Economic Issues and Optimization Initiatives of Nuclear Power Plants

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TEPCO

Outline

1. Current Status of Nuclear Power in Japan
2. Cost Analysis and Implication
3. Economic Optimization Initiatives
4. Conclusion

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2. Cost Analysis and Implication

3. Economic Optimization Initiative

4. Concluding

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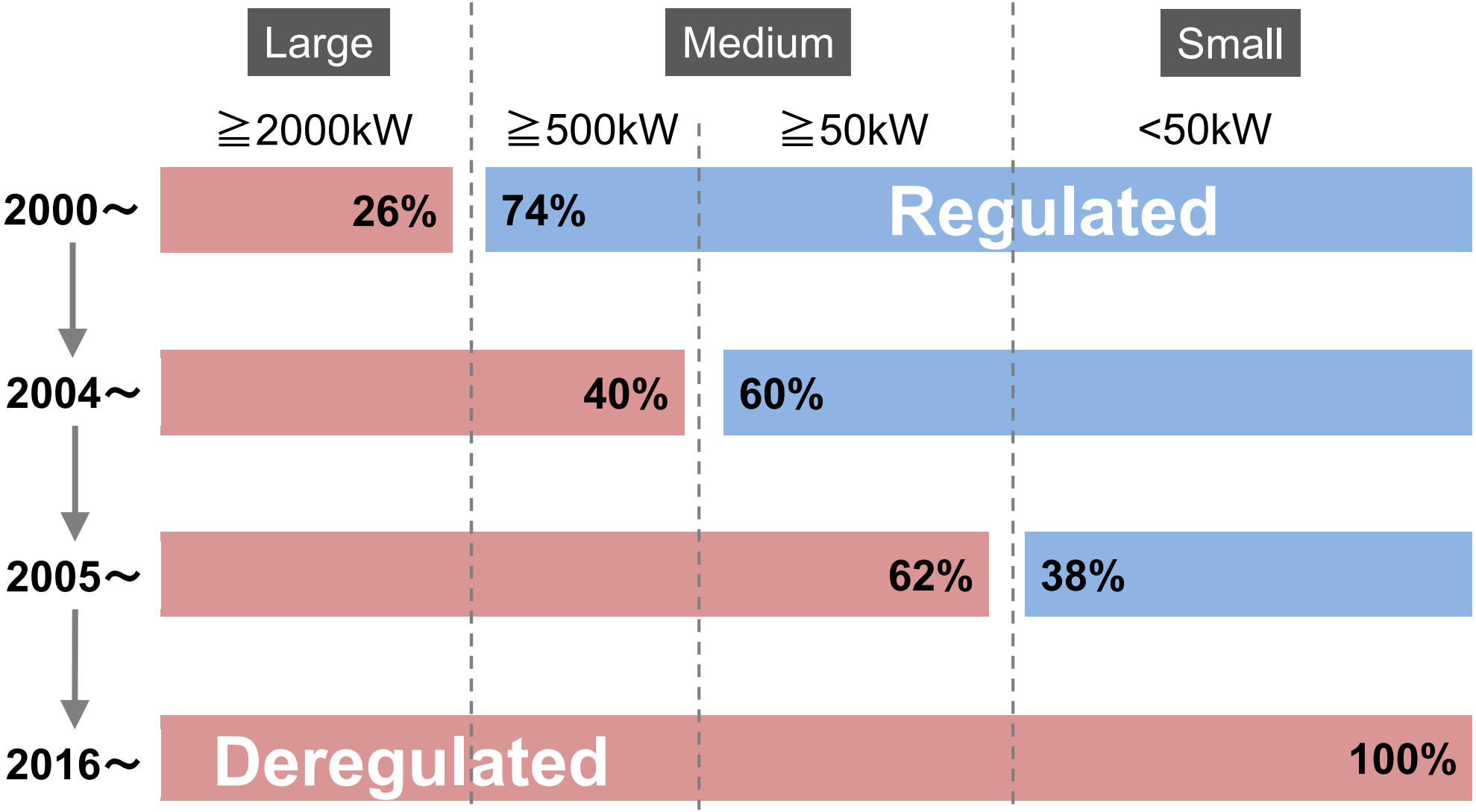
History of Deregulation



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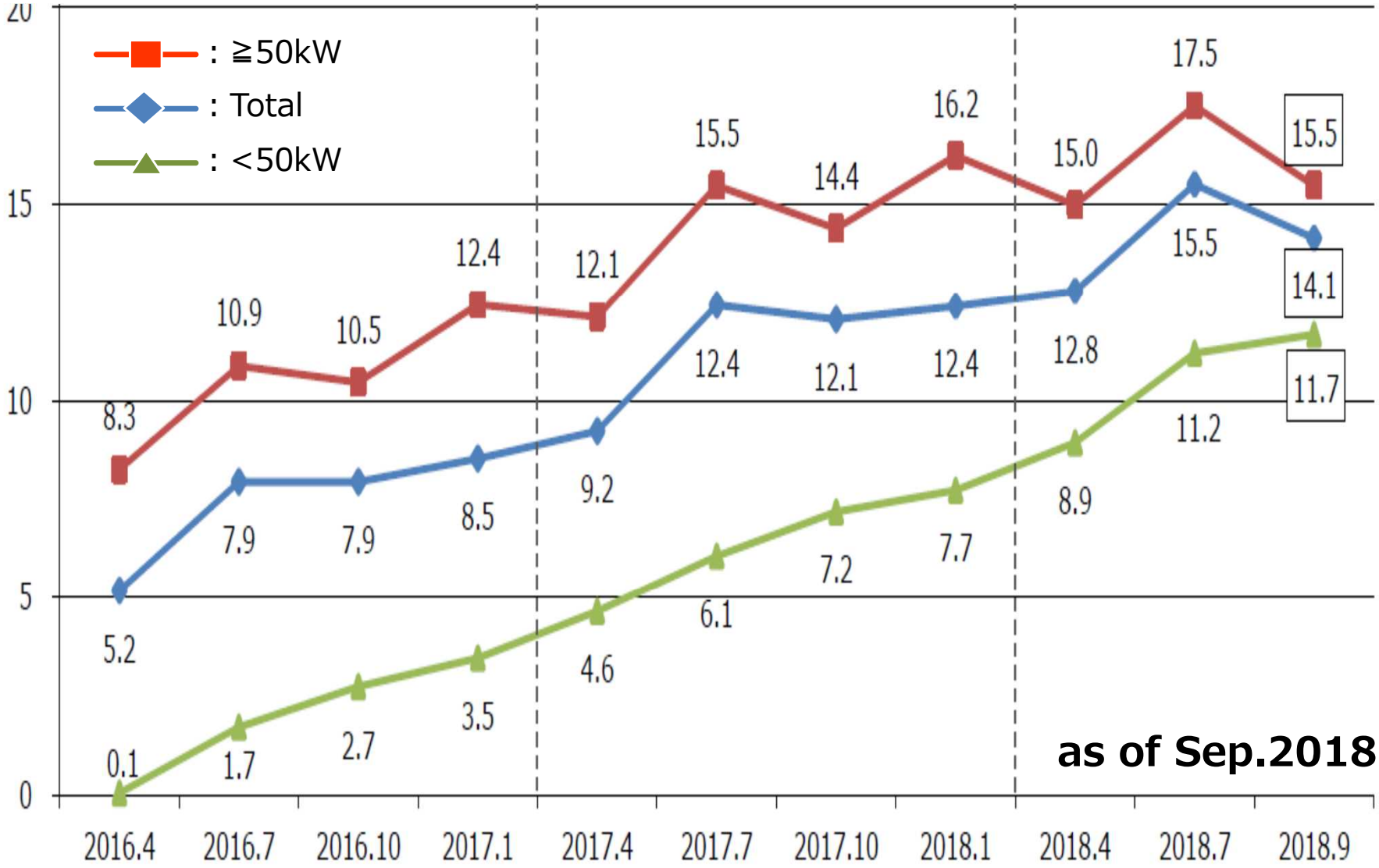
Share of New Power Company

■ About 4 million costumers in Tokyo area have switched after deregulation at 2016.

【All area in JAPAN】



【Tokyo Area】

18.5%(≧50kW)

18.1%(total)

17.1%(<50KW)

as of Sep.2018

http://www.meti.go.jp/shingikai/enecho/denryoku_gas/denryoku_gas/pdf/014_04_00.pdf
http://www.emsc.meti.go.jp/info/business/report/results.html

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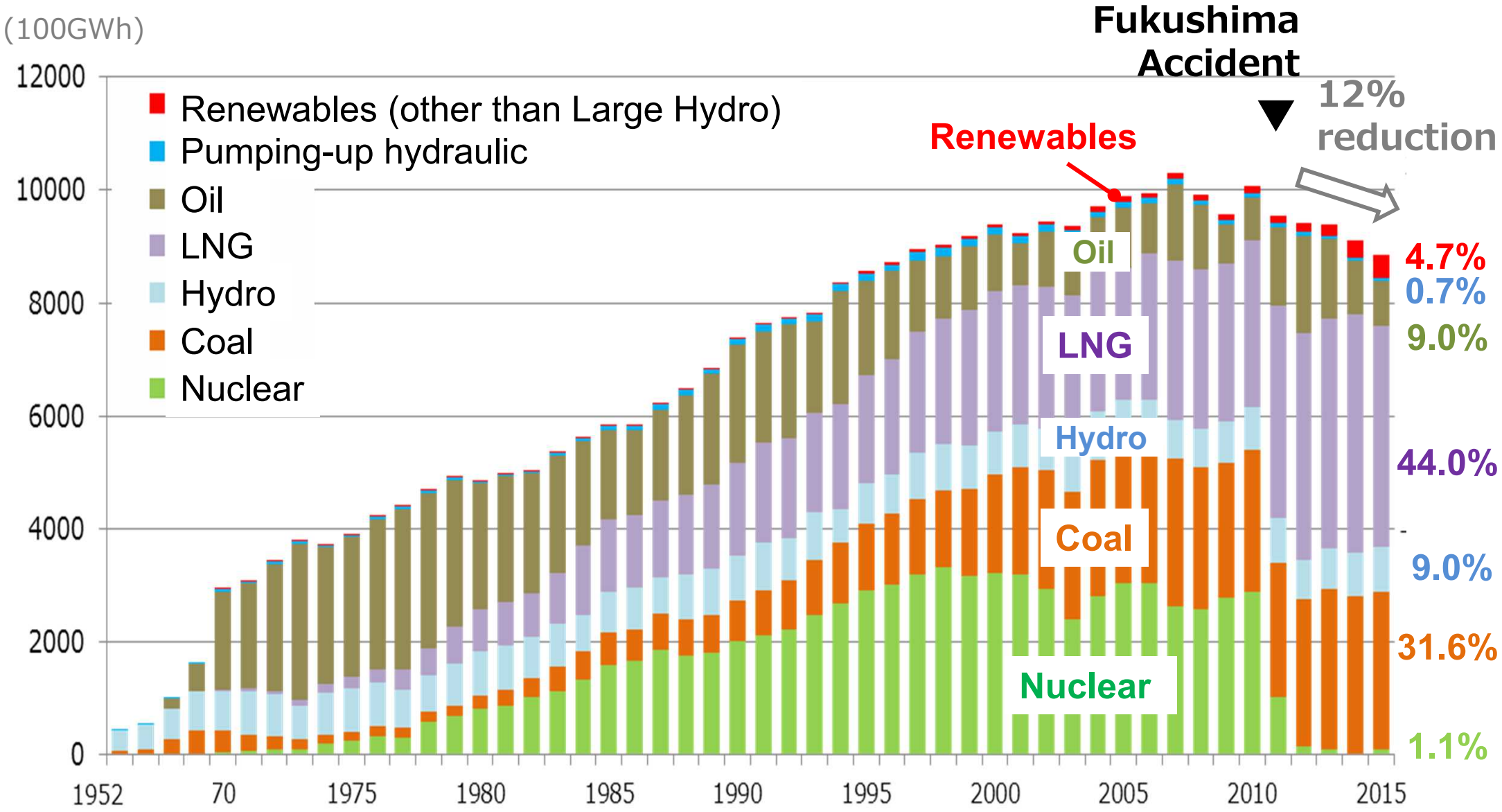
Generation Portfolio in Japan



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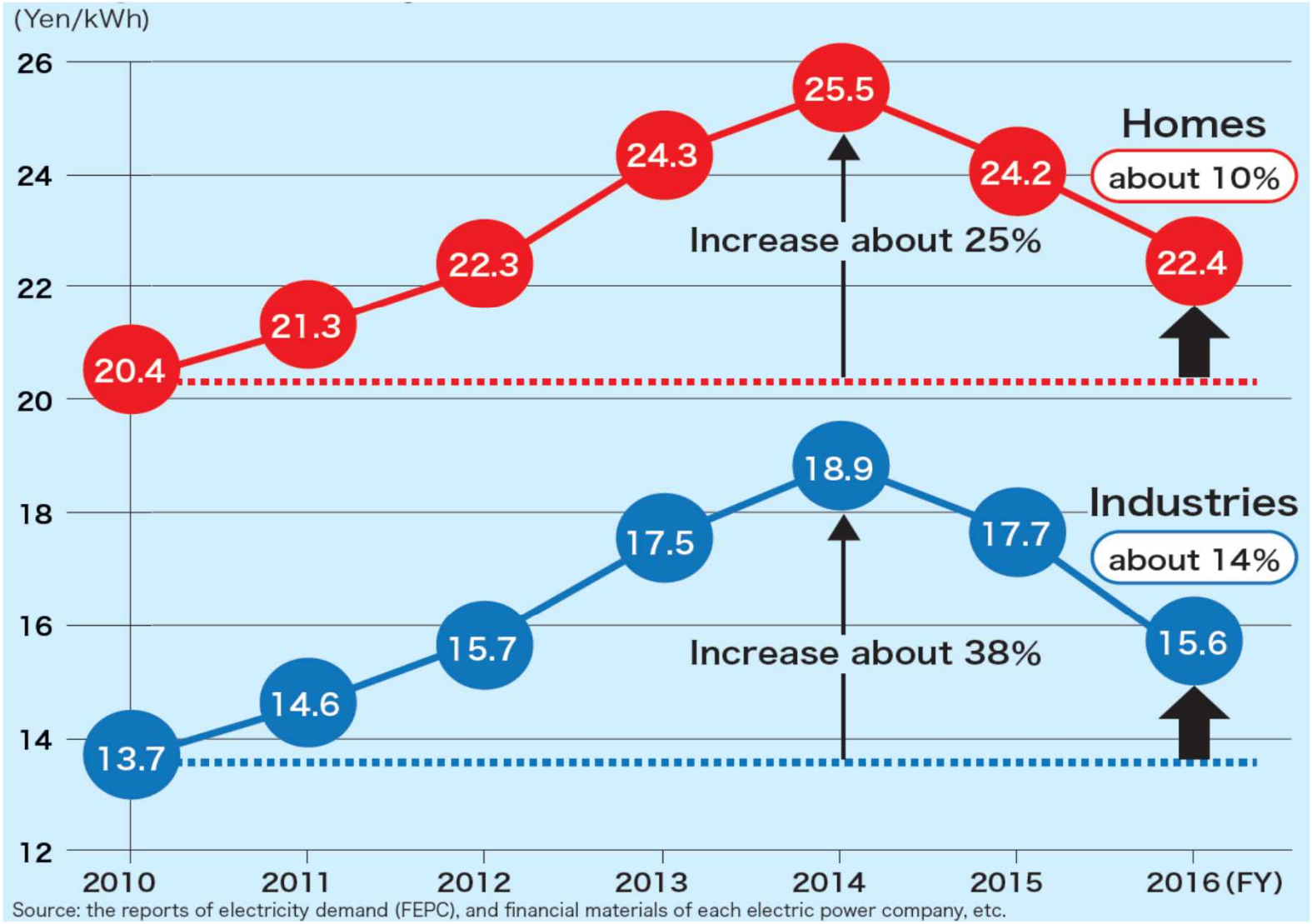
Changes in Electricity Rates

- In spite of the market deregulation, electricity rate have increased as a result of purchasing more fossil fuels due to prolonged nuclear shutdown



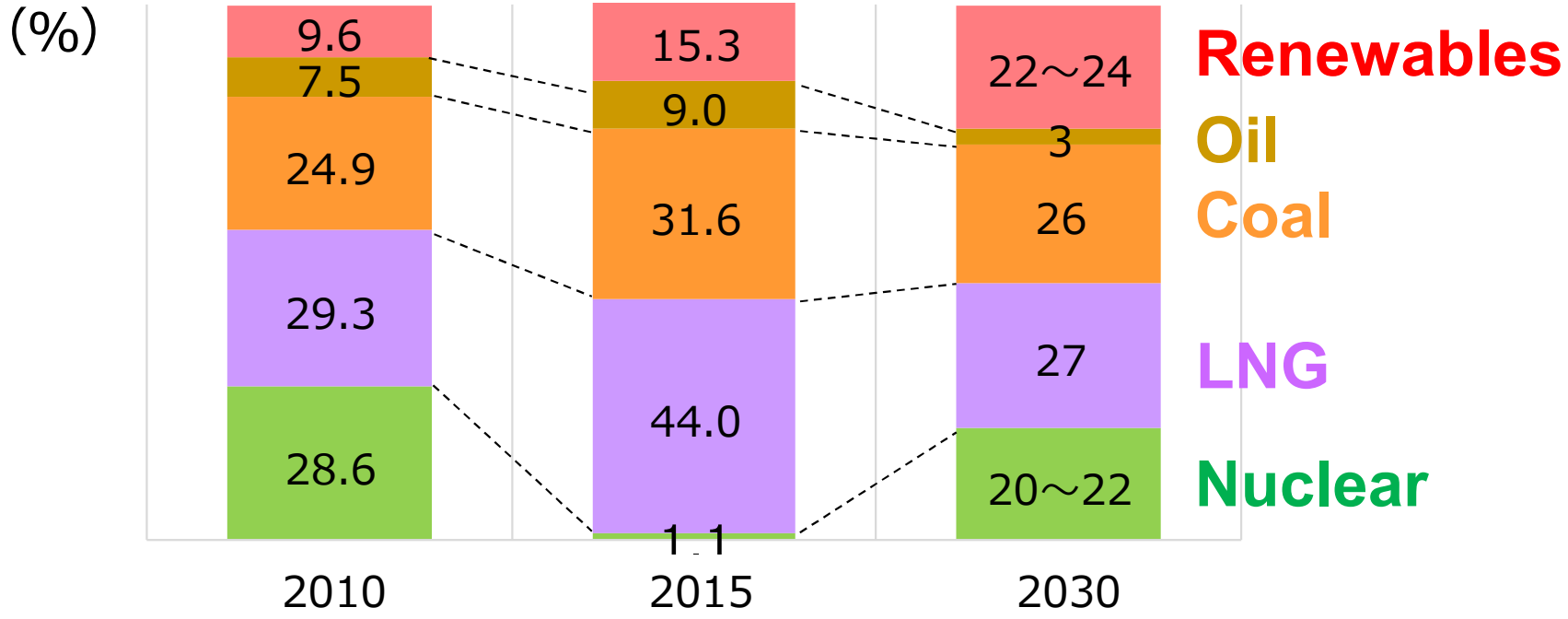
http://www.enecho.meti.go.jp/en/category/brochures/pdf/japan_energy_2017.pdf

Future Energy Plan in Japan

Basic Policy

- Reduce nuclear power dependence, while utilizing NPPs
- Adopt renewable energy as much as possible
- Improve the efficiency of thermal power plants
- Promote energy-saving (electricity-saving)

Generation portfolio



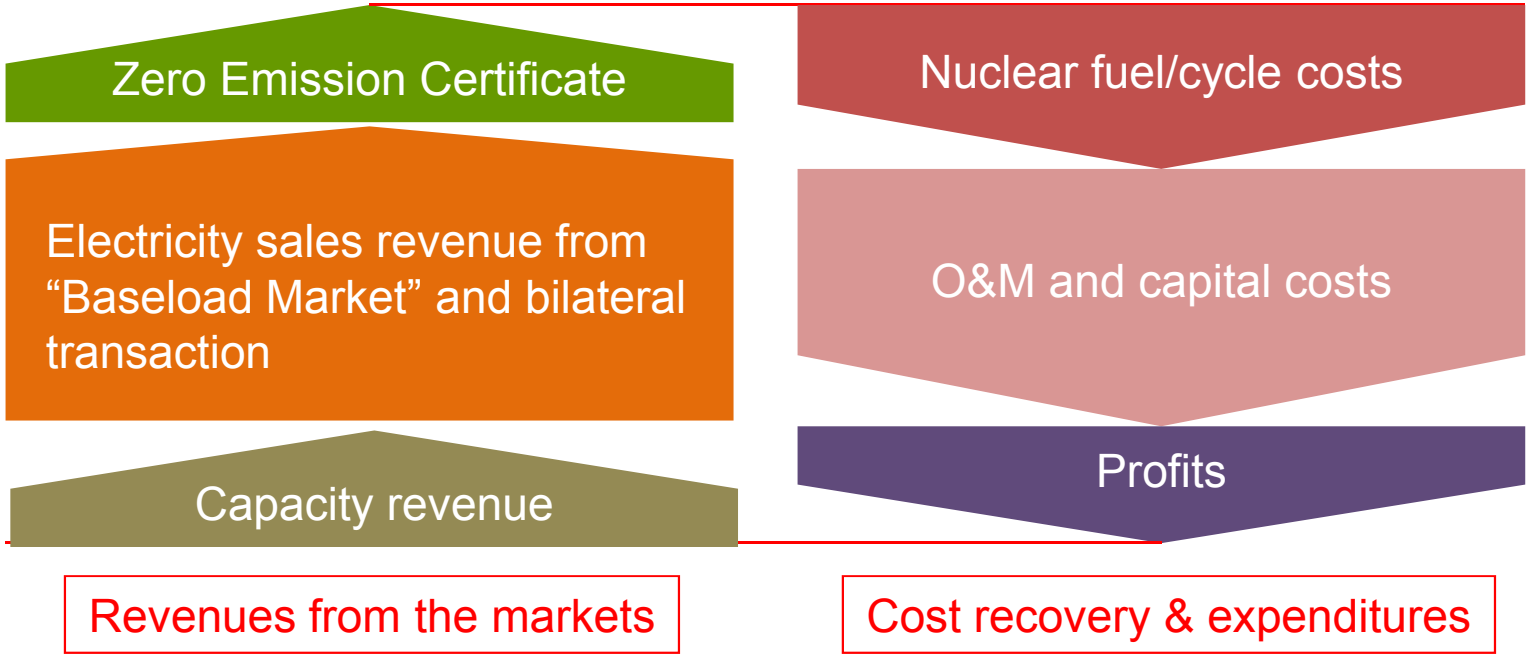
Electricity Market Reform

	Purpose of the market	Transaction	Delivery	Nuc
Wholesale energy market (kWh)	Meet energy demand	already under operation		-
Base load market (kWh)	Provide an easy access for new player to the base load generation	2019	2020	○
Capacity market (kW)	Ensure long-term grid	2020	2024	○
Imbalance & Ancillary service market (ΔkW)	Help balance the transmission system	2021		-
Zero emission certificate market (CO2)	Provide incentives for generators to maintain and develop zero emission sources	2019 (2018 start of FIT renewables market)		○

Electricity Market Reform

Drastic market reform is underway toward the creation of a set of markets similar to PJM. Among those, 3 markets (i.e. capacity, energy (base load) and zero emission certificate markets) directly impact the cost/revenue structure of nuclear power.

1. Zero emission certificate market (CO2)
2. Base load market (kWh)
3. Capacity market (kW)



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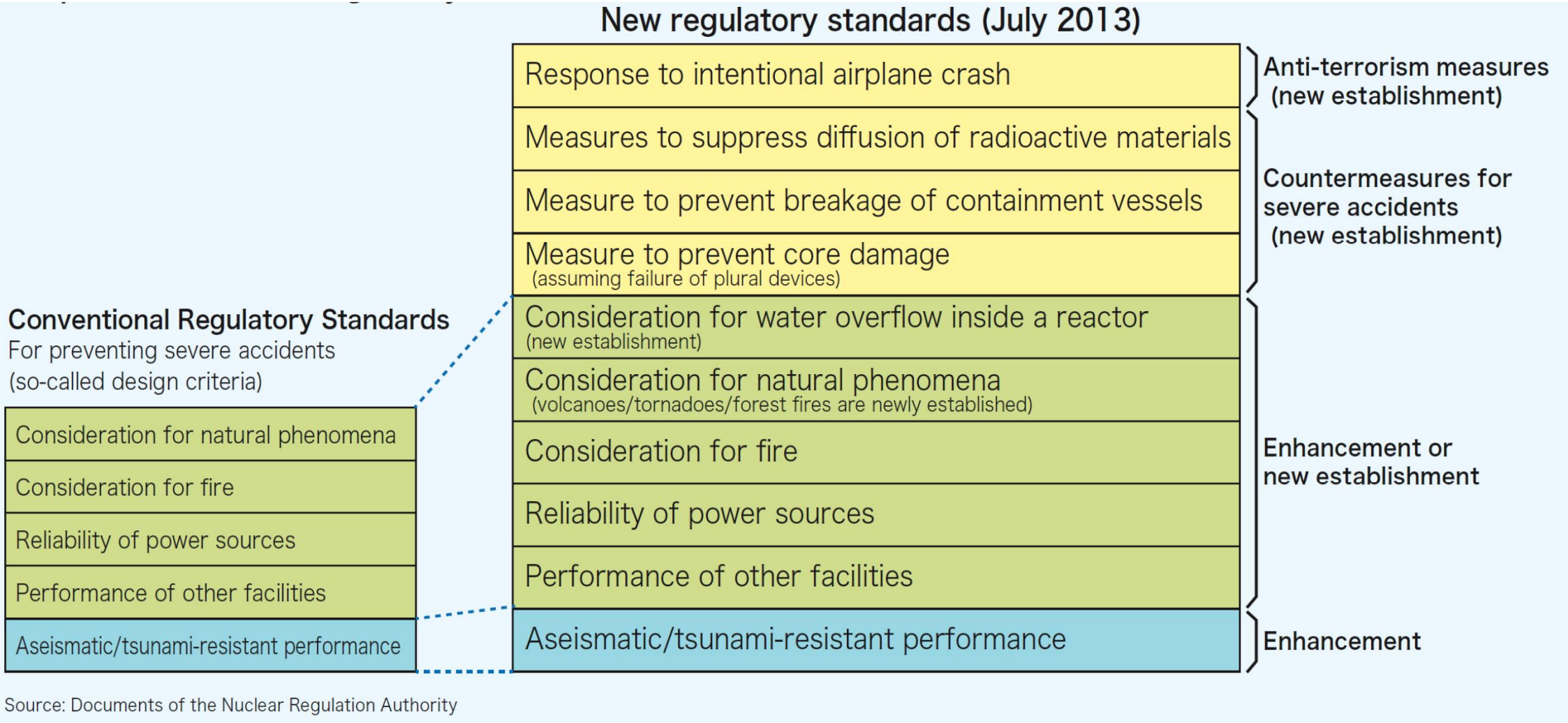
Response to the New Regulatory Standards

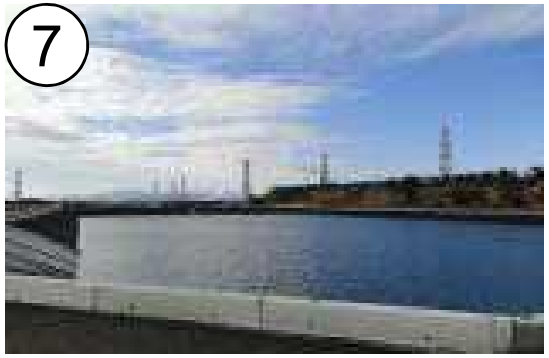
- To restart nuclear power plants, it is required to conform to new regulatory standards, which are much more demanding.



Source: Documents of the Nuclear Regulation Authority

http://www.enecho.meti.go.jp/en/category/brochures/pdf/japan_energy_2017.pdf

Safety Upgrade at Kashiwazaki-Kariwa



③Debris Removal Car

①Fire Truck・② Heat Exchanger Car

④Gas Turbine Generator Car・⑤Power Supply Car

⑦Reservoir

⑥Tsunami Wall

Underground light oil tank

Emergency Response Office

Emergency Switchboard

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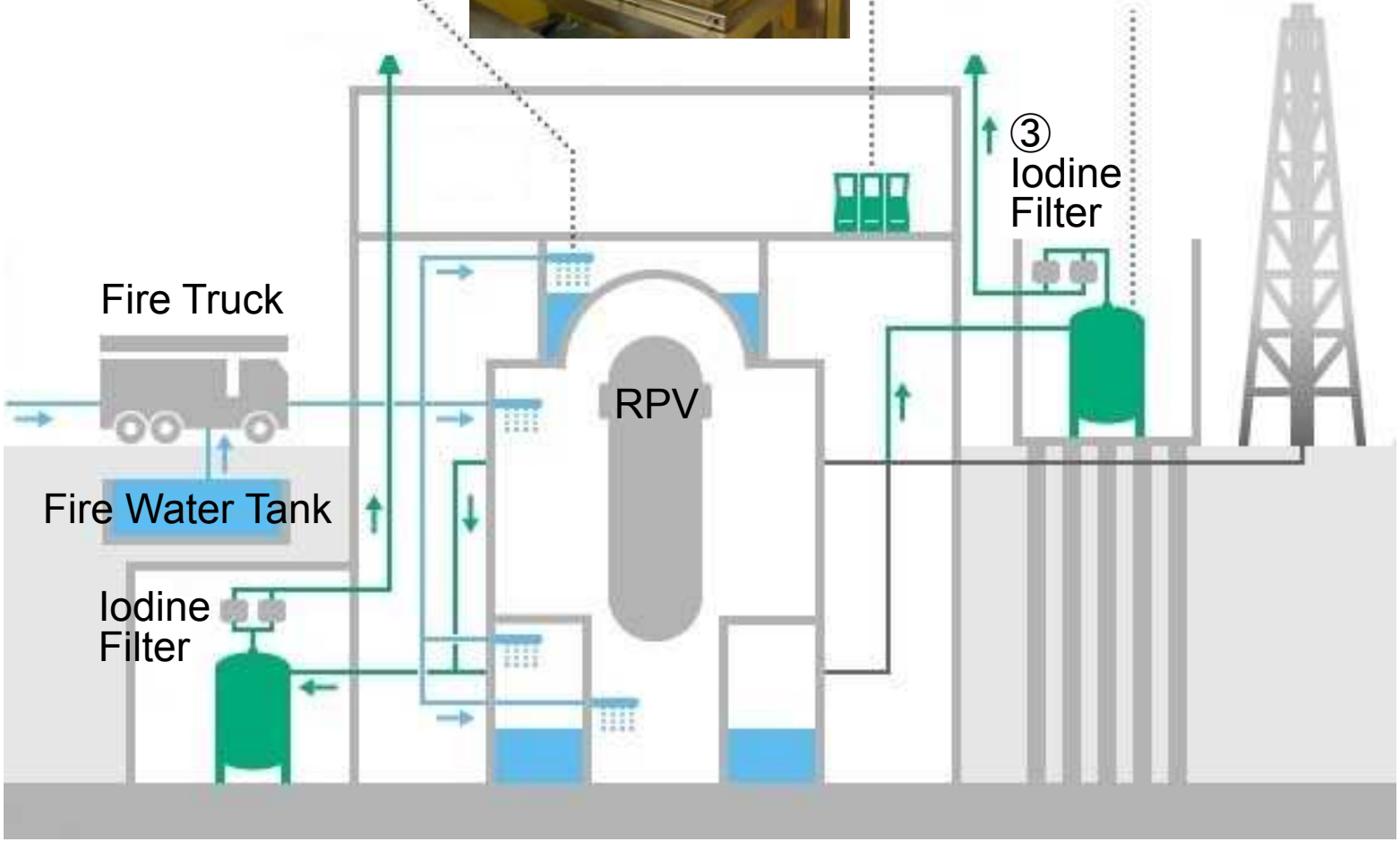
Safety Upgrade at Kashiwazaki-Kariwa

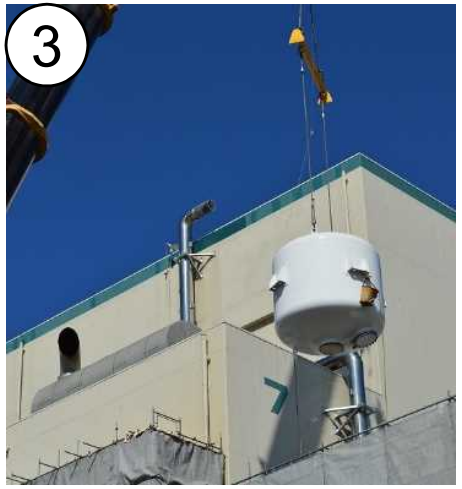
①Hydrogen Recombiner (PAR)

②Filtered Vent

③ Iodine Filter

Water filling facility on PCV top





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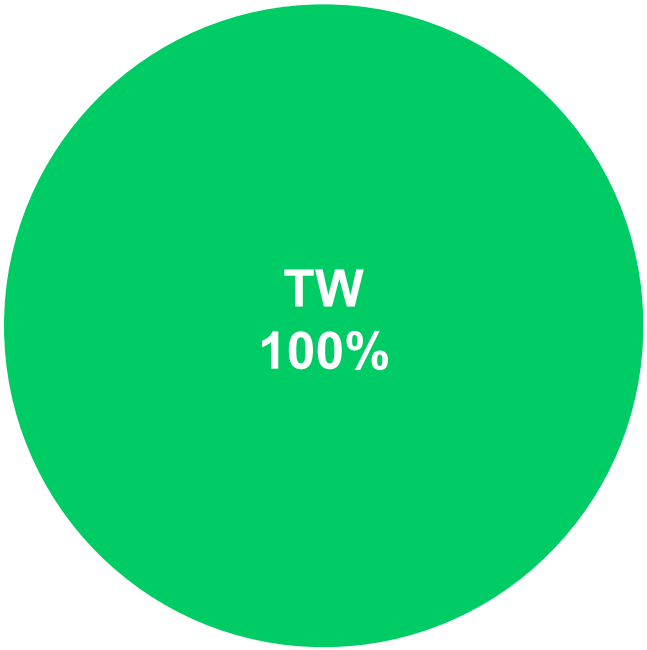
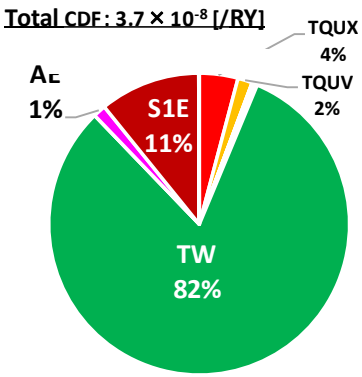
Core Damage Frequency (Internal at power, KK7)

Before



8.7×10^{-6} [/RY]

After



3.7×10^{-8} [/RY]

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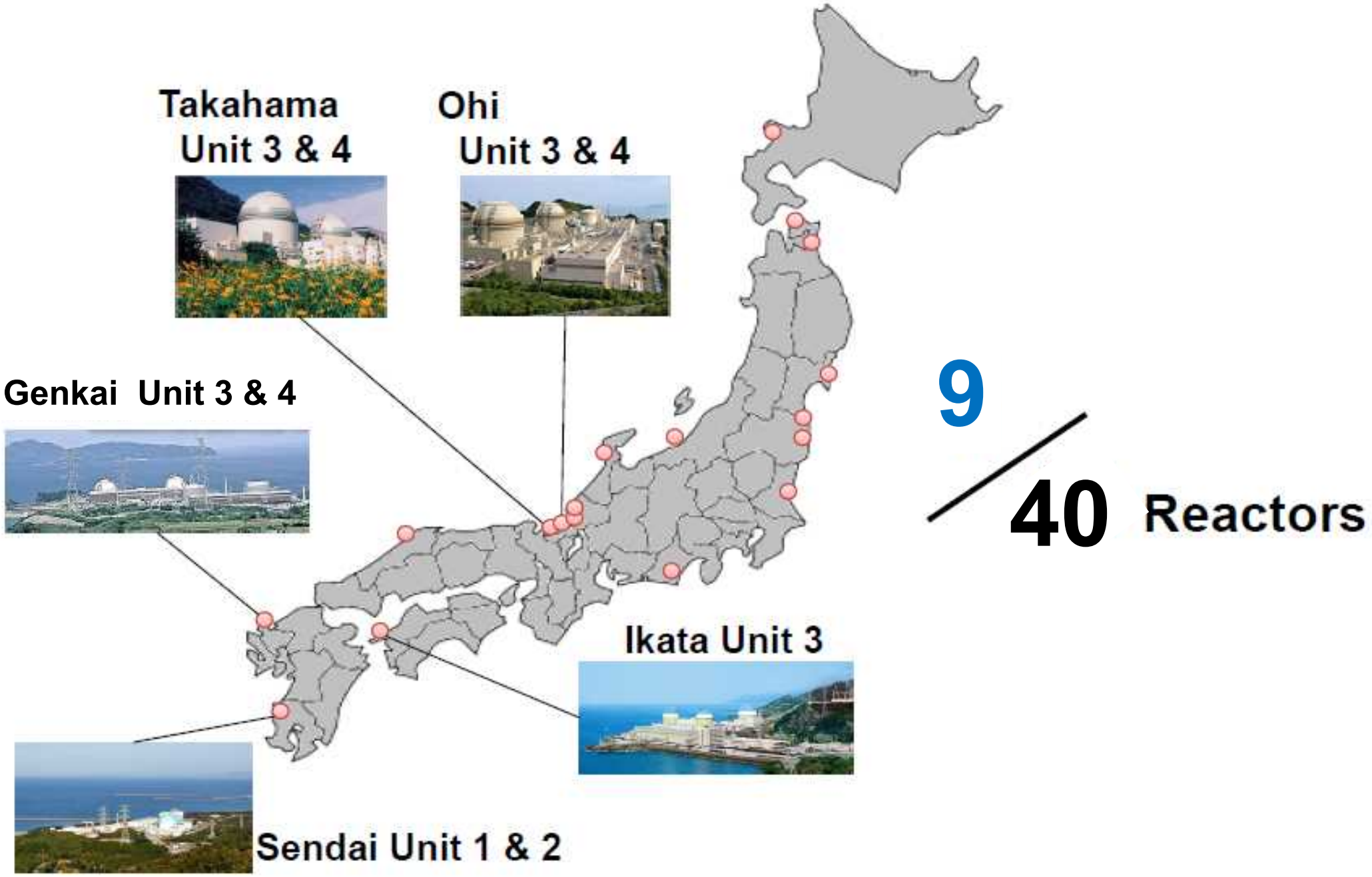
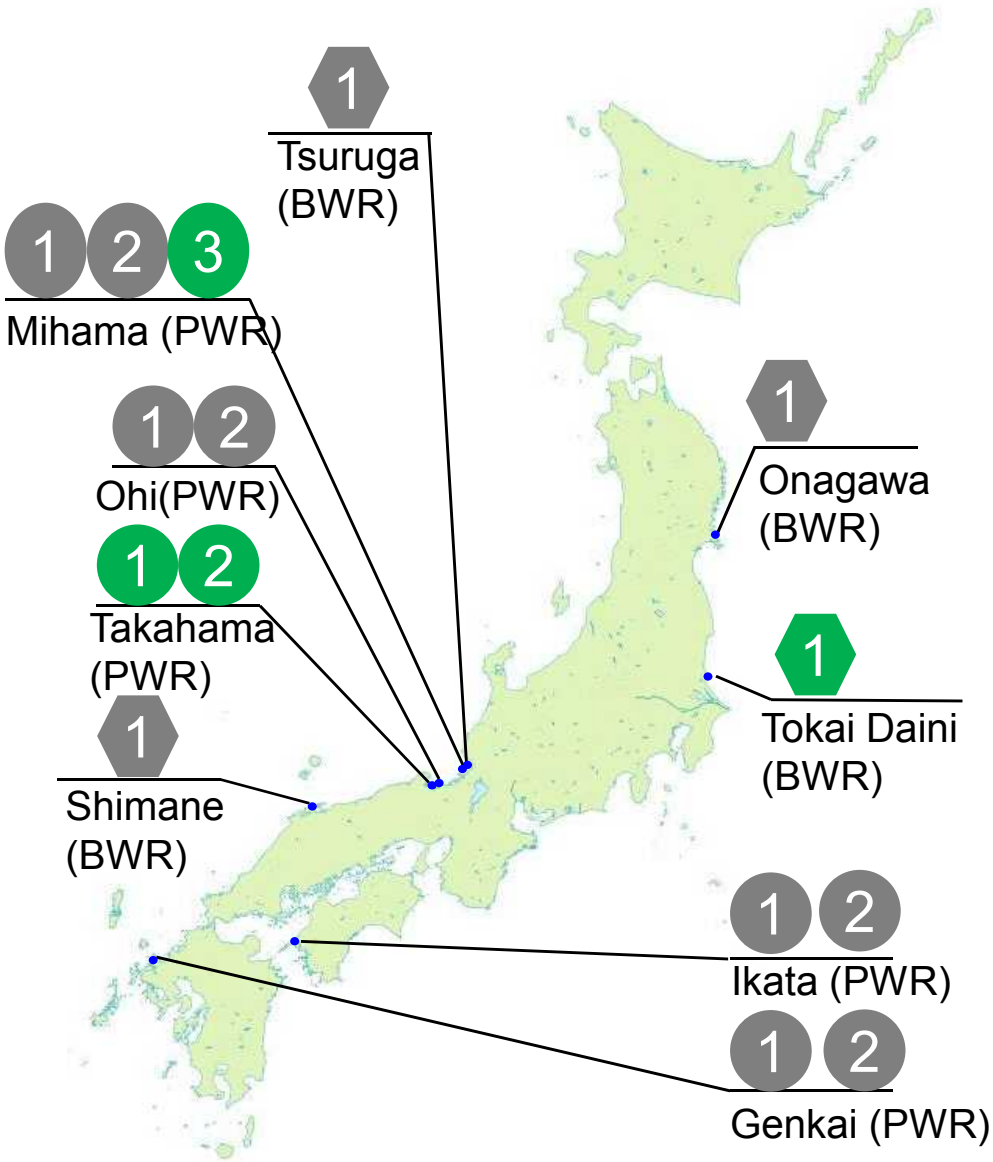
Restarted Nuclear Power Plants(As of Feb.2019)



Accelerated Decommissioning

- After Fukushima accident, reactor life is limited to be 40 years.
- This limit can be extended only once up to 60 years on condition that it go through special regulatory inspection.

Status	units
● Extended	4
● Decommissioned	11



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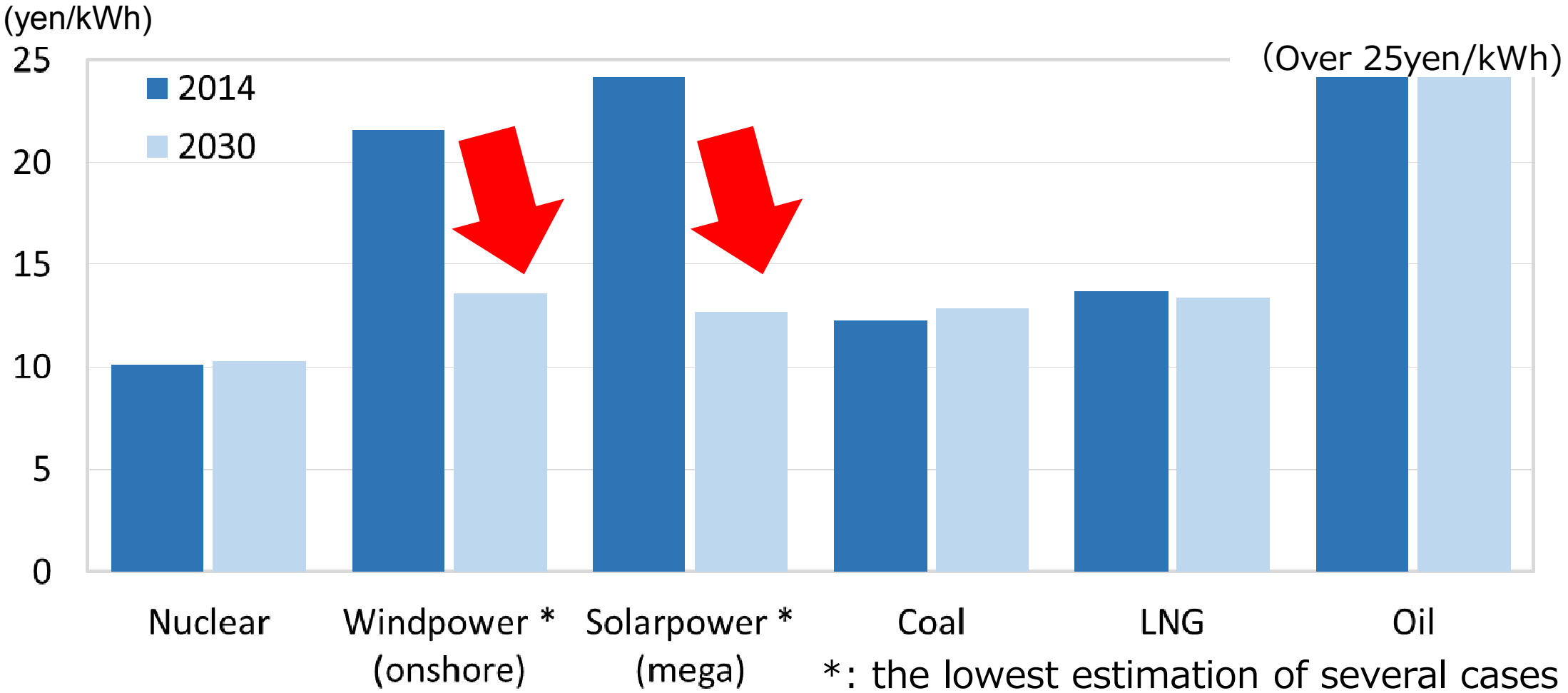
Cost Estimate by Government in 2014

- In spite of additional safety measures, Nuclear is still competitive.
- Considering cost reduction over long period, Renewable powers may be a good match for Nuclear.



http://www.meti.go.jp/english/press/2015/pdf/0716_01b.pdf

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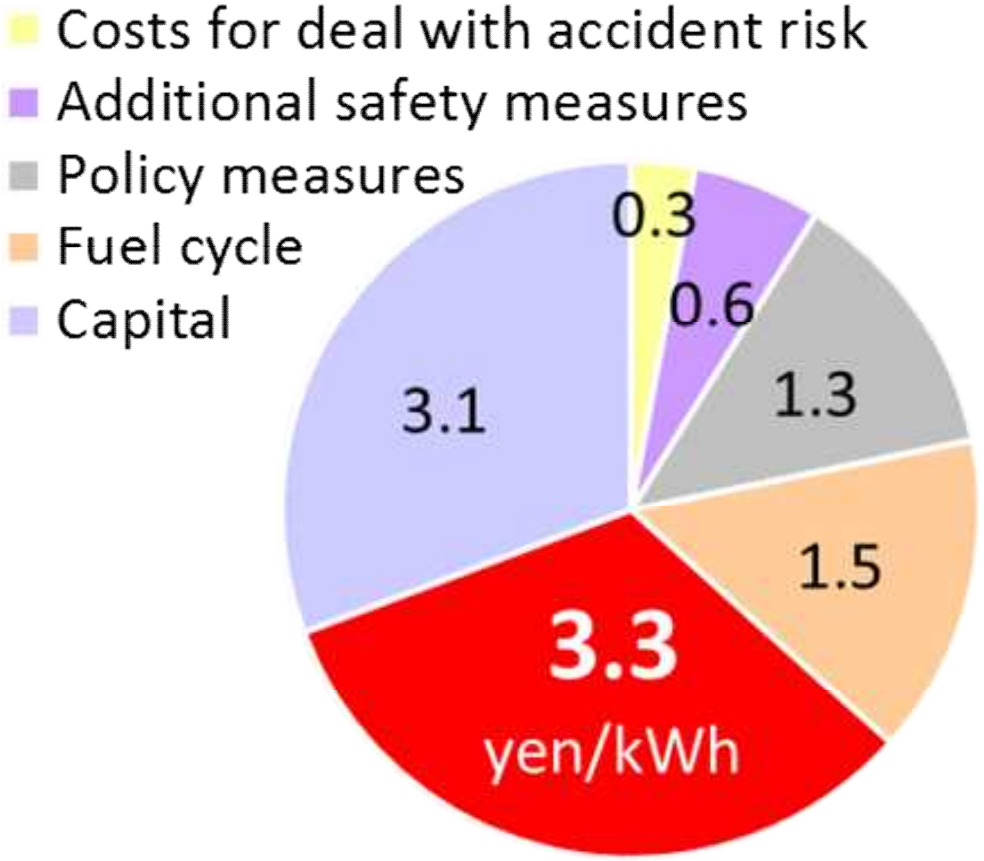
Key Factor for Economic Optimization

Assumption

- Capacity factor : **70%**
- Operation years : **40 years**
- Rated power : **1200MW**



Operation & maintenance

①Enhanced performance

②Reduction of O&M costs

http://www.meti.go.jp/english/press/2015/pdf/0716_01b.pdf

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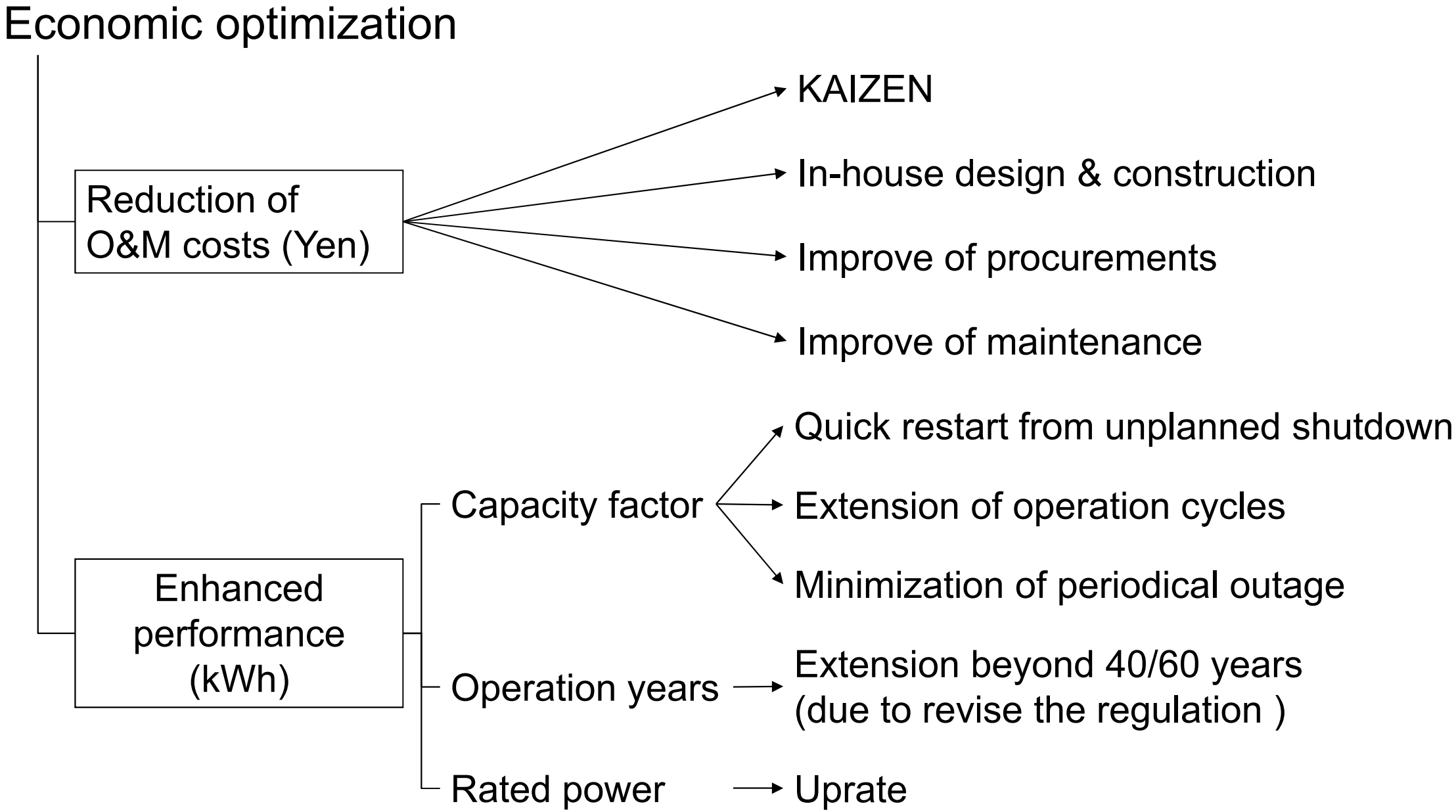
Outline of Economic Optimization



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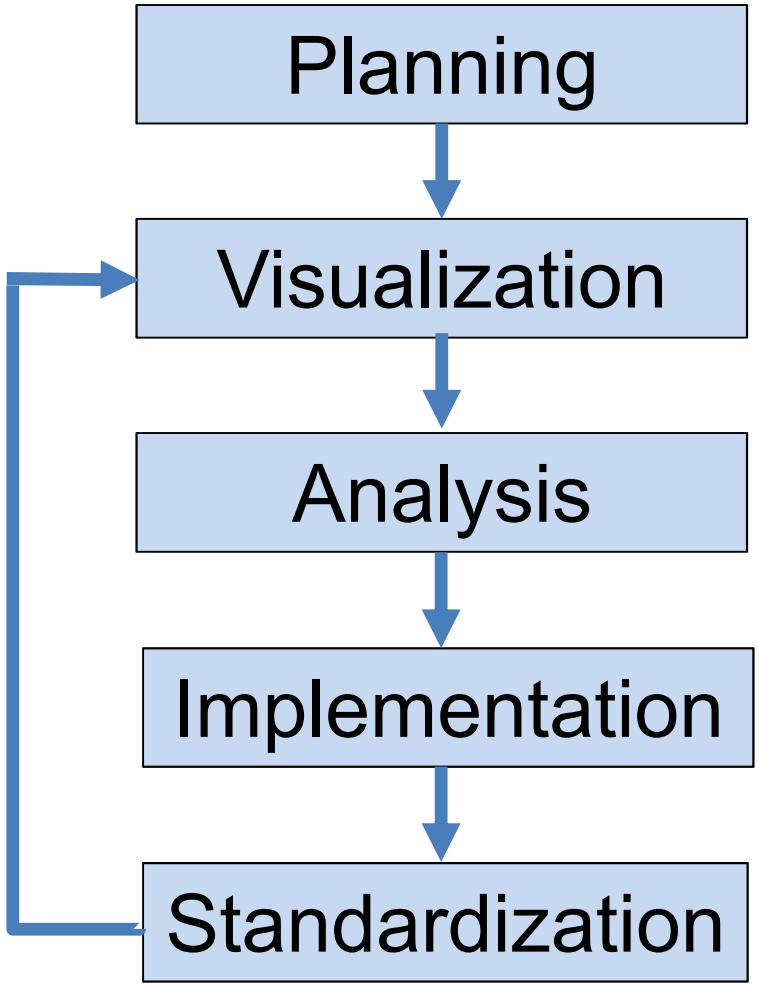
Introduction of TOYOTA KAIZEN Method

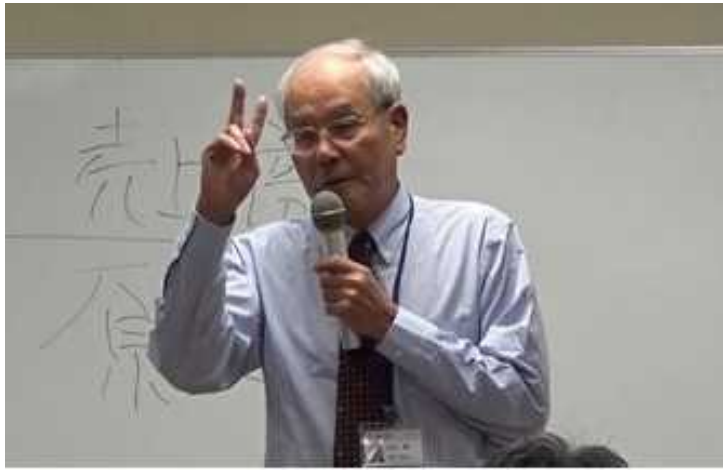
- KAIZEN (improvement) method first implemented for thermal power division and transmission/distribution division and now extend to nuclear power division.



Flow chart of work

5 why approach

KAIZEN Advisor
(ex-TOYOTA Executive)



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Example① of KAIZEN（Pump inspection）

■Development of a holding-jig allows one-man work

B E F O R E

2 persons

A F T E R

1 person

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Example① of KAIZEN（Pump Inspection）

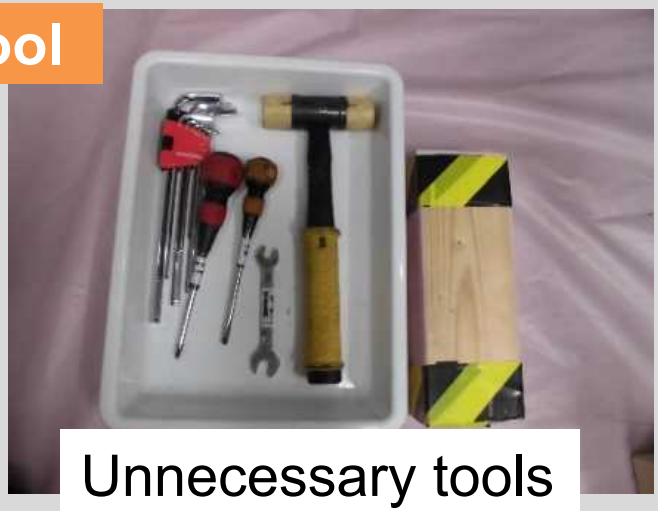
- Desk to improve working posture
- Appropriate tool to reduce work

B E F O R E

Posture

Sitting and Standing

Tool



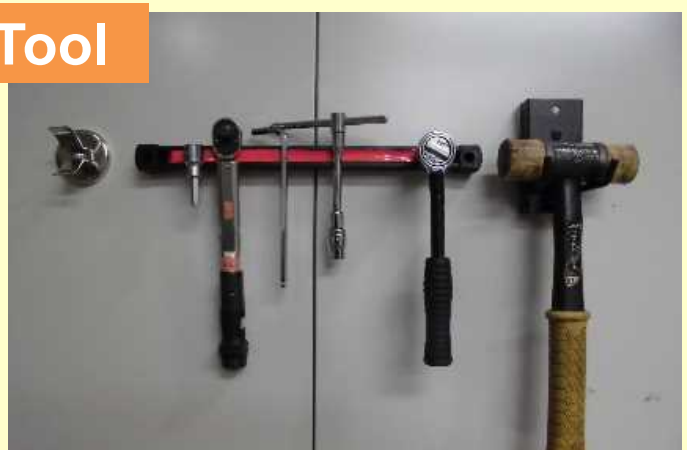
Unnecessary tools

A F T E R

Posture

Standing

Tool

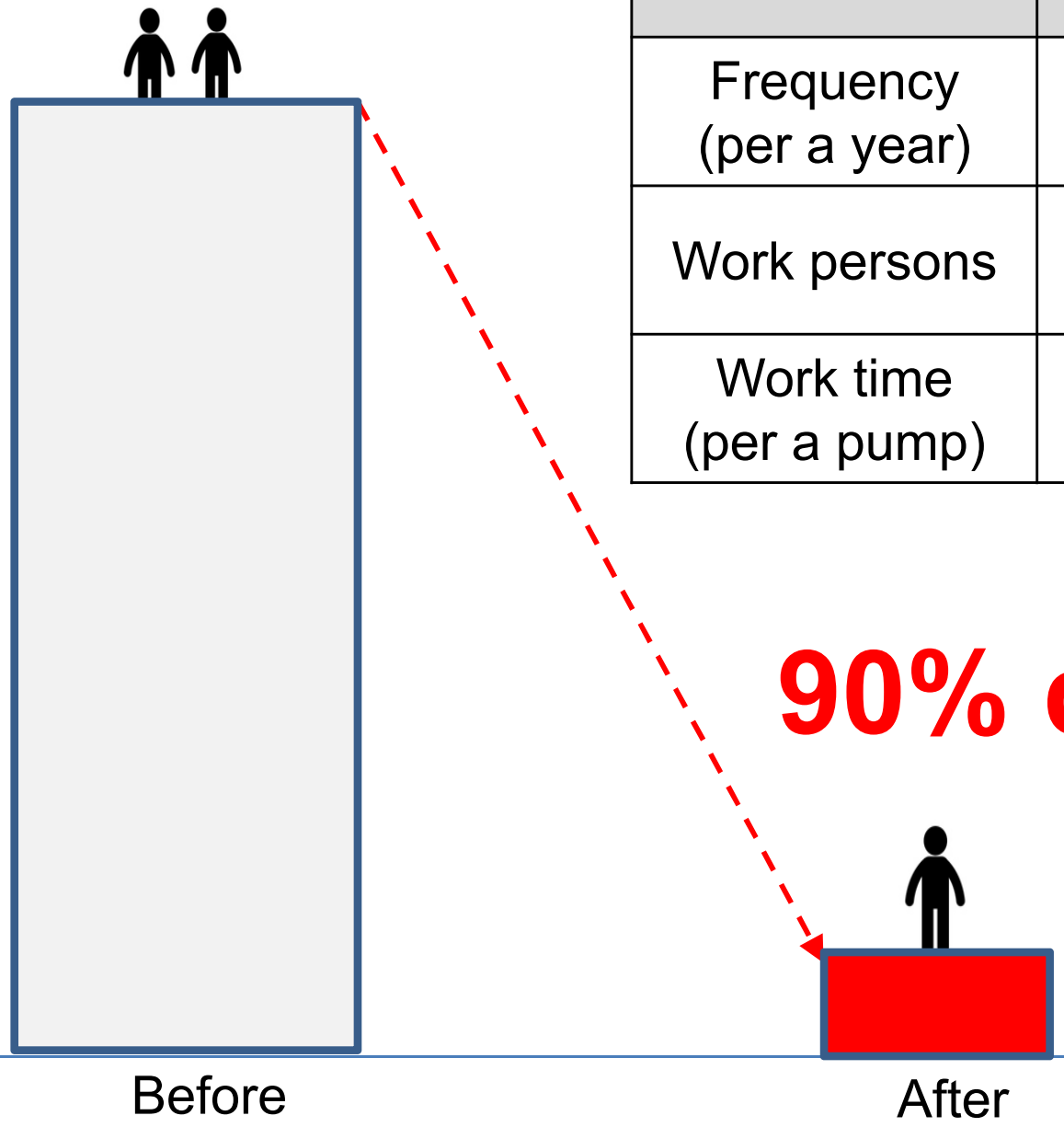


Minimal tool & Easy to take

Example① of KAIZEN（Pump inspection）

Effect

	Before	After
Frequency (per a year)	**2**	**1** (50%down)
Work persons	**2**	**1** (50%down)
Work time (per a pump)	**180** min.	**70** min. (60%down)

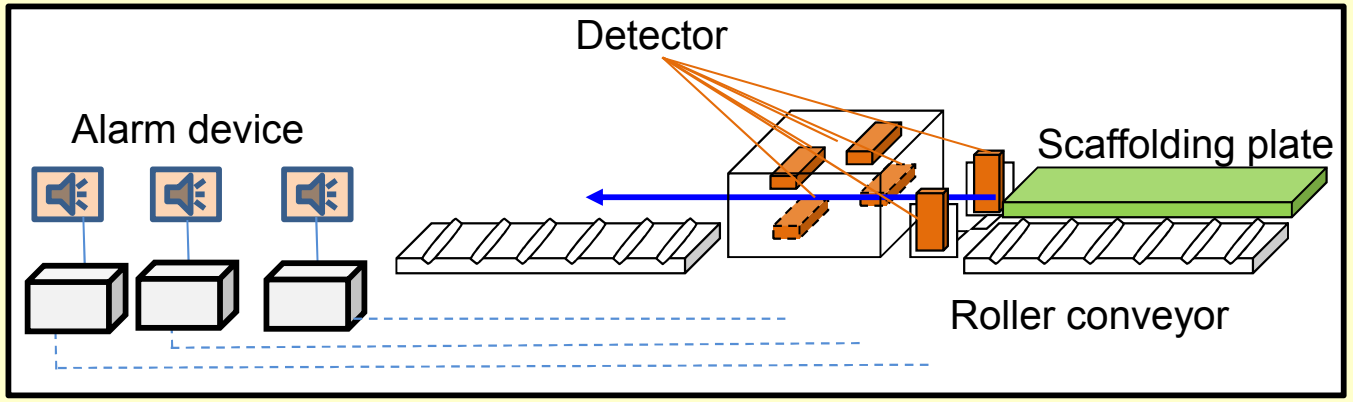


Example② of KAIZEN（Radiation Measurement）

■Measurement automation

B E F O R E

A F T E R



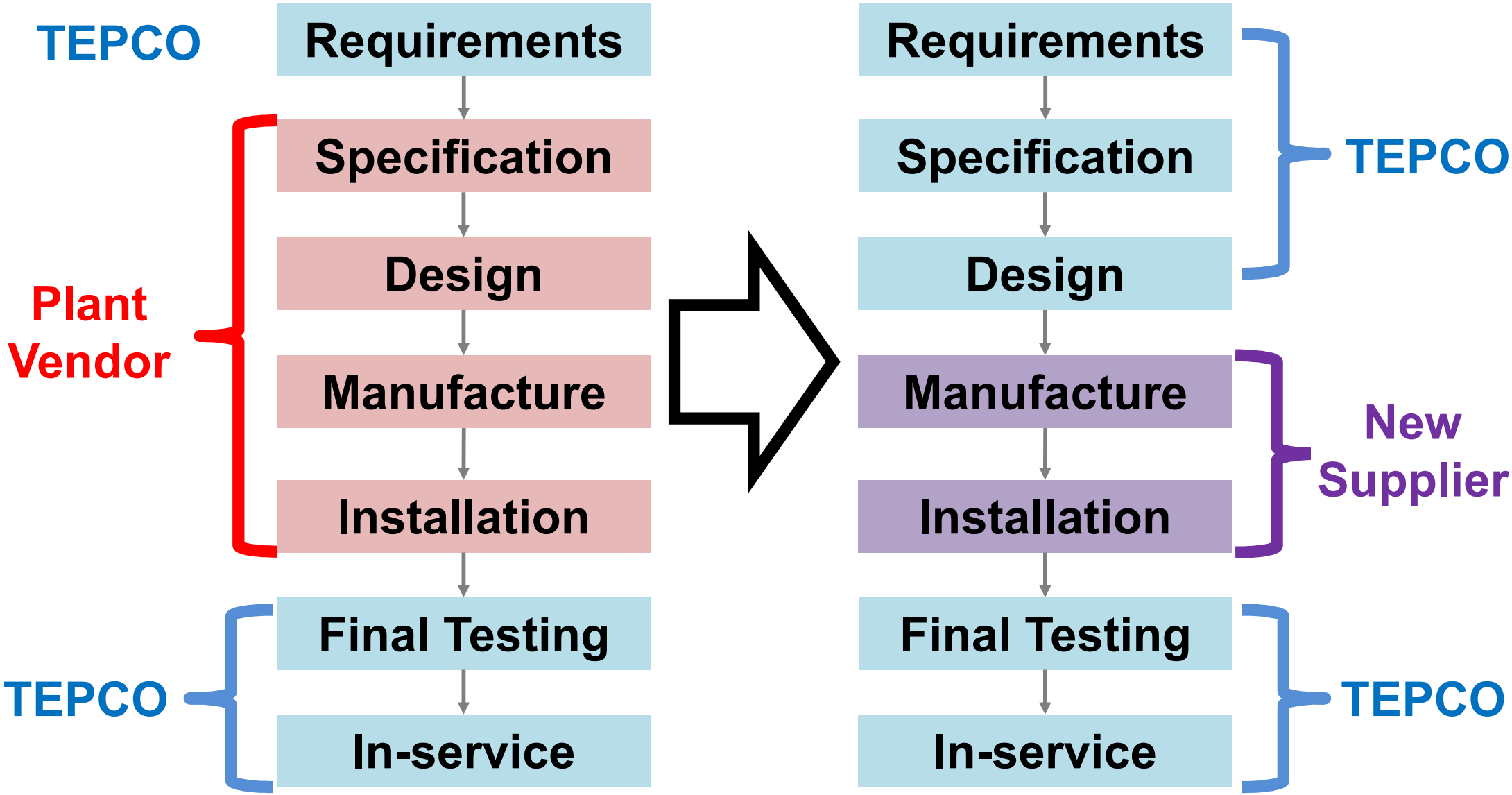
Effect

Shorter measurement time to 1/4

In-house Design & Construction

- Historically, TEPCO has depended on engineering capability of plant manufacturers.
- We are now making utmost efforts to enhance our own engineering capability.
  - ✓ Dedicated people for DIY engineering
  - ✓ Employment of plant manufactures' engineer
  - ✓ Engineering center (around 300 engineers) soon to be established

Process for Equipment Manufacturing



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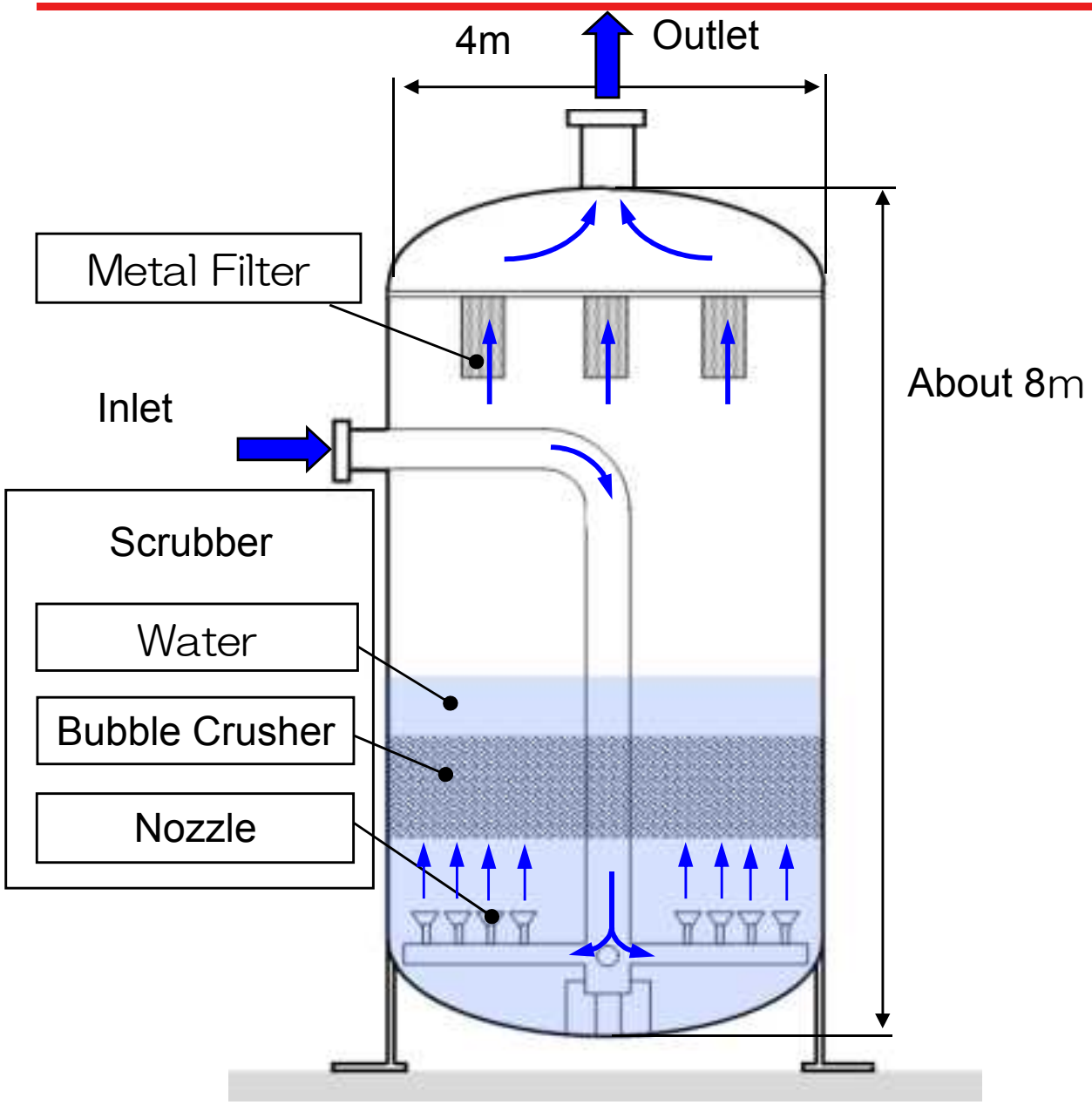
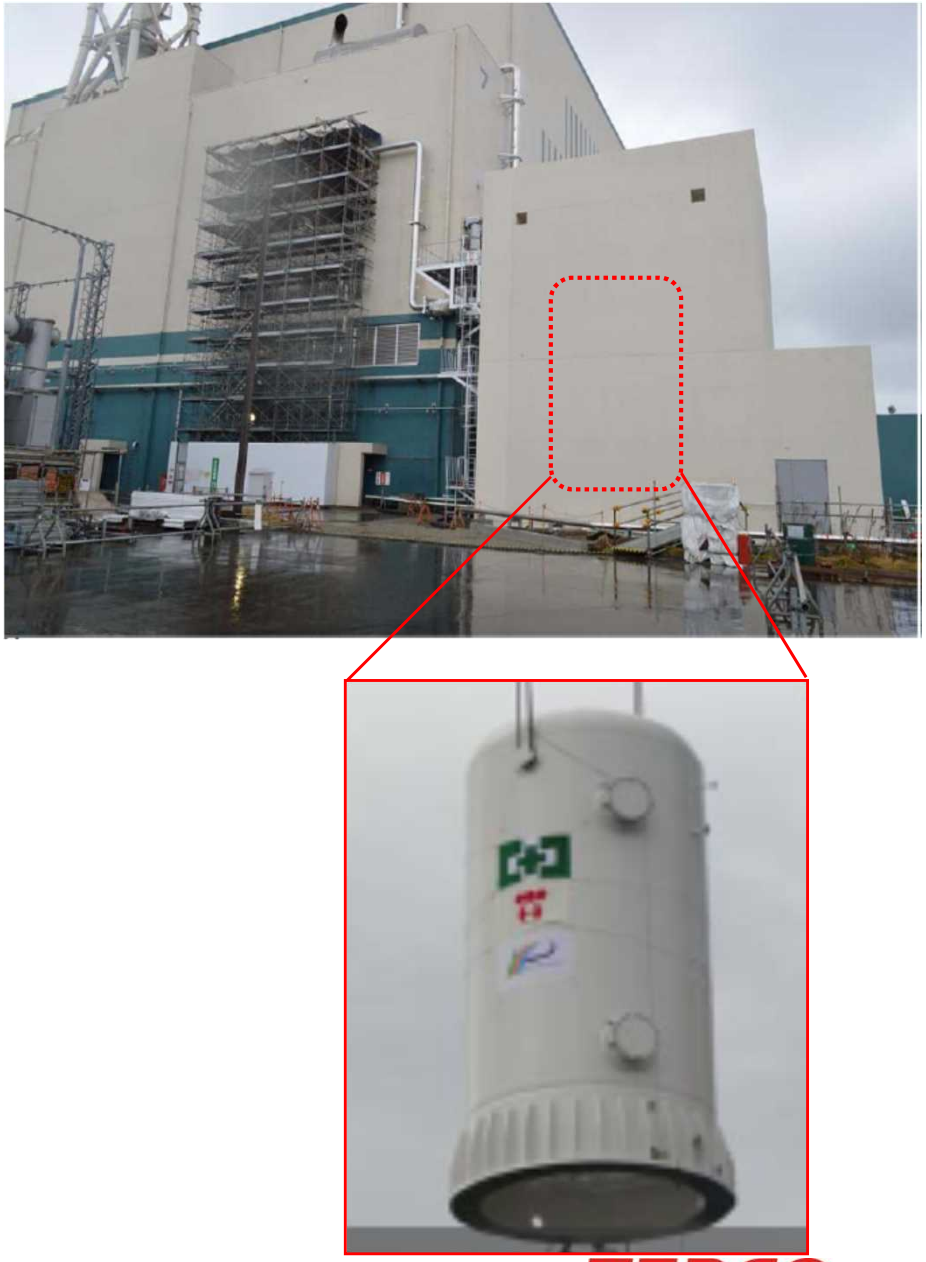
Structure of Scrubber (Designed by TEPCO)





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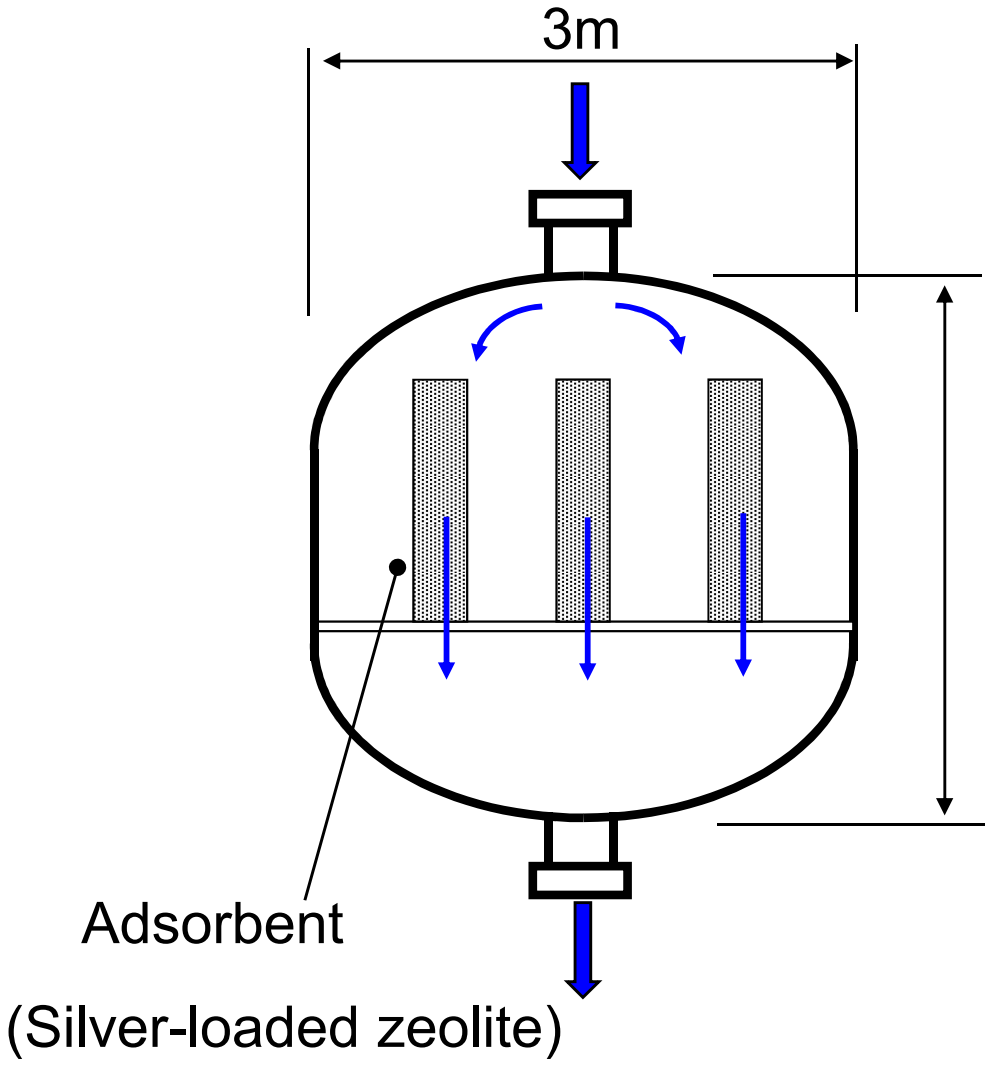

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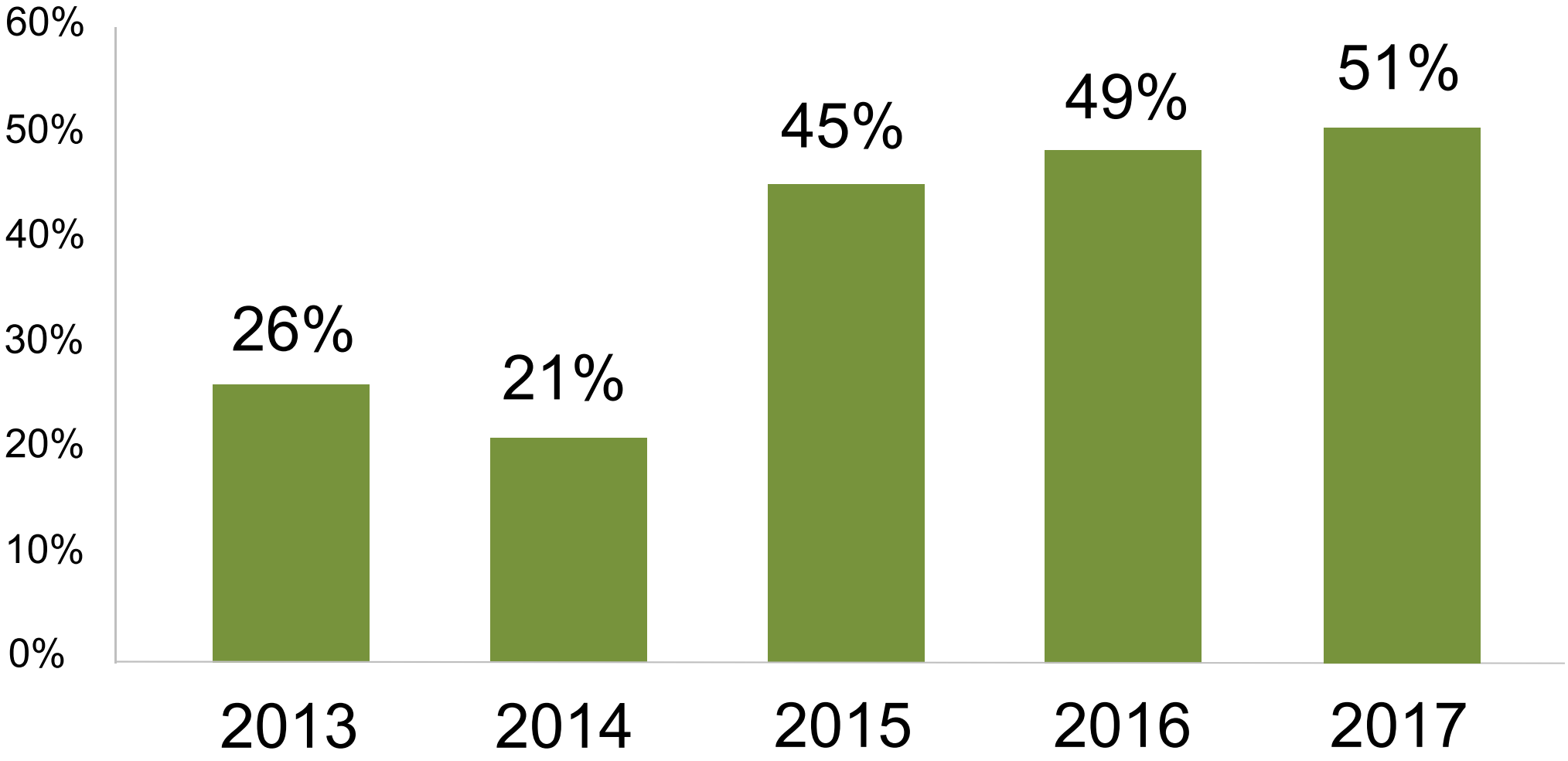
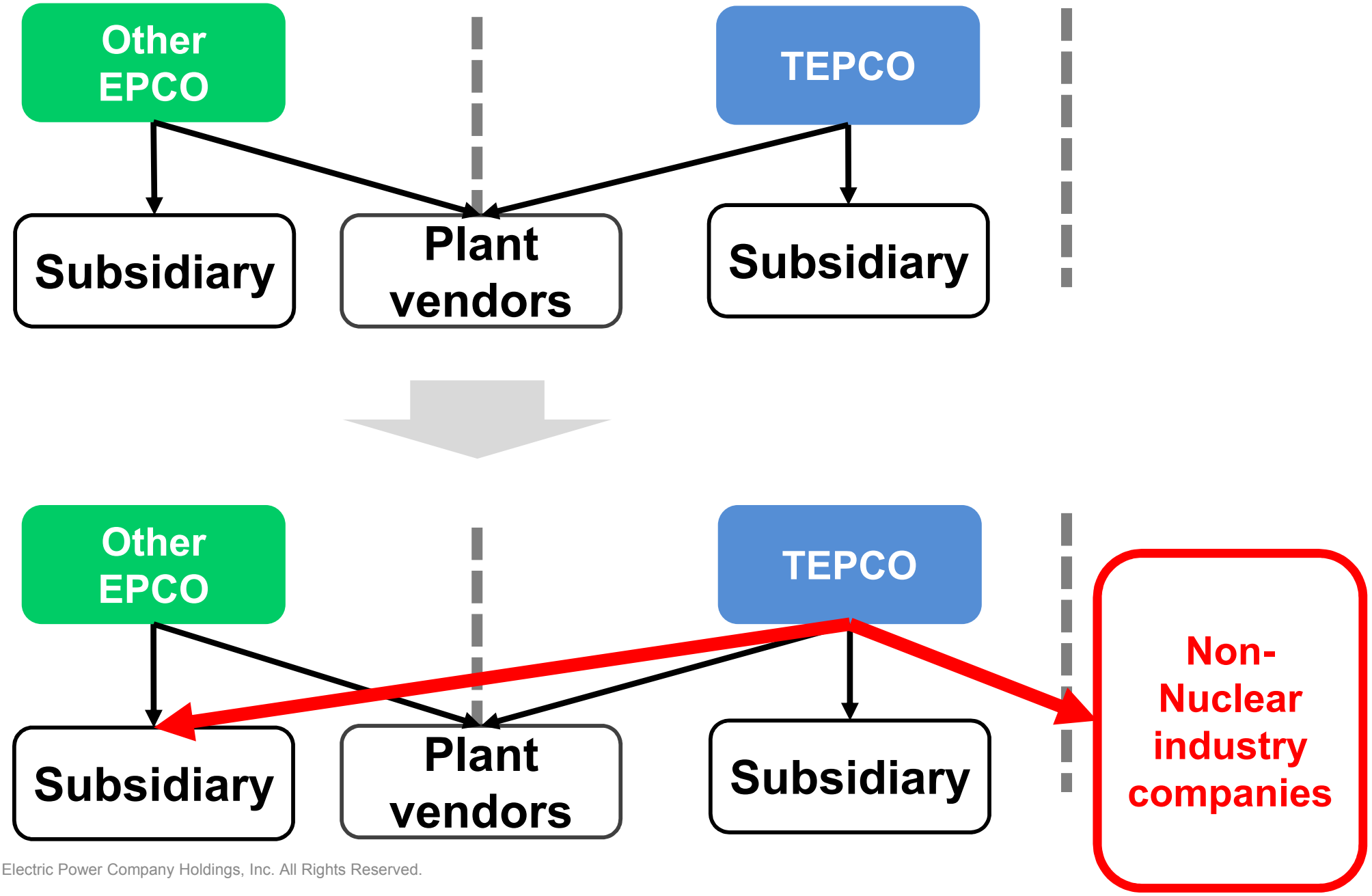
Improvement of Procurements

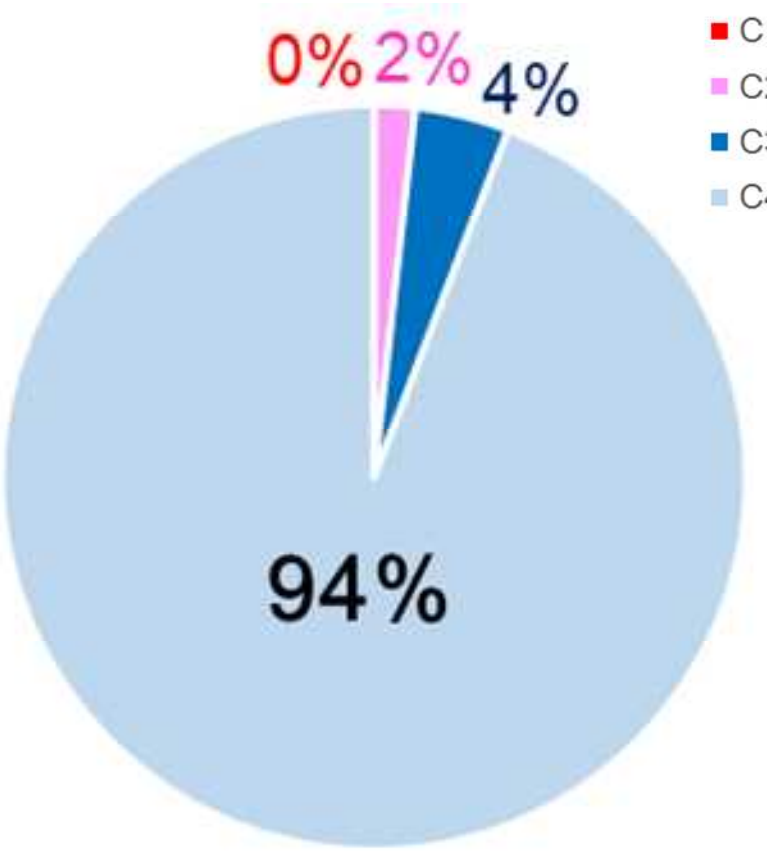
Ratio of Competitive Bid



Diversification of Supplier



Improvement of Maintenance



- C1 : lost the function
- C2 : need for repair
- C3 : right timing to repair
- C4 : early to repair

N=3148

Optimization

C3 100%

Example of the 10th cycle period inspection at KK7

Improvement of Capacity Factor

	As is	To be
Capacity factor	**Under 80%(~2011)**	**Over 90%**
Restart from unplanned shutdown	After reaching the agreements with NRA and local governments	Just after the emergency measures (depending event significance)
Operation cycle	13 months (due to current tech-spec)	24 months (regulated maximum term)
Duration for periodical inspection (planned outage)	3~4 months(~2011)	Less than 2 months

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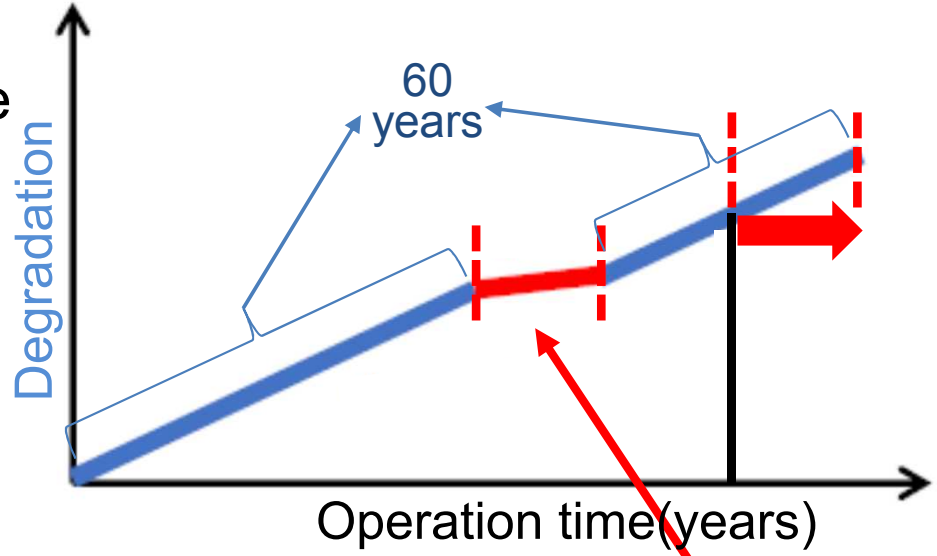
Lifetime Extension beyond 60 years

■There are two issues regarding reactor lifetime.
1.Politically determined lifetime (60 years)
2.No exclusion of prolonged outage from lifetime

➢To change the latter matter, we have compiled the technical report that explains the degradations during prolonged shutdown do not effect the safety.



Degradation	Cause	Effects during outage
Low cycle fatigue	fluctuation of thermal & pressure	**Non**
Irradiation embrittlement	Neutron	**Non**
IASCC	Neutron	**Non**
Thermal aging of stainless cast steel	high temperature	**Non**
Isolation degradation of electrical equipment	heat and radiation	**Not significance**
Strength degradation of concrete structures	heat ,radiation, vibration and salt	

Expected Schemes for Supporting Nuclear

■ To keep Nuclear power in Japan, new supporting schemes by governments are necessary.

Phase	Risks	Examples of supporting
Construction	Unavailability of large and long-term loan	• Loans by government-affiliated financial institutions • Loan guarantees by governments
	Delay for operation start due to the regulatory review	• Standard design certification such as GDA or DC
Operation	Fluctuant or low price at markets	• Stable income scheme such as FIT-CfD • Zero Emission Certificate
	Shutdown by local resident's oppositions or lawsuits	• Complement schemes by governments • Mutual aid scheme
Backend	Decommissioning cost increase	• Fund program with the upper limit of an operator's costs • Disposal of radioactive wastes by governments

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Conclusion

- Nuclear power is valuable source of energy for low-carbon sustainable future.
- In deregulated market and Post-Fukushima era, for nuclear power to remain competitive, enhanced performance of NPP and O&M cost reduction is essential
- In addition to operators' efforts, supporting scheme for nuclear power is expected

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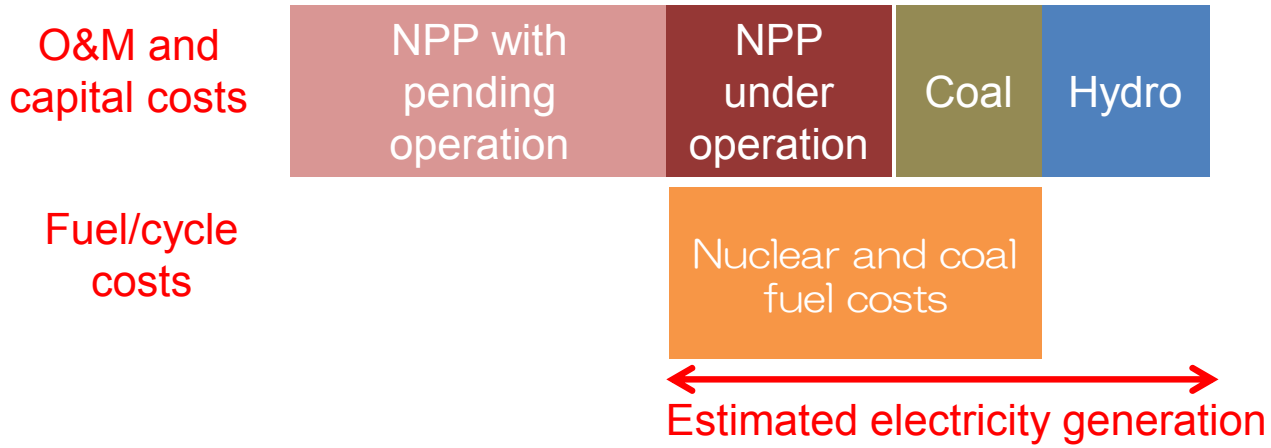
（reference）Base Load Market

Ceiling price for “Base load Market” is designed as follows

Generation costs（covering the costs shown below）- Partial revenues from other markets
Estimated electricity generation for the contracted period (one year forward)



- Base load market is designed to recover fixed and variable costs of base load generation when the highest bid price equals to the ceiling price of delivery.
- In addition, it is designed to include O&M and capital costs of nuclear power plants with pending operation (reflecting the unique situation of Japan).

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（reference）Zero Emission Certificate Market

Zero emission certificate market aims to

- make the value of zero emission sources realized and tradable
- create a mechanism for power retailers to facilitate the implementation of target to support Japan's climate commitment (i.e. "By 2030, 44% of electricity delivered should come from non-fossil fuel sources")
- provide incentives for power generators to maintain and develop zero emission sources – supporting the enabling environment for nuclear power

- Zero emission certificate is generated based on the verified generation (kWh) and is traded in every 3 months through auction.
- Auction rules and 3 classification of tradable commodities are as follows.

	FIT Renewables	Non-FIT Renewables	Non-FIT Other than renewables (large hydro and nuclear)
Pricing mechanism	Multi-price auction	Single-price auction	
Ceiling price for bidding	4 yen/kWh	tbd along with mid-term targets	
Floor price for bidding	1.3 yen/kWh	No setting	

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（reference）Electricity Market Reform

Positive Developments

- Base load market is potentially benefit the cost recovery of base load generation when the highest bid price equals to the ceiling price of delivery.
- Cost for decommissioning is separately treated under “decommissioning account” and is partially recovered through the wheeling service charge.
- Zero emission certificate market associated with an appropriate stepwise target for power retailers would create an additional revenue stream matching the value of nuclear power.

Challenges

- Baseload market aims to feed the baseload needs of new entrants (players other than the conventional utilities) and is therefore under pressure for the larger contract volume (up to 30% of entire demand) with lower price.
- Partial revenues from other markets (i.e. capacity and zero emission certificate markets) may be subtracted from the delivery price against the original purposes of these markets.
- Those twists in market rules and loss of long-term perspective for investment recovery create uncertainty.
- Unplanned outage along with orders and restrictions imposed by gov. or civilian authorities (e.g. temporary injunction to suspend operation) becomes a challenge under the new market condition.

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