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Pathways to a Bright Future ZC Society Based on Integrated Quantitative Analysis#

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ABSTRACT

A quantitative energy supply system toward a Zero Carbon (herein after abbreviated as ZC) society in 2030 and 2050 derived from our design platform has been developed.

Furthermore, the relationships between GDP and CO_2 emissions have been clarified quantitatively under the various conditions by applying our proprietary system with the integration of newly developed input-output table and above-mentioned energy supply system.

CO_2 emissions from daily life field can approach ZC relatively easily by using the ZC power supply. However, it is not easy to reduce CO_2 emissions from the manufacturing field to zero.

The relationships between GDP and CO_2 emissions in 2050 shall strongly depend on the industrial and social structure. By changing these structures under different conditions, the pathways to a bright future ZC society could be visualized.

Keywords: quantitative evaluation, input-output table, ZC society, GDP, CO_2 emissions

1. INTRODUCTION

Many countries are moving towards ZC society in 2050. However, the quantitative evaluation of energy supply system towards ZC and also the change in GDP have not been revealed in an integrated manner. We have developed a methodology for quantifying future costs and CO_2 emissions in a wide range. We have been creating a database that scientifically calculates future costs and CO_2 emissions in power sources as well as in manufacturing-related fields. We will present quantitative technology evaluation in 2030 and 2050 considering future costs and CO_2 emissions of PV, WP, geothermal, battery, H_2, CCS, DAC, steel, chemical, cement etc. Then, by integrating these data with our new input-output table [1],[2], we have been calculating the relationships between GDP and CO_2 emissions in the future ZC society. The CO_2 reduction rate in 2030 is about 50% and 100% in 2050. This part of daily life is relatively easy by using ZC power supply. However, it is not easy to reduce CO_2 emissions from this manufacturing sector to zero.

Toward 2050, innovative technologies will be gradually realized.

Japan's CO_2 emissions by industrial sector in 2019 were the highest at 47% in the total Japan as shown in Fig.1. This is a big issue that how to reduce CO_2 emissions from the steel, chemicals, and cement & ceramics fields, whose demand are expected to continue to be large quantities.

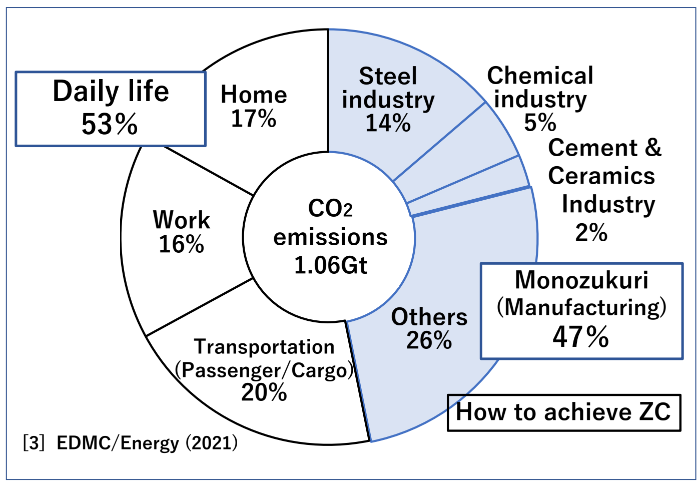

Fig.1 CO_2 emissions by Japanese sector （2019）

2. TECHNOLOGY DESCRIPTION BY LCS

2.1 CO_2 mitigation technologies developed by LCS

2.1.1 Platform for design and evaluation by LCS

LCS has been conducting mitigation technology evaluations using a proprietary platform (integrated design support system), a conceptual diagram of which is shown in Figure 2. First, a couple of data basis of process equipment costs and weights, etc. have been created, and these are used to calculate manufacturing costs and CO_2 emissions for representative mitigation technologies in accordance with the process design methodology.

Next, these data are used to construct an integrated as ZC power supply system.

Furthermore, a new input-output table has been created by adding various renewable energy sources, etc., and the industrial structure in 2030 and 2050 was concretely shown in order to explore the path to a future ZC society.

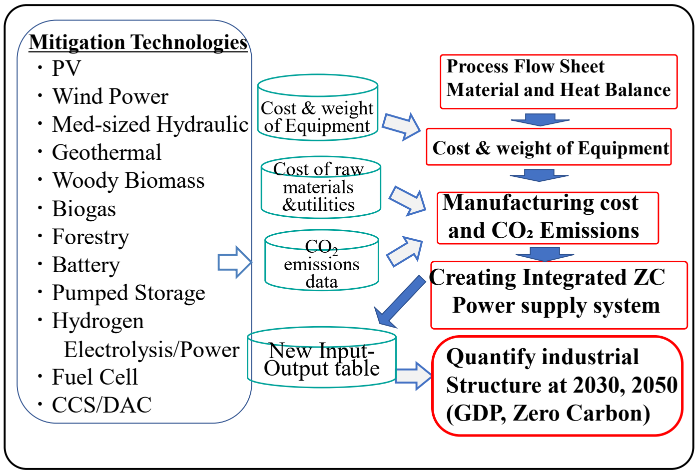

Fig. 2 Platform for Design & Evaluation by LCS

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2.1.2 PV Module/System Manufacturing Cost

Solar power generation is likely to occupy a large proportion of ZC power sources. In Fig.3, we show the performance improvement and cost estimation up to 2010, which we predicted in 1991[4], and the expected results after that. Their expected values are in good agreement with the actual situation. Such quantitative forecasts are useful for future planning and our methodology is currently in use.

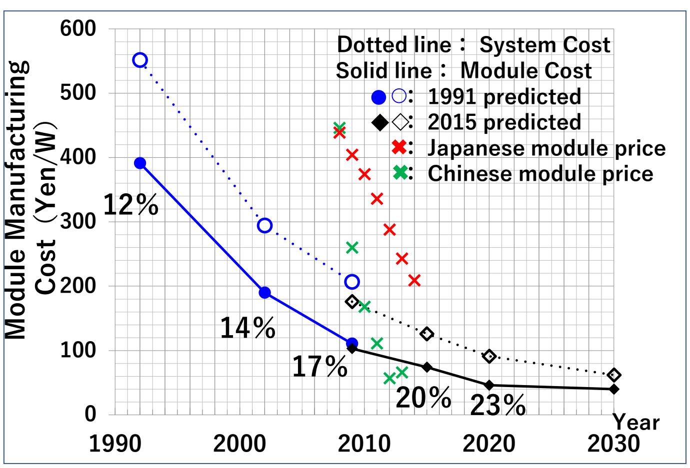

Fig.3 Photovoltaic module/System manufacturing cost forecast results from scientific view point

2.1.3 CO_2 Emissions, Energy Consumption and Sales in Japanese automotive sector

The number of vehicles used in the automobile sector in 2030 and 2050, CO_2 emissions and electricity consumption, which will be used in the future, are shown in Table 1. The number of automobiles will decrease by 9 and 27% in 2030 and 2050, respectively, but sales will be kept at the same level as the present due to higher functionality and CO_2 emissions will be reduced by 32% and 100% respectively. The demand of electricity in 2050 would be 54 TWh. This figure can be easily supplied in 2030 and in 2050.

Table 1 CO_2 emissions and energy consumption and sales in the automotive sector

Fiscal Year		2018			2030			2050		
Car Type		Million Units	CO_2 (Mt)	Electricity (TWh)	Million Units	CO_2 (Mt)	Electricity (TWh)	Million Units	CO_2 (Mt)	Electricity (TWh)
Passenger Cars	ICE	54.5	93.2		26.7	39.6				
	HV	7.8	12.1		20.0	21.8				
	PHV	0.1	0.1		4.9	2.2	1.9			
	EV	0.1		0.1	4.8		7.5	44		26
Trucks	ICE	14.9	76.6		11.5	55.0				
	HV	0.0	0.0		2.6	5.6				
	EV	0		0	0.3	0.0	6.3	12		25
Buses	ICE	0.2	4.1		0.2	2.7	0			
	HV	0.0	0.0		0	0.3				
	EV	0.0		0	0	0.0	0.7	0.2		2.7
Total		78	186	0.1	71	127	16	57	0	54
Sales & Units (T JPY / M Units)		101 / 5.2			116 / 4.2			147 / 3.4		

CO_2 reduction ratio: 34%@2030, 100%@2050. Sales have been increased by improving functionality

2.1.4 Changes in steel production and CO_2 emissions

A lot of CO_2 has been emitted during the steel production that is expected to remain in strong demand. In order to promote the shift to ZC, it is necessary to use recycled iron, to produce steel using ZC power supply as well as to reduce the amount. Table 2 shows the changes that these measures indicate that a 70% reduction can be achieved by 2050.

Table 2 Changes in steel production and CO_2 emissions

Year	2013		2030		2050	
Quantity / Product	Production (Mt)	CO_2 emission (Mt)	Production (Mt)	CO_2 emission (Mt)	Production (Mt)	CO_2 emission (Mt)
Blast, converter steel	86	185 2.2t-CO_2/t-Fe	48	95 2.0t-CO_2/t-Fe	20	30 1.5t-CO_2/t-Fe
Electric furnace steel	25	15	32	7	50	3
Total	111	200 (base-100%)	80	109 (-45%)	70	33 (-70%)

To achieve ZC in the Japanese steel industry by 2050, we propose a measure that combines CCS and DAC. This approach is to capture 90% of CO_2 emissions by the conventional amine process and to rely on DAC for the remaining 10% of CO_2 emissions. The calculation results are shown in Table 3. It will cost 4,000 yen per ton of steel, which is about twice the cost overseas. However, this cost increase is small as about 5% of the total cost.

Table 3 Cost and CO_2 Emissions of CCS & DAC

	Case 1	Case 2	Case 3	Case 4
	Domestic Site & Storage		Overseas site & Storage	
	DACS	CCS+DACS	DACS	CCS+DACS
	¥/kg-CO_2			
CO_2 Capture	35	7	25	5
CO_2 Transport	2	2	0	0
CO_2 Injection	0.1	0.1	0.1	0.1
Total	37	9	25	5

	Mt/year
CO_2 Captured by CCS	9.9
CO_2 Captured by DAC	1.1
Total	11

Note 1: Cost of CCS 1) For Domestic 4.1¥/kg-CO_2 2) For Overseas 2.6¥/kg-CO_2
Note 2: Steel production capacity : 5M t/year
Note 3: Price of NG & Electricity 1) For Domestic 1.5¥/MJ and 12 ¥/kWh,
2) For Overseas 0.35¥/MJ and 6 ¥/kWh
Note 4: Distance of transport 1) For Domestic ;1,000 km 2) For Overseas ; 0 km

2.1.5 Cost and CO_2 Emission on Battery

The current and future of storage batteries are shown in Table 4. As stationary storage batteries, lead-acid batteries are superior to LIBs in terms of both cost and CO_2 emissions. In addition, lead-acid batteries are easier to recycle than LIBs and have few resource constraints, so they will continue to be a useful technology in the future.

Table 4 ***Various rechargeable batteries***

■ **Lead-acid battery for stationary type**
■ **Lithium ion battery for EV**

Battery type	Lead	LIB
Energy density (Wh/kg) (Wh/ L)	40 (82)	250 (720)
Cell cost (¥/Wh) (current average)	8	18
Stationary type cell cost (¥/Wh)	5	15
Future cell cost (¥/Wh)	3.5	8.5
Cycle (times)	4,500	4,000
Energy efficiency (%)	87	95
System cost (¥/kWh)	14,000	30,000
CO_2 emissions (g/Wh)	15	122

2.2 Total cost of electricity and power supply

Future power demand is expected to increase endlessly due to the development of the information industry. The current annual power supply is 1,000TWh, but it was found that 1,200 TWh of power supply with 70% reduction in CO_2 emissions will be needed in 2030, and 3,000 TWh of ZC power supply will be needed in 2050.

Fig. 4 shows the calculation results of electricity cost and power supply in 2030 and 2050. In 2030, the cost is about 12 Yen/kWh, and in 2050, about 3000 TWh can be supplied at a cost of 21 Yen/kWh. In 2030, the electricity cost of PV will be expected as low as 5 Yen/kWh.

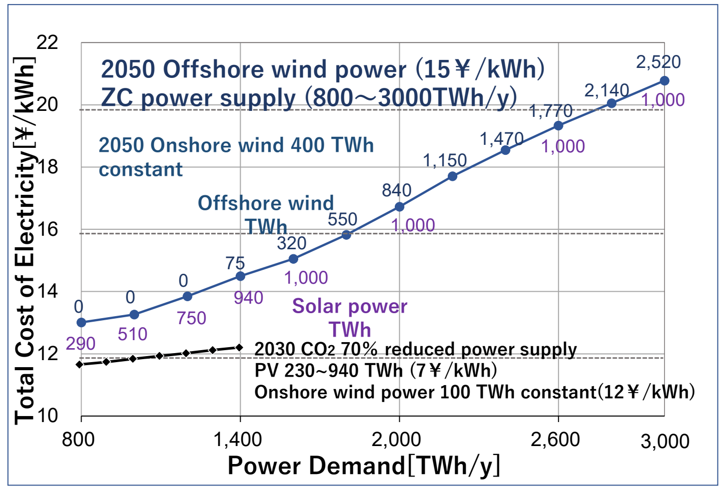

Fig.4 Total cost of electricity and power demand

2.3 GDP and CO_2 Emission by Input-Output Analysis

The cost of electricity and power supply from the ZC power system as well as the future scenarios for the manufacturing sector are shown in the upper part of the bold line in Table 5. Given these as inputs, our input-output analysis shall show the results for GDP and CO_2 emissions in the lower part of the bold line in Table 5.

The results show that in 2030, GDP will increase by about 12% compared to 2013 and CO_2 emissions will be reduced by about 43%.
By 2050, GDP will have doubled, and CO_2 emissions will have been reduced by 100%, or ZC, through the combination of CCS and DAC.

Table 5 GDP and CO_2 Emissions by Input-output Analysis

Year	2015	2030	2030	2030	2050	2050	2050
Elec. Demand (TWh)	1,000	1,190	1,200	1,210	1,710	1,860	3,080
CO_2 Reduction (%)	–	70	70	70	100	100	100
Elec. Cost (¥/kWh)	20.3	12.3	12.3	12.3	16.6	16.6	20.9
Software Exp. (T¥)	0.4	6.0	6.0	6.0	0.4	42.0	174.0
Software Imp. (T¥)	0.4	0.4	0.4	0.4	16.1	0.4	0.4
Machines Exp. (T¥)	9.8	11.7	13.9	15.9	20.0	20.0	20.0
Visitors (T¥)	1.1	1.7	4.6	6.8	16.0	16.0	16.0
GDP (T¥)	533	595	599	603	652	705	1,045
Export (T¥)	87	94	99	103	108	150	281
Import (T¥)	102	102	102	103	122	112	133
CO_2 Emissions (Mt)	1,227	740	748	755	0	0	0
Reduction Rate (%)	6	44	43	42	100	100	100

3. CONCLUSION

We have created a platform to clarify the manufacturing costs of energy-related equipment, steel, chemical products, CO_2 emissions, etc., and by using these data, we can quantify current and future technologies. We also created a new input-output table based on these quantified data that is enabling us to describe many aspects of Japanese society in 2030 and 2050.

REFERENCE

[1] Industrial Structure in 2030 and 2050 towards Zero Carbon Society LCS-FY2021-PP-09

[2] Changes of Industrial Structure towards Zero Carbon Society: Application of Extended Input output Table LCS-FY2019-PP-14

[3] EDMC/Energy (2021)

[4] Koichi Yamada, Hiroshi Komiyama "Photovoltaic Engineering" ISBN 978-4-8222-8148-9, Nikkei Business Publications, Inc. 2002