Section 7
Future Energy Policies and CO_2 Emission Factor Projections in Major ASEAN Countries and India

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Abstract

In this section, we focus on the greenhouse gas (hereafter, CO_2) emission reduction activities undertaken by various organizations and companies to achieve carbon neutrality to prevent global warming and consider how CO_2 emissions in major ASEAN countries and India will change.

In this section, we have estimated a formula for calculating the CO_2 emission factor[1] (CO_2-EF) from the breakdown of the energy mix by grasping the relationship between "energy mix[2]" and "CO_2-EF." Furthermore, we have used the formula to predict how CO_2 emissions will fluctuate in the future depending on the energy policies of these countries, in the case where each organization or company establishes a new base in the major ASEAN countries or India.

Furthermore, we used the formula to estimate Japan's CO_2-EF. If we were to switch to using renewable energy (RE) other than hydropower instead of coal fuel, we could halve the CO_2-EF. This model suggests that Japan, which has a high ratio of coal-fired power generation even among developed countries, must start by transitioning from coal to other fuels.

Introduction

To achieve carbon neutrality, various measures will need to be implemented by organizations and companies in the future, and as part of this, steps are being taken to reduce CO_2 emissions, such as saving energy, transitioning to electricity from fossil fuels, and introducing RE through solar power generation. These are areas where reductions can be made within internal departments, and this is the part that is considered to be self-help. On the other hand, power companies

1) CO_2 emission factor: An indicator that shows how much CO_2 is emitted to generate 1 kWh of electricity. When electricity is generated by burning fossil fuels, such as in thermal power generation, the amount of CO_2 emitted is high, and the CO_2 emission factor is high. On the other hand, when electricity is generated from natural sources, such as solar power, the amount of CO_2 emitted is low, as is the CO_2 emission factor.
2) Energy mix: The ratio of energy sources used in power generation. Energy sources include fossil fuels (coal, oil, gas), hydroelectric, nuclear, and renewable energy. The composition of the energy mix differs depending on the country or region.

are also working to reduce CO_2 emissions from the electricity that is purchased and used in business activities, and this is the part that is considered to be external cooperation. The amount of CO_2 emissions per unit of electricity purchased varies depending on how much CO_2 was emitted to generate the electricity, and this is referred to as the CO_2-EF (kg-CO_2/kWh). Purchasing electricity with a low CO_2-EF will also lead to lower CO_2 emissions for an organization or company, so it is necessary to promote CO_2 emission reductions through both self-help and external cooperation. The CO_2-EF values will vary depending on the energy mix in each country and region, and in the future, as we aim to achieve carbon neutrality and switch to an energy mix that reduces CO_2 emissions, these values will tend to decrease, so we must keep a close eye on these trends.

When considering new bases for future business, in addition to factors such as labor costs, electricity prices, and other costs, as well as the consumption market, we must also be very careful about CO_2 emissions reduction. In this report, we will focus on the major ASEAN countries (Indonesia, Vietnam, Malaysia, and Thailand) and India, and estimate the formula that will predict the impact on the CO_2-EF depending on how the energy policy of each country will develop in the future, and provide it as one of the indicators for selecting new bases.

1. The Importance of the CO_2-Emission Factor

As a way of strengthening the management foundations that will support the long-term growth of organizations and companies, ESG (environmental, social, and governance) investment is becoming an extremely important initiative. In the environment, clear numerical targets have been set with time deadlines for reducing CO_2 emissions, and organizations and companies are probably at the stage of considering measures to achieve these targets. When companies expand overseas to improve productivity and increase profits, it is thought that in the past, many cases of considering new bases have been carried out with an emphasis on points such as labor costs, electricity prices, etc., securing excellent human resources, location conditions, material procurement, and the relationship with consumer markets. However, as the SDGs are being strongly demanded internationally, companies must fulfill their responsibilities in terms of the environment, and it is impossible to continue or expand business operations while ignoring environmental issues.

The Paris Agreement, which resulted from the COP21 held in Paris in 2015 to discuss international agreements on reducing greenhouse gases, requires greenhouse gas emissions reduction targets, known as the Science Based

Targets initiative (SBTi)[3], and the agreeing parties are beginning to tackle this difficult issue by creating roadmaps for reducing CO_2 emissions in their respective organizations, including countries, companies, and groups, to achieve carbon neutrality by 2050.

While companies are constantly considering ways to expand their business scale, such as by building new factories, increasing the number of facilities in operation and developing more bases will naturally lead to increased energy consumption, such as electricity, and inevitably increase CO_2 emissions. The SBTi is a system that evaluates how much CO_2 emissions have been reduced from a base year (100%), and even if productivity improves and the CO_2 emissions per unit improves, if CO_2 emissions increase due to increased production, it will not be evaluated. In short, the upper limit of CO_2 emissions is set (Figure 1-7-1 shows an image).

Expanding the scale of business is an extremely important activity for ensuring the continued existence of a business, but it also becomes a very vexing issue when we also have to reduce CO_2 emissions. In the manufacturing industry in particular, even just achieving the reduction targets for 2030 will require the realization of quite fundamental and innovative changes to manufacturing processes, as well as the introduction of natural energy power generation

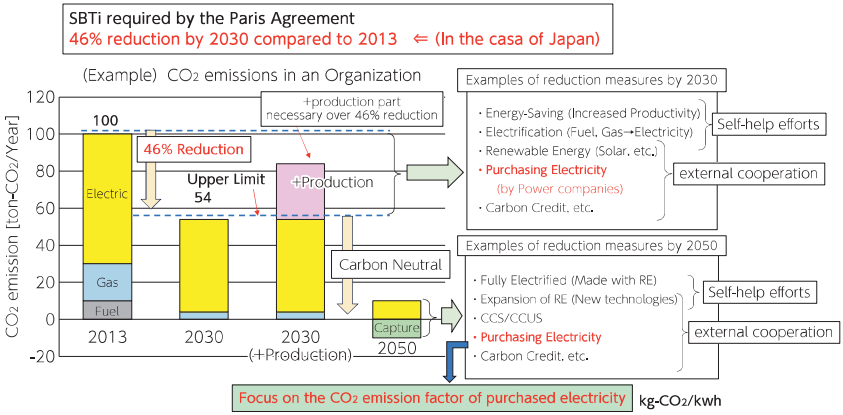

Figure 1-7-1 Scenarios of reducing CO_2 emissions

3) The Science Based Targets initiative (SBTi): Greenhouse gas reduction targets for companies that are consistent with the standards required by the Paris Agreement. The aim is to keep the rise in global temperatures well below 2°compared to pre-industrial levels and to limit it to 1.5°C. All countries submit and update their reduction targets every five years.

equipment such as solar power generation. This would require a large amount of capital investment and labor, and even if it were implemented, there would probably be cases where the target would not be reached.

As a proposal for reducing the amount of CO_2 emissions that have not been achieved, there are measures such as purchasing electricity with a low CO_2-EF generated by power companies, etc., using natural energy and RE. For companies, the value of the CO_2-EF will become a very important indicator because it allows them to reduce CO_2 emissions without having to make any investment themselves. This CO_2-EF differs depending on the energy mix of each country and region and to develop CO_2 emission reduction in the future, it is considered to be very important to understand the current situation and future trends.

2. Verifying of the Relationship between the Energy Mix and the CO_2-Emission Factor

When expanding business by establishing new bases overseas, in the past, the main focus was on "costs and market conditions," with locations chosen where labor costs, electricity costs, etc. were cheaper than in Japan. However, as already mentioned, reducing CO_2 emissions is now becoming one of the important issues to be addressed. If production in Japan is reduced by moving bases from Japan to overseas, CO_2 emissions in Japan will be reduced. However, the CO_2-EF of the relocated base is also important, because if the CO_2-EF of the relocated base is higher than that of Japan, the CO_2 emissions will increase. This section focuses on this issue.

In this section, we will first examine the relationship between the current energy mix and CO_2-EF in various countries around the world, to verify how the current situation and future energy policies in each country will affect the CO_2-EF when expanding to new bases in major ASEAN countries (Indonesia, Vietnam, Malaysia, Thailand) and India.

Table 1-7-1 shows the CO_2-EF obtained from the International Energy Agency (IEA) and the energy mix of various countries (31 countries in this section) obtained from the Energy Institute, as well as the fuel ratios such as the non-fossil fuel ratio (Non-FFr) and the coal ratio calculated from the energy mix. The data is as for 2021. Based on Table 1, the relationship between the Non-FFr and the CO_2-EF is shown in Figure 1-7-2.

Looking at the graph in Figure 1-7-2, it can be said that there is a fairly clear relationship between the CO_2-EF and the Non-FFr. Furthermore, taking into account the energy mix, it can be explained as follows.

First, countries with a high CO_2-EF have a low Non-FFr of less than 30%

Table 1-7-1 CO_2 emission factor and energy mix in the World (2021)

Rank	Country	CO_2 Emission Factor [kg-CO_2/kWh]	Electricity Generation [TWh]							
			Coal	Oil	Natural Gas	Nuclear	Hydro	Renew-ables	Other	Total
1	China	0.609	5,329	12	287	408	1,300	1,149	50	8,534
2	US	0.368	978	21	1,698	821	249	622	13	4,401
3	India	0.713	1,274	2	60	44	160	173	1	1,715
4	Russia	0.363	181	8	520	222	215	6	5	1,157
5	Japan	0.463	302	34	326	61	80	136	81	1,020
6	Brazil	0.134	24	20	87	15	363	145	2	656
7	Canada	0.118	34	3	80	92	383	50	5	647
8	South Korea	0.456	212	7	178	158	3	40	4	602
9	Germany	0.347	165	5	90	69	20	214	26	589
10	France	0.052	4	2	35	379	59	61	7	548
11	Saudi Arabia	0.611	0	158	234	0	0	1	0	393
12	Iran	0.482	1	34	291	4	15	2	0	345
13	Mexico	0.407	14	33	189	12	35	47	0	330
14	Indonesia	0.778	190	7	56	0	25	32	0	309
15	Turkey	0.422	103	0	111	0	56	64	0	335
16	UK	0.204	7	2	123	46	5	117	9	309
17	Spain	0.150	6	10	72	57	30	96	5	274
18	Taiwan	0.569	129	5	108	28	3	12	5	291
19	Italy	0.282	16	12	144	0	45	68	3	289
20	Australia	0.649	137	5	48	0	16	61	0	267
21	Vietnam	0.562	114	0	26	0	76	28	0	245
22	South Africa	0.896	206	3	0	12	2	16	5	244
23	Egypt	0.402	0	11	174	0	14	10	0	210
24	Malaysia	0.618	78	1	61	0	31	4	0	175
25	Thailand	0.466	36	1	113	0	5	22	-0	176
26	Poland	0.648	130	2	16	0	2	28	1	180
27	UAE	0.474	0	0	132	11	0	6	0	149
28	Argentina	0.308	2	13	90	10	20	17	1	153
29	Netherlands	0.311	17	1	57	4	0	40	3	122
30	Kazakhstan	0.487	75	0	27	0	9	3	0	115
31	Ukraine	0.289	37	1	10	86	10	11	0	155

Rank	Country	CO_2 Emission Factor [kg-CO_2/kWh]	Energy-Mix [%]						
			Coal	Oil Natural Gas	Non-Fossil Fuels				
					Nuclear	Hydro	Renew-ables	Other	Total
1	China	0.609	62%	4%	5%	15%	13%	1%	34%
2	US	0.368	22%	39%	19%	6%	14%	0%	39%
3	India	0.713	74%	4%	3%	9%	10%	0%	22%
4	Russia	0.363	16%	46%	19%	19%	0%	0%	39%
5	Japan	0.463	30%	35%	6%	8%	13%	8%	35%
6	Brazil	0.134	4%	16%	2%	55%	22%	0%	80%
7	Canada	0.118	5%	13%	14%	59%	8%	1%	82%
8	South Korea	0.456	35%	31%	26%	1%	7%	1%	34%
9	Germany	0.347	28%	16%	12%	3%	36%	4%	56%
10	France	0.052	1%	7%	69%	11%	11%	1%	92%
11	Saudi Arabia	0.611	0%	100%	0%	0%	0%	0%	0%
12	Iran	0.482	0%	94%	1%	4%	1%	0%	6%
13	Mexico	0.407	4%	67%	4%	11%	14%	0%	29%
14	Indonesia	0.778	61%	20%	0%	8%	10%	0%	18%
15	Turkey	0.422	31%	33%	0%	17%	19%	0%	36%
16	UK	0.204	2%	40%	15%	2%	38%	3%	57%
17	Spain	0.150	2%	30%	21%	11%	35%	2%	68%
18	Taiwan	0.569	44%	39%	10%	1%	4%	2%	17%
19	Italy	0.282	6%	54%	0%	16%	24%	1%	40%
20	Australia	0.649	51%	20%	0%	6%	23%	0%	29%
21	Vietnam	0.562	47%	11%	0%	31%	12%	0%	43%
22	South Africa	0.896	84%	1%	5%	1%	6%	2%	14%
23	Egypt	0.402	0%	88%	0%	7%	5%	0%	12%
24	Malaysia	0.618	45%	36%	0%	18%	2%	0%	20%
25	Thailand	0.466	20%	65%	0%	3%	12%	0%	15%
26	Poland	0.648	72%	10%	0%	1%	16%	1%	18%
27	UAE	0.474	0%	89%	7%	0%	4%	0%	11%
28	Argentina	0.308	2%	67%	7%	13%	11%	0%	31%
29	Netherlands	0.311	14%	47%	3%	0%	33%	2%	38%
30	Kazakhstan	0.487	65%	24%	0%	8%	3%	0%	11%
31	Ukraine	0.289	24%	7%	55%	7%	7%	0%	69%

Source: IEA, "World Energy Balances Outlook 2023"; Energy Institute, "Statistical Review of World Energy"

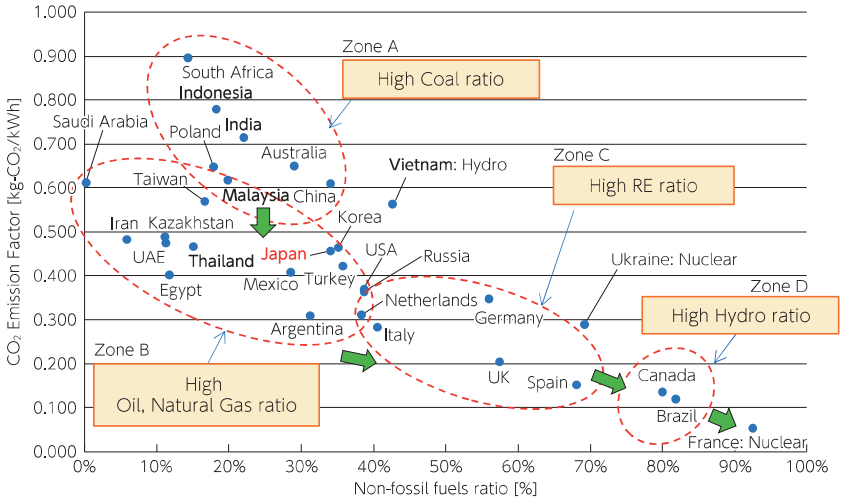

Figure 1-7-2 Relationship between non-fossil fuels ratio and CO_2 emission factor

Source: IEA, "World Energy Balances Outlook 2023"; Energy Institute, "Statistical Review of World Energy"

and a high coal ratio of more than 40%, such as South Africa, Indonesia, India, Australia, Poland, Malaysia, and China, and these are in zone A, whose CO_2-EF is 0.609 to 0.896 kg-CO_2/kWh. Then, countries such as Saudi Arabia, Iran, UAE, Thailand, Egypt, Mexico, and Argentina, which have a similar low Non-FFr but a ratio of oil and natural gas of over 60%, fall into zone B, with a CO_2-EF of 0.308 to 0.611 kg-CO_2/kWh. Next, countries with a high ratio of RE other than hydropower and a Non-FFr of more than 40%, such as Germany, the Netherlands, the UK, and Spain, comprise zone C, with a value of 0.150 to 0.347 kg-CO_2/kWh. As a characteristic example, Canada and Brazil, which are geographically rich in hydroelectric, have a Non-FFr of around 80%, and fall into zone D, with a value of 0.118 to 0.134 kg-CO_2/kWh. Furthermore, France, which has a very high nuclear electric power ratio of 69% and a Non-FFr of 92%, has a much lower value of 0.052kg-CO_2/kWh. There will be some errors that cannot be accurately classified by energy mix alone, depending on the scale and age of power generation equipment in each country, but to a certain extent, this graph reflects the relationships between the breakdown of the energy mix and the CO_2-EF.

3. Estimating the CO_2-Emission Factor

Figure 1-CA-2 shows the relationship between the CO_2-EF and the Non-FFr, and it can be said that it clearly shows the breakdown of the energy mix. To verify the extent to which the breakdown of the energy mix affects the CO_2-EF, we conducted a regression analysis. The explanatory variables are the coal ratio, the oil and natural gas ratio, the RE ratio, and the hydro ratio. As the number of samples for a single year (i.e. the number of countries) is small (31), we decided to use data from the past 10 years (from 2012 to 2021). Table 1-7-2 shows the results of the regression analysis.

Looking at the regression statistics in Table 1-7-2, the multiple coefficient determination R2 value is high at 0.893. Looking at the t-values, the coal ratio is 35.992 and the oil and natural gas ratio is 21.262, so it can be said that these are explanatory variables that have a significant impact on increasing the CO_2-EF. On the other hand, the RE ratio is -2.226, and the hydro ratio is -0.099, and these were explanatory variables that had the opposite effect of reducing the CO_2-EF. Table 1-7-2 can be expressed as an equation as follows.

Table 1-7-2 Regression analysis results using excel

Regression Statistics

Multiple Correlation R	0.945
Multiple Coefficient of Determination R^2	0.893
Adjusted R^2	0.892
Standard Error	0.066
Number of Observations	310

Analysis of Variance (ANOVA)

	Degrees of Freedom	Variation	Variance	Observed F-Ratio	Significance F
Regression	4	11.161	2.790	635.980	0.000
Residual	305	1.338	0.004		
Total	309	12.499			

Coefficients

Variable	Coefficient	Standard Error	t	P-Value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.021	0.022	0.963	0.336	-0.022	0.064	-0.022	0.064
Coal Ratio	0.915	0.025	35.992	0.000	0.865	0.965	0.865	0.965
Oil and Natural Gas Ratio	0.507	0.024	21.262	0.000	0.460	0.554	0.460	0.554
RE Ratio	-0.112	0.050	-2.226	0.027	-0.211	-0.013	-0.211	-0.013
Hydropower Ratio	-0.003	0.032	-0.099	0.921	-0.067	0.061	-0.067	0.061

CO_2-EF Y =

	+0.021	+0.915×C	+0.507×OG	-0.112×RE	-0.003×H	……formula (1)
t	(0.963)	(35.992)	(21.262)	(-2.226)	(-0.099)	

Y: CO_2 emission factor
C: Coal ratio
OG: Oil and natural gas ratio
RE: Renewable energy ratio
H: Hydro ratio

Using Formula (1), the amount of change in the CO_2-EF when each energy ratio is changed is as follows. If the coal ratio is increased by 1%, the change in the CO_2-EF will increase by 0.009, and if the oil and natural gas ratio is increased by 1%, it will increase by 0.005. If the coal ratio is reduced by 5% and that 5% is transitioned to oil and natural gas, the value will decrease by 0.020, and if it is transitioned to RE other than hydropower, the value will decrease by 0.046. The reason why the ratio of RE other than hydropower is negative is that even if the denominator [kWh] increases due to power generation, the CO_2 emissions [kg] in the numerator do not increase, so the CO_2-EF decreases. We can understand the effect of lowering the coal ratio and lowering the CO_2-EF. Based on the model, the following is the case. The factor for the coal ratio is 0.915, and the impact is high. If we use formula (1) to calculate the predicted value for Japan's energy mix in 2021, the CO_2-EF is 0.464 kg-CO_2/kWh. In 2021, if the coal ratio is reduced from 30% to 0%, and the RE ratio other than hydropower increases from 13% to 43%, the amount of change in CO_2-EF is -0.271, and the CO_2-EF could be greatly reduced to 0.193 kg-CO_2/kWh. In Figure 1-7-2, countries with a high proportion of coal also have a high CO_2-EF, so we must first start by transitioning from coal to other fuels.

By substituting the energy mix of each country's future energy policy into this formula (1), we can predict the CO_2-EF in the future.

4. Future Energy Policies in Major Economies

We have gathered information on the future energy policies of various countries that have been announced to date, to the extent that it is available.

In Japan, "The 6th Strategic Energy Plan" was announced in October 2021. If we select the specific figures from this plan, they are as follows. The energy mix for 2030 (ambitious forecast) is 19% for coal, 22% for oil and natural gas, 20-22% for nuclear (21%), and a 36-38% ratio of renewable energy (of this, 11% is

to be hydroelectric power, so the total renewable energy ratio is set at 38%, with 27% being RE other than hydropower).

Regarding India, we have adopted the target of "aiming for a Non-FFr of 50%" announced by Prime Minister Modi at COP28, and have estimated the energy mix as follows. RE ratio to other than hydropower is set at 40%, and the hydro ratio is estimated at the current level of 10%.

India is the third-largest emitter of CO_2 after China and the United States (see Reference Table 1-7-3). At COP28, Prime Minister Modi stated that India's goal of carbon neutrality would be achieved in 2070, not in 2050. As the reason, he stated that India's greenhouse gas emissions are only around 4% of the world's total, so its impact is low, and it may be that they are expressing their intention not to follow the rules made by developed countries that have already achieved economic development. Nevertheless, India has indicated a direction of achieving economic development while reducing CO_2 emissions, so there is a possibility that it could be a new base for overseas expansion.

Concerning Indonesia, we decided to estimate from the graph for 2030 in the "Indonesia Long-Term Strategy 2050 (July 2021)." Indonesia is expected to see an increase in electricity demand due to economic development in the future. It is stated that the increase in demand will be covered by solar power and geothermal power. The only specific measures mentioned are to reduce the coal ratio from 61.6% to around 55% and to convert this to oil. By 2050, the RE ratio will only be able to be increased to 50%, but its policy is to use coal fuel and develop initiatives to reduce CO_2 emissions by utilizing 'carbon capture'[4]. Major companies from around the world are planning to build underground CO_2 storage facilities in Indonesia. Although it is necessary to reduce CO_2 emissions, carbon capture does not emit CO_2 into the atmosphere, so it is important to observe future trends, such as the timing of its practical application and the expected amount of reduction.

Indonesia predicts that the demand for electricity will be six-fold by 2050 compared to 2020 due to economic growth. To ensure that economic development does not grind to a halt while continuing to use fossil fuels to generate electricity, the aim is to achieve carbon neutrality by implementing carbon capture and encouraging foreign investment and the construction of factories in Indonesia.

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4) Carbon capture: Carbon dioxide capture and storage (CCS). A technology that separates and captures only CO_2 from the exhaust gas and stores it in an underground layer that does not allow CO_2 to pass through. CO_2 emissions can be significantly reduced, in addition to carbon dioxide capture, utilization and storage (CCUS), a technology that makes effective use of stored CO_2.

In Vietnam, "The Power Development Plan 8 (PDP 8)" has been issued, but it does not include a description of its energy mix, mentioning only power generation facility capacity composition, so it is not possible to make an accurate prediction. If we read this plan, we can see that Vietnam plans to increase its total power generation capacity by 7 to 9 times compared to 2020 by 2050 due to economic growth, and that it has set a target of completely phasing out coal-fired power generation and increasing the ratio of renewable energy power generation capacity to 70% by 2050, from 28.6% in a 2030 plan. Accordingly, the RE ratio is set at 28.6% (an increase of 15.2% compared to 2022). Furthermore, since the plan is to make up for the shortfall in power generation capacity with imported LNG and reduce the coal ratio, the oil and natural gas ratio is set at 25%, an increase of 14.1% compared to 2022, and the coal ratio is estimated to decrease by 27.4% compared to 2022 to 11.4%, combined with the increase in the RE ratio. The plan is to promote the introduction of offshore wind power and solar power.

In Malaysia, the "Malaysia Renewable Energy Roadmap" published by the Sustainable Energy Development Authority (SEDA) in 2021 describes the energy mix for 2035. It states that the coal ratio will be 18%, the oil and natural gas ratio will be 41%, the hydro ratio will be 18%, and the RE other than the hydro ratio will be 22%. In addition, the National Energy Transition Roadmap (NETR) announced in August 2023 states that carbon neutrality will be achieved by 2050, and as part of this initiative, numerical targets have been set to eliminate oil-fired power generation and increase the RE ratio to 70%.

Although Thailand has also announced its energy policy, we were unable to obtain information that would allow us to predict the future energy mix, so we could not make any predictions for 2030.

5. Summary

(1) The breakdown of energy mix and CO_2-EF are theoretically related to each other. In particular, the coal ratio has a strong impact. The transition from coal to oil and natural gas can reduce CO_2 emissions, which in turn decreases CO_2-EF. In addition, transitioning to renewable energy such as solar and wind can further lower CO_2-EF. In this study, we have estimated a formula that can quantify the impact of this conversion. By understanding the energy policies of each country, it is possible to predict the future trend of CO_2-EF, so we hope that this will be useful as reference data for initiatives to reduce CO_2 emissions when organizations and companies consider expanding their business to major ASEAN countries and India.

(2) The SBTi of the Paris Agreement set 2050 as the target year for carbon

neutrality. For major ASEAN countries and India, efforts to achieve carbon neutrality while prioritizing economic development will be quite a challenge. It is still unclear how much electricity demand can be covered by transition to RE, and when hydrogen and carbon capture will be put into practical use. As we approach 2030, we will see a situation where feasible specific measures and numerical targets are set, so it is necessary to understand the content and timing of the targets to be achieved, and to choose a new base after fully understanding them.

(3) There are also issues in Japan. Among developed countries, Japan has a high coal ratio and a high CO_2-EF. The coal ratio use is to be reduced to 19% by 2030, but even this is higher than the level of developed countries as of 2021. Furthermore, even if the coal ratio use is reduced to 0% and the RE ratio is increased by the same amount in 2050, CO_2 emissions will not reach zero. To achieve the target, it will be necessary to further reduce the oil and natural gas ratio, and to introduce technologies such as carbon capture.

(4) The 2015 Paris Agreement aims to balance global warming countermeasures and economic growth. Most recently, however, generative AI has been exploding around the world, and the amount of power demand in data centers is expected to increase tenfold or one hundredfold in the future due to the "pre-training" of new large language models (LLMs) and the enormous amount of "inference" by individual users. Furthermore, according to the United Nation's "World Population Projections (2024)," the world's population is expected to grow until the mid-2080s, a 26% increase compared to 2024, or a rise of about 2.1 billion. According to an IEA report, renewable energy deployment is expected to expand 10 to 20 times by 2050, compared to 2022. However, this level will not be able to cover the projected electricity demand values due to the economic growth brought about by the increased demand for generative AI and the population growth mentioned earlier. The overall situation has changed significantly from the assumptions set in 2015, and the achievement of the SBTi goal is in considerable jeopardy.

To achieve carbon neutrality and sustainably maintain a livable global environment for the next generation of humankind, it is necessary to develop several new ultra-innovative technologies in addition to the early implementation of new RE and carbon capture technologies.

Table 1-7-3 CO_2 emissions in the World (2023)

Rank 1~25

Rank	Country	CO_2 Emission [Million-ton]
1	China	11,218.37
2	US	4,639.71
3	India	2,814.32
4	Russia	1,614.73
5	Japan	1,012.78
6	Indonesia	701.42
7	Iran	683.64
8	Saudi Arabia	620.41
9	Germany	571.86
10	South Korea	571.22
11	Canada	519.51
12	Mexico	489.87
13	Brazil	451.05
14	South Africa	425.04
15	Turkey	411.10
16	Australia	376.12
17	UK	327.30
18	Vietnam	305.41
19	Italy	301.28
20	UAE	287.17
21	Malaysia	284.66
22	Poland	270.28
23	Thailand	269.71
24	Taiwan	265.52
25	France	254.56

Rank 26~50

Rank	Country	CO_2 Emission [Million-ton]
26	Spain	246.80
27	Egypt	232.08
28	Singapore	224.38
29	Kazakhstan	221.15
30	Argentina	190.92
31	Pakistan	189.56
32	Iraq	168.22
33	Netherlands	156.07
34	Philippines	152.58
35	Algeria	144.67
36	Qatar	132.51
37	Venezuela	120.85
38	Uzbekistan	120.07
39	Bangladesh	118.21
40	Colombia	110.21
41	Ukraine	105.32
42	Belgium	103.28
43	Kuwait	93.94
44	Turkmenistan	93.87
45	Chile	86.48
46	Oman	85.11
47	Czech Republic	82.88
48	Morocco	69.11
49	Hong Kong S.A.R	65.89
50	Israel	65.51

Source: Energy Institute

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