Importance of the renewal energy R&D for global warming mitigation

— Cost and CO_2 emissions of future power generation —

30 June 2014

France-Japan Symposium on Advanced Materials Key Role in Enabling Best Energy Future

Koichi Yamada

- University of Tokyo
- Center for Low Carbon Society Strategy, JST

Topics

1 Global warming till 2100
Relation between a temperature rise and social activity

2 Reduction of CO_2 emissions from a daily life

3 Technology structuring for the quantitative cost evaluation of energy systems

4 Example of cost and CO_2 emissions of future electric power system

Equation for temperature rise ΔT

$\Delta T = 0.46(1.8 + 10^{-6} C_t)$ (ΔT from 1870 by Matthews Equation. in Nature **495**,829(2009))

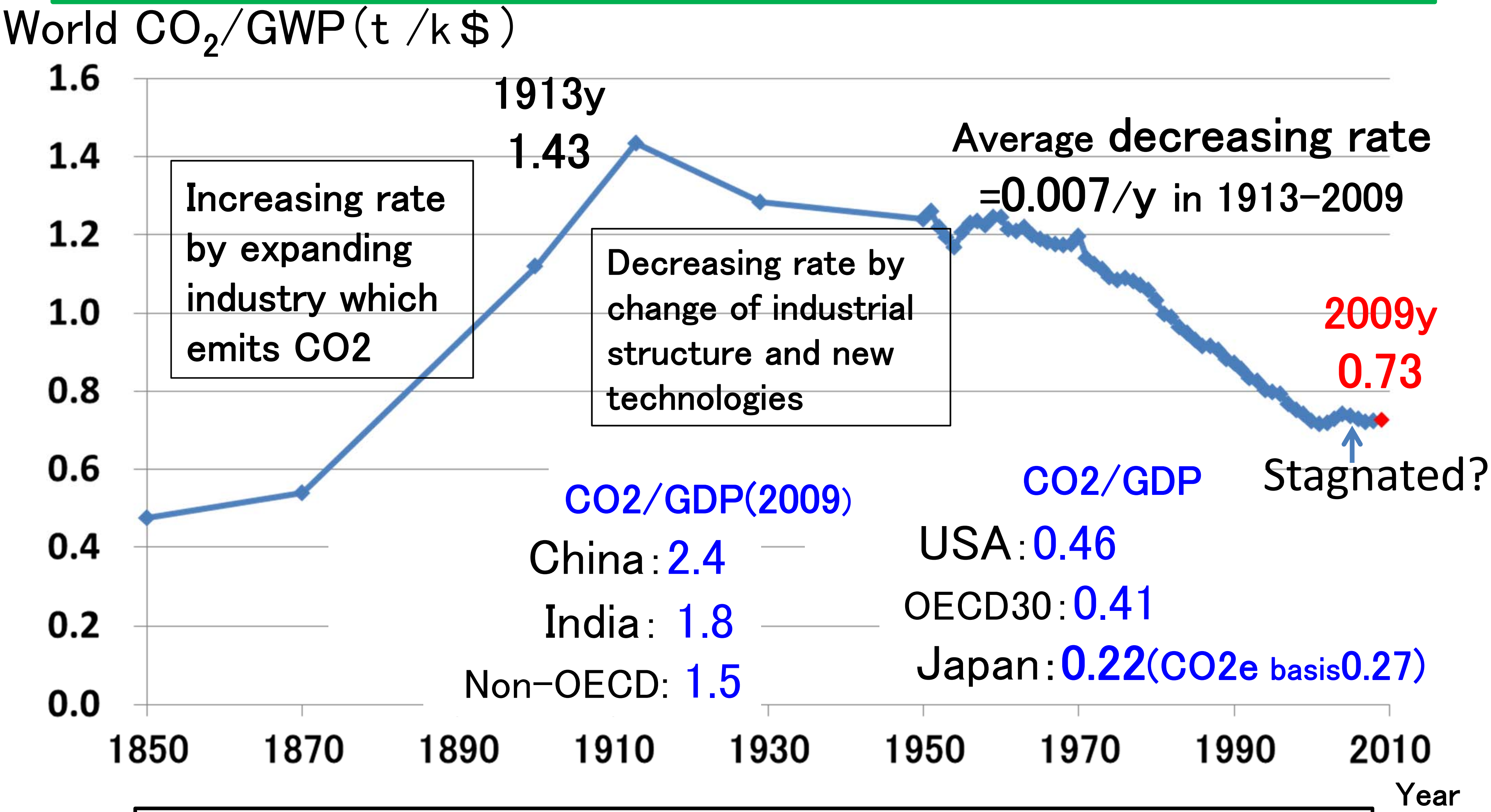
$GWP_t = 40{,}300\,(1+\text{Annual growth rate of GWP})^{t-2009}$

$C_t / GWP_t = 0.73 \times 1.2 \times \{1 - ADR\,(t - 2009)\}$ (t, AD)

- C_t : Cumulative CO_2e emissions in the year of t (M ton of CO_2e after 2009)
- ADR : Annual decreasing rate of C_t / GWP
- GWP_t : Gross World Product in t years, Bln$

If we assume an economic growth rate and ADR, we can calculate ΔT using above equations.

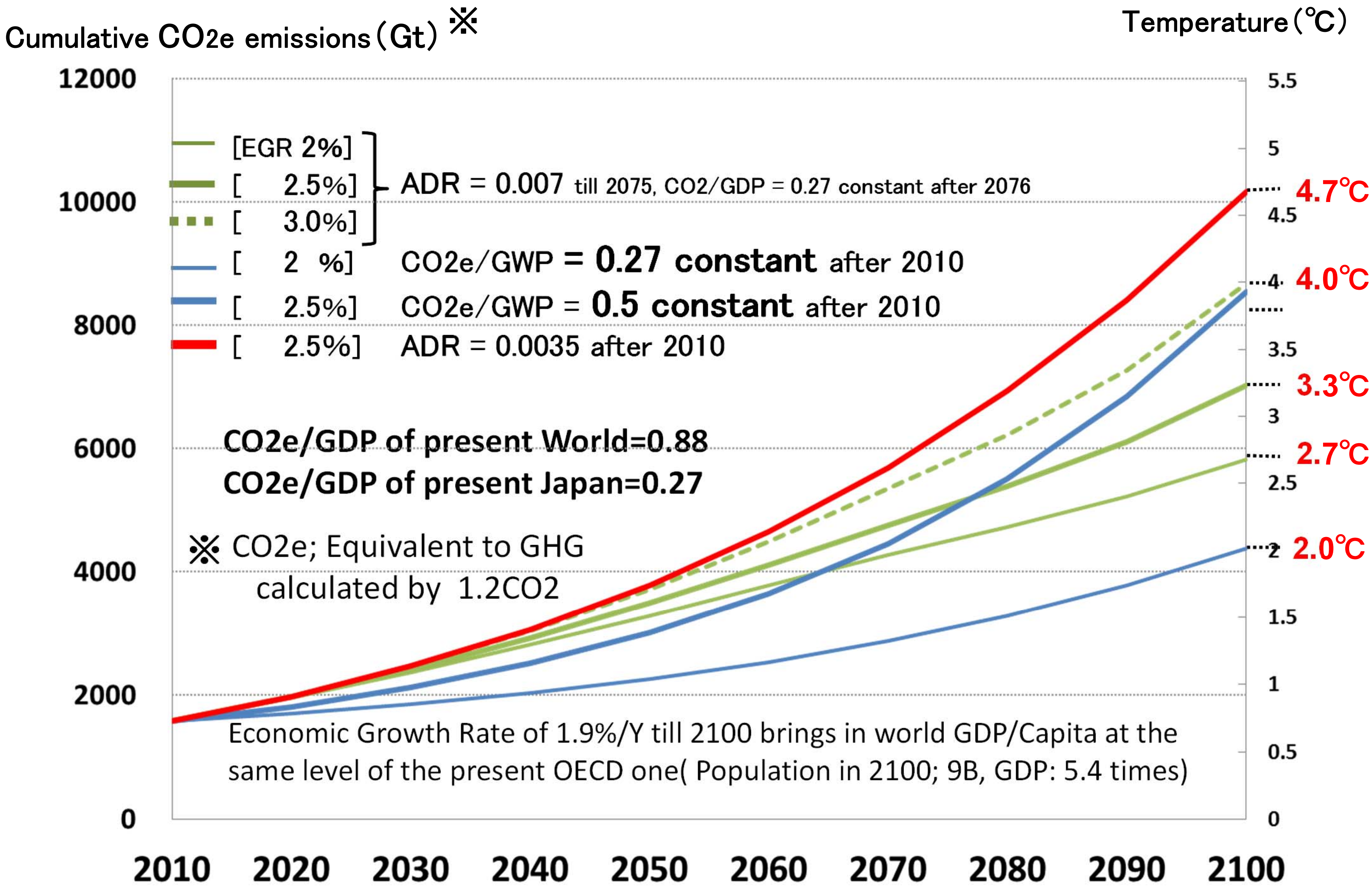
Historical change of CO_2/GWP in the world



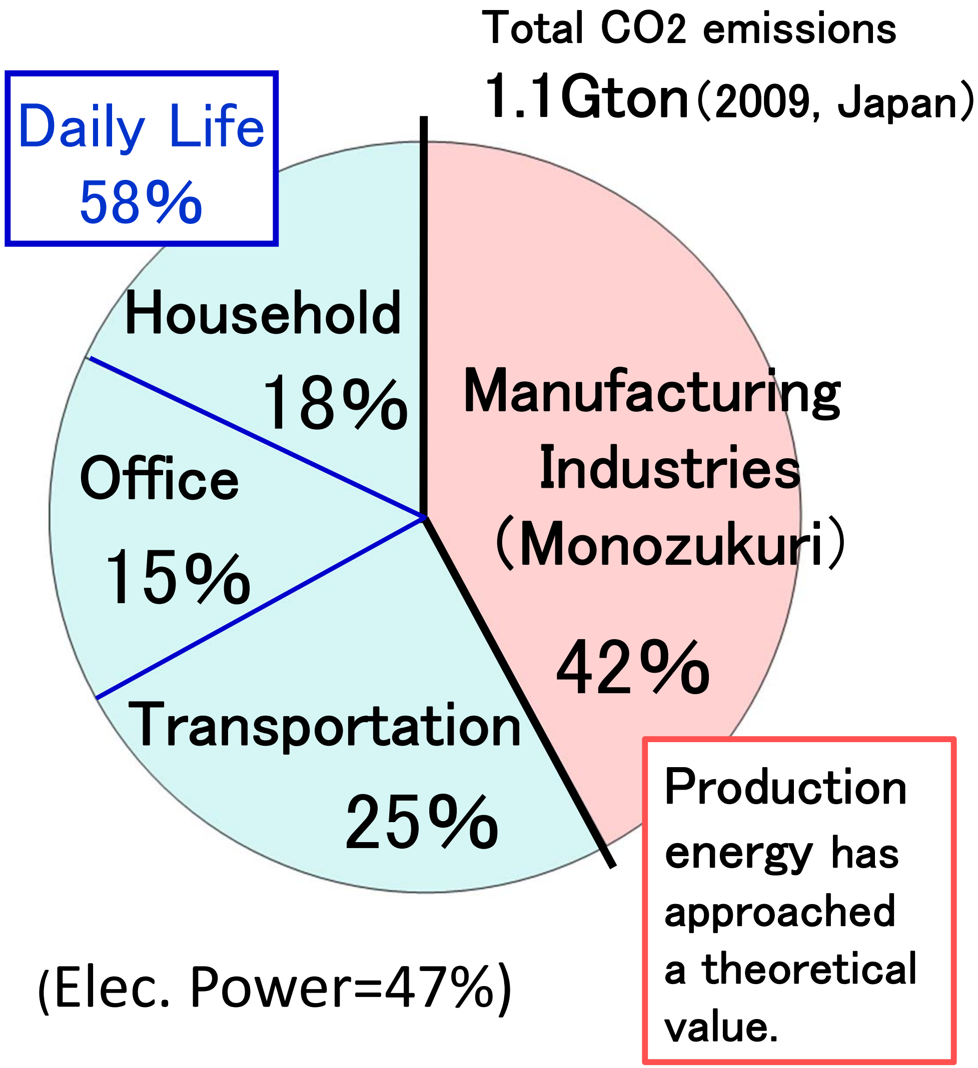
	1870-2009	1950-2009	1970-2009	1990-2009
World annual economic growth rate （%）	2.9	3.7	3.1	2.6

Calculated using GDP data of Angus Maddison, “Monitoring the World Economy 1820-1992” before 1950

Cumulative CO_2 Emissions and Temperature Rise



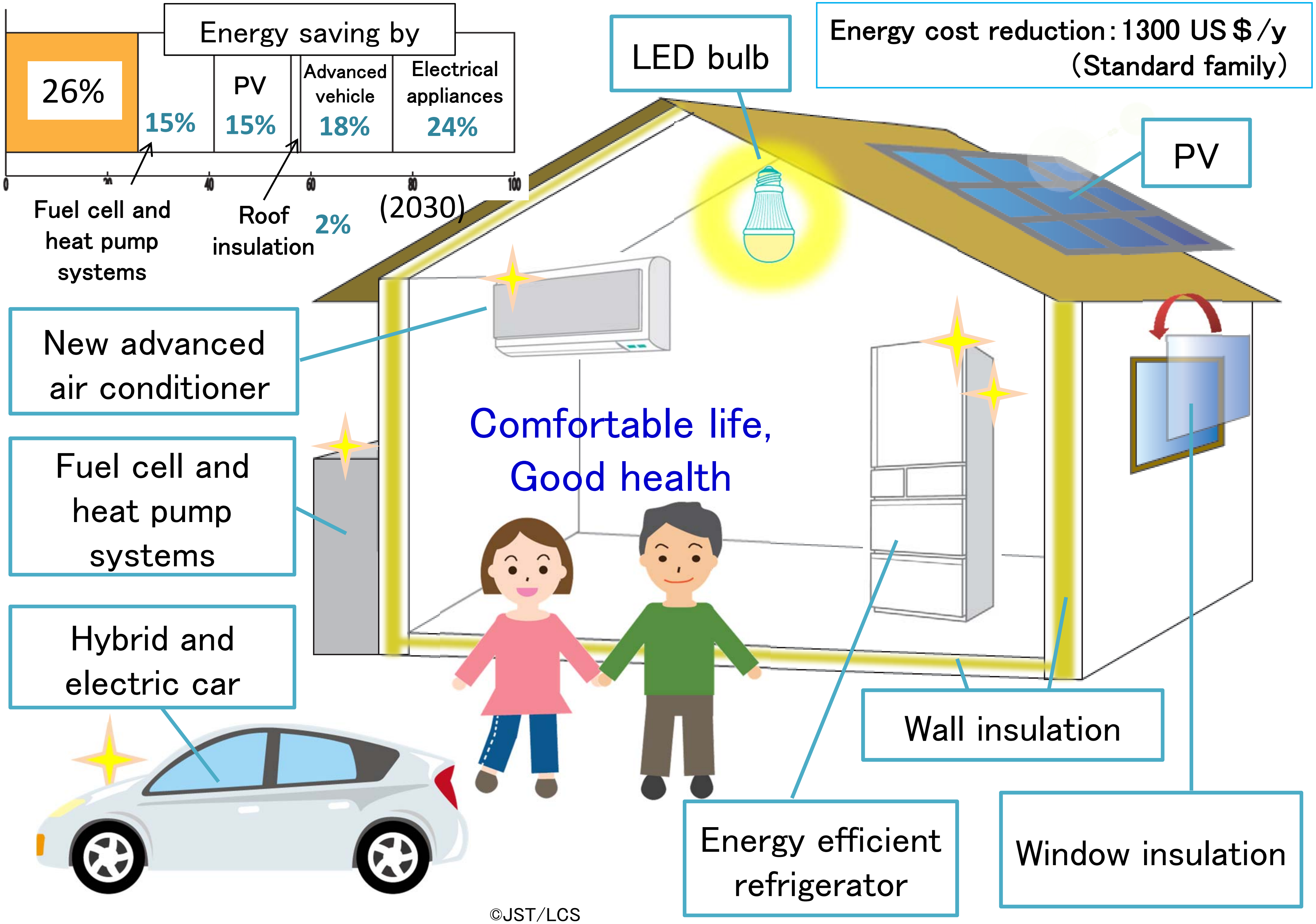
CO_2 emissions rate from daily life and manufacturing industry



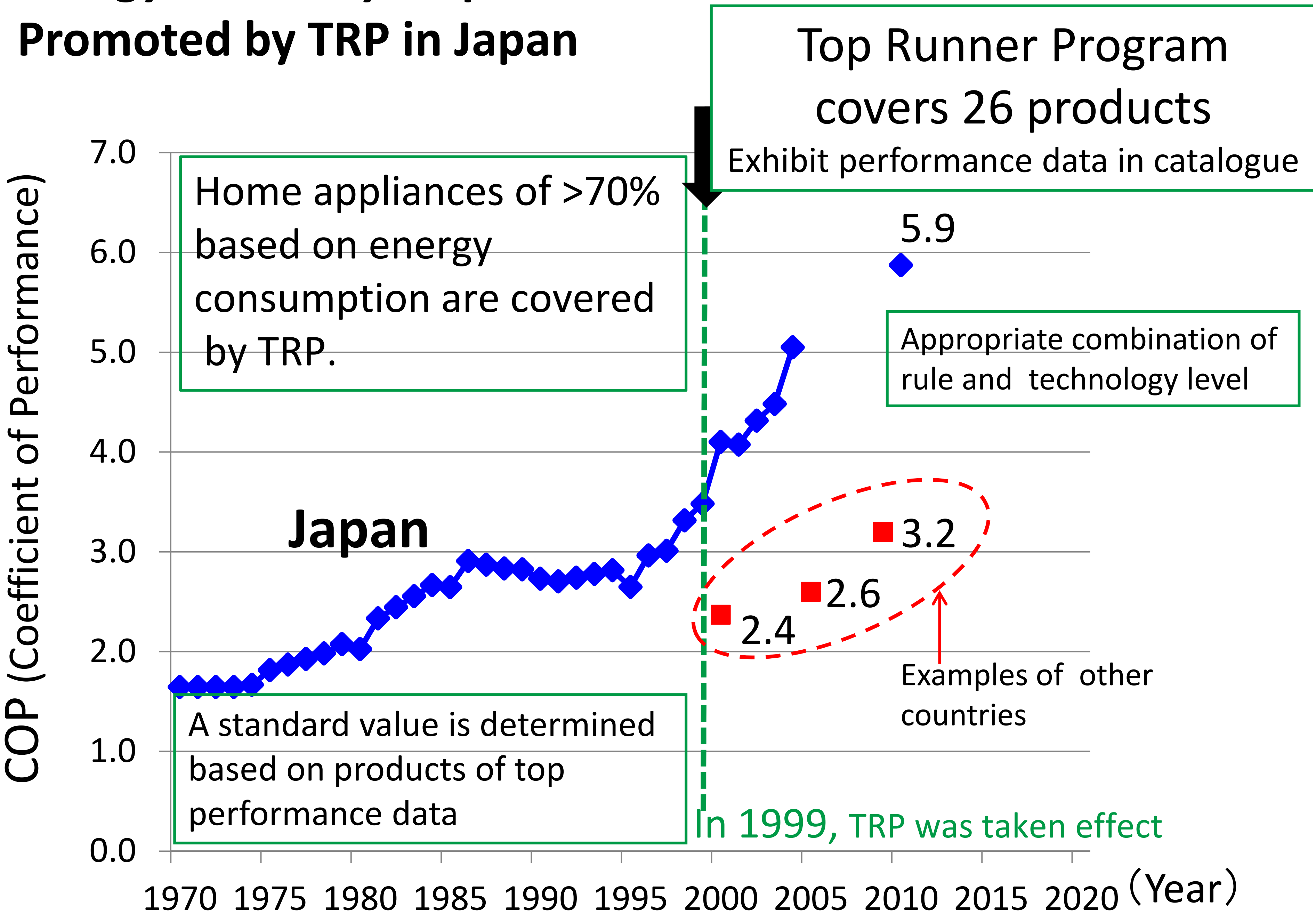
Low Carbon Society led by CO_2 reduction in daily life and energy saving product

Source: Handbook of Energy & Economic Statics in Japan (2012)

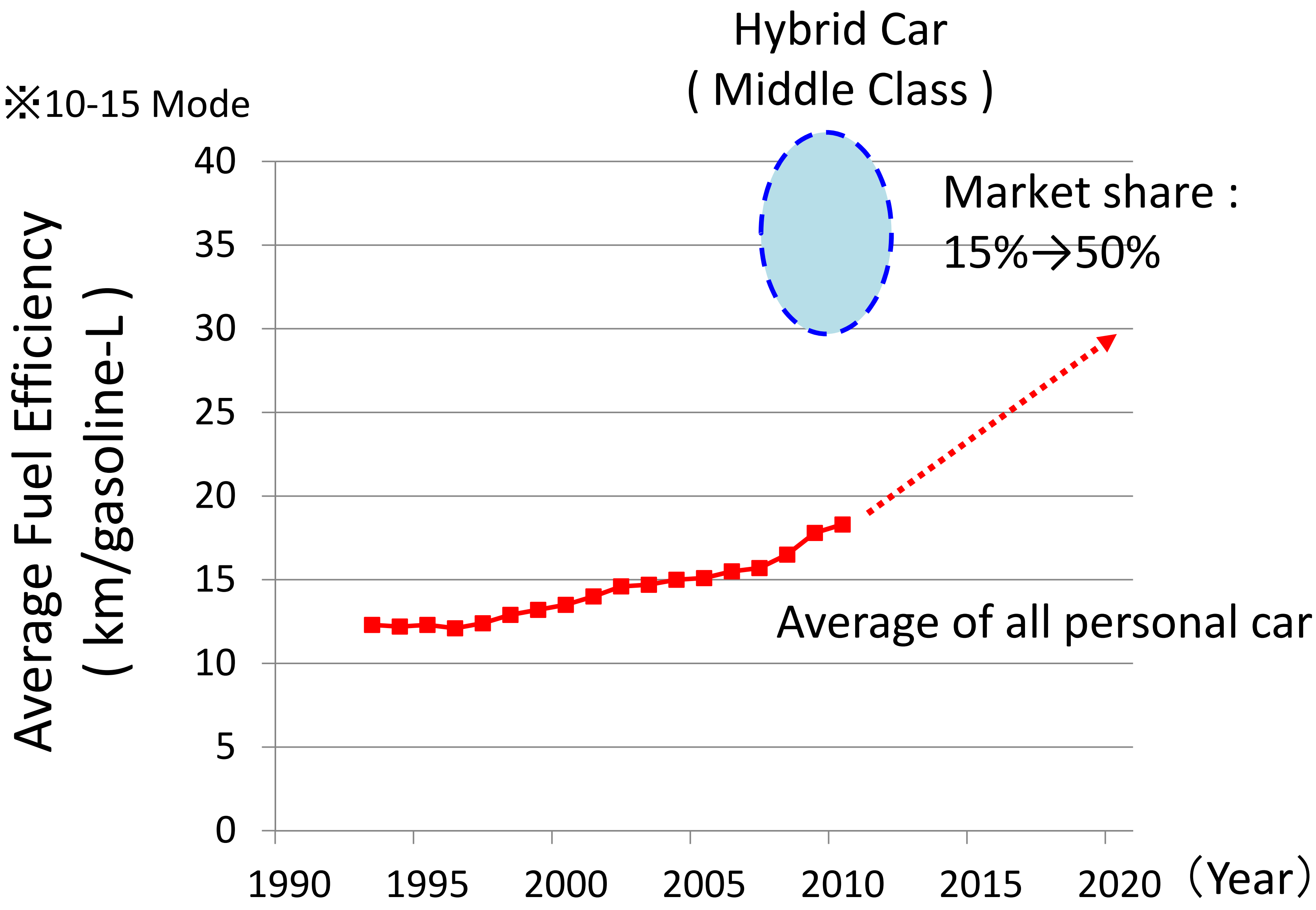
Energy consumption in daily life can be reduced by 75%

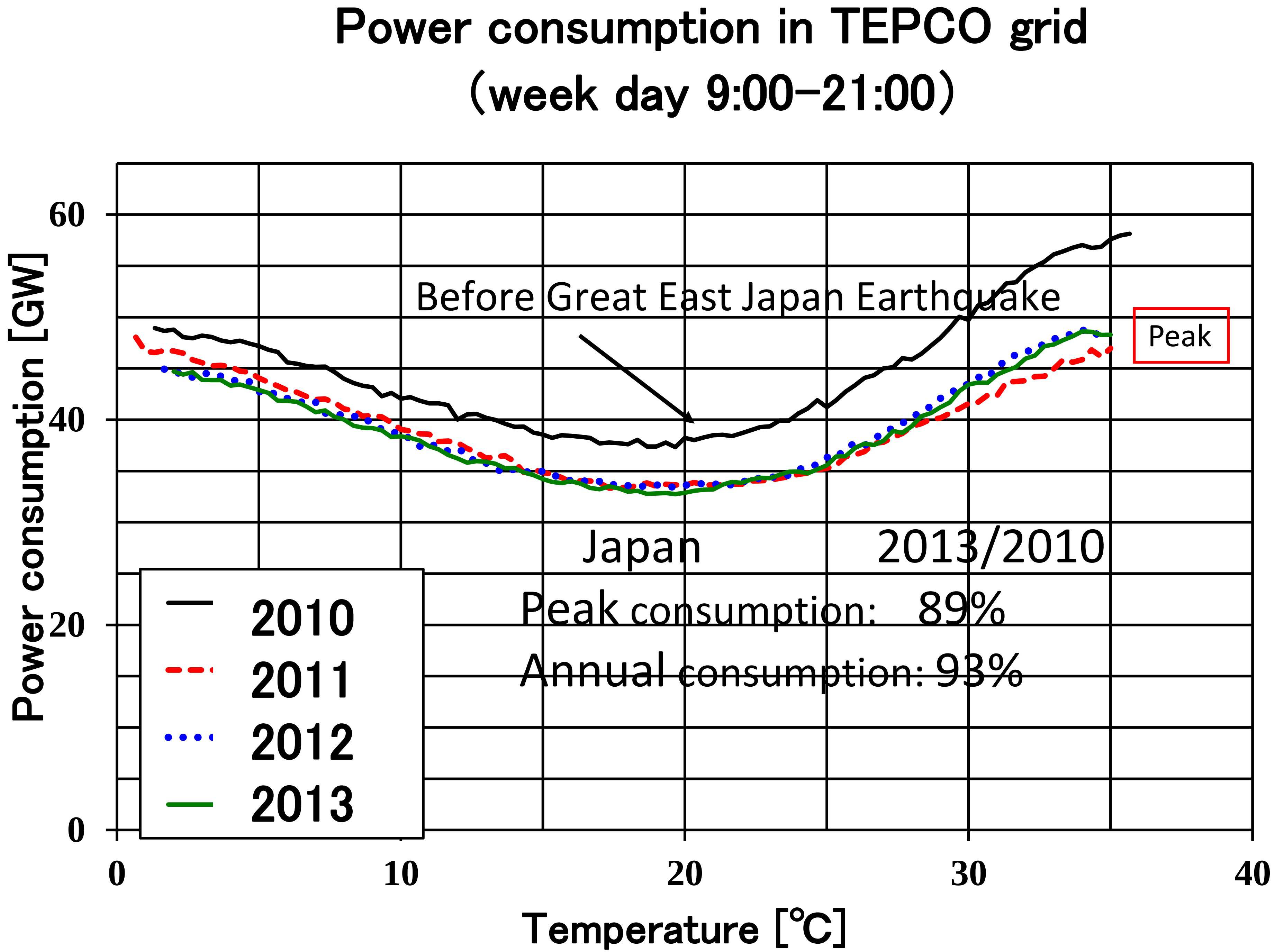


Energy efficiency Improvement of Home Air Conditioners Promoted by TRP in Japan

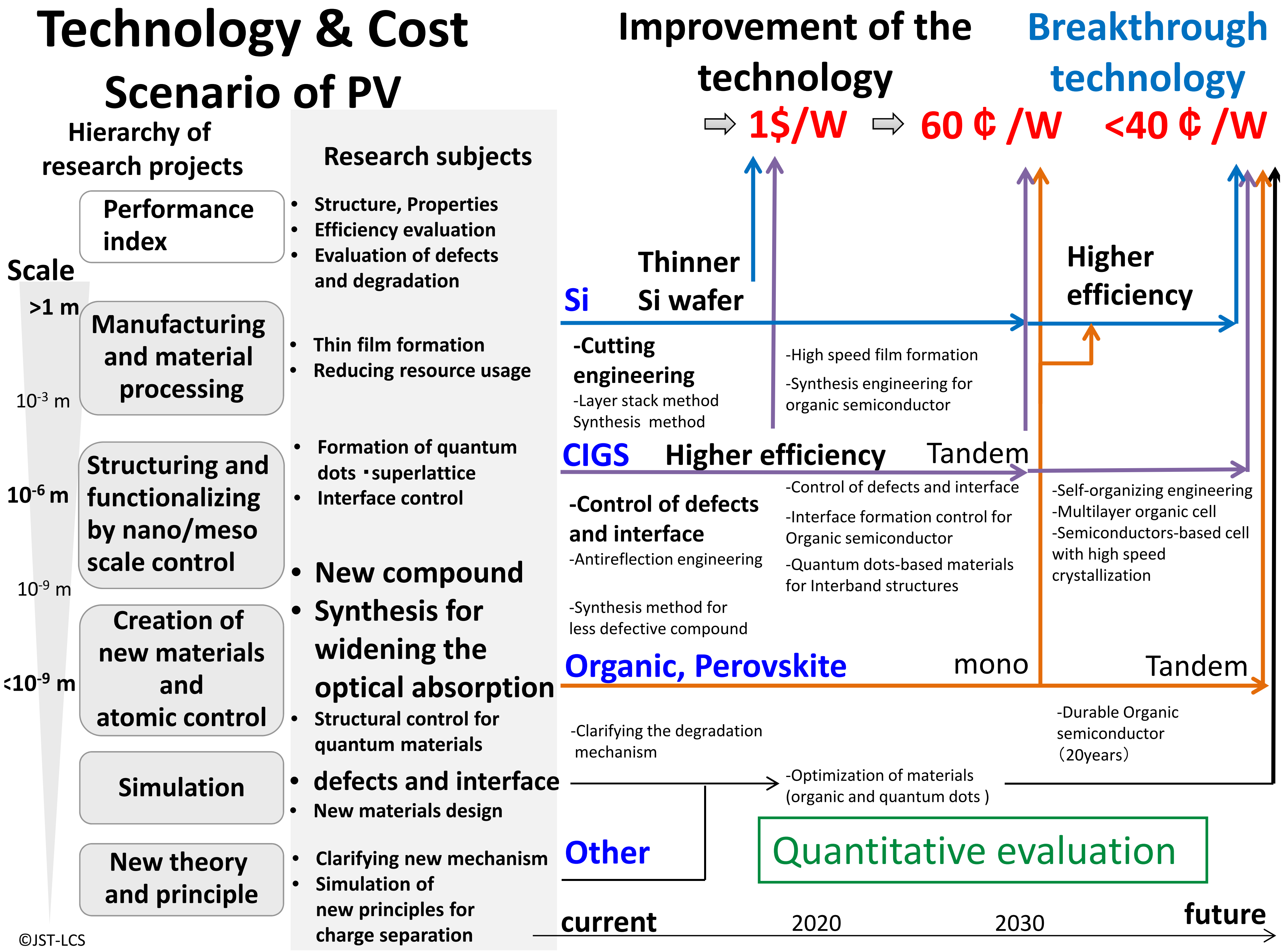


Energy Improvement of Vehicles (JAPAN)

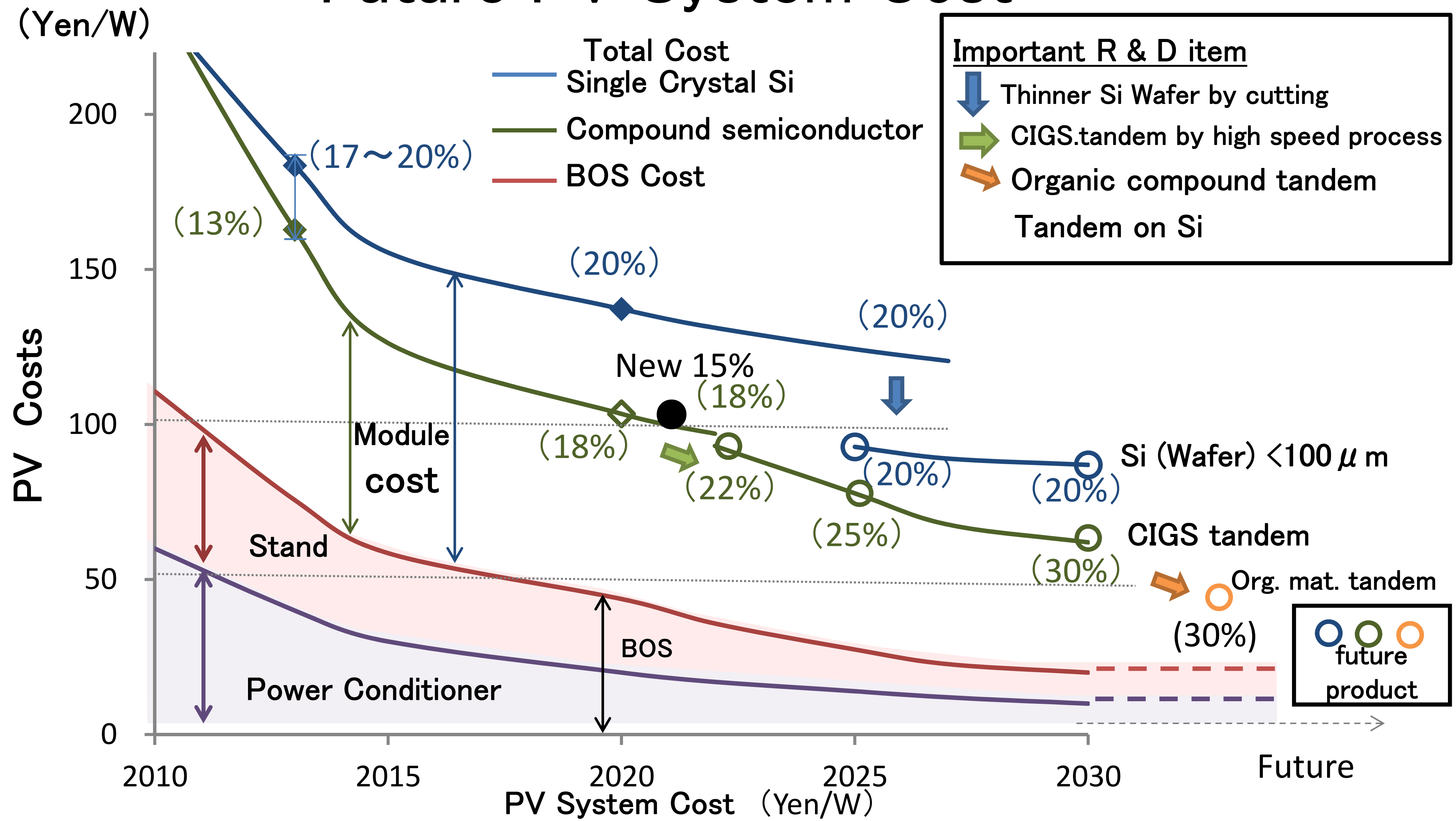




Power consumption in TEPCO grid
(week day 9:00-21:00)
Power consumption [GW]
60
40
20
0
Before Great East Japan Earthquake
Peak
Japan 2013/2010
Peak consumption: 89%
Annual consumption: 93%
2010
2011
2012
2013
0
10
20
30
40
Temperature [℃]


Technology & Cost
Scenario of PV
Hierarchy of research projects
Research subjects
Improvement of the technology
Breakthrough technology
⇨ 1$/W ⇨ 60￠/W <40￠/W
Scale
>1 m
10-3 m
10-6 m
10-9 m
<10-9 m
Performance index
• Structure, Properties
• Efficiency evaluation
• Evaluation of defects and degradation
Manufacturing and material processing
• Thin film formation
• Reducing resource usage
Structuring and functionalizing by nano/meso scale control
• Formation of quantum dots・superlattice
• Interface control
Creation of new materials and atomic control
• New compound
• Synthesis for widening the optical absorption
• Structural control for quantum materials
Simulation
• defects and interface
• New materials design
New theory and principle
• Clarifying new mechanism
• Simulation of new principles for charge separation
Si
Thinner Si wafer
Higher efficiency
-Cutting engineering
-Layer stack method Synthesis method
-High speed film formation
-Synthesis engineering for organic semiconductor
CIGS
Higher efficiency
Tandem
-Control of defects and interface
-Antireflection engineering
-Control of defects and interface
-Interface formation control for Organic semiconductor
-Quantum dots-based materials for Interband structures
-Self-organizing engineering
-Multilayer organic cell
-Semiconductors-based cell with high speed crystallization
-Synthesis method for less defective compound
Organic, Perovskite
mono
Tandem
-Clarifying the degradation mechanism
-Durable Organic semiconductor (20years)
-Optimization of materials (organic and quantum dots)
Other
Quantitative evaluation
current
2020
2030
future
©JST-LCS

Future PV System Cost



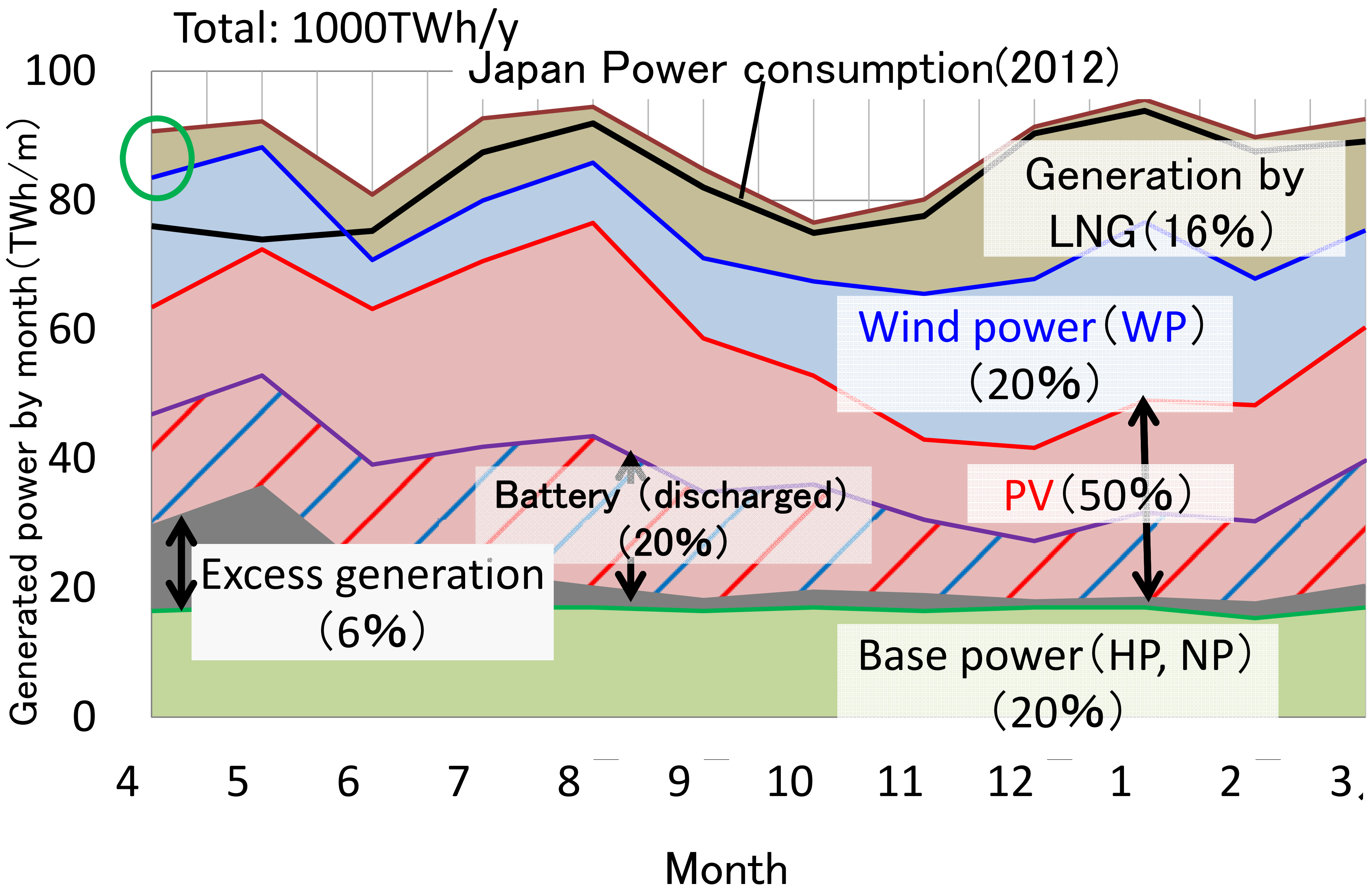
	2012	2020	2030	Future PV
Module	80	60	40	20
BOS	100	50	20	20
PV System	180	110	60	40

Future stationary battery cost

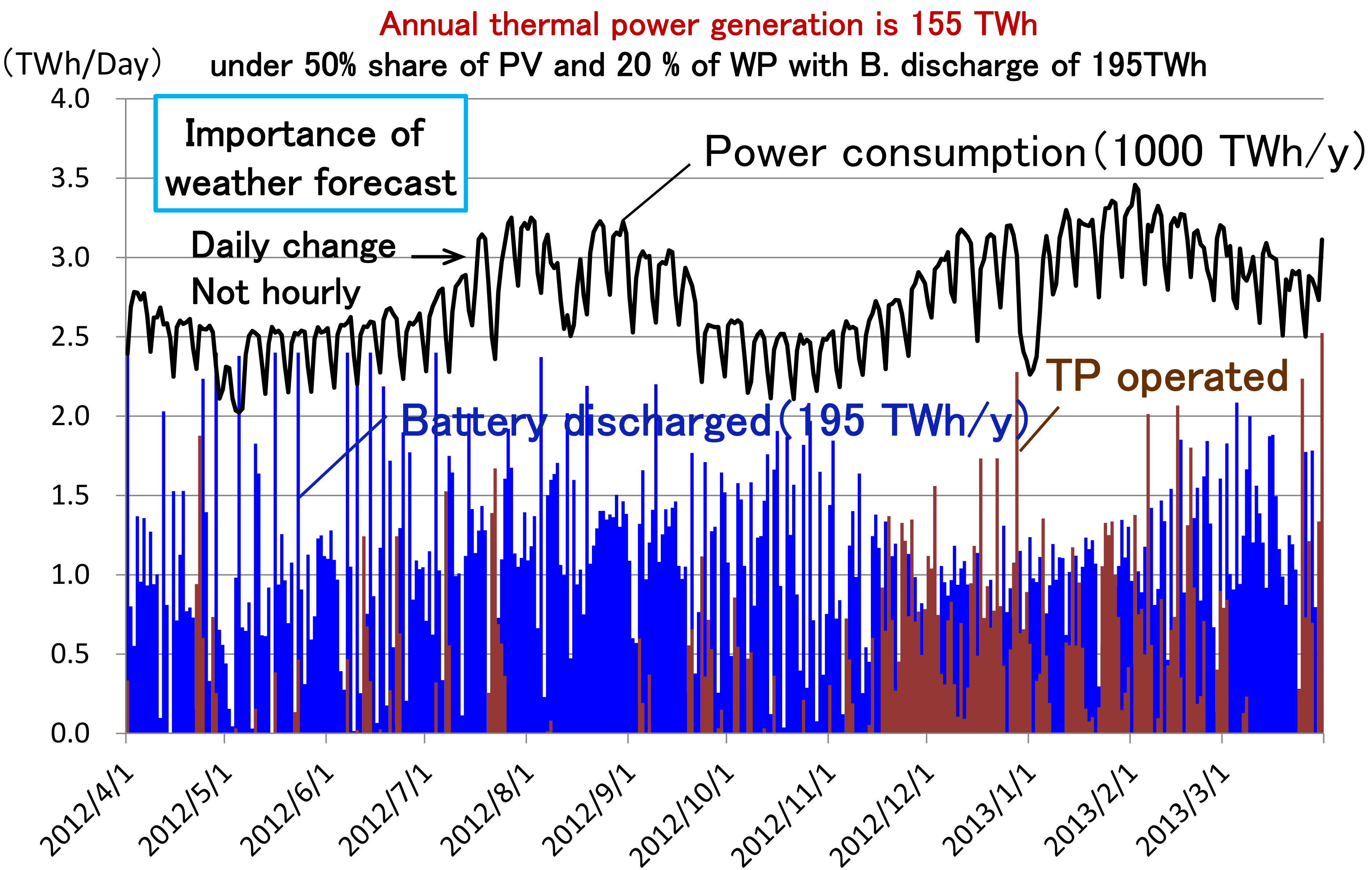
		Present	2020	2030
Energy density [Wh_{ST}/kg-battery]		200	270	490
Electrode material		$LiCoO_3$/Graphite	Complex oxide/ Carbon	
Storage system Cost [¢/Wh_{ST}]	Battery	13	7	4
	Control circuit	3.3	1.7	0.8
	Storage box	2.7	2.3	1.6
	合　計	19	11	6

Monthly power consumption and supply

(Generation rate/y :PV 50%, WP 20,TP 16,HP 10,NP 10%)



Daily power consumption, battery discharge and thermal power generation



Annual power consumption and RE availability in power grids

(TWh/y)

		Hokkaido	Tohoku	**Tokyo**	**Chubu**	Hokuriku	**Kansai**	Chugoku	Shikoku	Kyusyu	Okinawa	Total
Power consumption	In 2010	44	108	349	154	48	170	91	58	125	9	1,157
	Standard case	**38**	**93**	**302**	**133**	**42**	**147**	**79**	**50**	**108**	**8**	**1,000**
	Low power consump. case	19	47	151	67	21	74	39	25	54	4	500
RE availability	PV（eff.30%）	38	89	163	89	33	76	65	35	105	7	691
	WP（Land）	306	159	9	17	17	28	20	11	46	13	614
	HP	6.5	17.4	16.4	17.4	8.9	17.7	4.4	4.2	7.0	0.0	100
	Total	350	265	188	124	59	122	89	50	158	19	1,305
Excess RE in each grid												
Excess capacity (TWh/y)	**Standard case**	**310**	**166**	**−136**	**−18**	**15**	**−36**	**5**	**−4**	**41**	**11**	
	Low Energy consump. case	329	213	15	48	36	38	44	21	96	15	

Additional transmission cost　2 ¢ /kWh（Hokkaido･Tohoku ⇔ Tokyo 1600km　56～70GW ）

Future power costs and CO_2 emissions

Power Structure \ Case		2030 PV+WP 9% NP10% 1000TWh/y	2050 ① RE 50% NP10% 1000TWh/y	2050 ② RE 84% NP10% 1000TWh/y	2050 ③ RE 81% NP12% 800TWh/y	2050 ④ RE 94% 500TWh/y
Generated Power (TWh/y)	PV	47	200	480	360	180
	WP	44	200	320	240	120
	HP	90	100	100	100	100
	RE Others	0	0	0	0	100
	Nuclear Power	100	100	100	100	0
	LNG [operation rate]	720 [54%]	404 [34%]	77 [7%]	59 [7%]	32 [7%]
	Total	1001	1004	1077	859	532
Storage Battery (GWh_{ST})		9	400	2400	1800	900
Generation cost (¢/kWh) (Storage Battery cost)		9.8 (SB 0.02)	9.3 (SB 0.2)	10.9 (SB 1.4)	10.8 (SB 1.4)	11.9 (SB 1.1)
CO_2e (Mt/y) (Based on 2005)		517 (100%)	234 (45%)	66 (13%)	52 (10%)	30 (6%)

current power cost :12.9 ¢ /kWh

Conclusion

1.The global temperature rise was calculated using equations related to an economic growth rate and social structure. If rates of technology progress and/or its result transfer were low, the temperature rise became much higher than 2 ℃ in 2100.

2. The importance of quantitative economic evaluation of future energy system using a technology structuring method for a future power system design was shown.

3. A possibility of an economic and low CO2 power system realization in 2050 by a 2030 technology level was suggested

4. Importance of advanced material development for future energy system is clear