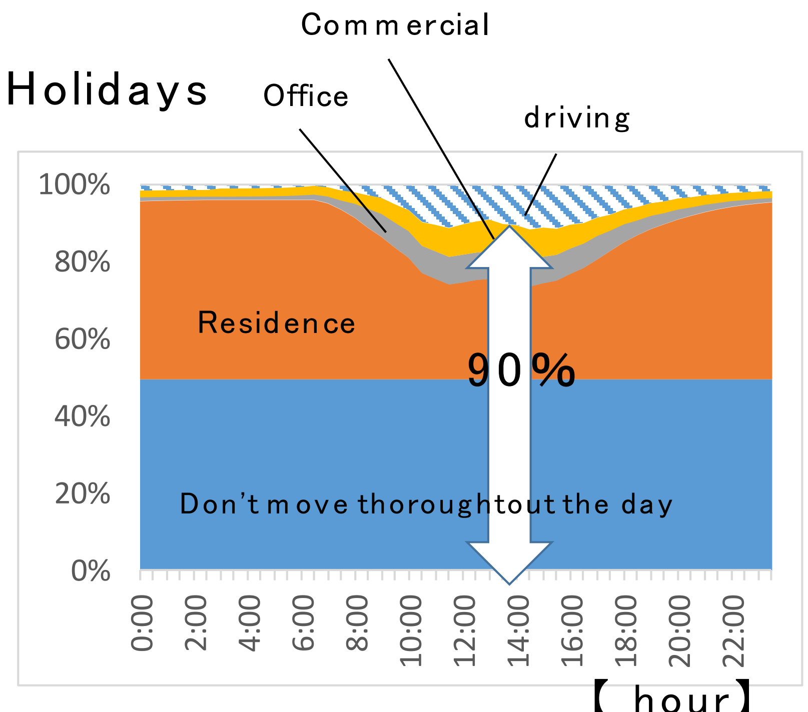
- When 20% of S capacity of EVs is available for TSO/DSO, they will need no DER output curtailment.
- In addition, S will provide kW value and replace BERs.



How to make effective use of S of EVs

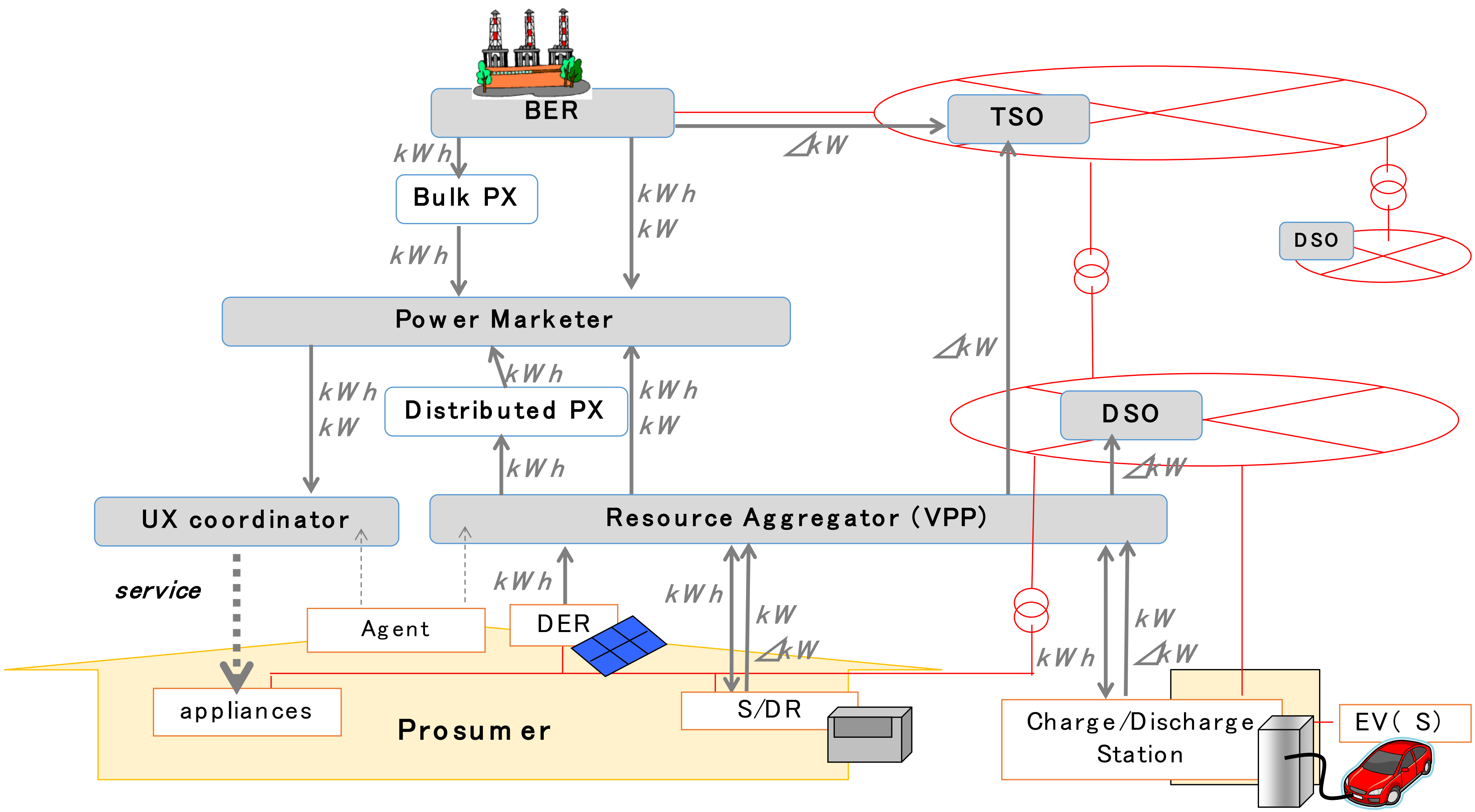
- 90% of cars are stopped. There is a possibility that storages of stopped EVs can be effectively utilized as a source of kW value & ⊿kW value. Challenges are;
  - Wireless charging and discharging system
  - Autonomous driving
  - Sharing & control system of EVs (TSO / DSO or Resource Aggregators)





Source : Shinoda(2017)

Electricity market 3.0



TEPCO

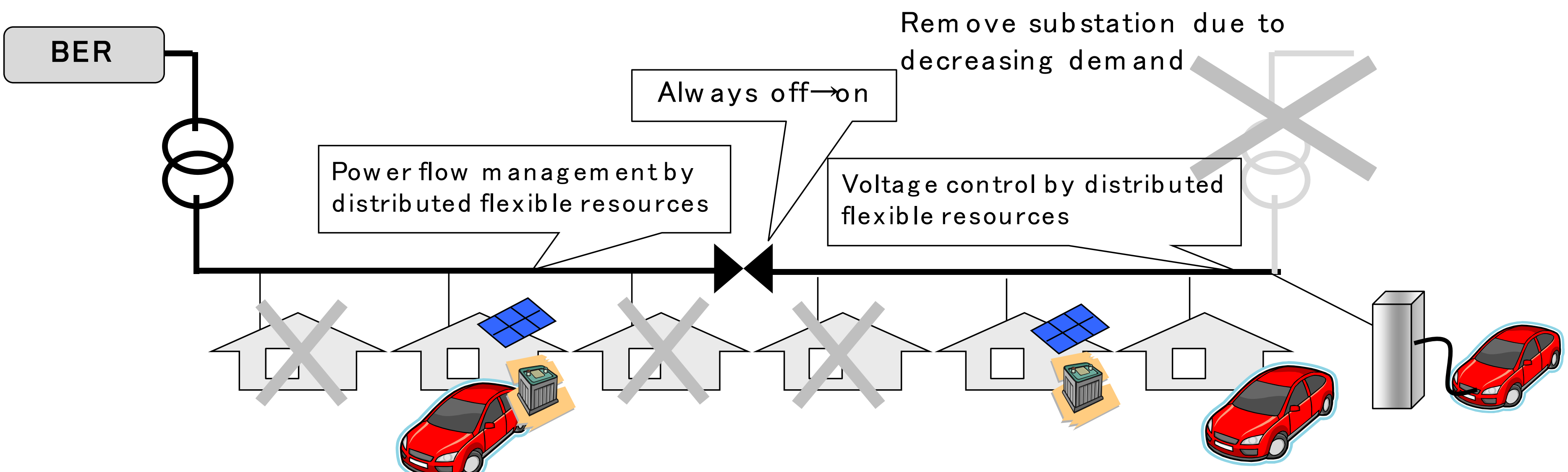
Explanation of some selected terms

- Bulk PX
  - System-wide power exchange.
  - kWh value will be traded in **MWh** unit
- Distributed PX
  - Local power exchange
  - kWh value will be traded in **kWh** unit or less
- Resource aggregator
  - Aggregate locally distributed flexible demand side resources (storages, heat pumps, other appliances)
  - Operate them as if they were one virtual power plant (VPP) and produce value (kWh, kW, ⊿kW).
- UX coordinator
  - Provide user experiences (UX) realized by consumption of electricity as a service
  - Appliances will be interfaces for providing UX as a service, Electricity bill is merged into service fee, it is no longer visible to consumers.

TEPCO

Smart downsizing of distribution NW

- Depopulation will require systematical downsizing of distribution NW.
- DSO will be able to utilize a lot of flexible resources connected to the NW for smart downsizing.



□ Depopulation is concerned with the sustainability of all infrastructure services including transportation, water supply and sewerage, etc..

□ Smartly overcoming this problem is a common challenge for all infrastructures. => next page

TEPCO

Depopulation is common issue for all infrastructure

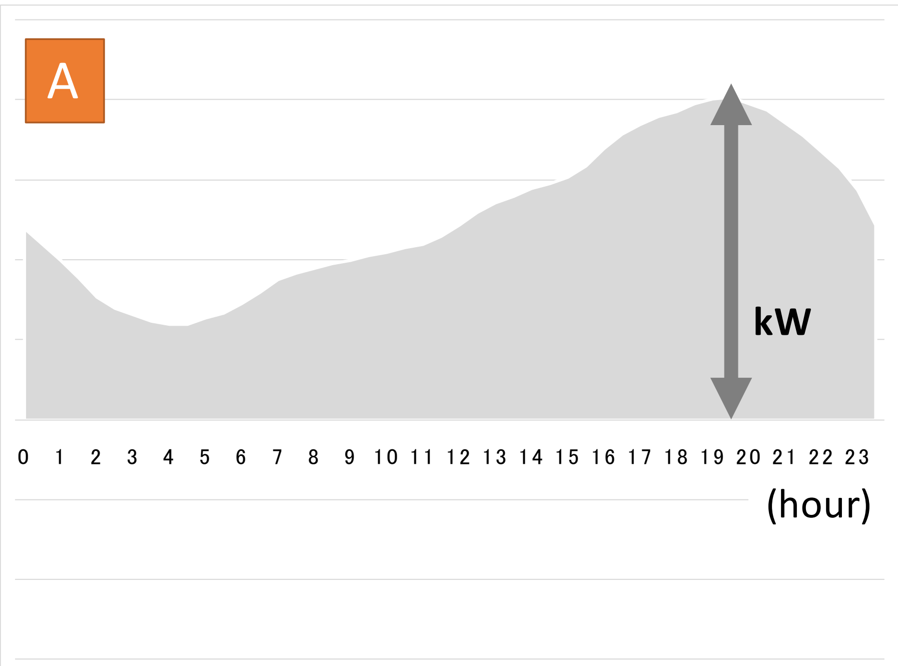
- In local areas in Japan, because the density of housing is low, the efficiency of infrastructure development has been low. In the future of depopulation, the density will fall further, and the efficiency will fall further.
- In order to avoid the above situation, the Ministry of Land, Infrastructure and Transport and Tourism (MLIT) has adopted measures to promote compact city formation. Efforts include to enhance the quality of infrastructure services through consolidation and sophistication, and to consolidate disorderly developed residences there.
- Even though important, there is no remarkable effort in the electricity T&D NW infrastructure. It may be because of the universal service rule, under which the T&D NW can be used at the same charge.
- In order to ensure the sustainability of T & D business in Japan, it may be one solution to form a municipal-based utility integrated with other infrastructure services.
- Providing universal service means the internal subsidies from cities to high-cost local areas. It may be undermine the incentive for the local government to seek a solution.
- For promoting it, doubting the universal service may be the first step.

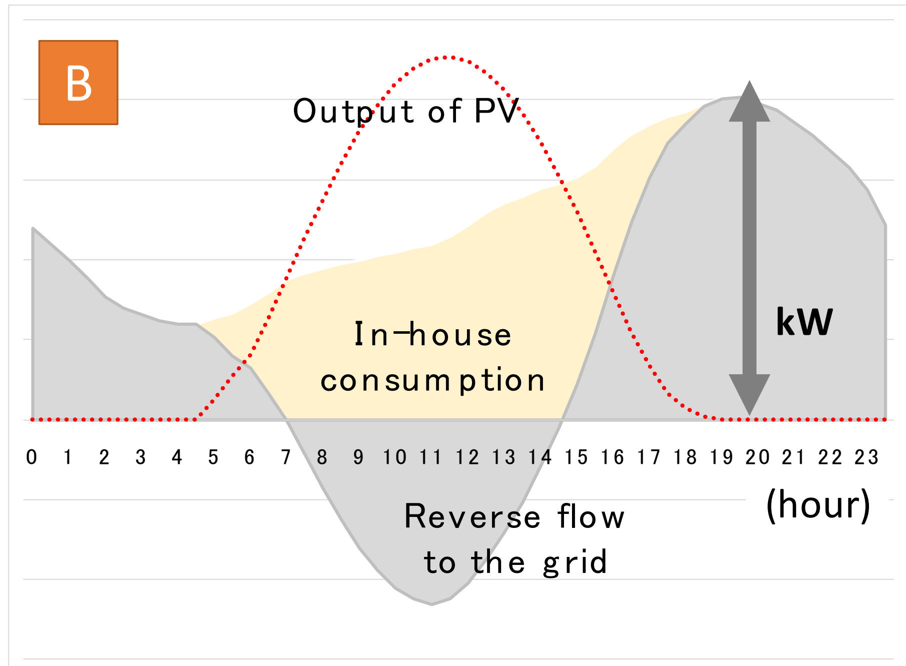
What should the NW fee be in the days of 5Ds?

- Issues of current fee structure
  - NW cost is 98% fixed cost. (Fixed cost: not proportional to kWh)
  - 70% of the cost recovery depends on kWh charge. (80% for residential).
- How to reform the fee structure?
  - Goal : sustainability, appropriate incentives
  - Ideally, cost should be recovered 100% by kW fee. KWh fee should be zero.
- Appropriate incentives? 100% kW fee will;
  1. Improve social welfare (from the viewpoint of economics). Since most of the NW cost is a fixed cost, the marginal cost of NW service is nearly zero. Therefore, making kWh fee zero improves resource allocation.
  2. Correct excessive incentives for introducing PV to consumers. In the current fee structure, consumers can to avoid payment of fixed costs of NW which should not actually be avoided.
  3. Be an incentive to make effective use of storages on the demand side. With kWh fee, despite the marginal cost being zero, billing will occur for each charge and discharge, hampering effective use of storages.

Example of inappropriate incentives

- Under the current NW fee structure, consumers introducing PV (B) will avoid the burden of fixed costs.
- So-called "Utility Death Spiral"





Toward the IEN realization

- Necessary reform of social system and market system.

1. Design a market that can precisely evaluate kW & ⊿kW value looking to the days when kWh is abundant.
   IoT technology will help the work.
2. Build a layering market structure, which consists of a system-wide market and some small regional markets.
3. In order to provide appropriate incentives, charge per kWh for NW usage shall be zero.
4. Build a social system that shares EVs and can utilize them to optimally provide both mobility and kW & ⊿kW value.
5. Rethink universal service to encourage integration of infrastructures in depopulated areas.
6. Transparent carbon price is also important, although this presentation have not described.

More….

TEPCO

References

BNEF(Bloomberg New Energy Finance)(2016) "2016 lithium-ion battery price survey"

Diamandis,P.H., Kotler S.(2012) "Abundance: The Future Is Better Than You Think"

DOE(Department of Energy)(2016) "The SunShot Initiative's 2030 Goal : 3¢ per Kilowatt Hour for Solar Electricity" SunShot 2030 White Paper

Eurelectric(2011) "RES Integration and Market Design: Are Capacity Remuneration Mechanisms Needed to Ensure Generation Adequacy?"

LBNL(Lawrence Berkeley National Laboratory)(2016) "Utility-Scale Solar 2015: An Empirical Analysis of Project Cost, Performance, and Pricing Trends in the United States"

METI(Ministry of Economy, Trade and Industry) (2015) "Long-term Energy Supply and Demand Outlook"

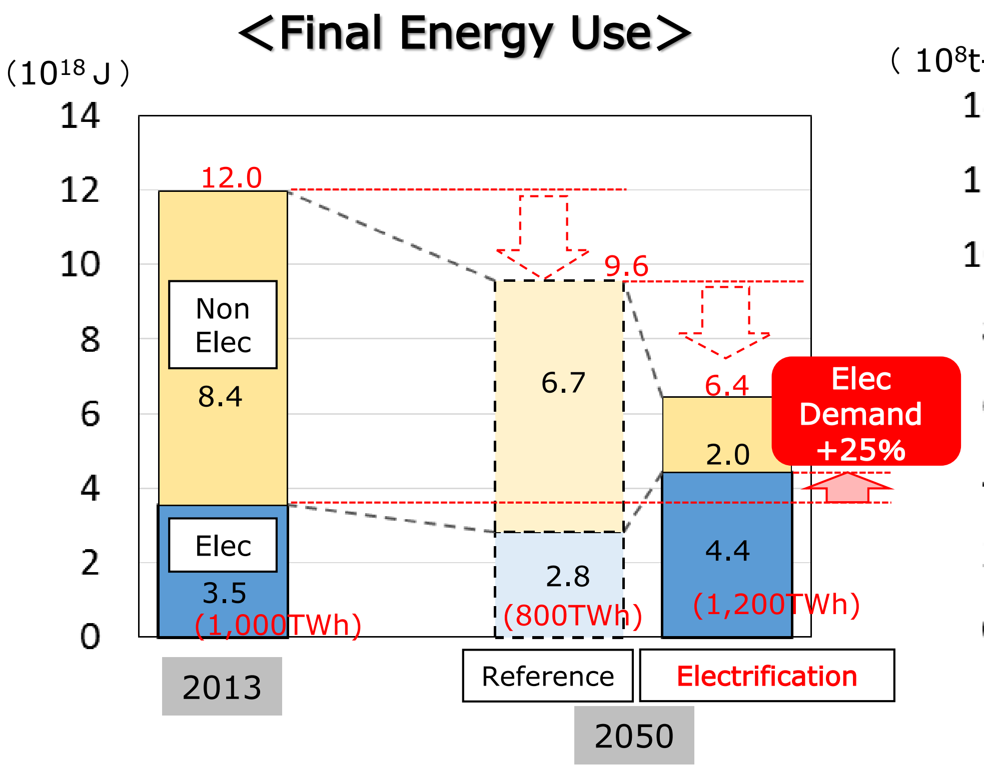
MLIT(Ministry of Land, Infrastructure, Transport and Tourism) (2014) "Grand Design of National Spatial Development towards 2050, Japan"

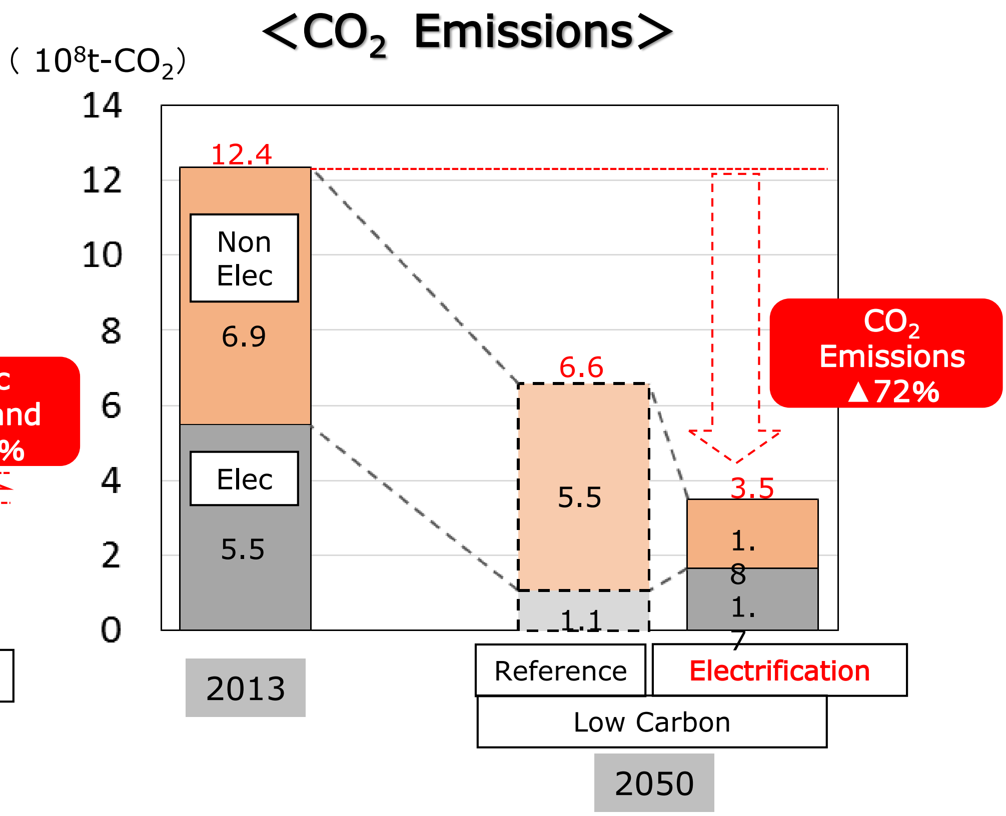
MOE(Ministry of the Environment)(2014) "2050 Reports on potential possibility of distributed energy dissemination including renewable energy" written in Japanese

Shinoda Yukio(2017) "Efforts to date on EVs and expectations for the future" written in Japanese

Ref: De-carbonization by Electrification

- TEPCO Research Institute (TRI) calculated the potential of electrification in CO2 emissions reduction.
  - Supply side : Low-carbon generation mix (65% carbon-free)
  - Demand side : Electrification as much as possible





TEPCO

Ref: De-carbonization by Electrification (details)

Demand side

※ Electrification rate : final energy use

sector	Electrification rate(2013)	potential	Alternative appliance
Residential	49%	100%	・ Heat pump ・ Induction heater (IH)
Commercial	59%	100%	・ Heat pump ・ Induction heater (IH)
Transport	2%	100% except Aviation and shipping (72%)	・ EV
Industrial	31%	100% except direct combustion (51%)	・ Heat pump ・ Induction heater (IH)
Total	30%	69%	

Supply side

※ Renewable : based on the high case of potential research in MOE(2014)

Renewable	Nuclear	Thermal
55% (PV23%, Wind 11%, Others 21%)	10%	35%

TEPCO