Study on energy scenarios for realizing a secure, economical and low-carbon society

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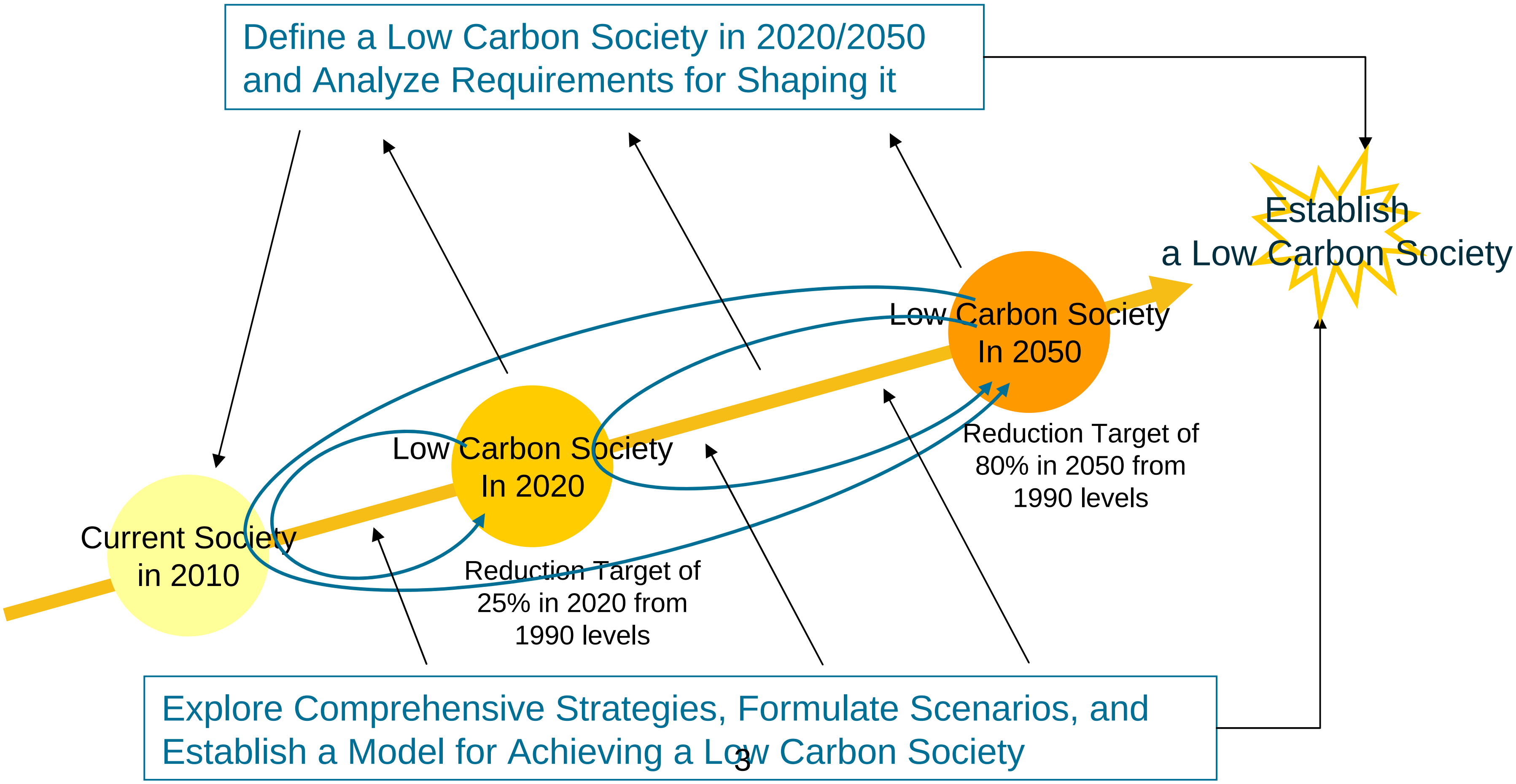
Background of establishing LCS

- **The Goal of LCS is establishment of strategies to move present societies to sustainable and affluent low carbon societies.**

- **LCS was established in Dec.2009 in Japan Science and Technology Agency with the above aim.**

Center for Low Carbon Society Strategy（LCS）

Established in December 2009
in Japan Science and Technology Agency（JST）



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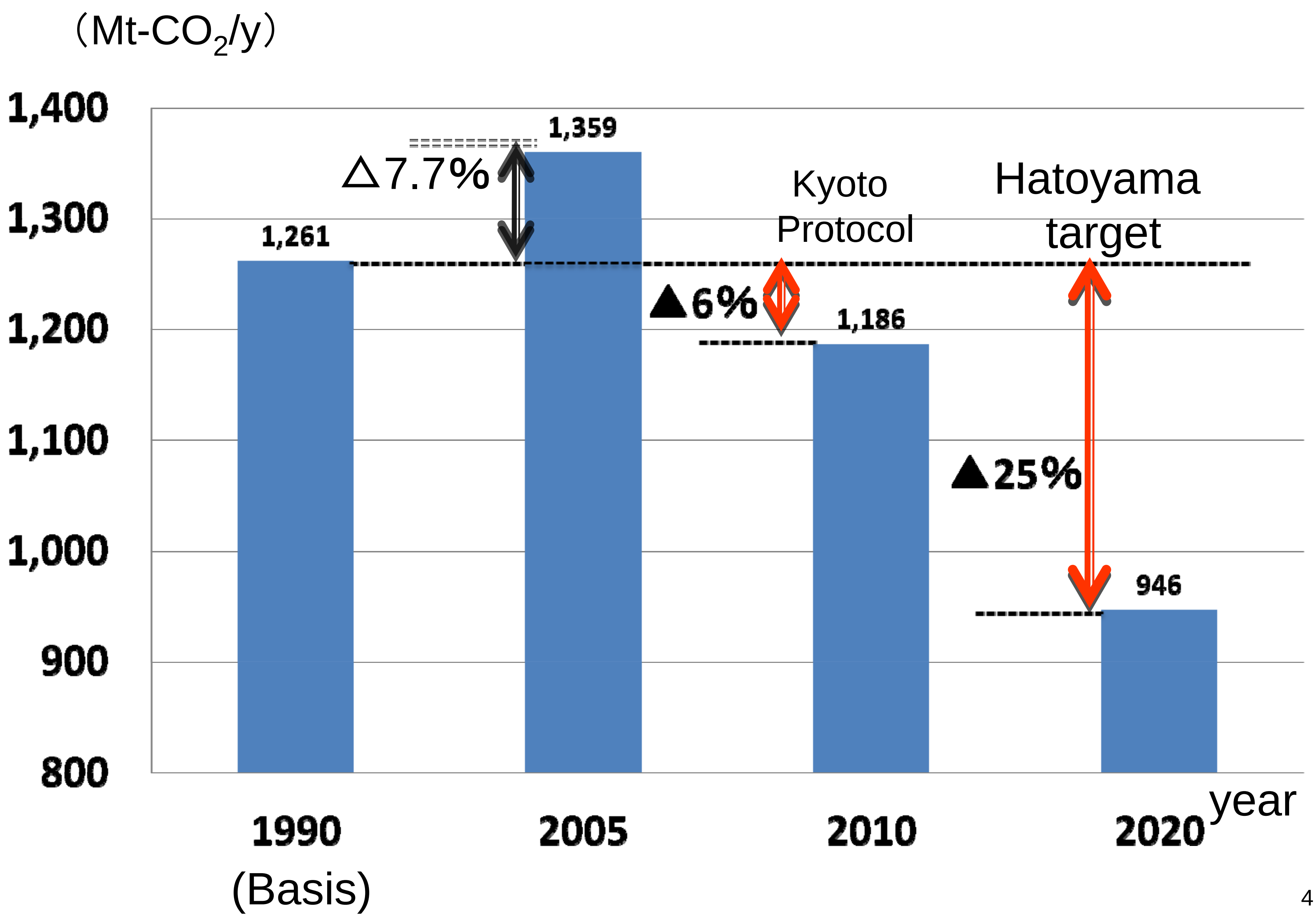
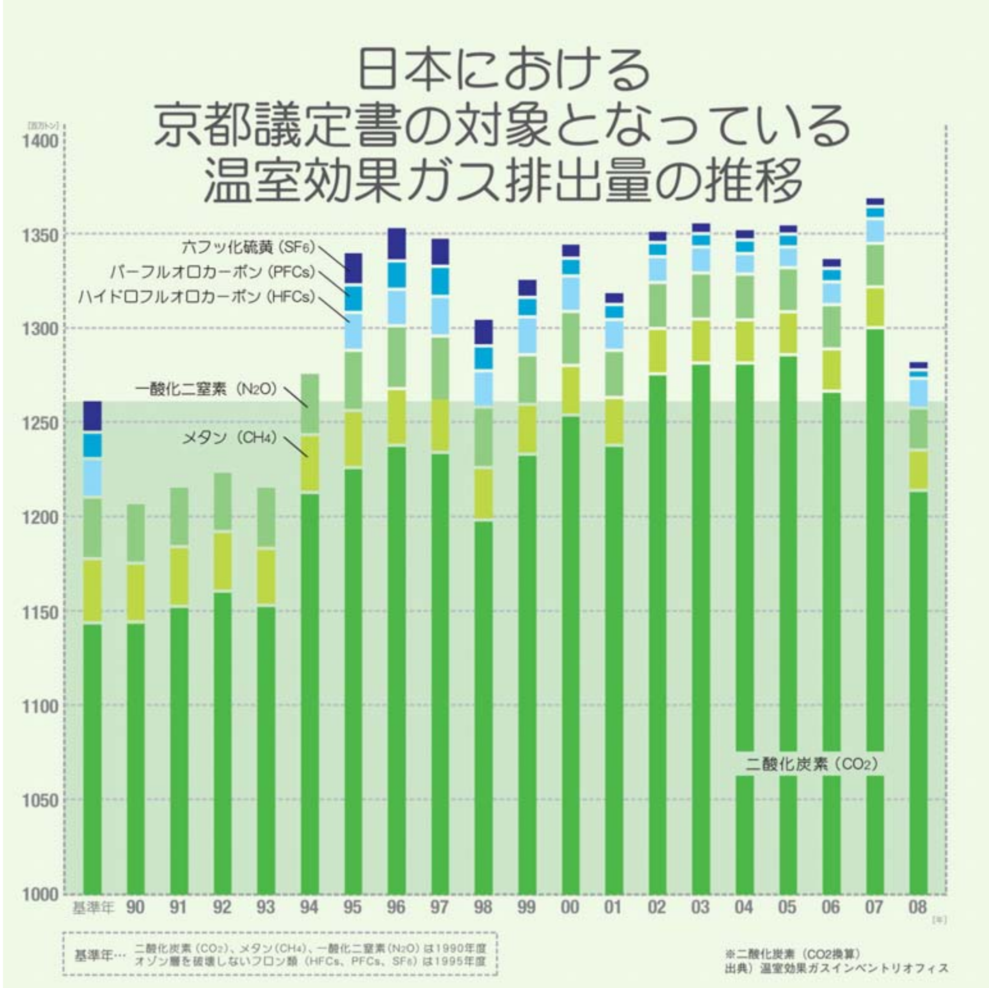
CO2 Reduction Target of Japan





Quoted from JCCCA web site

Japan's GHG emissions in 2008 fiscal year is estimated to be approximately +1.6 % relative to 1990. Forest sink contribute to 3.8% reduction from this number. Using Kyoto mechanisms, Japanese government acquired approximately 95 million ton (annually 19 million ton), while Japanese industries acquired 350 million ton (annually 70 million ton). These corresponds to more than 6% of annual domestic GHG emissions in 1990.

As conclusion, we estimate Japan could comply with Kyoto Protocol even with economic revival in future.

Strategic Scheme for Green Innovation by MEXT

Social System Transformation for Low Carbon Society

Low Carbon Society R&D Strategy Bureau

Control overall strategy
（Prioritize R&D Items ）

Consulting

Low Carbon Society R&D Strategy Promotion Committee

Mitigation Tech. Diffusion to Society

Realization of Climate Change Adaptation Society

Linkage to Related Ministries, Agencies, Local Governments,

Field Experiment Strategy

〇Field experimental research of Low Carbon Technology

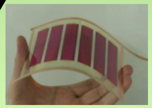
◆ Society system reform program toward new society corresponding to climate change
5Million Yen(New)

Mitigation Strategy

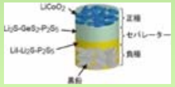
Innovative technology contributing to Greenhouse Gases Reduction

Apply collective R&D efforts from Univ., Agencies, Institutes

◆Advanced Low Carbon Related Technologies etc
5,809Million Yen（1,339Million Yen）


High-performance sensitizedsolar cell


Superconducting power transmission cable


Next-generation high-performance storage cell


Super high-temperature resistant alloys

〇Promote R & D of Near & Long Term Energy Technology

Utilize full results of *Basic Research Strategy*（JST’s CREST etc）

Adaptation Strategy

Research for adaptation of environmental change caused by global warming

◆Climate Change Adaptation Strategy Initiative etc
3,158Million Yen（2,316Million Yen）

〇Promote Climate Change Projection and Data Integration as common platform technology


Earth Simulator


Data Integration & Analysis Systemy(DIAS)

Apply full results of *EO Strategy*

Diplomatic Strategy

Int’l Cooperation・S&T Diplomacy

〇Contribute to UNFCCC /IPCC/GEOSS etc
〇Support to Developing Countries、Capacity Bldg

General Strategy

〇Research analysis on realization of new technology

◆Social Scenario Research for Low Carbon Society
300Million Yen（New）

◇JST Low Carbon Social Strategy Center Establishment

〇Research Analysis on possibilities of adoption and diffusion of technology considering utility to public and lifestyle change

〇Research analysis on influence of new technology to society

Impacts of the Great East Japan Earthquake and Fukushima Dai-ichi Nuclear Plant Accident

On March 11, 2011, a great earthquake devastated the East Japan region. The earthquake and subsequent tsunami also cut off all power, including emergency backups, to the Tokyo Electric Power Company's Fukushima Dai-ichi Nuclear Plant, causing a critical situation. Now we can only hope for a speedy resolution and recovery. This, the biggest nuclear accident in Japanese history, will inevitably affect the country's future energy and anti-global warming policies.

Major Policies on Global Warming Countermeasures, Dec. 28, 2010
Ministerial Committee on the Global Warming Issue

1. Reduce GHG emissions by 25% below 1990 levels by 2020, premised on the establishment of an equitable and effective international framework in which all major economies participate and agree on ambitious targets.
2. Domestically, implement the Basic Energy Plan to reduce CO2 from energy use to 30% or more below 1990 levels by 2030.
3. Flexibly and strategically reshape policies to adapt to changing domestic and international conditions, enhance environmental and energy technologies and accelerate green innovation.
4. From FY 2011, introduce a global warming tax. Increase the tax rate on oil and coal in proportion to the amount of CO2 emissions created to give a final increase in tax revenues of approximately 1.5 times (approx. 240 billion Yen).
5. During the current session of the Diet, propose laws to require power companies to purchase all energy produced from renewable sources (cost of purchases to be passed on to customers).
6. Give careful consideration to the establishment of a cap and trade emissions trading scheme.
7. The Japanese government will work with industry, agriculture, consumer and regional groups etc., to support global warming mitigation initiatives such as bilateral and domestic credits.
8. Secure financial resources and promote policies to absorb greenhouse gases through forestry, etc.

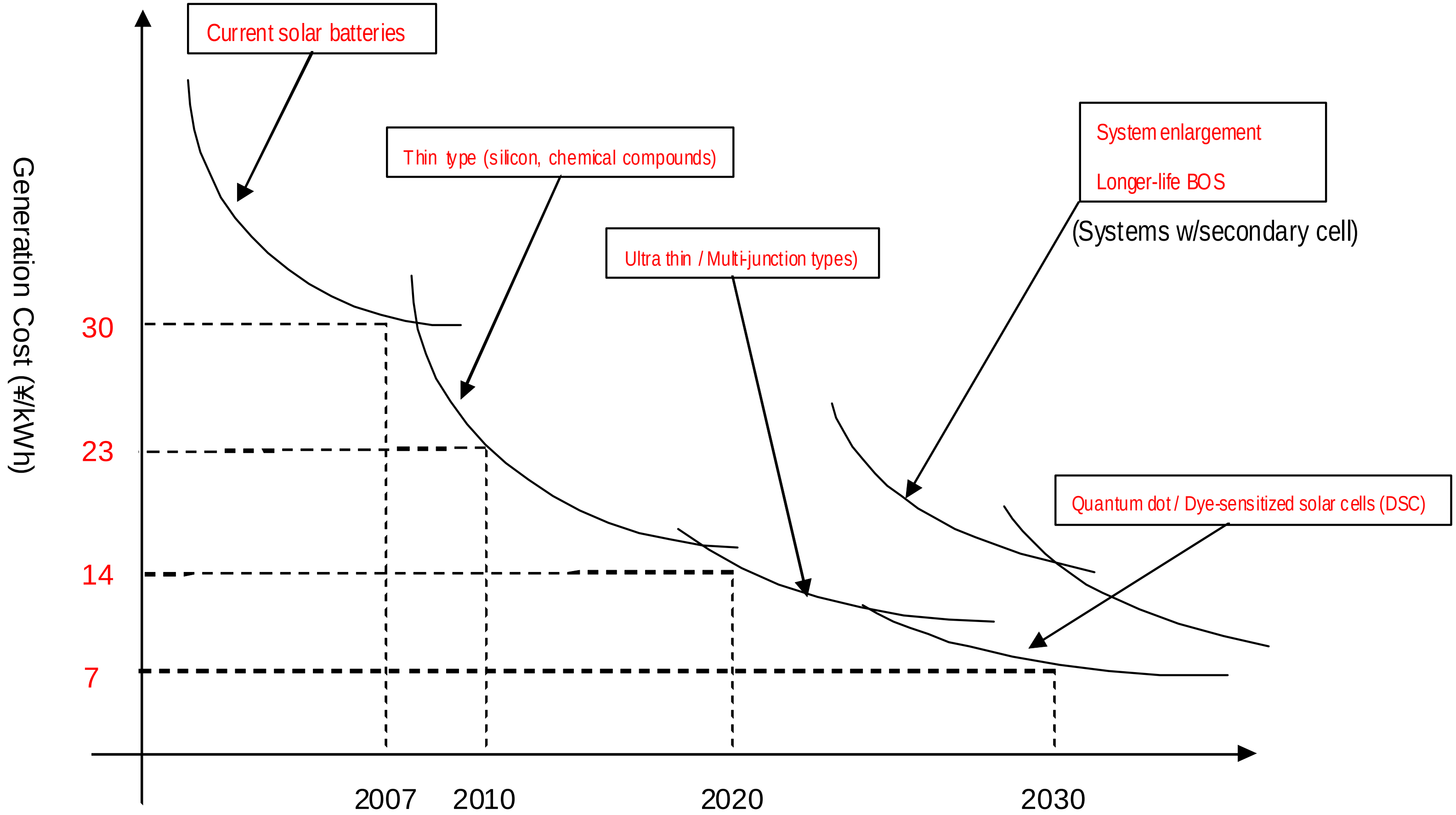
Costs of PV system and batteries

YEAR	2012	2020	2030
PV system (yen/W)	250	175	120
Efficiency (%)	15	20	30
BOS (yen/W)	150	100	70
Cost (yen/kWh)	25	18	12
Li-ion batteries (yen/Wh)	19	10	8
Lifetime 5years 20h (yen/kWh)	76	40	16 (10years)
5h (yen/kWh)	19	10	4 (10years)
Total (5h, yen/kWh)	44	28	16

Reference: LCS

Model of technology innovation for PV

Cautious R&D and a strategy for deployment are vital in achieving replacement with next-generation PV systems.



Model of market penetration for PV
-Estimation of feed in tariff-

<u>We modeled the deployment of PV using Logit model.</u>

Utility of purchasing PV in i prefecture

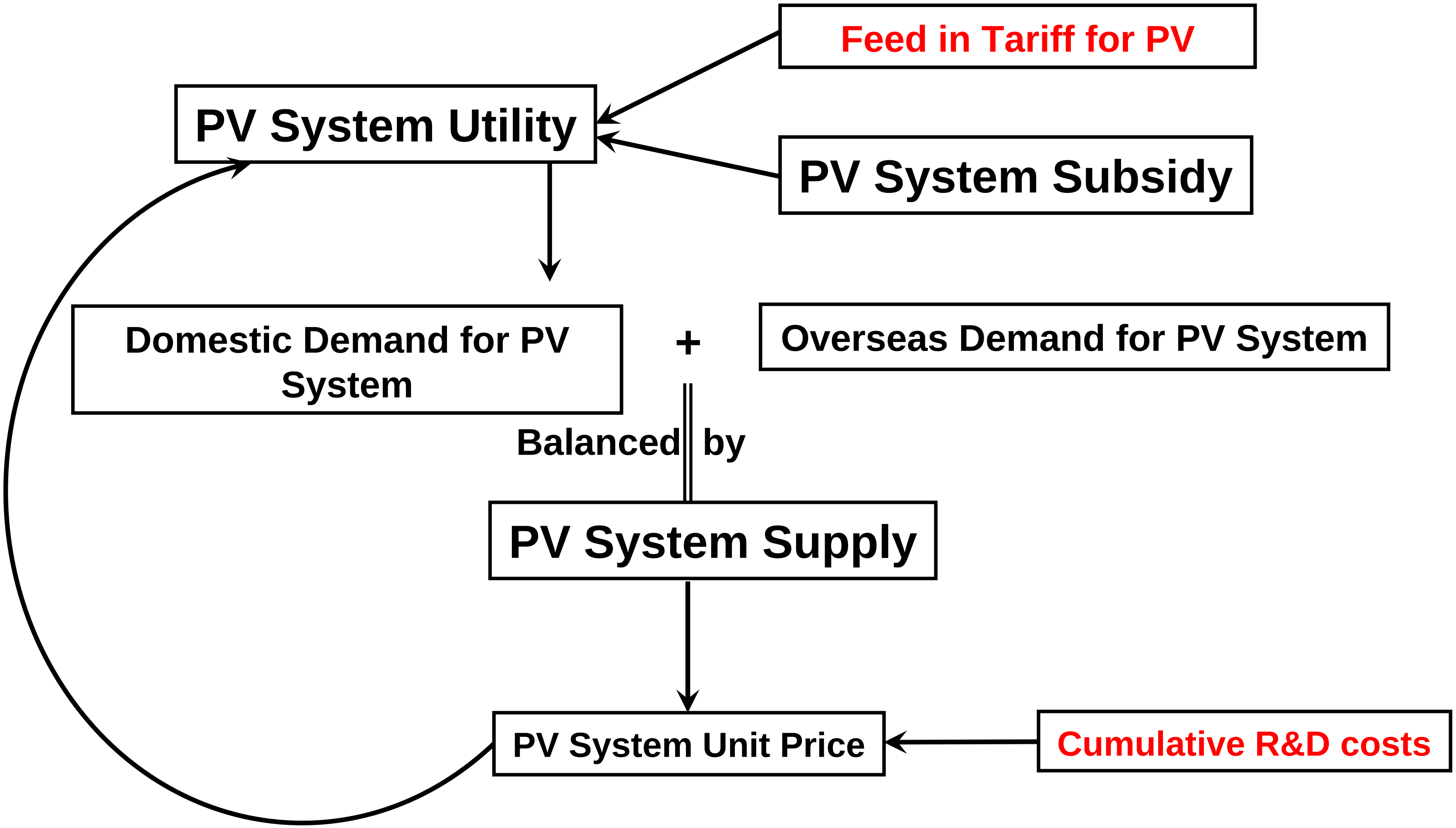
$$U_i = \theta_1 W_i - \theta_2 I_i + \theta_3 S_i + \theta_4$$

Rate of purchasing PV in i prefecture

$$P_i = \frac{\exp(U_i)}{1+\exp(U_i)}$$

W_i：Potential generation（kWh／kW）, I_i：Initial investment（10000yen／kW）,
S_i：Selling price of electricity in the feed in tariff（yen／kWh）

Synergy of technology and market innovation



1. Framework in this analysis

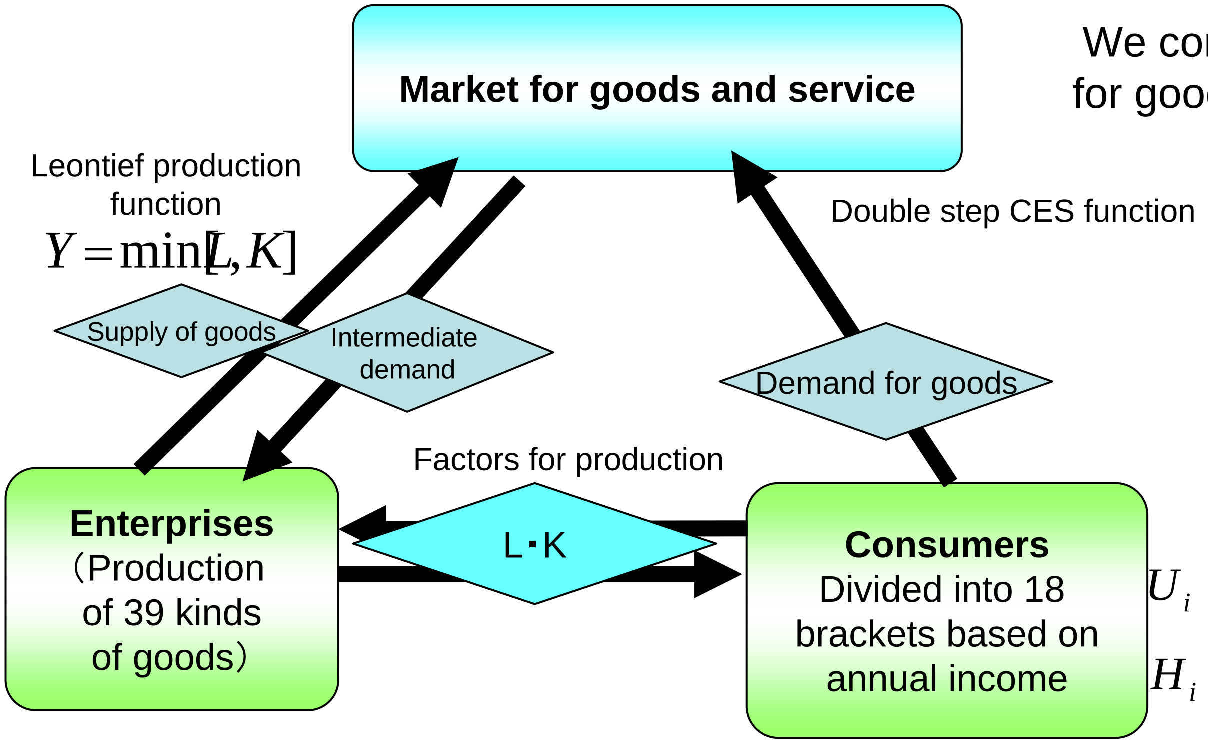
Overview of our analysis

Computable General Equilibrium Model

Multi-regional Power Planning Model

Final Energy Demand Model for Households

Structure of our CGE model



We compute the point, in which markets for goods and services are in equilibrium.

U（Utility）
H（Present consumption）
C（Future consumption）,
X (Consumption of goods),
l (Consumption of leisure)

$$U_i = \left[\alpha_i^{1/\sigma_{2i}} H_i^{\nu_i} + (1-\alpha_i)^{1/\sigma_{2i}} C_{Fi}^{\nu_i}\right]^{1/\nu_i}$$

$$H_i = \left[\beta_i^{1/\sigma_{1i}} l_i^{\phi_i} + (1-\beta_i)^{1/\sigma_{1i}} X^{\phi_i}\right]^{1/\phi_i}$$

Consumers are divided into 18 brackets based on annual income.
⇒ Evaluation of economic impact by introducing technologies.
⇒ Evaluation of economic impact in each income bracket.

Consumption and production sectors of our CGE models

Decrease by energy saving

Increased cost

Increased cost

Decrease by energy saving

		1	2	···	18
1	Food				
2	Dwelling				
3	Electricity				
4	Gas				
5	Light & Fuel				
6	Water & Sewage				
7	Durable goods				
8	Heating & Cooling				
9	General furnitures				
10	Other furnitures				
11	Clothing and shoes				
12	Medical & Health				
13	Transport				
14	Automobiles				
15	Gasoline				
16	Communication				
17	Education				
18	Entertainment				
19	Other consumptions				

1	−200
2	200−250
3	250−300
4	300−350
5	350−400
6	400−450
7	450−500
8	500−550
9	550−600
10	600−650
11	650−700
12	700−750
13	750−800
14	800−900
15	900−1000
16	1000−1250
17	1250−1500
18	1500−

Brackets by income

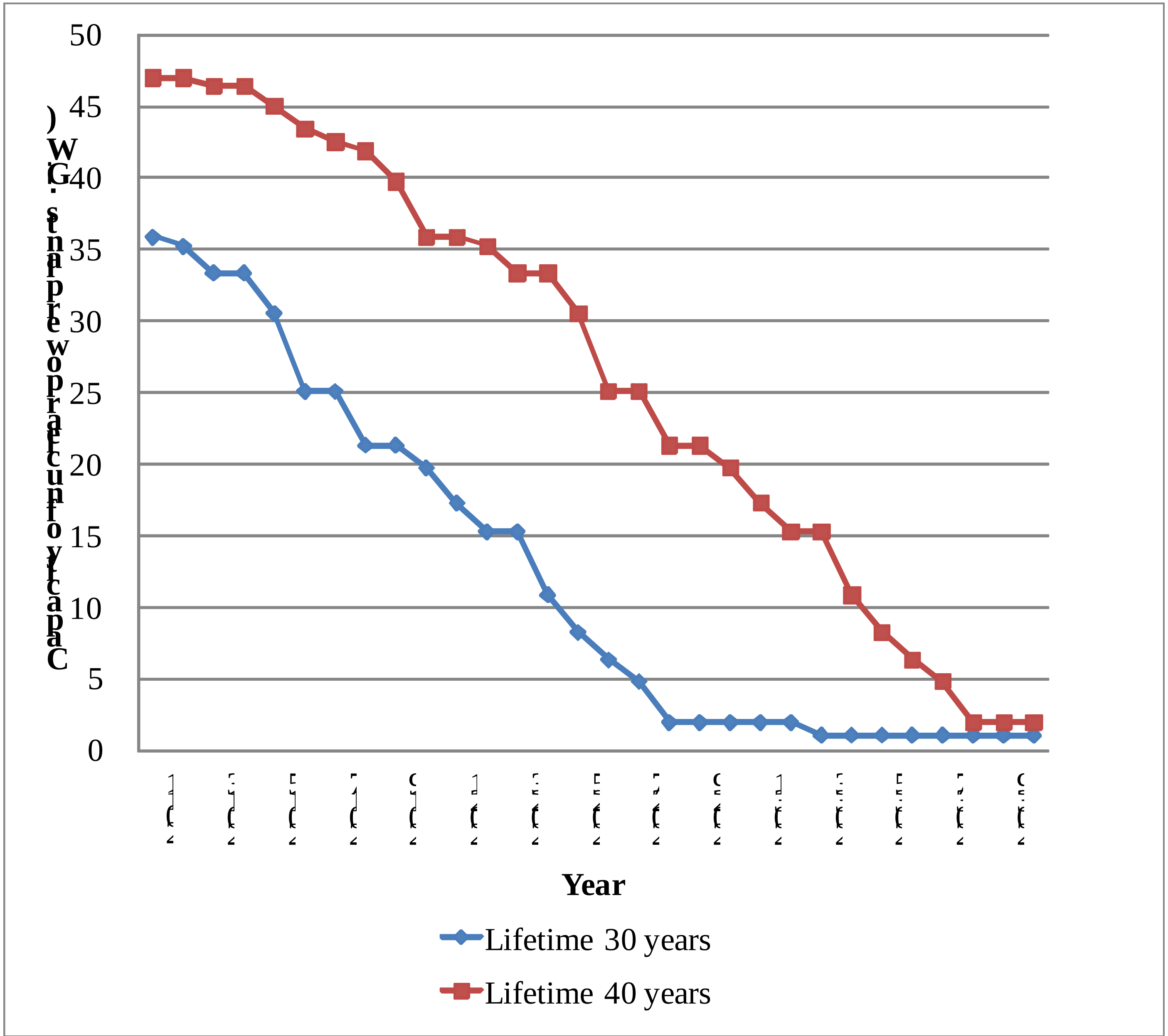
1	Agriculture, forestry and fishery	20	General machinery
2	Limestone	21	Electric machinery
3	Coal	22	Automobiles
4	Oil	23	Transport machinery
5	Natural gas	24	Precision machinery
6	Other minerals	25	Other manufacturing
7	Food	26	Construction
8	Textiles	27	Electricity
9	Wood products	28	Gas
10	Pulp & paper	29	Heat
11	Printing	30	Water & Sewage
12	Chemicals	31	Waste disposal
13	Petroleum products	32	Commerce
14	Coal products	33	Finance & Insurance
15	Ceramic products	34	Real estate
16	Cement	35	Transport
17	Iron & steel	36	Broadcasting
18	Non-ferrous metals	37	Service
19	Metal products	38	Governmental service
		39	Private non-profit

19 consumption goods ↔ 39 production goods

Scenarios of energy supply in 2030

Case 1: The nominal case.
The nominal case does not adopt any measures to reduce greenhouse gas emissions. GDP is assumed to grow at an annual rate of 1.3% from 2005 to 2020 and 0.5% from 2020 to 2030.
Case 2: Increasing nuclear plants.
With the same GDP growth rate as in Case 1, in Case 2 we assume that 14 new nuclear power plants will have been constructed by 2030; note that the 6 reactors at the Fukushima Dai-ichi Nuclear Power Plant are assumed be decommissioned by 2020. We also assume that the operating ratio of all nuclear plants will have improved to between 90% by 2030. Moreover, generation from solar power systems is assumed to increase to 53 GW in 2030.
Case 3: Maintaining nuclear plants.
Assumptions are same as Case 2 except we assume that no further construction of nuclear plants will occur in future.
Case 4: Decreasing nuclear plants.
We assume that no further construction of nuclear plants will occur in the future, and that all other existing nuclear power plants will be decommissioned after 40 years of operation. Power shortages resulting from closing the nuclear plants will be compensated for mainly by coal, oil and natural gas power plants. Solar power generation is assumed to increase to 53 GW in 2030. All other assumptions are identical to Case 2.

Power capacity of existing nuclear power plants over their estimated lifetime



Common policies and measures adopted in this analysis for energy efficiency improvement

Scenarios without energy saving

Scenarios with energy saving

① The percentage of next-generation energy efficient homes (1999 standard) as a stock base is assumed to be 48% in 2030, in accordance with the National Institute of Construction.

② The percentage of next-generation passenger cars as a stock base is assumed to be 50% in 2030. Next-generation passenger cars are hybrid, plug-in-hybrid, electric, fuel cell vehicles and the like.

③ The "Top runner" system is assumed to be continued for domestic electrical appliances and automobiles.

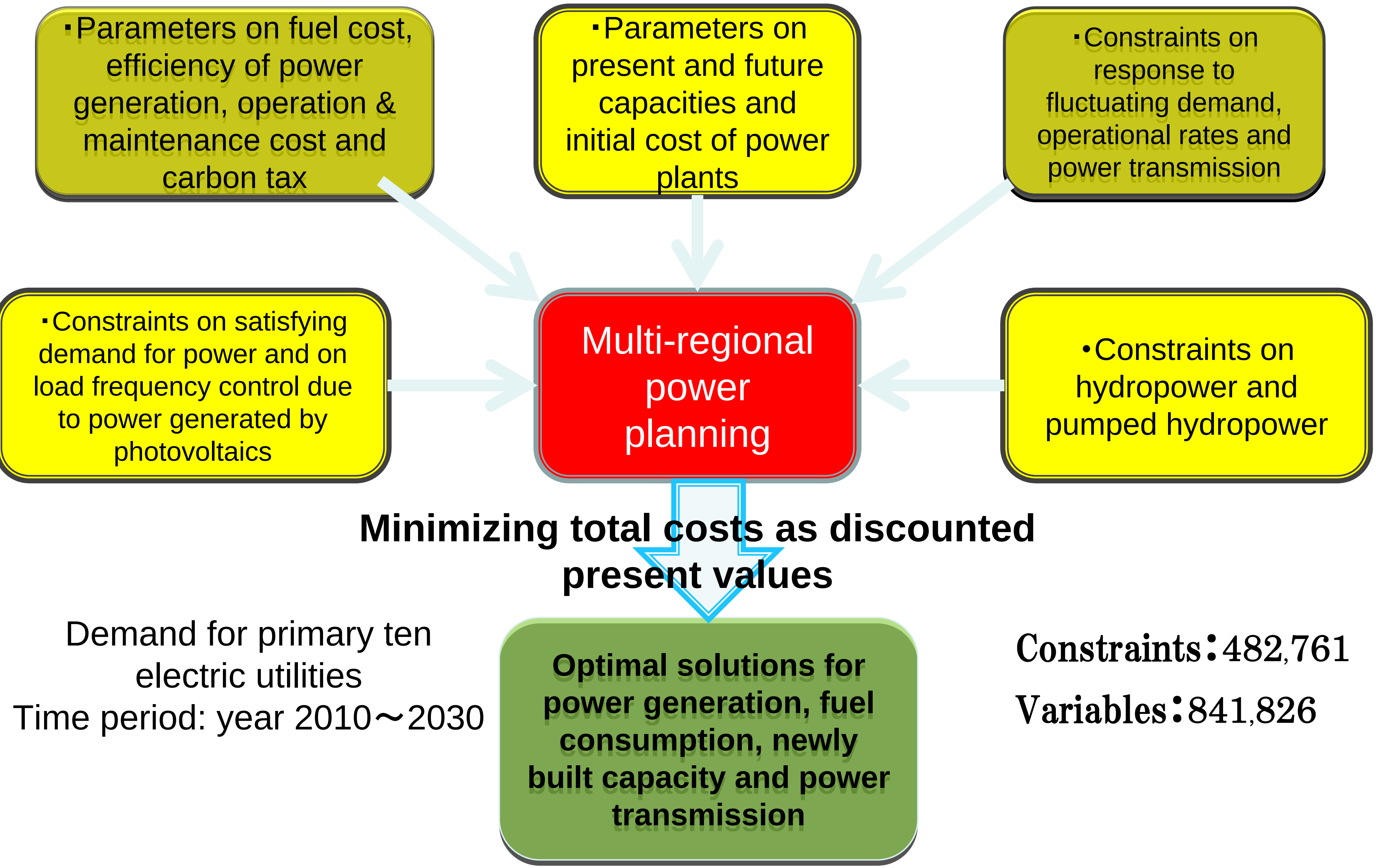
④ Natural gas is assumed to replace 80% (relative to 2005 levels) of petroleum products and fuel, including heavy oil, used by all manufacturing sectors (except the petrochemical industry).

⑤ Promoting modal shift: based on input-output analysis of distribution, CO_2 emissions in the transportation sector are assumed to be cut by up to 44%.

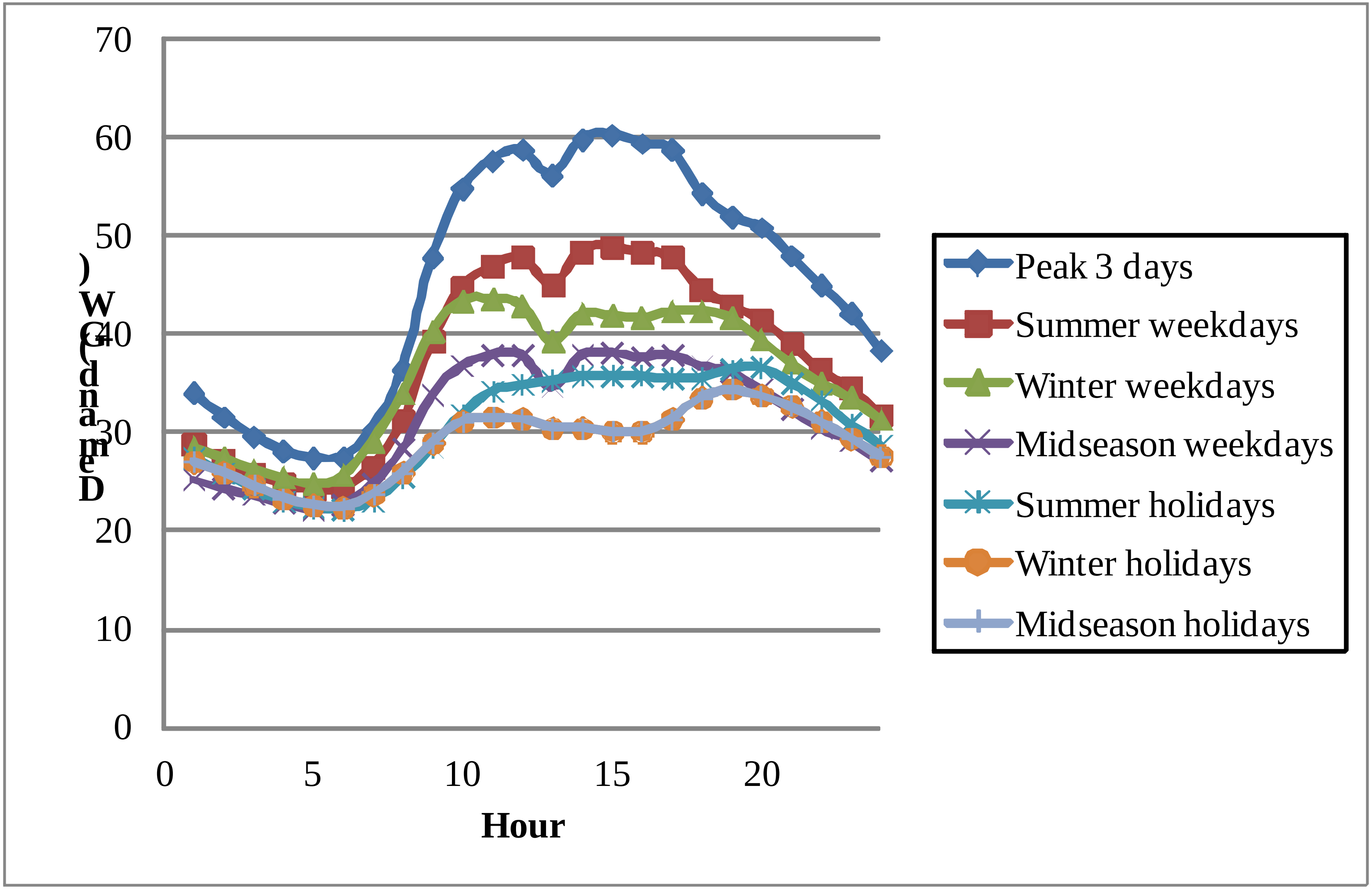
⑥ Promoting energy savings in industrial sectors: in accordance with the law promoting energy conservation, the annual improvement of energy intensity in each industry is assumed to be 1%.

2. Overview of Power Planning model and influence by introducing huge amount of photovoltaics

Multi-regional power planning model
-Parameters and constraints-



Electricity demand in the power planning model
－Load curves of days in typical seasons －

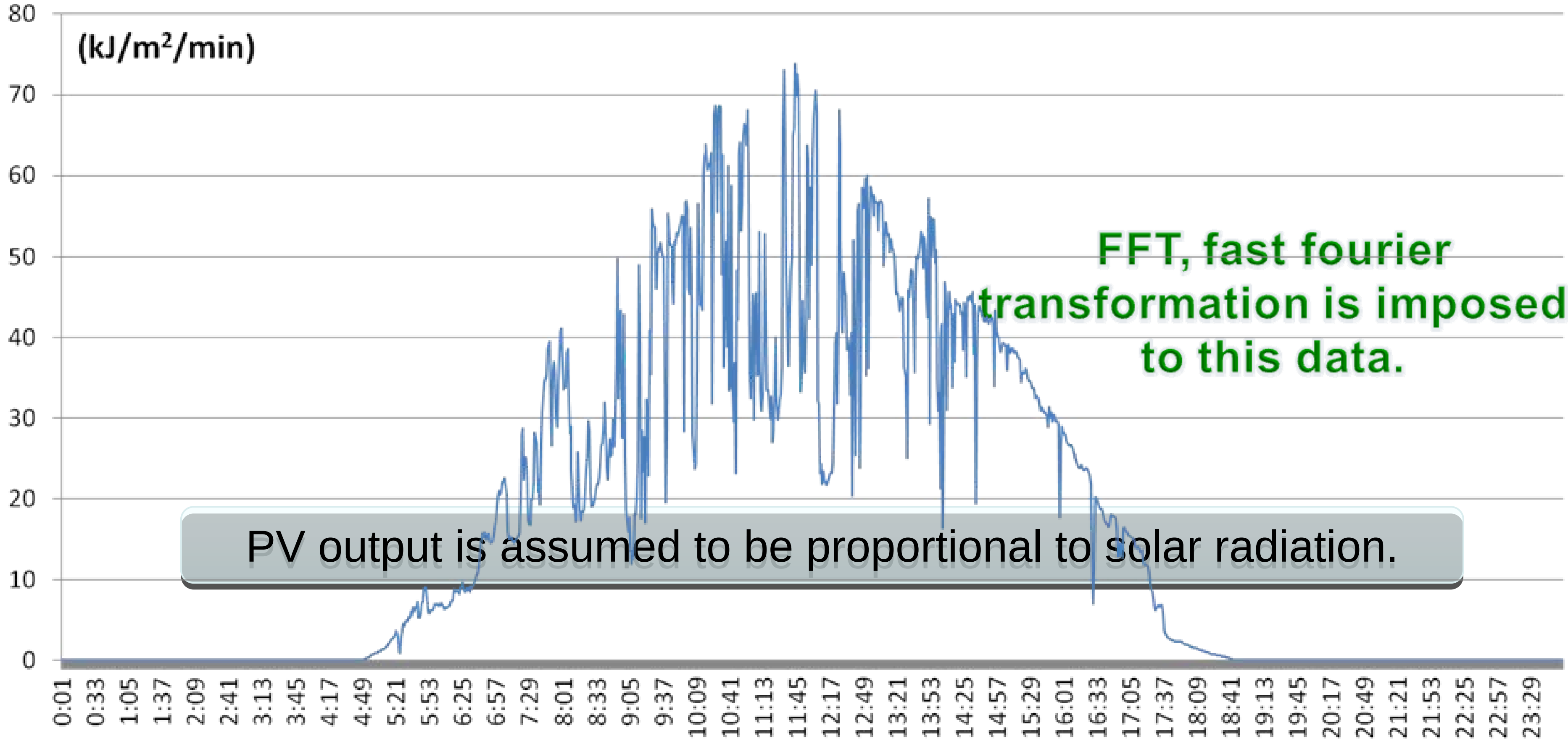


2. Estimation of fluctuation on PV output

-Smoothing effect estimated by the transfer hypothesis-

- **Smoothing effect : PV systems are distributed in wide regions, so that output fluctuation is suppressed compared with individual fluctuations. This smoothing effect is estimated according to the transfer hypothesis. Ref. Hiroyuki Nagoya et. al. A method for presuming total output fluctuation of highly penetrated photovoltaic generation considering mutual smoothing effect, IEEJ Transactions on Electronics, Information and Systems, Vol.131 No.10 pp.1688-1696**

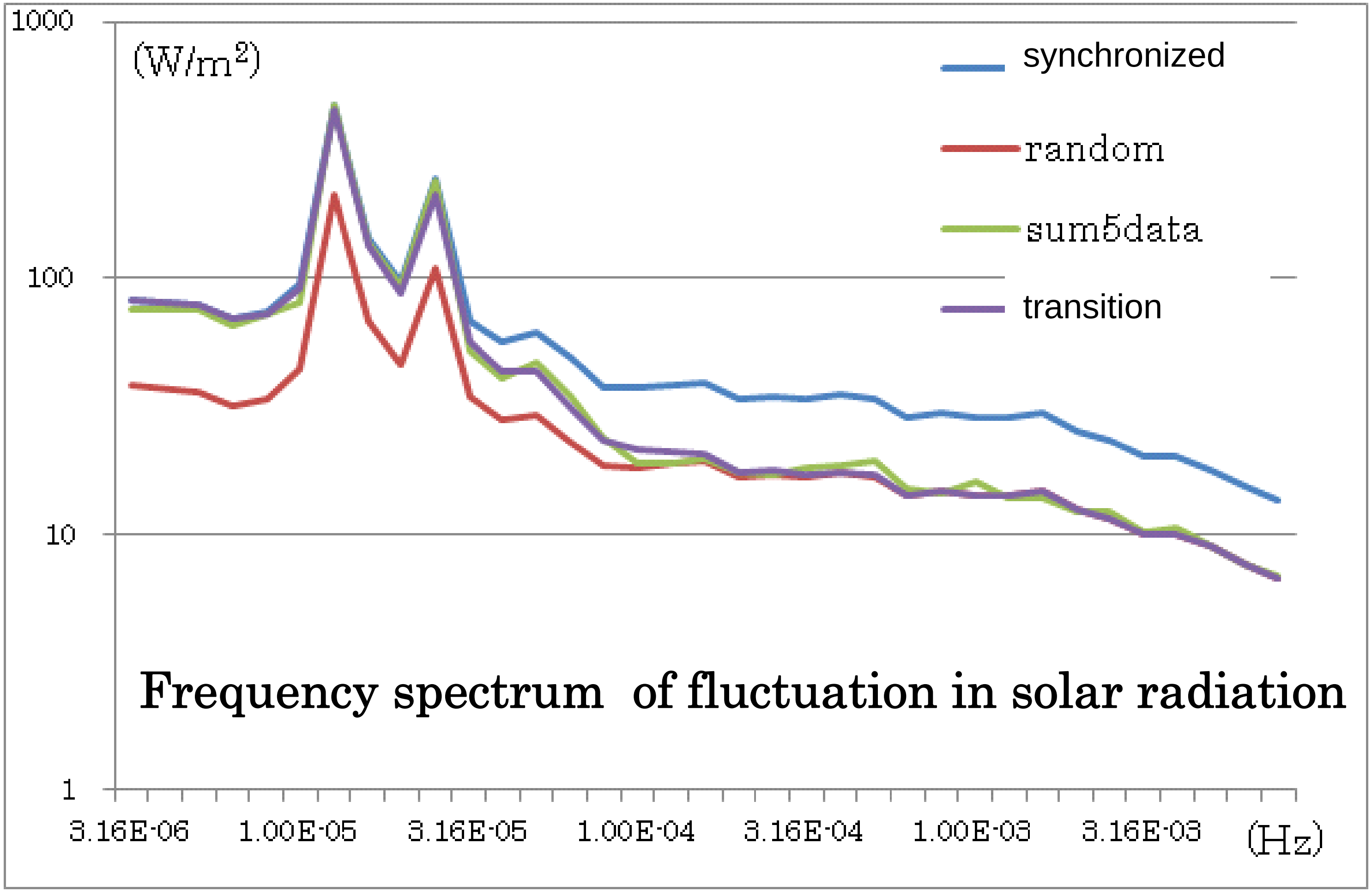
$$S_{tra}(f) = \left| \frac{S_{syn}(f) + j \cdot T_x \cdot f \cdot S_{ran}(f)}{1 + j \cdot T_x \cdot f} \right|$$



Data on solar radiation in each minute in Tokyo Meteorological Station. (2009/7/25)

2. Estimation of fluctuation on PV output

-Smoothing effect estimated by the transfer hypothesis-



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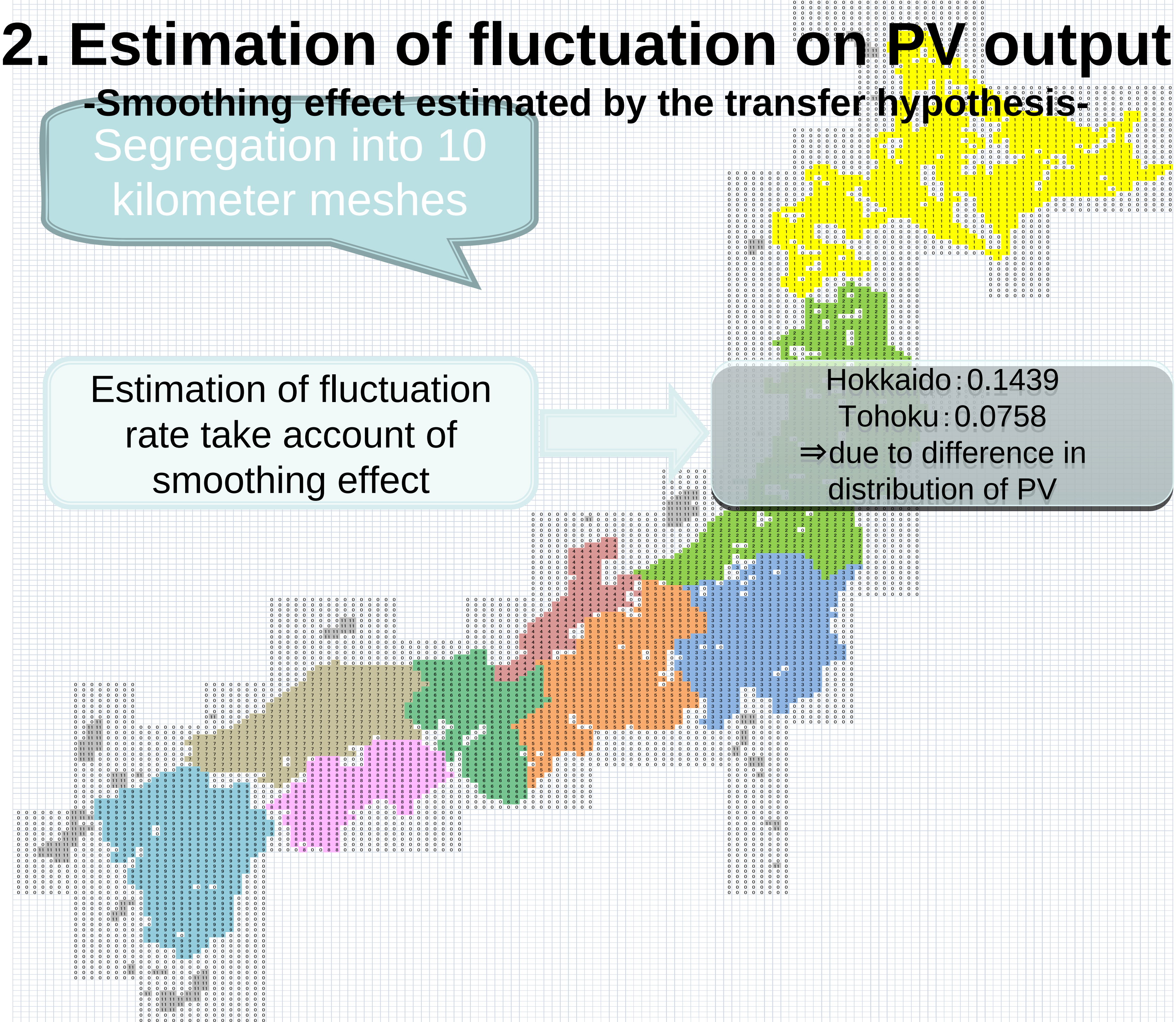
2. Estimation of fluctuation on PV output

-Smoothing effect estimated by the transfer hypothesis-

Segregation into 10 kilometer meshes

Estimation of fluctuation rate take account of smoothing effect

Hokkaido：0.1439
Tohoku：0.0758
⇒due to difference in distribution of PV



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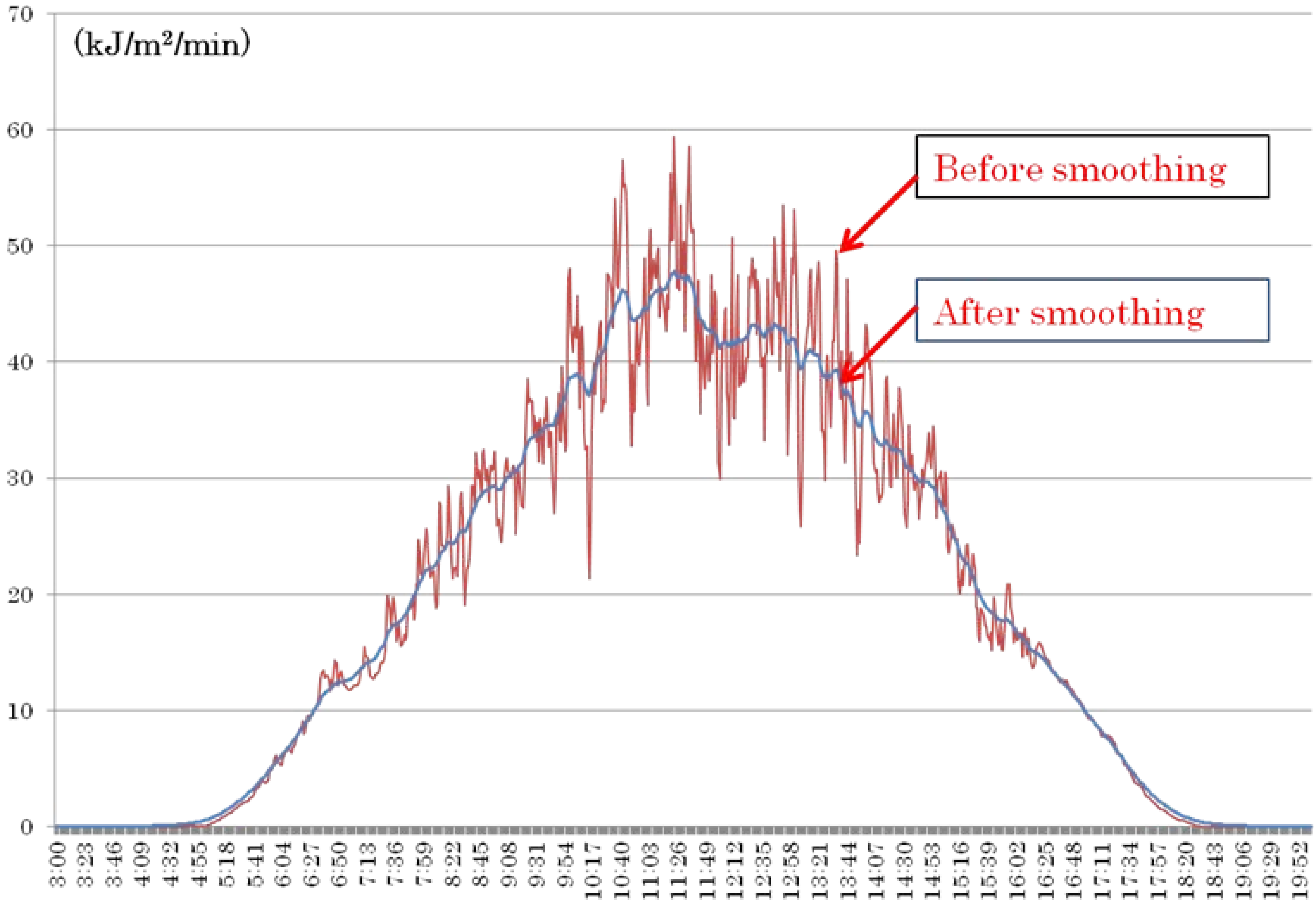
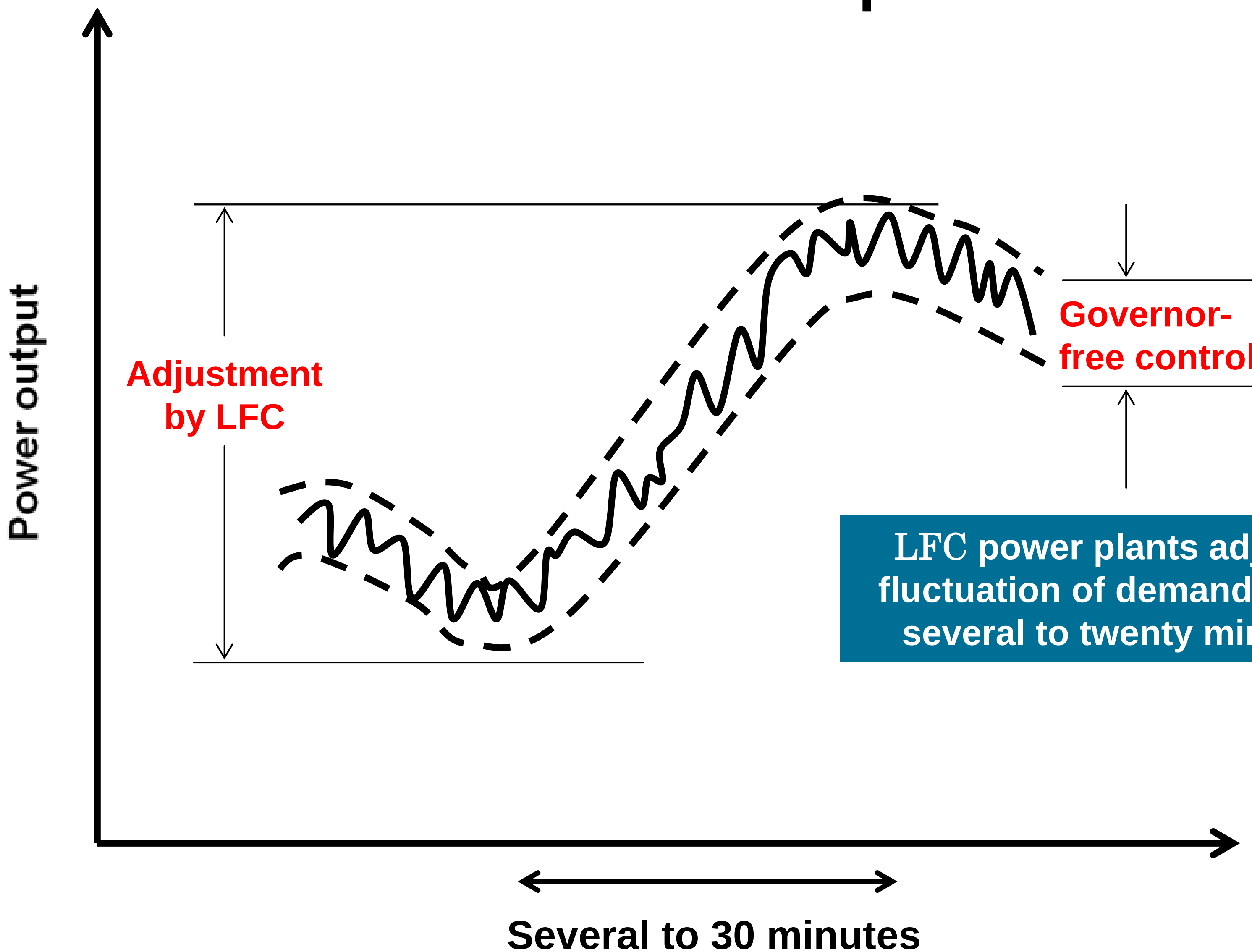


Estimation of necessary adjustments by LFC
-Based on fluctuation of power demand-



Multi-regional power planning model
-Constraints regarding LFC-

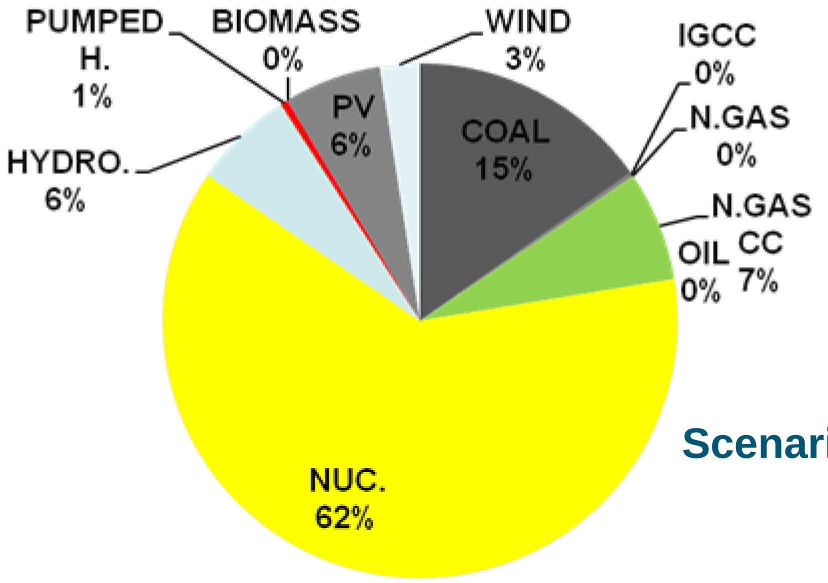
1. $$O(t,r,g,h,d) \le \{C(t,r,g) \cdot MaxUtil\_D(g,d) - LFC\_C(t,r,g,h,d)\} + LFC\_C(t,r,g,h,d) \cdot (1 - lfc\_range(g)/2)$$

Output of generators under LFC operation, must be less than those under ordinary operation by the LFC adjustment width.

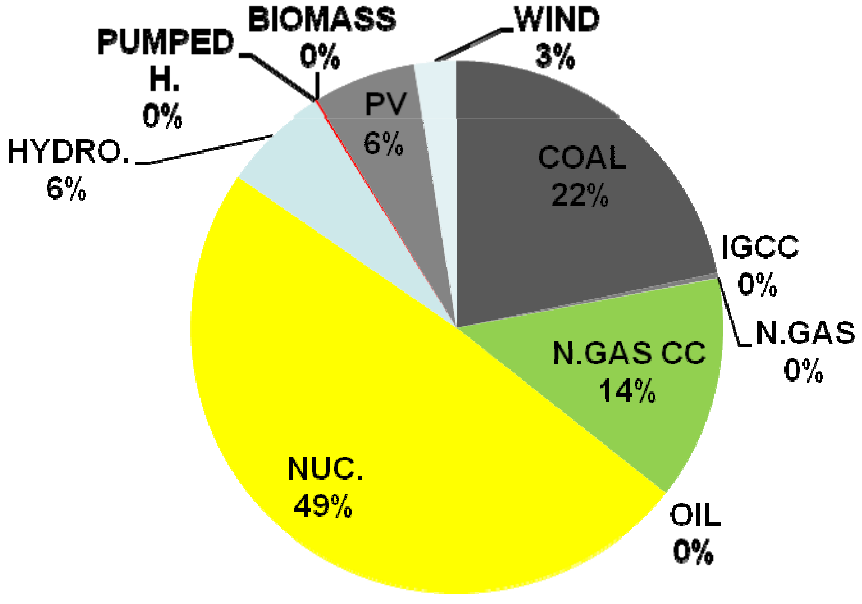
2. $$\sum_g \{LFC\_C(t,r,g,h,d) \cdot lfc\_range(g)\} + ePV\_DMD(t,r,h,d) \cdot remain \ge \{ePV\_DMD(t,r,h,d) \cdot lfc\_dmd + PV\_GEN(t,r,h,d) \cdot lfc\_sun(r)\}$$

LFC capacity added by residual adjustment in power grids must be larger than fluctuation of PV output added by fluctuation in demand.

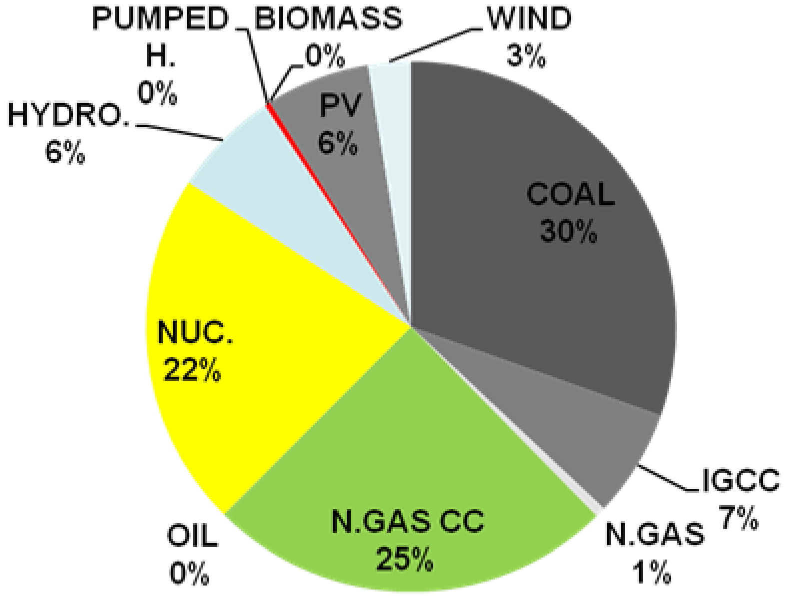
Share of electricity generated (Energy saving case)



Scenario increasing nuclear



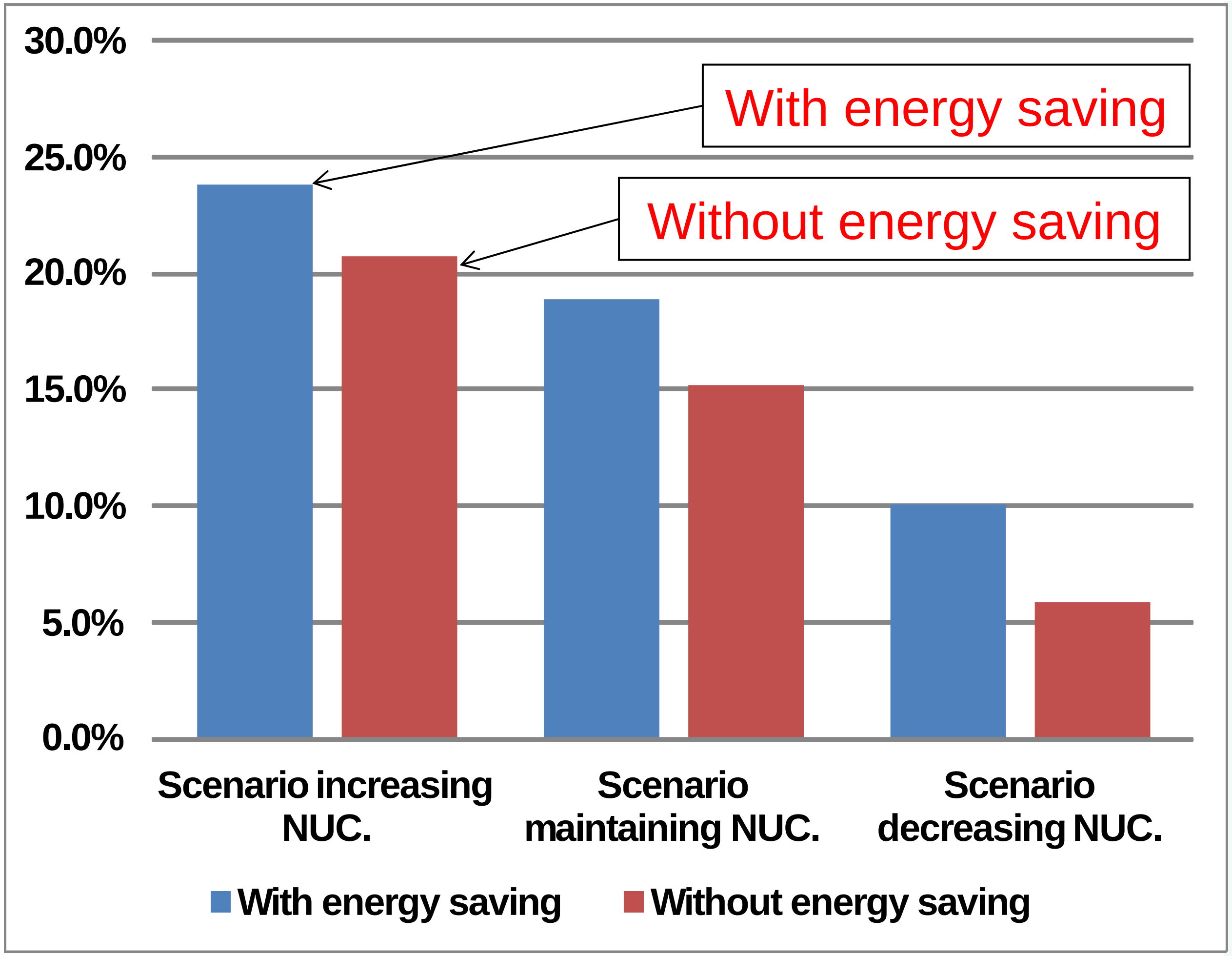
Scenario maintaining nuclear



Scenario decreasing nuclear

3. Is affluent low-carbon society feasible?
-Impact of green technology-

Simulation Result 1 using the CGE Model

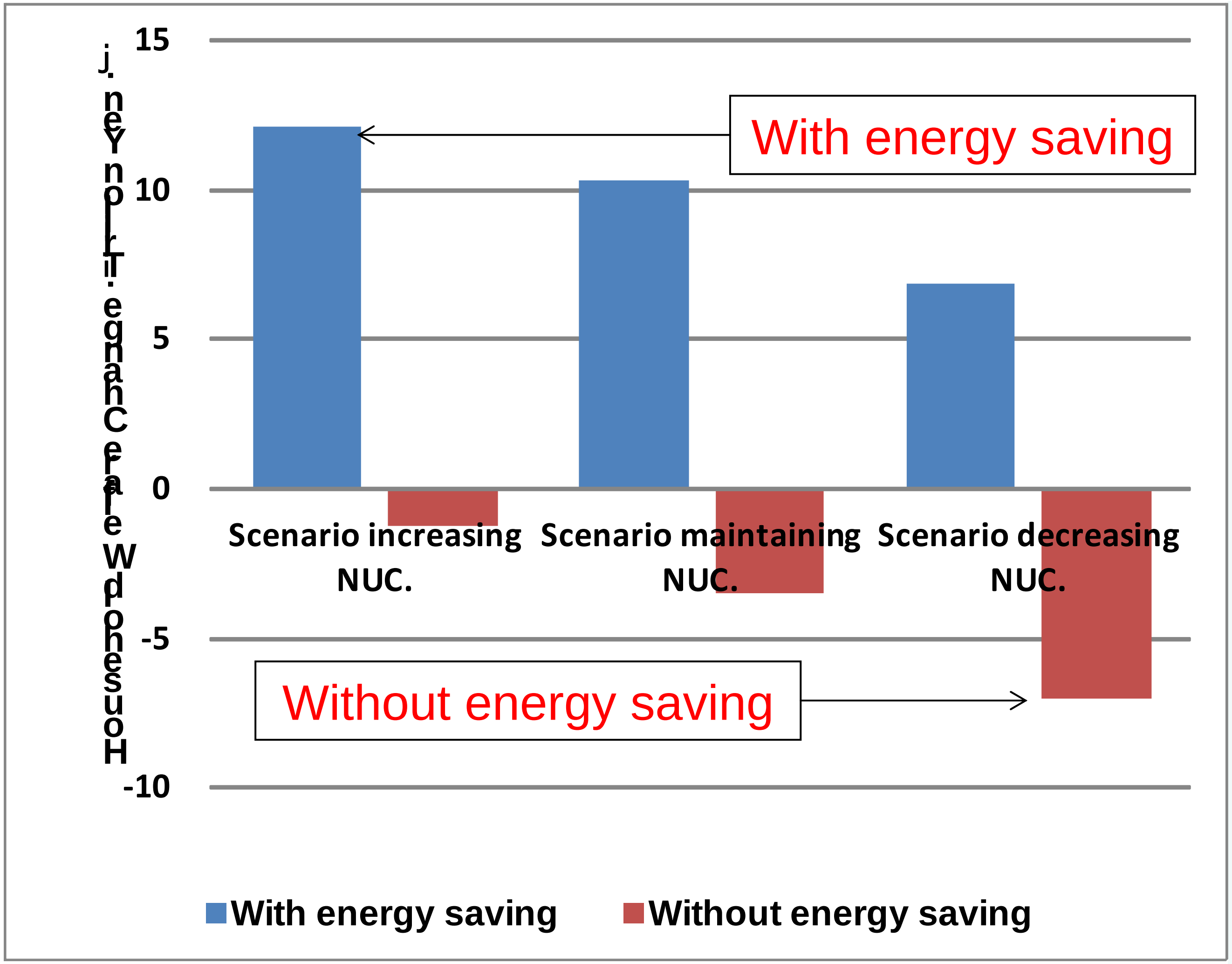


Reductions in CO_2 emissions compared with 1990

The effect of the recent disaster on CO2 emissions will be extremely high due to the reduced operating ratio of existing nuclear plants and postponement of new construction.

This is why there are 13.7～14.8% difference between scenarios increasing and decreasing nuclear power plants.

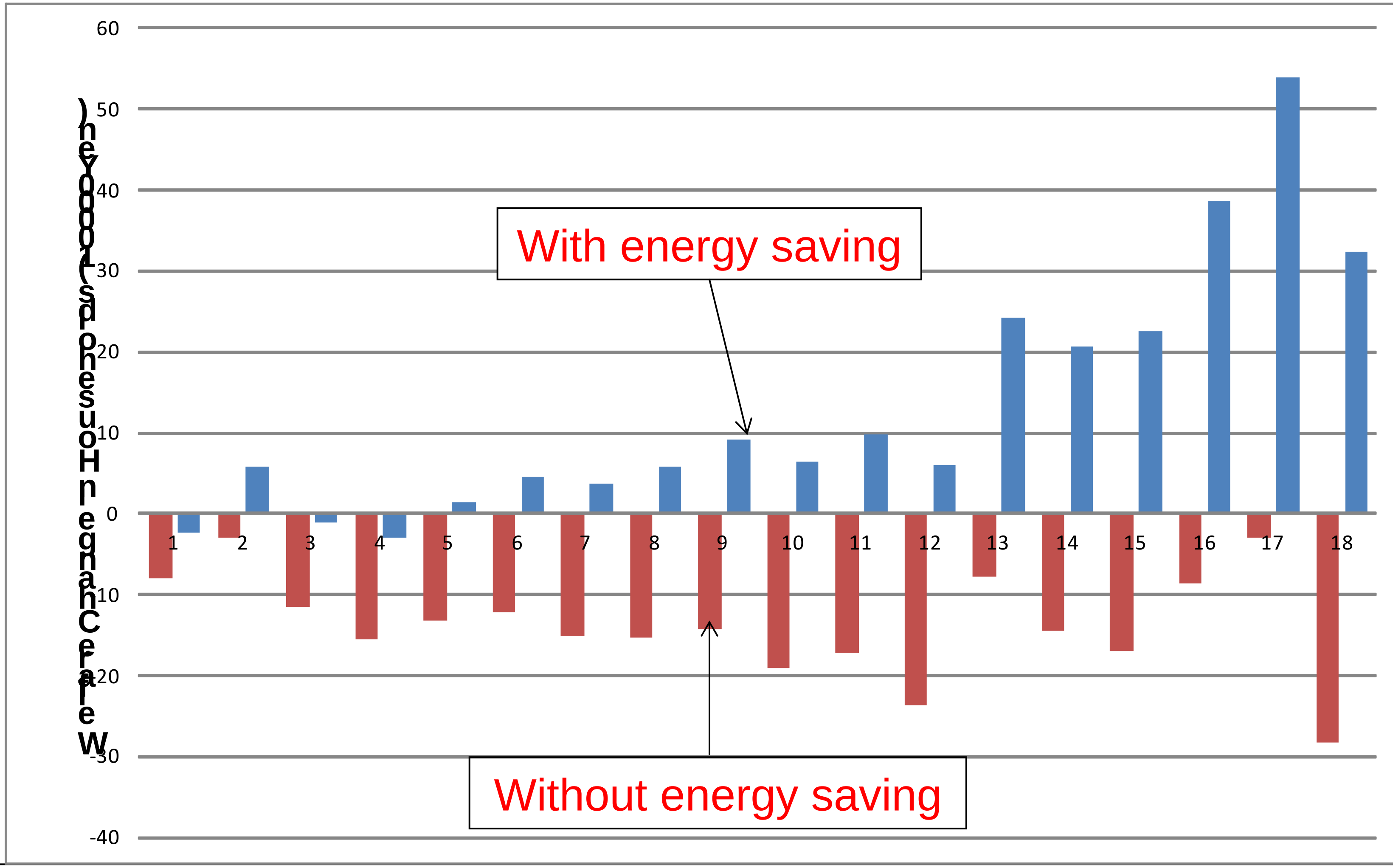
Simulation Result 2 using the CGE Model



Aggregate Welfare Change in Households compared with no reduction case

The computed results imply that the utilities of households could be considerably improved by the spread of energy-saving products, such as high-efficiency electrical appliances and automobiles. Thus, measures to promote the spread of these products are crucial, regardless of the increase or decrease of nuclear power plants.

Simulation Result 3 using the CGE Model



If there are no efficiency improvements in domestic appliances and automobiles (red bars in the above diagram), household welfare decrease in all income brackets. On the contrary, if there are efficiency improvements, household welfare increase in most income brackets as blue bars in the diagram.

Study on energy scenarios for realizing a secure, economical and low-carbon society

1. **If we can no longer expect the planned new nuclear plant construction, this will have an extremely large effect on the amount of CO2 emissions in 2020.**
2. **Therefore green technologies such as photovoltaics are expected. Synergy of technology and market innovation would be effective for prolifering PV.**
3. **In Japan, increase photovoltaics could be supported by LFC power plants in electric power grids until 2030.**
4. **As refards the impact of low carbon policies to household welfare, efficiency improvement is an effective way to increase welfare as well as renewable energy.**