Current status and future prospects of low carbon technology and power system

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Koichi Yamada

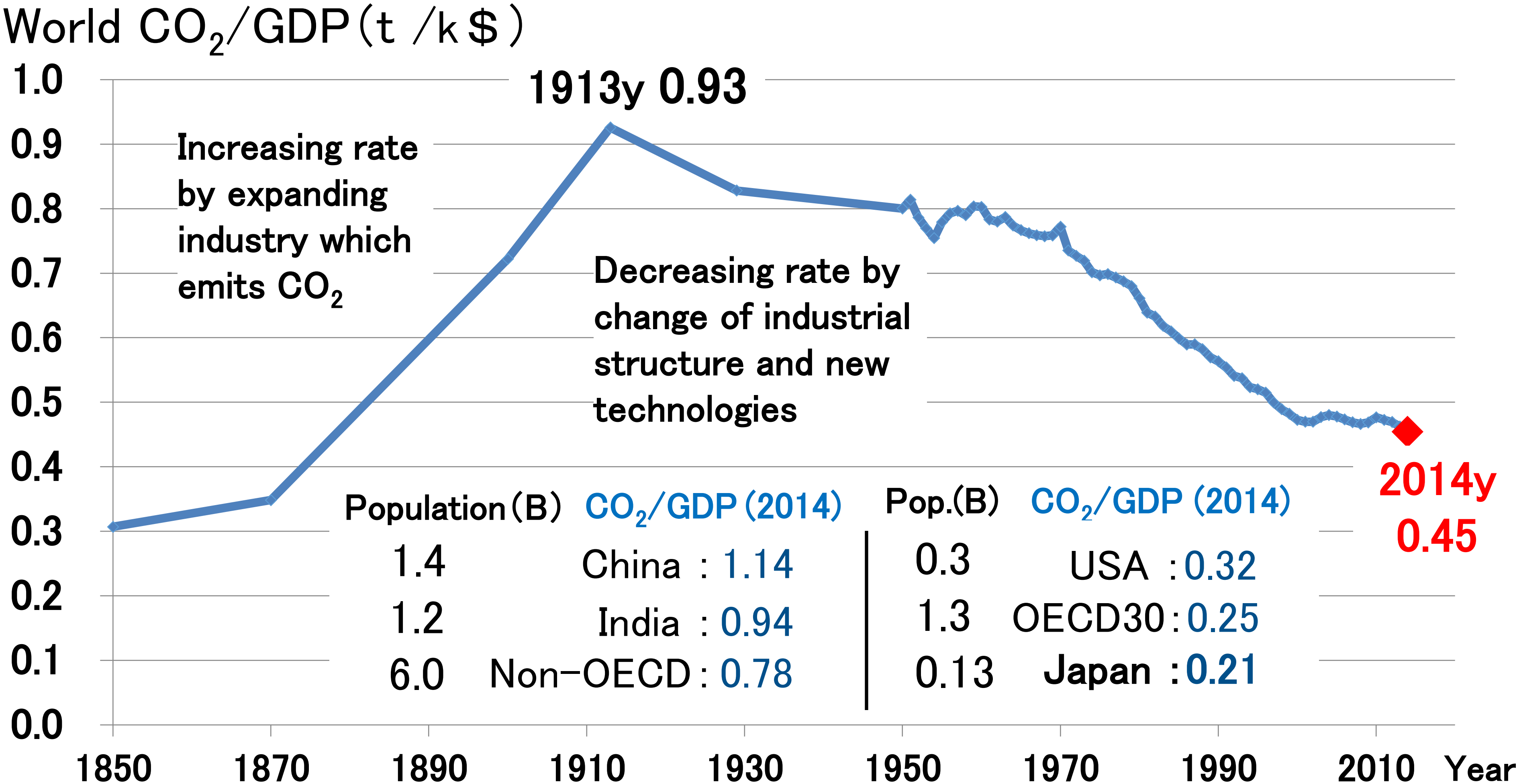
Center for Low Carbon Society Strategy

Japan Science and Technology Agency

Contents

- Global warming temperature
- Design & evaluation platform for low carbon technology
- Evaluation result of renewable energy system
- Evaluation result of carbon free hydrogen
- Evaluation result of low carbon power supply system
- Value of R&D result for reducing electricity cost

Historical change of CO_2/GDP in the world



World annual economic growth rate (%)	1870–2014	1950–2014	1981–1990	1991–2000	2000–2007	2008–2014
	2.7	3.6	3.2	3.0	3.4	2.2

Calculated using GDP data of Angus Maddison, "Monitoring the World Economy 1820–1992" before 1950

Global temperature rise

$$C_t / GWP_t = 0.45 - ADR(t - 2014) \quad (t = AD)$$

$$GWP_t = 73{,}000(1 + \text{annual growth rate of GWP})^{t-2014}$$

$$\Delta T = 0.64\left(1.4 + 10^{-6}\sum_{2015}^{t} C_t\right) \quad (\Delta T\text{: Temperature rise after 1870, °C}) ※$$

ADR : Annual decreasing rate of C_t / GWP（$t\text{-}CO_2/M\$/y$）

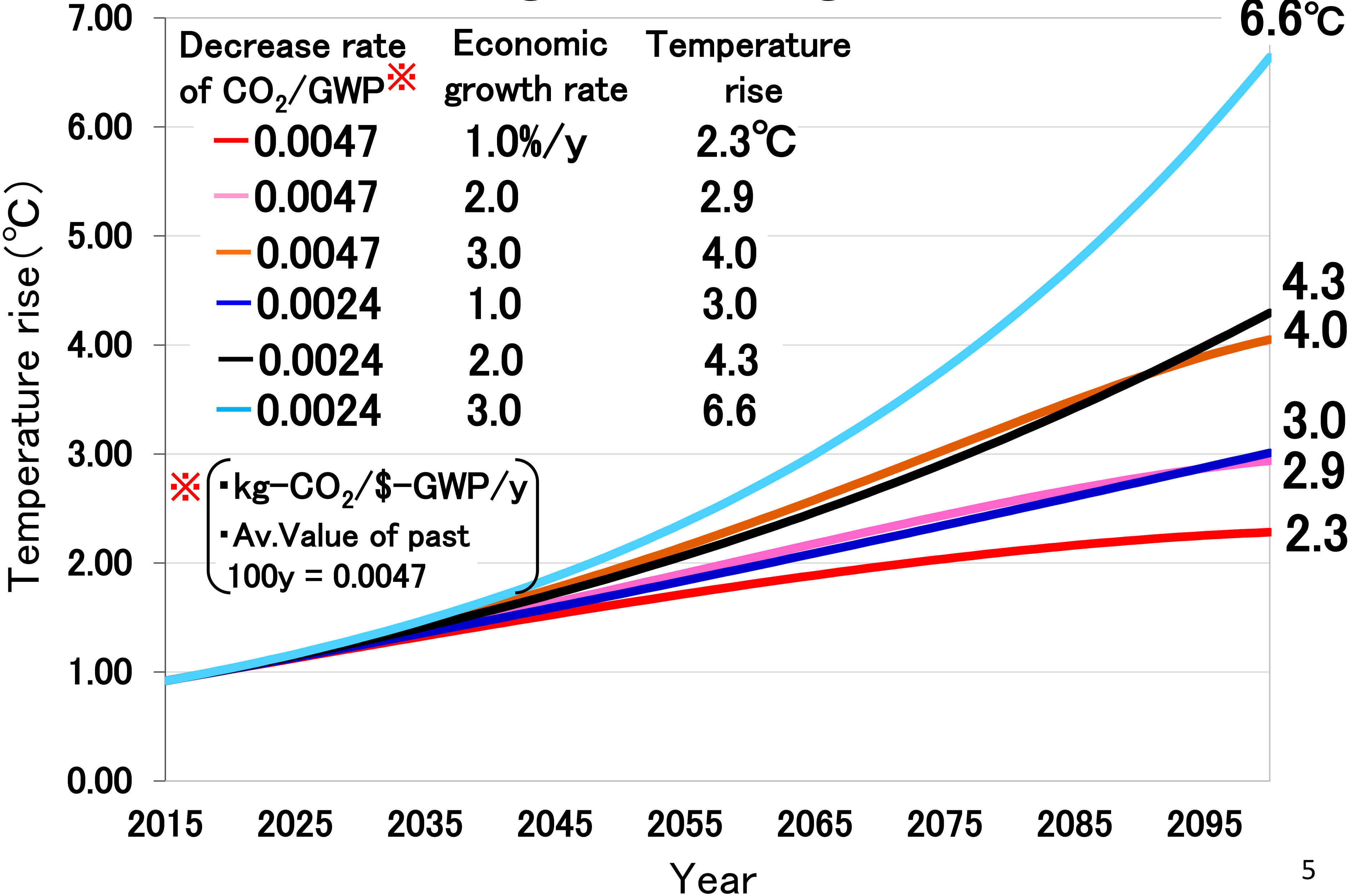
GWP_t : Gross world product after 2015（ B$/y）

C_t : CO_2 emissions（$Mt\text{-}CO_2/y$）

ΔT can be calculated by using global economic growth rate and ADR

※ H.D.Matthews et al. Nature 459（June 09）

Effects of technology progress and economic growth on global warming

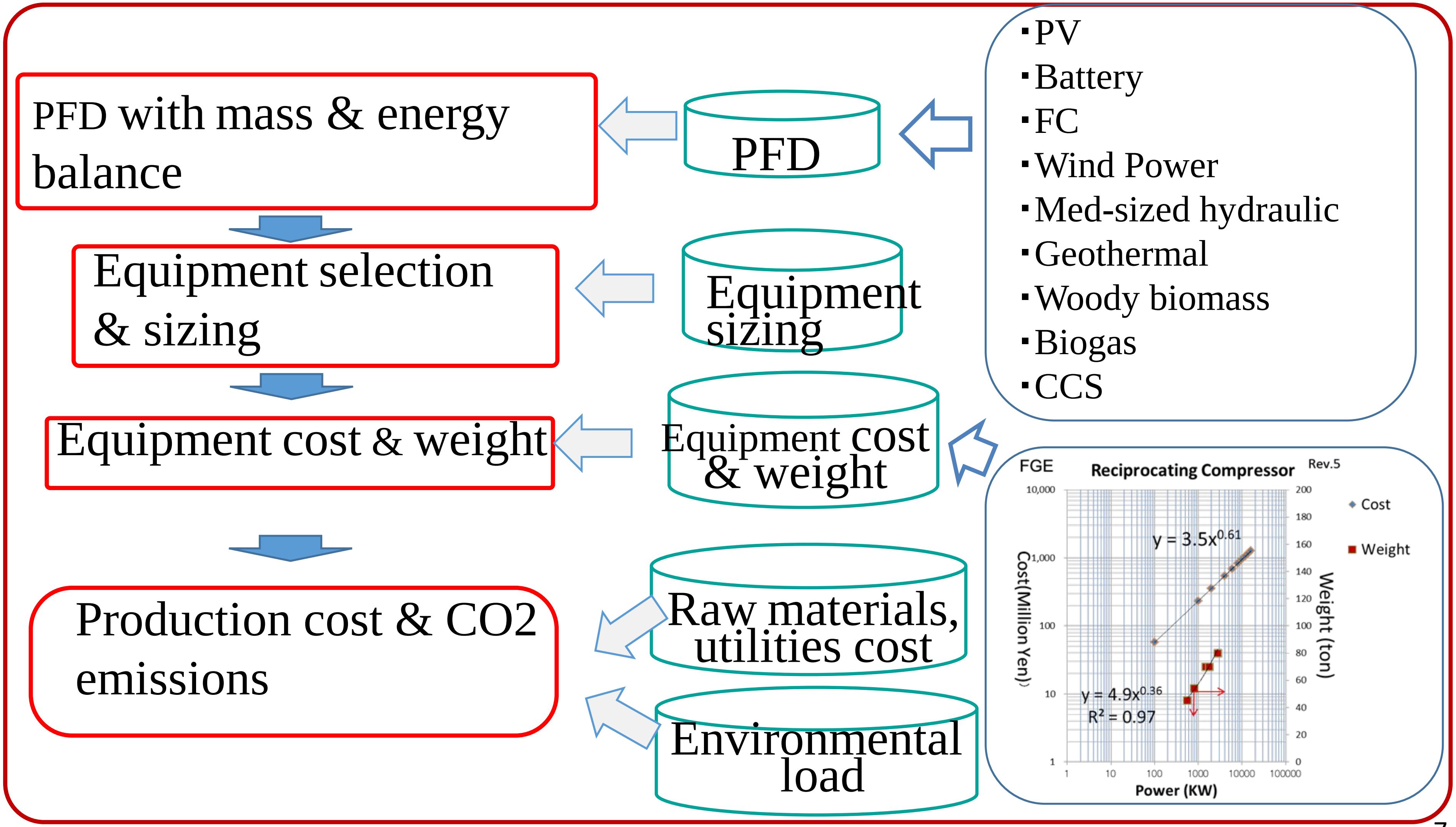


Items for designing low carbon power supply system

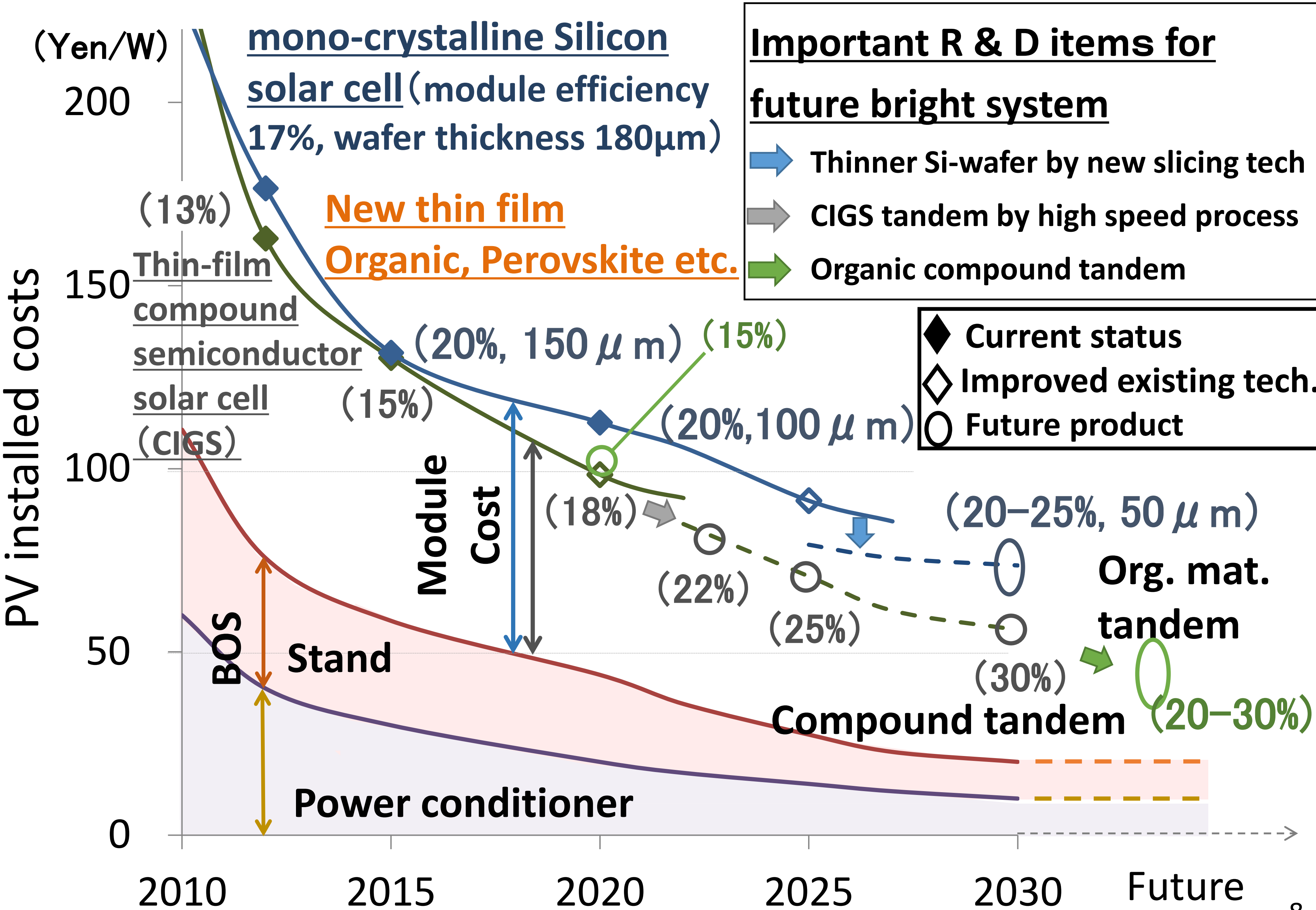
1 Low environmental impact
2 Low cost
3 Stable supply system
   Time scale: From 0.1 second to minutes (GF),
   10 minutes (LFC), hour to year (storage)
4 Amount of renewable energy available in each region
5 Power transmission system
6 Flexibility of demand system
7 Power supply construction scenario towards CO_2 emissions of 0

Platform for Design & Evaluation of LCT (“Modeling Tool”)

Automated process design support system developed by LCS.



Prospects of PV System Cost

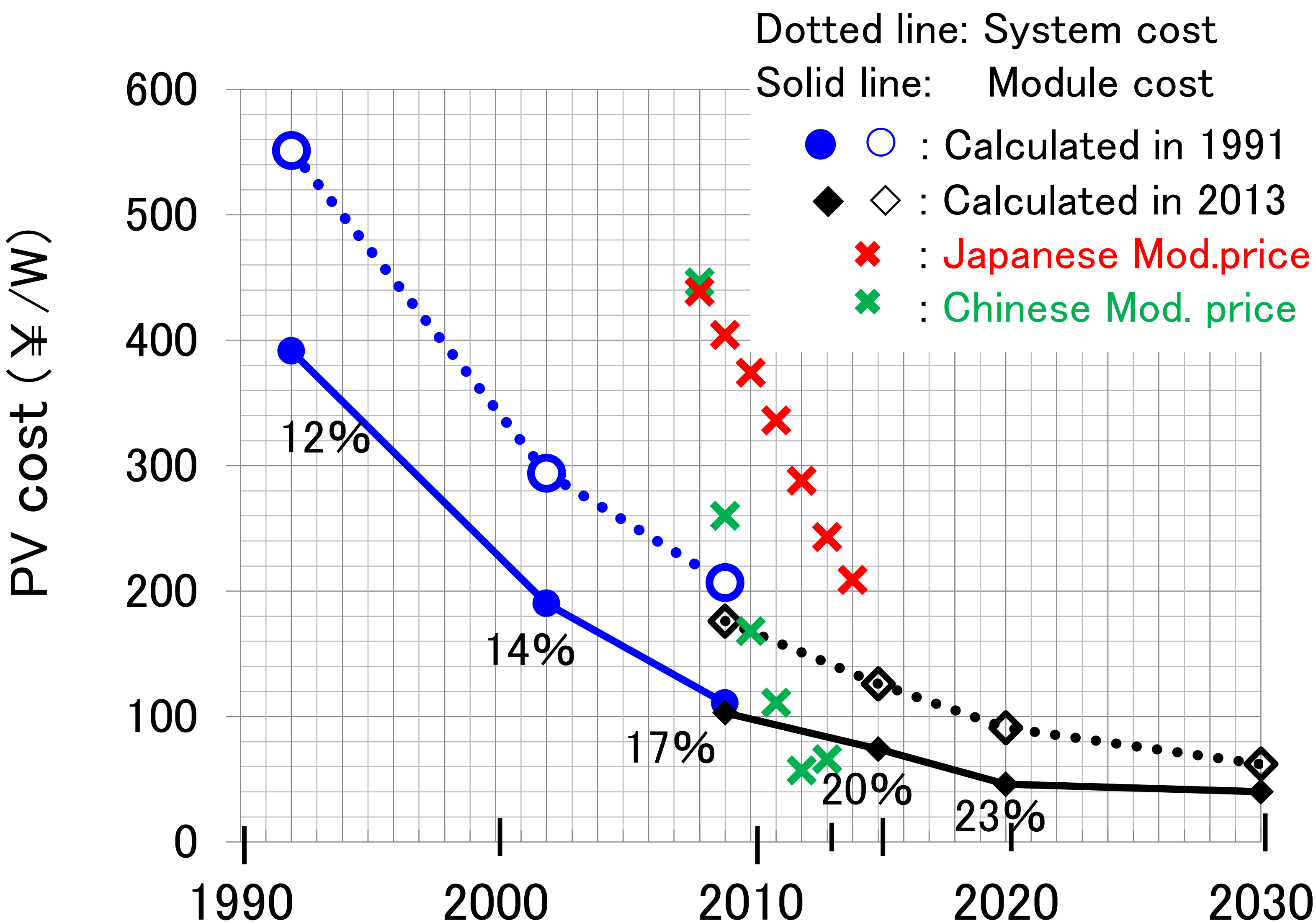


PV module and system cost breakdown

(Yen/W)

		2015		2020		2030		Future
Type of PV (generation efficiency)		Single crystal Si 150 μ m th. (20%)	CIGS (15%)	CIGS (18%)	New thin film (15%)	Single crystal Si 50 μ m th. (25%)	CIGS tandem (30%)	Organic tandem (30%)
V. C	Material	56	51	40	34	35	29	17
	Utility	4	2	1	2	1	1	1
F. C	Equipment, Labor	14	14	9	12	6	7	6
Subtotal		74	67	50	48	42	37	24
BOS	Stand	22	29	27	32	12	10	10
	Inverter	30	30	15	15	10	10	10
Subtotal		52	59	42	47	22	20	20
Total Cost		126	126	92	95	64	57	44

PV module and system cost



Current and future scenarios of LiBs

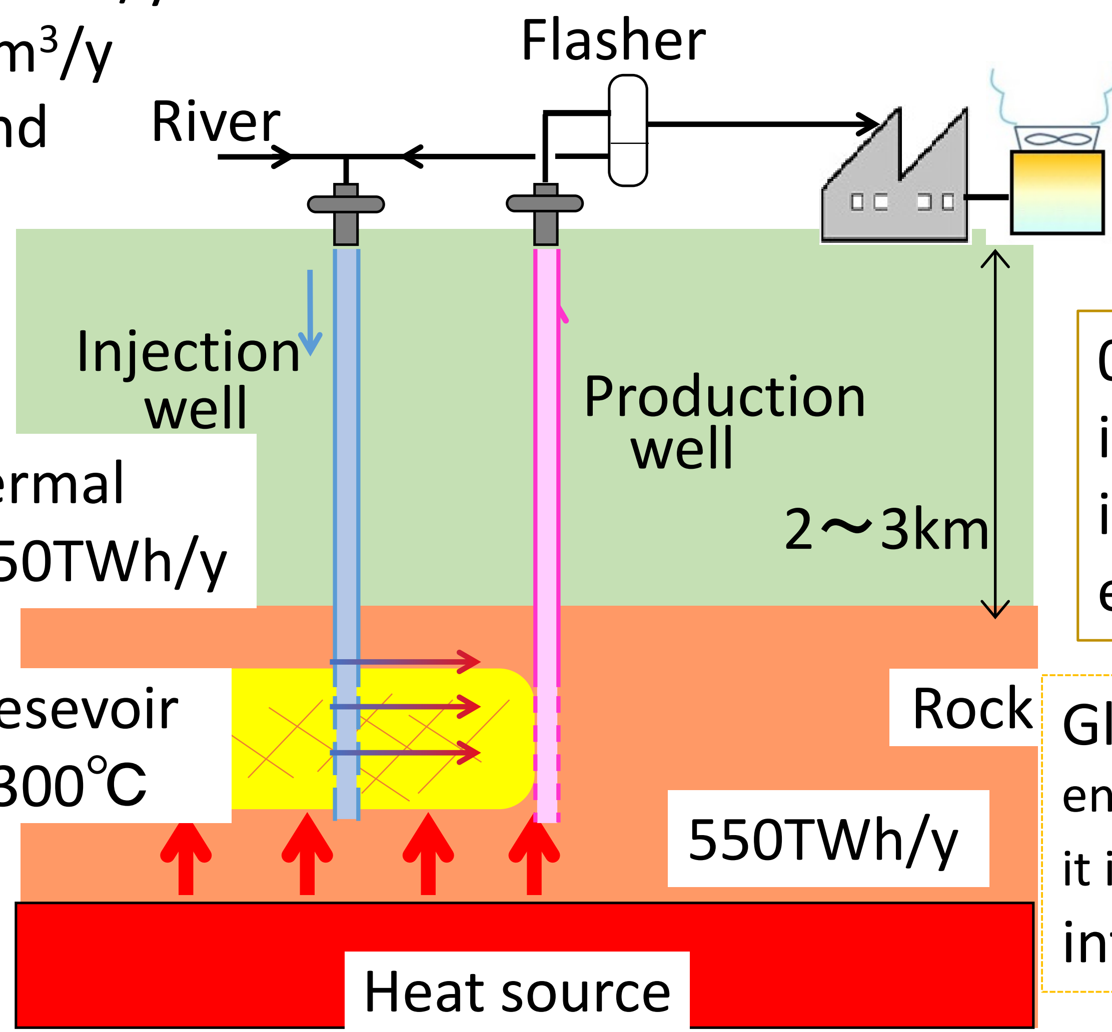
			2015	Year 2020	Year 2030
Production scale [GWh_{ST}/y]			1 (10)	10	10
Yield [%]			66 (90)	90	90
Specific energy [Wh_{ST}/kg]			250	340	500
Cathode/Anode			$LiNi_{0.85}Co_{0.12}Al_{0.03}O_2$ /Graphite	$LiNi_{0.85}Co_{0.12}Al_{0.03}O_2$ /Graphite	Li_2S–C/ Li
Cathode/Anode capacity [mAh/g]			200/300	270/380	880/3300
Ratio of actual to theoretical capacity (Cathode/Anode)			0.71/0.78	0.97/0.99	0.75/0.85
Production cost [JPY/Wh_{ST}]	Variable cost	Material	10.2 (7.5)	4.8	
		Utilities	0.5 (0.4)	0.3	
	Fixed cost		3.2 (1.7)	1.4	
	Total		**13.9 (9.6)**	**6.5**	**4**

Geothermal power generation (Hot dry rock)

Rainfall 640 Gm^3/y

River 240 Gm^3/y

Water demand 80 Gm^3/y



0.04- 5.0% of injection energy is converted to earthquake

Global earthquake energy is 1.2EJ/y , it is 0.1% of earth interior energy

Water usage = 2.3 Gm^3/y for 200TWh(30GW) by HDR, water eff. of 98%

Electricity Cost Estimation of Hot Dry Rock System

Plant Site	Kakkonda		Minase
Water from River	1,400t/h		5,600t/h
Water Recovery Rate	50%	98%	98%
Reservoir Temp.	280℃	280℃	280℃
Generation Output	38MW	157MW	650MW
Efficiency	16%	16%	16%
No. of Injection Well	1	7	19
No. of Production Well	4	14	57
Total Investment Cost	19B¥	57B¥	180B¥
Variable Cost	1.2¥/kWh	0.3¥/kWh	0.3¥/kWh
Fixed Cost	9.1¥/kWh	6.6¥/kWh	5.0¥/kWh
Electricity Cost	10.2¥/kWh	6.8¥/kWh	5.3¥/kWh

Annual expense rate 10%, Operating factor 80%, Variable cost = Water cost (20¥/m^3)

Electricity generation cost & potential of renewable energy (Japan)

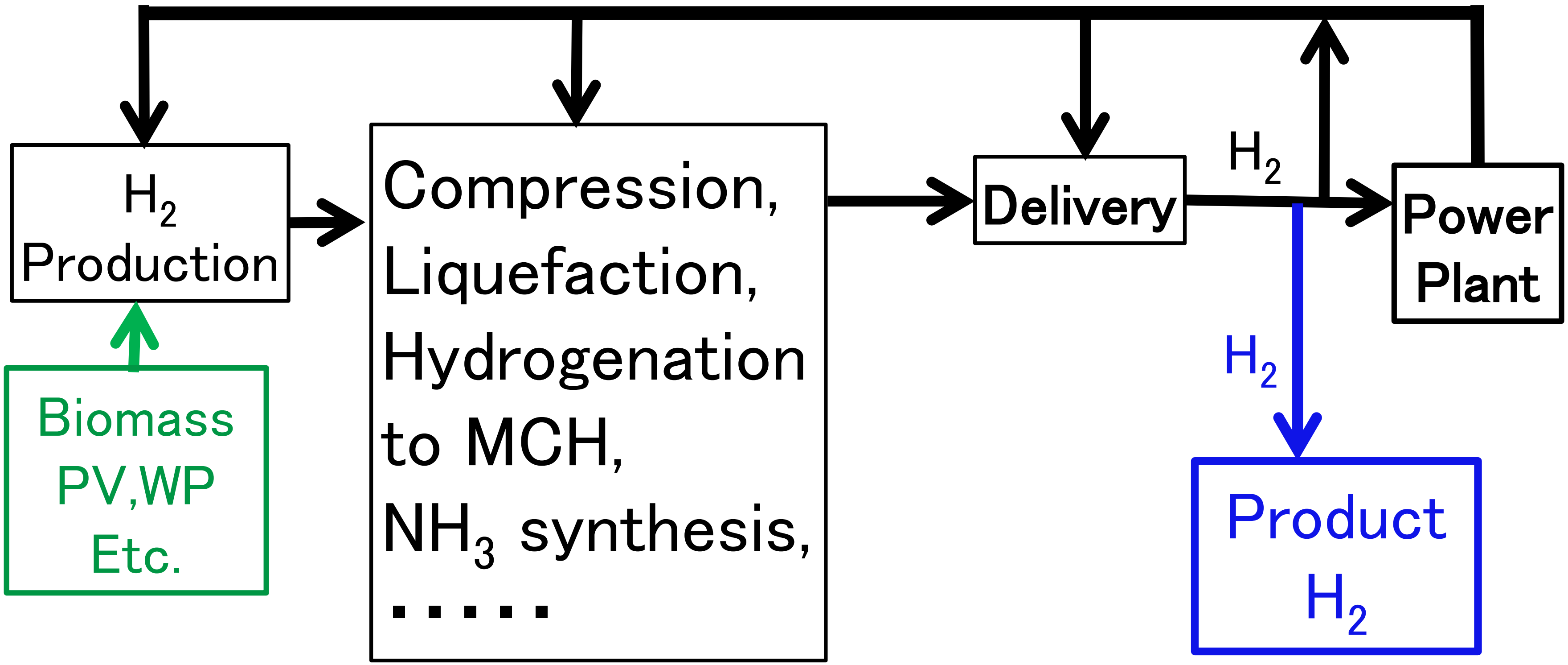
	Cost(￥/kWh)		Potential(TWh/y)
	Present	2030	
Photo voltaic	24	6	>400
WP(land)	16	8	>500
Geothermal	25	8	500
Hydro(small/medium)	30	15	70
Biogas	25(13)	13(5)	15※
Biomass	25(18)	12(4)	40

( ): Fuel cost

Power consumption = 1000TWh/y

Biogas※: 20% of Fermentation potential($5 \times 10^9 m^3$/y)

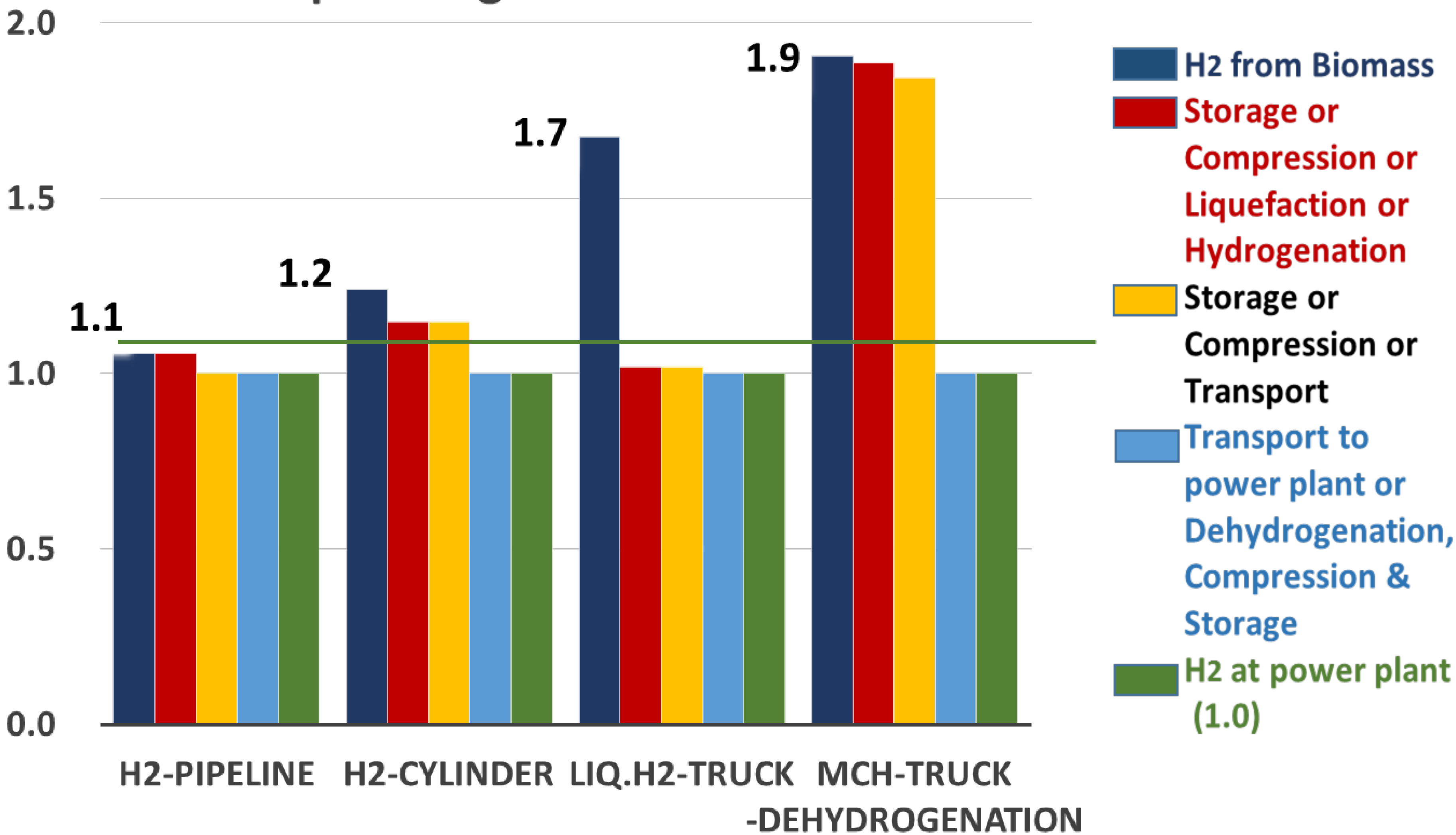
Carbon Free Hydrogen for Fuel



18.8MJ/kg-biomass, ¥10/kg, ¥0.53/MJ

Delivery by truck, tank lorry, pipeline

Energy change from Biomass to H2 product for power generation　distance:100km



Production cost of H_2 from biomass
H_2 cost at power plant（¥/MJ）

Transportation: 100km（200km※）

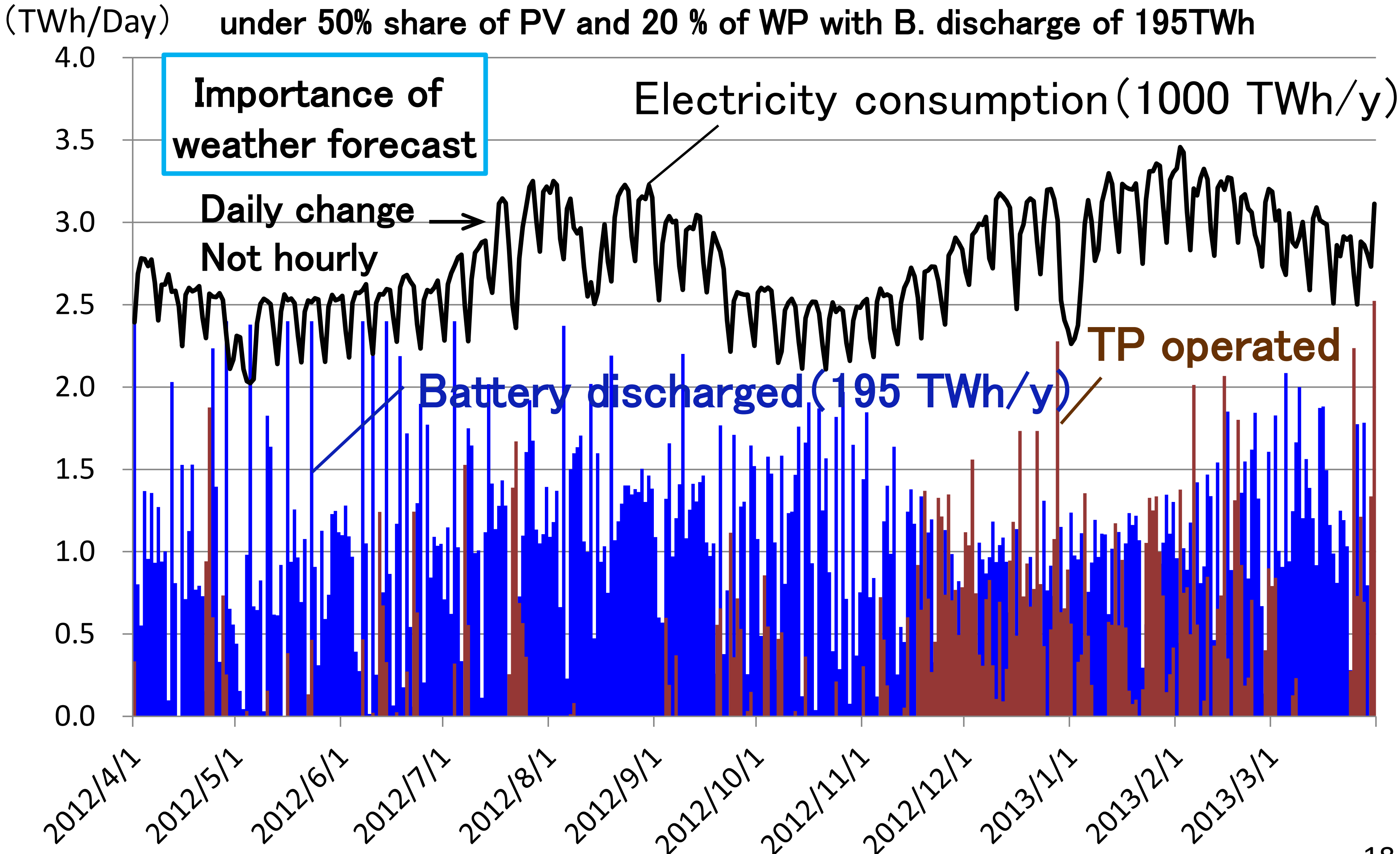
Details \ Case	1 H_2Gas Pipe	2 H_2Gas Cylinder −Truck	3 Liq. H_2 Tank −Truck	4 MCH/ Dehydration Tank−Truck
Biomass	1.6	1.9	2.5	2.9
Gasification	0.6	0.7	1.0	1.0
Transportation etc.	1.1	2.1	2.6	2.1
Total	3.3 (4.1※)	4.7 (6.6※)	6.1 (6.9※)	6.1 (6.9※)

The cost of H_2 produced by PV and used for power plant is 6～13 ¥/MJ（Occupancy rate of electrolyser 10 ～ 30%）, Gasoline price= 4¥/MJ

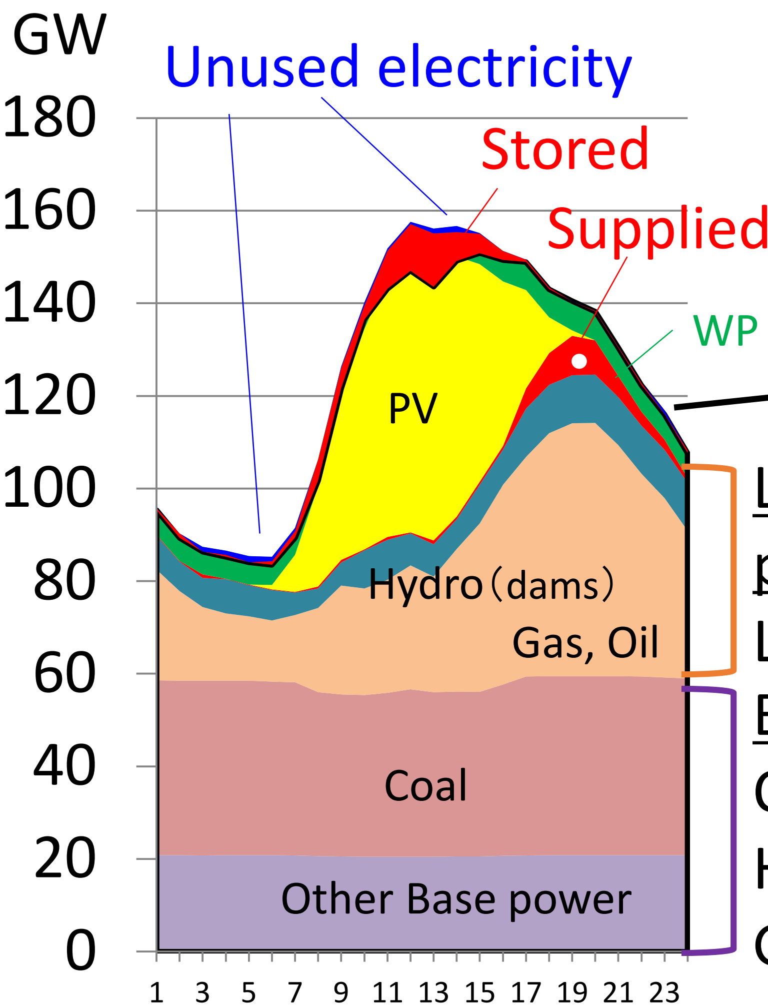
Daily electricity consumption, battery discharge and thermal power generation

Annual thermal power generation is 155 TWh

under 50% share of PV and 20 % of WP with B. discharge of 195TWh



Multi-regional power generation model



Average output of Peak days (energy saving, low CO2 case)

Storage system ■ Stored ▣ Supplied

Battery, Pumped hydro

Power generation with fluctuation

■ PV, ■ Wind power

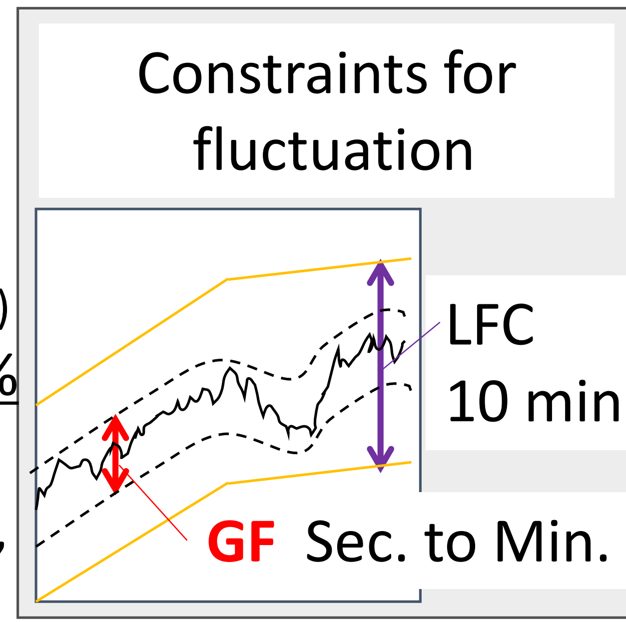
Demand curve

Load following power plants

LNG, Oil, Hydro(dams)

Baseload plant,>50%

Coal, Nuclear, Hydro(ROR), Biomass, Geothermal



※ Outputs of thermal power plant and storage system are calculated while that of other plants are given by scenarios.

*ROR: Run-of-the-river hydroelectricity

LFC: Load frequency control, GF: Governor-free control

Power Cost, 80% reduction of CO_2 (565 →113Mt/y, 2050)

Case		1	2	3	4	5
Power demand (TWh)		700	800			1,000
Generation Power (TWh)	NP	0	0	0	100	0
	HP	130	130	130	130	130
	Coal	55	16	61	119	0
	LNG	179	277	166	21	238
	PV	284	327	306	291	528
	WP	73	77	60	59	174
	Geothermal	12	12	12	12	12
	Geothermal (Hot dry rock)	0	0	100	100	100
	Biomass	31	31	31	31	31
	Total	764	870	866	863	1,213
H_2 Generation (TWh)		0	0	0	0	46
Storage Battery (GWh)		367(109)	451(135)	400(120)	362(110)	827(234)
Generation Cost (¥/kWh)		11.4	11.5	10.8	10.3	12.3

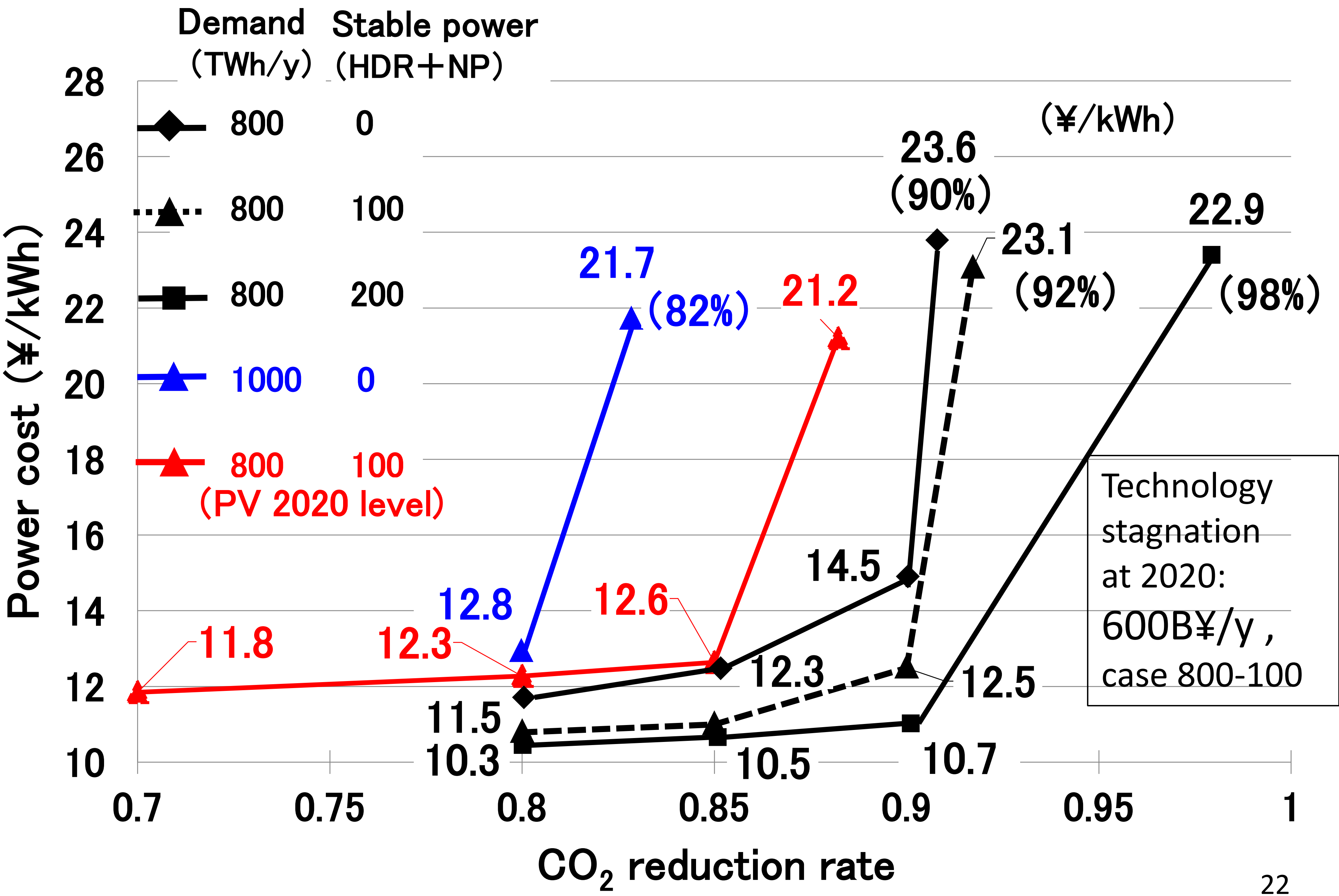
(¥10/kWh = €85/MWh) **(TWh)** Supplied electricity by battery

Power cost & Power demand with high CO_2 reduction rate

Case		6	7	8	9
Power demand (TWh)		700	800	1000	1200
Generation Power (TWh)	NP + HDR	200	200	200	200
	HP	110	119	123	130
	LNG	2	31	124	241
	PV	474	519	570	603
	WP	219	240	256	290
	Geothermal	6	6	12	11
	Biomass	16	20	25	27
	Total	1,028	1,135	1,310	1,503
H_2 Generation (TWh)		100	98	82	78
Storage Battery (GWh)		334(45)	322(76)	531(121)	744(166)
Generation Cost (¥/kWh)		**26.3**	**22.9**	**20.3**	**19.1**
CO_2 reduction rate		100%	98%	92%	85%

(¥10/kWh = €85/MWh) **(TWh)** Supplied electricity by battery

Power cost and CO_2 reduction rate (2030 technology level)



Conclusion

- Reduction of CO_2 emissions from power generation by 80% in 2050 can be realized at almost the same current cost in Japan.
- Toward CO_2 zero emissions electricity, stable power supply (power generation with inertia) by geothermal, H_2 etc. becomes more important after 2050.
- The difference in technology level between 2020 and 2030 is a difference of about 600 billion yen in the electricity cost at the time of the CO_2 emission reduction rate of 80% in 2050.