Deloitte.
デロイト トーマツ

The list of technologies aimed at achieving carbon neutrality by 2050

The GX tech List for 2050

Contents

Preface

Introduction

Introduction

On October 26, 2020, the Japanese government declared its intention to reduce overall greenhouse gas emissions to zero by 2050, i.e., to achieve a carbon-neutral, decarbonized society by 2050[*1]. While greenhouse gases include carbon dioxide (hereinafter referred to as CO2), methane, dinitrogen monoxide, and chlorofluorocarbons, CO2 accounts for over 90% of the total amount[*2]. In this series of reports, we target CO2, and focus on technologies that aim to achieve net zero emissions by offsetting CO2 emissions with absorption amounts.

Achieving carbon neutrality by 2050 in Japan calls for practical solutions (pathways) aimed at the social implementation of technologies that contribute to reducing CO2 emissions to net zero. The government plans to achieve this goal in its policies by combining various technologies related to CO2 emission reduction and CO2 absorption, but as this plan takes shape, it will be important to adjust to its progress and make steady and consistent efforts to fine tune the technological development and social implementation led by the public and private sectors.

The Deloitte Tohmatsu Group's science and technology initiative, Deloitte Tohmatsu Science and Technology (hereinafter referred to as "DTST") has attempted to organize technologies that contribute to carbon neutrality by perspectives such as the potential for reducing CO2 emissions, cost for reducing CO2 emissions, and technology readiness, and has prepared a list comparing these factors (hereinafter referred to as the "list of technologies").In the first three versions, we started developing the research methodology, and added the research items and analysis cases while expanding the number of the technologies listed. In the fourth version, we applied a text mining (information extraction) algorithm to the news article data for the purpose of a simple evaluation of the direction of investment and development and compiled the results of calculating the number of articles related to each technology as the relative degree of attention to each technology. We also set search keywords (queries) that characterize each technology, extracted articles highly related to the key words, using the text mining method, and visualized the degree of attention paid to each technology in Japan and foreign countries.

In this report, which is the fifth version, the number of listed technologies has been expanded to 63, and the technological fields have also been expanded, focusing on agriculture and heat utilization of renewable energy.

In addition, to improve the objectivity of the list, the opinions of external experts, mainly university researchers, were reflected for some of the technologies.

In the future, we plan to expand the list by sequentially adding promising technologies, conduct a close examination and periodic review of the data as well as an expert review of each technology, deduct interactions and double-counting among technologies by considering integrated models for each technology, and link the list to each technology player. We hope that the list of technologies will be helpful in the planning of social implementation strategies for technologies aimed at achieving carbon neutrality in Japan, as well as helping companies and local governments consider what to include in their approaches.

Background and objectives

Background and objectives

In recent years, the public and private sectors have been actively working on planning policies and developing technology aimed at achieving carbon neutrality by 2050. However, while there are a wide variety of technologies, no single comparable list can be found that also shows factors such as the potential for reducing CO2 emissions, the costs required from technology development to social implementation, and the current technology readiness level.

In addition, there is also only scattered information on the status of technological development by research institutes and companies, as well as the status of development of legal systems and other frameworks by government agencies. This can be considered a challenge as it inhibits discussions that take the big picture into account, making it difficult to know where to start.

By taking the various technologies aimed at achieving carbon neutrality in Japan, using the same perspectives (e.g., the potential to reduce CO2 emissions) to organize these into a list of technologies, and making this list widely available to society, we hope to make it easier to involve diverse stakeholders and move discussion forward for the social implementation of promising technologies, even if only by one step.

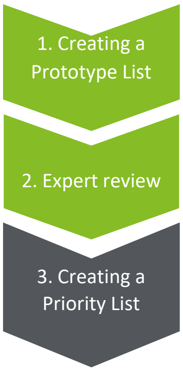
In the future, we will continue to update the list of technologies in order to provide a comprehensive overview of each technology, including not only existing technologies, but also identifying new promising technologies and researching and listing factors such as their potential for reducing CO2 emissions, their estimated cost for reducing CO2 emissions, the number of patents, and the technology readiness based on laws and regulations and so on.

(Note: This list of technologies is provided as a reference which has been calculated based on certain assumptions, and therefore we ask that you do not make decisions based solely on this list. In no event shall we be liable for any damages or failures arising from or in connection with this report, regardless of the reason.)

Procedure for preparing the list of technologies

Design philosophy for the list of technologies

In this report, we assumed the following steps would be used when designing the list of technologies



1. Creating a Prototype List
Open source research on each technology
Unify assumptions, investigate and list each technology based on open source
2. Expert review
Clarification of the numerical basis of each technology by experts in various fields Enhance the survey with the cooperation of technical experts
3. Creating a Priority List
Refinement of the technology list so that each technology can be compared and studied from a bird's-eye view
Create and publish priority lists for social implementation of each technology

Figure 1: Design concept of technical listing

We are currently at the beginning of “2. Expert review.” In this step, the research results of each technology are reviewed by external experts such as researchers, with the aim of refining the technology evaluation methods and reflecting innovative research information.

Procedure for preparing the list of technologies

■ **Gathering candidate technologies to target in research and analysis**

The target technologies were compiled based on the June 18, 2021 version of the Ministry of Economy, Trade and Industry’s “Green Growth Strategy Through Achieving Carbon Neutrality in 2050” [*3], as well as research on technologies in related fields.

■ **Defining the type of technology**

In the list of technologies, we defined three main types of technology for carbon neutrality-related technologies (described below) based on the presence of CO2 emissions during operation and categorized each technology as one of these. Since some of the technologies are used in combination with other types of technology in actual operations, the same technology may be listed in multiple categories depending on what it is.

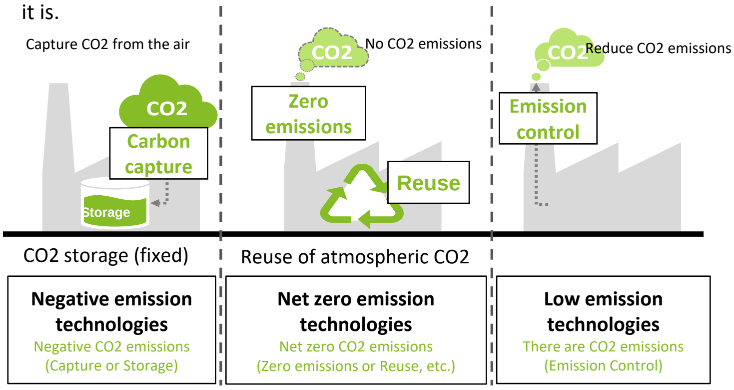


Figure 2: Illustration of each technology type

➢ Negative emission technologies

- We defined technologies that collect or store CO2 from the atmosphere (left side of Figure 2) as negative emission technologies. These are technologies for which emissions are negative due to the collection or storage of CO2; in other words, they are technologies which absorb CO2.
- Examples include DAC (Direct Air Capture) technologies, which directly collect CO2 from the atmosphere, and Carbon dioxide Capture and Storage (CCS) technologies, which store CO2.

➢ Net zero emission technologies

- We defined technologies that do not create new emissions of CO2 into the atmosphere (middle of Figure 2) as net zero emission technologies. These are technologies which do not emit CO2, or that capture CO2 from the atmosphere, etc., and reuse it, resulting in net zero CO2 emissions. Examples include renewable energy sources such as wind power and carbon recycling technologies such as biomass-sourced green LPG.
- We defined technologies that limit the amount of CO2 emitted into the atmosphere (right side of Figure 2) as low emission technologies. These are technologies which emit CO2, but for which the amount of CO2 emitted is limited compared to current technologies.
- Examples include improved efficiency for thermal power plants and technologies for conserving energy by leveraging next-generation automobiles.

■ **Selecting technologies**

The technologies selected were those related to negative emission, net zero emission, and low emission technologies introduced in the "Green Growth Strategy Through Achieving Carbon Neutrality in 2050“, as defined in the definition of technology type on the left column. Achieving carbon neutrality calls for combining negative emission technologies, net zero emission technologies, and low emission technologies in order to reach a total of zero CO2 emissions (Figure 3). Consequently, from among these technologies, we selected technologies that were considered major and that are researchable as the targets of our research in part two.

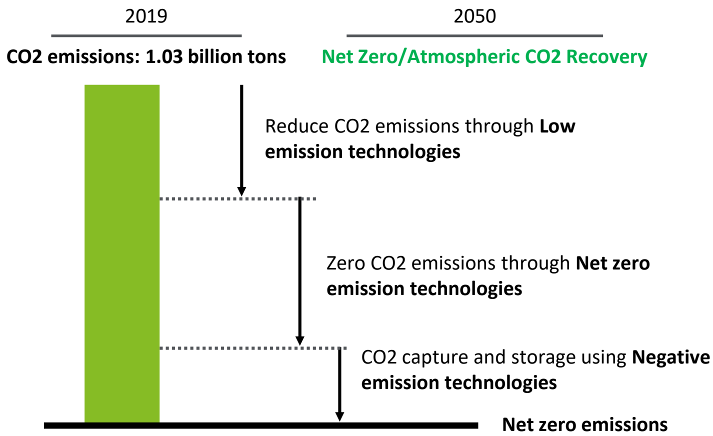


Figure 3: Japan's Vision for 2050 (Image of net zero emissions)

■ **Analysis items for target technologies**

We defined the following four items as items to include in the list of technologies.

➢ Amount of reduced CO2 emissions

- We assumed a case where all instances of the current technology are replaced with the new technology, and estimated the amount of reduced CO2 emissions as the potential amount of CO2 emissions that could be reduced. This is shown as the annual amount of reduced CO2 emissions, and is expressed in units of 1,000,000 t-CO2 / year.

➢ Cost for reducing CO2 emissions

- This indicates the cost needed to reduce CO2 by one ton using each technology, and is expressed in units of thousands JPY / t-CO2.

➢ Number of patents

- This indicates the number of technology patent applications filed worldwide related to each technology, and is expressed in units of cases.
- We performed research on the number of patents using the search conditions in Table 1.

Table 1: Search conditions for investigating the number of patents

Database	Derwent Innovation [*4]
Survey target country	All countries covered by Derwent Innovation, including Japan, the United States, Europe, and the major countries in the region (more than 90 countries)
Search expression	International Patent Classification (IPC) for the art, established using technical keywords relating to the art

➢ Technology Readiness Level

- This indicates the current achievement level for each technology. For the technology readiness level, we referred to the definitions in the "Technology Readiness Level Definitions" released by the National Institute of Advanced Industrial Science and Technology (AIST) (Table 2) *[5, 6].
- In the list of technologies we published in version one, we used an eight-level scale for technology readiness level (hereinafter referred to as "TRL") conforming with the TRL definitions released in the Ministry of the Environment's "Manual for Using TRL Calculation Tools", however, a nine-level TRL scale is widely used globally, so we decided to use a nine-level TRL scale.

Table 2: List of technology readiness level definitions in the list of technologies

Level	Definition	Phase
9	Start of mass production	Later stage of research
8	Implementation of pilot line	
7	Top user test (system level)	
6	Demonstration/prototype model (system level)	
5	Laboratory test (elemental technology stage)	Early stage of research
4	Applied development (elemental technology stage)	
3	Confirmation of technical concept	
2	Extension of principles and phenomena	Basic Research
1	Discovery of basic phenomena and development of prototype devices	

Source: AIST*[5, 6]

■ **Information sources**

In order to organize each technology based on objective information in our research of them, we utilized the following types of information sources.

➢ Materials released by the government, public institutions, etc.

➢ Materials released by research institutions such as universities and research centers

➢ Materials released by companies that possess the technologies

■ **Evidence types**

The evidence for each information source was categorized into the following four types (Table 3). This list of technologies was prepared based on information sources falling into Evidence Types I to III as displayed in Table 3.

We prepared this list of technologies to be used with the aim of achieving carbon neutrality in Japan, and we would like to continue to take Japan's unique circumstances into account. For example, there are cases where the

same product's CO2 emissions in its Life Cycle Assessment (hereinafter referred to as "LCA") may differ depending on the CO2 emissions of the energy source(i.e., electricity) used in manufacturing it. In the future, we would also like to factor in the impact on profitability from Japan's unique laws and regulations, real estate conditions, and other business conditions.

Because of this, we have made it our policy to use data sets from within Japan as much as possible.

Table 3: Evidence Types

No.	Evidence type	Overview
I	Datasets in Japan	Information sources from demonstration experiments in Japan
II	Datasets in foreign countries	Information sources from demonstration experiments in foreign countries
III	Papers	Information sources from papers

■ **Assumptions and constraints in the estimation of amount of reduced CO2 emissions and the cost for reducing CO2 emissions**

In estimating the amount of reduced CO2 emissions and the cost for reducing CO2 emissions in Japan, there are various constraints such as the type and amount of data that can be utilized and differences in the assumptions in each information source. Consequently, we performed the estimate by aligning the assumptions as shown below, and with the recognition that constraints were present.

➢ About the target period

- We assumed a case where all instances of the current technology are replaced with the new technology by 2050 and estimated the potential amount of reduced CO2 emissions.

➢ About the amount of reduced CO2 emissions

- The amount of reduced CO2 emissions is the potential amount that indicates the degree to which CO2 emissions could be reduced in 2050. We calculated this by assuming that all current demand and supply would change over to the new technology and that it could be used to its maximum potential. We do not estimate or consider the demand or supply amounts for 2050.
- For our calculation of the amount of reduced CO2 emissions, we did our best to consider the entire product life cycle (LCA) spanning the procurement of raw materials for a product to the product's disposal, etc., when comparing current technologies with new technologies.
- For the amount of reduced CO2 emissions, we did not considerdouble counting with other technologies.

➢ About the cost for reducing CO2 emissions

- For our calculation of the cost for reducing CO2 emissions, we used the costs for reducing CO2 emissions and technology introduction/operation costs (technology development costs were not included).
- For our calculation of the cost needed in the introduction/operation of technologies, we used open-source data if any was available, and in cases where we deemed this to be insufficient at the present time, we based the calculation on similar case studies, etc. In cases where there were no similar case studies, etc., we made an estimate using several researchable figures
- For the useful life, we used the information that was available, if any, and if no information was available, we uniformly assumed the useful life to be 20 years.

➢ About the granularity of the technologies

- While there is almost no limit to how fine the granularity used to classify technologies can be (e.g., materials and methods used, operating conditions), setting a granularity level so fine that data cannot be found for it inhibits the creation of the list itself, so we limited ourselves to the level of general technical names.

➢ About cannibalization between technologies and double counting

- We decided not to consider cannibalization between related technologies, such as a decline in the share of one technology as another technology grows.

➢ About the overall numerical results of the calculations and TRL validity

- While we understand that there are many cases where opinions differ according to the expert and the granularity of the technology, it is impossible to make comparisons without making calculations or evaluations based on the data, regardless of these potential differences. As such, priority was given to including a wide range of data rather than pursuing validity.
- However, in making the calculations and evaluations, a multilayered confirmation process was used, in which multiple DTST professionals with backgrounds in science and technology reviewed a single technology to cross-check the validity of the calculation, the basis of the values, and the calculated figures. This entire process was then confirmed by an overseer.
- Furthermore, multiple Deloitte Tohmatsu Group professionals from a different firm than the working members of this report performed further reviews on the entirety of this report.

List of technologies (prototype) - 1/2

About the list of technologies

The fifth version of the list of technologies lists 63 technologies (Table 4, Table 5, and Table 6).
The results of this research were calculated by DTST professionals with backgrounds in science and technology based on the “procedure for preparing the list of technologies" described on a previous page, but these results are only an example calculated using one of numerous possible calculation methods.

Table 4: Technical list for negative emissions

No.	Technical solution	Reduction in CO2 emissions [1 million t-CO2/year]	Cost of reducing CO2 emissions [1,000 JPY/t-CO2]	Number of patents	Technology Readiness Level	Evidence type
1	CO2 fixation by spreading of elite trees	250	(Under investigation)	(Under investigation)	8	Datasets in Japan[*7–*13]
2	BECCS (Bioenergy with carbon capture and storage)	93	2.8	(Under investigation)	7	Datasets in foreign countries[*262–*264]
3	Carbon negative concrete	30	410	1,879	7	Papers[*3, *14–*17]
4	CO2 fixation by input of biochar in farmland	7.6	190	(Under investigation)	7	Datasets in Japan[*18–*25]
5	Utilization of blue carbon in shallow coastal ecosystems[**1]	7.5	540	(Under investigation)	8	Datasets in Japan[*28–*30]
6	Separation and compression of CO2 by membrane separation, chemical and physical absorption	3.8–7.7	7.0	7,029	4	Papers[*26–*27]
7	CO2 recycling by microorganisms	0.18	(Under investigation)	916	4	Datasets in Japan[*31–*32]
8	DAC: Direct Air Capture (until separation/capture)	(Under investigation)	44	(Under investigation)	6	Datasets in Japan[*33–*37]

Table 5: Technical list for net zero emissions

No.	Technological solution		Reduction in CO2 emissions [1 million t-CO2/year]	Cost of reducing CO2 emissions [1,000 JPY/t-CO2]	Number of patents	Technology Readiness Level	Evidence type
9	Offshore wind power generation	Fixed type	500	23	11,119	9	Datasets in Japan[*38–*42]
		Floating type	(Under investigation)	(Under investigation)	(Under investigation)	7	
10	Commercial solar power generation		480	13	45,351	9	Datasets in Japan[*39–*44]
11	Onshore wind power generation		440	25	(Under investigation)	9	Datasets in Japan[*39–*42, *45]
12	Residential solar power generation		170	14	45,351	9	Datasets in Japan[*39, *41, *42, *44, *46]
13	Nuclear fusion reactor		140	(Under investigation)	(Under investigation)	2	Papers[*39, *47–*57]
14	High-temperature gas cooled reactor (only for power generation)		130	11	(Under investigation)	3	Papers[*39, *47, *55, *58–*65]
15	Fast reactor		130	550	(Under investigation)	5	Datasets in Japan[*39, *40, *47, *55, *66–*71]
16	Small modular reactor (SMR)		130	(Under investigation)	(Under investigation)	6	Papers[*39, *40, *47, *55, *72–*77]
17	Hydrogen boiler		130	170	(Under investigation)	8	Datasets in Japan[*78–*88]
18	Co-firing of ammonia in coal fired thermal power generation		124	22	481	5	Papers[*41, *94–*96]
19	Hydrogen power generation	Reverse shift reaction + FT synthesis	110	320	855	5	Datasets in foreign countries[*89–*93]
		Methanol synthesis + MTG	(Under investigation)	(Under investigation)	(Under investigation)	8	
20	Hydrogen power generation	Co-firing	(Under investigation)	(Under investigation)	(Under investigation)	7	Datasets in Japan[*39, *78, *97–*99]
		Single firing	88	(Under investigation)	704	6	
21	Geothermal power generation		64	17	1,655	8	Datasets in Japan[*39–*42, *100,*101]
22	Water electrolysis equipment		50	19	(Under investigation)	6	Datasets in Japan[*35, *78–80, *102–104]
23	LCCM housing		51	(Under investigation)	(Under investigation)	6	Datasets in Japan[*-105*108]
24	Plastic raw material (olefin) by artificial photosynthesis		45	343	(Under investigation)	4	Papers[*109–*117]
25	ZEH (for single houses)		39	43	(Under investigation)	6	Datasets in Japan[*106, *108, *118–*120]
26	Synthetic methane		33–36	50–56	433	6	Papers[*35, *46, *121–*124]
27	Small and medium hydroelectric power generation		36	12	(Under investigation)	9	Datasets in Japan[*39–*42, *125]
28	ZEB		32	210	(Under investigation)	6	Datasets in Japan[*118, *126–*130]
29	SAF (Sustainable Aviation Fuel)	HEFA	(Under investigation)	(Under investigation)	(Under investigation)	8	Datasets in Japan[*131–*135]
		FT-SPK	31	(Under investigation)	(Under investigation)	7	
		SIP-HFS	(Under investigation)	(Under investigation)	(Under investigation)	6	
		ATJ-SPK	(Under investigation)	(Under investigation)	(Under investigation)	6	
30	Ocean thermal energy conversion		24	56	(Under investigation)	6	Papers[*39, *40, *136–*139]
31	Ammonia-fuelled ship		22	(Under investigation)	(Under investigation)	4	Papers[*140–*149]
32	Hydrogen cogeneration (single firing)		22	(Under investigation)	(Under investigation)	2	Datasets in Japan[*150–*156]
33	Tidal power generation		13	82	(Under investigation)	6	Papers[*39, *40, *136, *137, *157–*162]
34	Fuel conversion (utilization of biomass for the heat source for the paper industry)		13	140	(Under investigation)	9	Datasets in Japan[*39, *40, *163–*171]
35	Renewable energy thermal utilization	Geothermal heat utilization[**2]	12	170	(Under investigation)	9	Datasets in Japan[*278–*287]
36		Solar heat utilization	10	298	(Under investigation)	9	Datasets in Japan[*267–*277]
37	Bioplastic (limited to microbial production)		10	410	1,879	8	Datasets in Japan[*3, *172–*177]
38	Wave power generation		9.1	67	(Under investigation)	6	Papers[*39, *40, *136, *137, *178–*180]
39	CO2 reduction through the spread of wooden high-rise buildings		6.0	(Under investigation)	(Under investigation)	7	Datasets in Japan[*181, *182]
40	Carbon capture at waste disposal facilities		3.3	29	(Under investigation)	6	Papers[*183, *184]
41	Biogas production		2.8	9.2	108	5	Datasets in Japan[*185–*189]
42	Development/introduction of crops with high CO2 fixation capabilities[**3]		2.5	70	(Under investigation)	7	Datasets in Japan[*265, *266]
43	Renewable energy thermal utilization	Snow-and-ice cryogenic energy	1.8	237	(Under investigation)	9	Datasets in Japan[*288–*292]
44	FC Bus		1.5	580	2,993	8	Datasets in Japan[*58, *90, *152, *190–*200]

[**1] Cost for reducing is based on the case where a new absorber is constructed using steel slag. If no new absorbers are created, only maintenance and management costs will contribute to CO2 reduction.
[**2] The scope of calculation is based on the use of heating for single houses.
[**3] The scope of calculation is based on the use of heat from pellets made from erianthus.

(Note: The values in the list of technologies have been calculated based on certain assumptions, and they are provided as a reference, therefore we ask that you do not make decisions based solely on this list. In no event shall we be liable for any damages or failures arising from or in connection with this report, regardless of the reason.)

List of technologies (prototype) - 2/2

About the list of technologies

The fifth version of the list of technologies lists 63 technologies (Table 4, Table 5, and Table 6).
The results of this research were calculated by DTST professionals with backgrounds in science and technology based on the “procedure for preparing the list of technologies" described on a previous page, but these results are only an example calculated using one of numerous possible calculation methods.

Table 6: List of technologies related to low emissions

No.	Technological solution		Reduction in CO2 emissions [1 million t-CO2/year]	Cost of reducing CO2 emissions [1,000 JPY/t-CO2]	Number of patents	Technology Readiness Level	Evidence type
45	Electric car		96	130	28,431	9	Datasets in Japan[*90, *152 *198, *201–*205]
46	High-efficiency heat pump[**1]		51	293	(Under investigation)	9	Datasets in Japan [*46,*297–*315]
47	Natural refrigerant		49	220	(Under investigation)	9	Papers[*206–*218]
48	Gas cogeneration		14	79	(Under investigation)	9	Datasets in Japan[*150–*154, *219–*222]
49	Blast furnace hydrogen reduction ironmaking		11	(Under investigation)	(Under investigation)	5	Datasets in Japan[*223–*227]
50	Stationary fuel cell		6.5	180	(Under investigation)	9	Datasets in Japan[*78, *97, *195, *228–*231]
51	Microwave heating		5.6	(Under investigation)	(Under investigation)	8	Datasets in Japan [*316–*323]
52	LNG fuelled ship		4.8	39	48	8	Papers[*140–*144, *232–*235]
53	Waste power generation		3.6	110	(Under investigation)	9	Datasets in Japan[*236–*238]
54	Extension of mid-drying period for wet-rice cultivation (methane emission control)		3.6	0	(Under investigation)	9	Datasets in Japan [*334–*337]
55	Fuel cell ship		3.5	220	539	7	Papers[*146, *195, *223, *239–*245]
56	Methane emission control (feeding)[**2]	3NOP	2.9	32	(Under investigation)	7	Datasets in Japan [*324–*333,*338–*340]
		Microalgae *Euglena* / seaweed *Kagikenori* feeding	(2.9)	(129)	(Under investigation)	3	
		Feeding cashew nut shell liquid to cattle	(1.5)	(76)	(Under investigation)	7	
57	Electric ships		2.9	100	49	8	Papers[*243–*252]
58	Change in livestock waste management methods (methane emission control)		2.5	61	(Under investigation)	9	Datasets in Japan[*327,*328,*341–*345]
59	Composite materials (for passenger cars)[**3]		1.8	(Under investigation)	(Under investigation)	3	Datasets in Japan[*293, *294]
60	Renovation of existing buildings		1.2	(Under investigation)	(Under investigation)	6	Datasets in Japan[*253–*255]
61	Amino acid balance improved feed (N2O emission control)		0.26	(Under investigation)	(Under investigation)	9	Datasets in Japan[*327, 328, 342, 343, *346-*350]
62	Changing in streetlights to LED		0.13	93	(Under investigation)	9	Datasets in Japan[*256, *257]
63	Composite materials (for aircrafts)[**3]		0.09	(Under investigation)	(Under investigation)	5	Datasets in Japan[*295, *296]

[**1] The calculation of CO2 emissions reductions for both the consumer and industrial sectors includes both the electrification of thermal sources and efficiency improvements through the renewal of heat pumps.
[**2] Technologies to control methane emissions in livestock feeding are treated as a whole (3NOP is used as a representative value).
[**3] The amount of CO2 reductions is calculated by assuming the effect of improved fuel efficiency resulting from reduction of moving weights.

(Note: The values in the list of technologies have been calculated based on certain assumptions, and they are provided as a reference, therefore we ask that you do not make decisions based solely on this list. In no event shall we be liable for any damages or failures arising from or in connection with this report, regardless of the reason.)

Example calculation

About example calculations

CO2 emission reductions from carbon negative concrete and biomass-sourced LP gas production are presented as examples of how to estimate the emission reductions for each technology in the list of technologies in this report. In the calculations for each technology, we used publicly available information sources (carbon negative concrete[*3, *14–*17] and biomass-sourced LP gas production[*185–*189]).

Example calculation 1 for amount of reduced CO2 emissions

The following assumed values were used in the specific estimation method and estimate of the amount of reduced CO2 emissions from carbon-capturing concrete. (Formula 1 and Table 7).

Equation 1: Equation used to estimate used to estimate CO2 emission reduction of carbon negative concrete

CO2 emission reduction = (CO2 emissions from existing Technologies – CO2 emissions from new technologies) x (Domestic shipments of ready-mixed concrete)

Table 7: Assumptions used in the estimation of CO2 emission reduction of carbon negative concrete

Items	Value	Remarks
CO2 emissions from existing technologies	330 [kg/m ^ 3]	This value is the maximum value of CO2 emissions from ordinary concrete listed in the development of carbon recycled concrete "T-eConcrete ®/Carbon-Recycle" announced by Taisei Corporation[*29] .
CO2 emissions from new technologies	-55 [kg/m ^ 3]	This value is the maximum value of CO2 emissions from CO2 absorbing concrete listed in the development of carbon negative concrete "T-eConcrete ®/Carbon-Recycle" announced by Taisei Corporation[*29] .
Domestic shipments of ready-mixed concrete	79 million [m ^ 3/year]	This value is the value of the demand forecast for ready-mixed concrete in FY 2020 in the FY 2020 Major Construction Materials Demand Forecast Report by the Ministry of Land, Infrastructure, Transport and Tourism[*30] .

Example calculation 2 for amount of reduced CO2 emissions

The following assumed values were used in the specific estimation method and estimate of the amount of reduced CO2 emissions from biomass-sourced green LP gas production. (Formula 2
and Table 8).
Green LP gas manufactured from biogas is carbon neutral, and we assumed that if all LP gas obtained from fossil fuels was replaced by biogas-sourced LP gas, the CO2 emissions would be reduced by that amount.

Equation 2: Equation used to estimate used to estimate CO2 emission reduction of biomass-sourced green LP gas production

Reduction in CO2 emissions = CO2 emissions from existing LP gas
= （CO2 emissions in LCA per unit of existing LP gas） × （DME ※3 generation potential ）

（DME formation potential） = （potential amount of available biogas） × （DME formation amount per unit biogas amount）

※3 DME：Di-Methyl Ether（dimethyl ether） ：A combustible gas that can be treated in the same manner as LP gas

Table 8: Assumptions used to estimate CO2 emission reductions for the production of green LP gas by biomass

Items	Value	Remarks
Potential amount of biogas available	1,600 million [m ^ 3/year]	This value is the sum of the potential methane production for each waste product multiplied by the utilization potential in the materials on reducing the carbon content of LP gas by mixing DME by the Japan LP Gas Association (March 25, 2021)[*107] and the situation data on biomass utilization by the the Ministry of Agriculture, Forestry and Fisheries[*108].
Amount of DME produced per unit biogas	5.1 [t-DME/10,000 m ^ 3]	This value is annual DME production volume divided by raw material biogas volume. Annual DME production volume was calculated from the plant scale and annual working days of the workshop report on green LP gas production technology development by the Japan LP Gas Association (May 12, 2021)[*106].
CO2 emissions per unit of existing LP gas in LCA	3.3 [t-CO2/t-LPG]	This value is the value of LP gas in carbon dioxide emission intensity by energy in the LP gas reading book by the Japan LP Gas Association[*110].

Reflecting the opinions of external experts

About reviews by academia

In the technological researches listed below, opinions of experts from universities, companies, and other organizations with knowledge of technologies were incorporated to improve objectivity and to reflect the latest findings in the relevant field. In reflecting their opinions, we shared the estimation methods and references shown on the next page with them, and had them review the validity of the values based on the latest case studies and information.

Table 9: Items reflecting opinions from external experts in the list of technologies

Technological solution	Items reflected in the list of technologies
Offshore wind power generation (Fixed type)	• Updated the calculation of CO_2 reduction costs using the values in the latest literature (26 → 23 [thousand JPY / t-CO2]) • Updated the TRL from 6 to 7
Onshore wind power generation	• Updated the calculation of CO_2 reduction costs using the values in the latest literature (22 → 24.6 [thousand JPY / t-CO2])
Commercial solar power generation	• Updated the calculation of CO_2 reduction costs using the values in the latest literature (16 → 13.1 [thousand JPY / t-CO2]) • Since solar power generation cannot be a base-load power source, there are restrictions on the amount of power that can be introduced without combining it with other power sources such as storage batteries. The current CO_2 reduction cost estimates do not include the cost of storage batteries, and it should be noted that solar power generation, which as a CO_2 reduction potential of 170 [million t-CO2 / year], cannot be introduced at a cost of 13.1 [thousand JPY / t-CO2].
Residential solar power generation	• Updated the calculation of CO_2 reduction costs using the values in the latest literature (15 →13.6 [thousand JPY / t-CO2]) • Since solar power generation cannot be a base-load power source, there are restrictions on the amount of power that can be introduced without combining it with storage batteries, and others. It should be noted that the current CO_2 reduction cost estimates do not include the cost of storage batteries, and that solar power generation, which as a CO_2 reduction potential of 170 [million t-CO2 / year], cannot be introduced at a cost of 13.6 [thousand JPY / t-CO2]. • According to the literature*, the introduction potential of residential solar power generation is estimated to be 47.1 to 137.3 [billion kWh/year], taking business feasibility into account, with the CO_2 reduction potential of about 31 to 91 [million t-CO2 / year]. *Japan's renewable energy introduction potential (introduction summary) Ver. 1.0, April 2022, Ministry of the Environment
Geothermal power generation	• In the reduction potential, the amount of CO_2 contained in steam was considered according to the greenhouse gas inventory. • Updated the calculation of CO_2 reduction costs (14 → 16.5 [thousand JPY / t-CO2]) (cost increase due to decrease in reduction potential by taking steam into account). • Updated the TRL from 9 to 8
Stationary fuel cell	• Nothing in particular.
Water electrolysis equipment	• Revised the CO_2 emission factor of new technology, considering the CO_2 emissions related to plant constructions (0.00 → 18.25 [g-CO2/MJ]) • Based on the above, updated the amount of reduced CO_2 emissions (72 → 50 [million t-CO2 / year]) • Updated the TRL from 3 to 6
Co-firing of ammonia in thermal power generation by coal	• Updated the calculation of the amount of reduced CO_2 emissions using the values in the latest literature (100 → 124 [million t-CO2 / year]) • Updated the calculation of CO_2 reduction costs for the following reasons (20 → 22 [thousand JPY / t-CO2]) (1) Updated the calculation of CO_2 reductions (2) Updated the capital investment and operating costs
Electric car	• Updated some parameters • Based on the above, updated the CO_2 reduction potential (95 → 96 [million t-CO2 / year]) • Updated the calculation of CO_2 reduction costs for the following reasons (170 →130 [thousand JPY / t-CO2]) (1) Updated the calculation of CO_2 reductions (2) Updated some parameters (3) Revised operating costs to be consistent with other technologies (excluded insurance premiums to be consistent with FCVs)
FC Bus	• The calculation method of CO_2 reduction cost is consistent with that of other technologies (BEVs). However, the figures for FC Bus remain unchanged.
Utilization of blue carbon in shallow coastal ecosystems	• Updated the name of technology (Blue carbon using steel slag → Utilization of blue carbon in shallow coastal ecosystems) • The amount of CO_2 reduction has been updated from a method of subtracting the current 2019 value from 2030 value to a method not subtracting the current value (3.4 → 7.5 [million t-CO2]) • We noted that the cost for reducing is based on the case where a new absorber is constructed using steel slag, and that if no new absorbers are created, only maintenance and management costs will contribute to CO_2 reduction.
SAF (Sustainable Aviation Fuel)	• Updated the TRL from 5 to 6
Synthetic fuels (alternative to gasoline)	• There are no changes in reduction potential and costs. • Updated the TRL from 6 to 5. Since the TRL varies depending on the fuel production method, it is subdivided and shown for each production method.
Synthetic methane	• Updated the calculation of CO_2 reduction potential considering the following two points (37 → 33 to 36 [million t-CO2 / year]) (1) Baseline and boundary were aligned (2) Methane yield during methane synthesis reaction is considered • Updated the CO_2 reduction cost according to the above (49 → 50 to 56 [thousand JPY / t-CO2])
Plastic raw material (olefin) by artificial photosynthesis	• Re-estimated the CO_2 reduction cost to include the methanol production process (370 → 343 [thousand JPY / t-CO2]) • Updated the TRL from 5 to 4
DAC: Direct Air Capture (until separation/capture)	• The following notes were added regarding CO_2 reduction potential and CO_2 reduction costs. • CO_2 reduction potential: It should be noted that this estimation is for centralized DACs, but the potential could be larger if decentralized DACs are also considered. • CO_2 reduction costs: It should be noted that this estimation assumes CO_2 absorption in alkaline solution, but other literature reports the costs to be around 100 to 1,000 [USD/t-CO2] (13,000 to 130,000 [JPY/t-CO2] @130 [JPY/USD]), and that there is a considerable range depending on the elemental technologies.
Separation and compression of CO_2 by membrane separation, chemical and physical Absorption	• Updated the calculation of CO_2 reduction potential using the values in the latest literature (4.9 → 3.8 to 7.7 [million t-CO2 / year]) • Some estimates suggest that the cost of separation/capture in 2050 could be less than 1,000 JPY/t-CO2[*1] or 3,000 JPY/t-CO2 in the future[*2], instead of the current 5,000 to 10,000 JPY/t-CO2. • [*1]: CCS long-term road map study group final summary, March 2023, Agency for Natural Resources and Energy • [*2]: Cost Evaluation of CCS Technology and Deployment Scenarios in Japan, February 2007, RITE

Analysis examples of the list of technologies

Purpose of these analysis examples

While it is assumed that the cost and potential of each technology disclosed in the list of technologies require further revision and discussion, it is also assumed that various insights may be obtained by analyzing the current list of technologies. We envision sharing examples of analysis of data that have been estimated up to this point, obtaining feedback on the analysis methods and insights, and making use of them in the future utilization methods and improvement policies of the technology list.

Analysis example (1): Simple evaluation of investment value by understanding the positioning of each technology using scatter diagrams

The purpose of this analysis is to understand the current positioning of each technology using scatter diagrams and to simply evaluate the direction of investment and development.

Although the data in the list of technologies is used for the analysis, since these data change depending on the renewal period, this evaluation is positioned as a snapshot of the current state of the technology. Please note that the evaluation is subject to change from moment to moment due to the timing of data updates and changes in the evaluation methods of each technology.

- **Analysis scope**

  Among the 63 technologies covered in the list of technologies, 45 technologies are included in this analysis for which the CO_2 emission reduction cost and technology maturity level are known.

- **How to analyze technology overviews**

  A scatter diagram for all 45 technologies is shown in Figure 4, with the following axes:
  - Horizontal axis: technology maturity [level] (~assumed as investment risk)
  - Vertical axis: CO_2 emission reduction cost [thousand JPY/t-CO_2] (~assumed as cost effectiveness)

- **How to organize positioning**

  The following thresholds were set to organize each technology:
  - Horizontal axis: technology maturity: Level 6 or higher
    - To distinguish between technologies that are in demonstration phase or beyond and those that are not (please see Table 2 for details on technology maturity).
  - Vertical axis: CO_2 emission reduction cost: 50,000 JPY/t-CO_2
    - The Net-Zero Emissions Scenario (1.5°C scenario) of the International Energy Agency (IEA) “World Energy Outlook 2021” estimates a carbon price of 250 USD /t-CO_2 in developed countries in 2050.
    - Assuming the final social implementation, to be a reliable investment target, the price would have to be less than 50,000 JPY/t-CO_2, which is about twice of said amount.

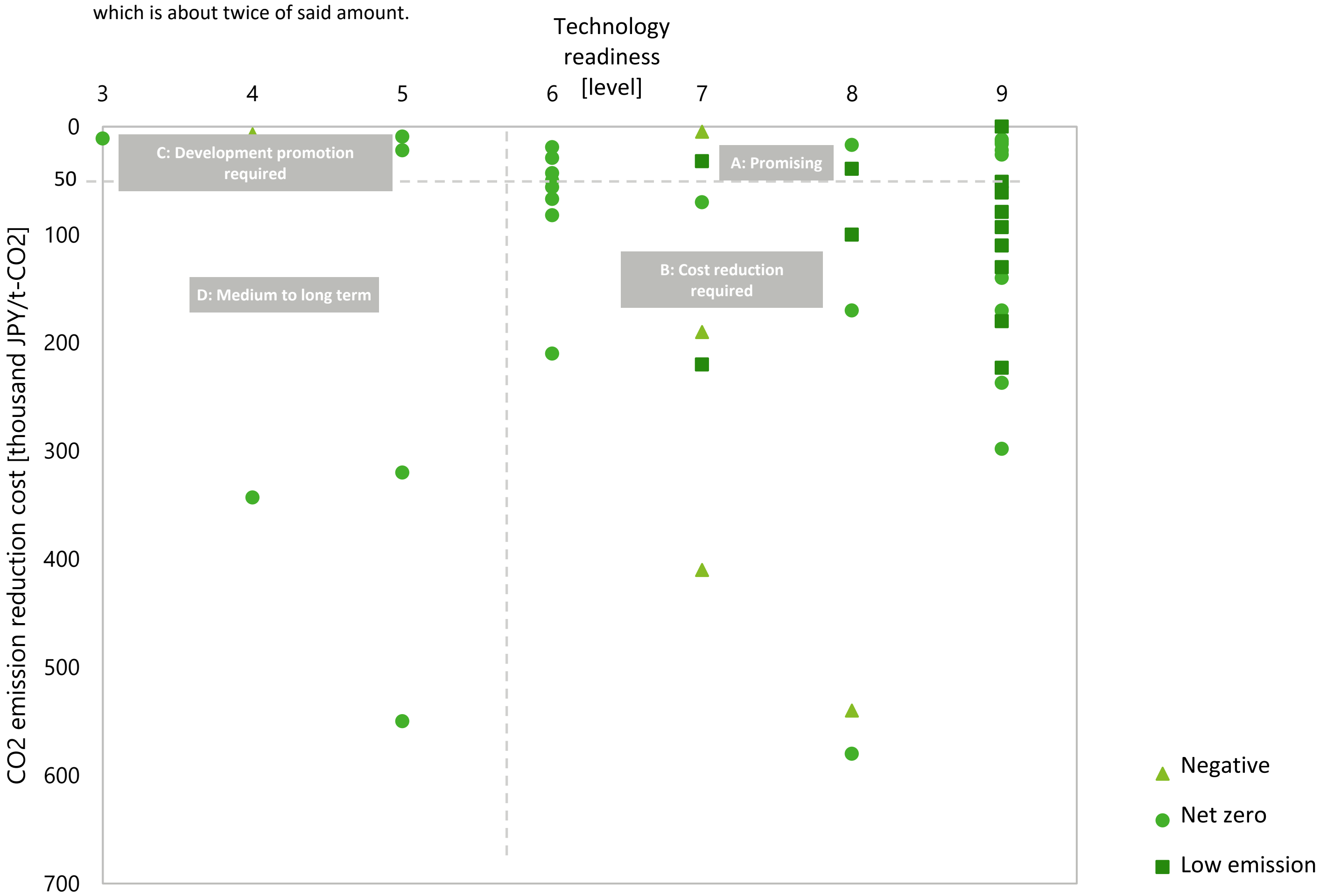


Figure 4: Positioning analysis for each technology overview

Analysis of technology for each position

The technologies are classified as follows according to the thresholds set in the previous section, and a brief thought for each group is added.

A: Promising
B: Cost reduction required
C: Development promotion required
D: Medium to long term

[A: Promising]

This group has already entered the demonstration test level or higher and is a group that is assumed to have some prospects for demonstration in terms of cost. It is believed that prioritizing investment in technologies in this group will lead to more economical and reliable social implementation.

At present, 14 technologies are included in this group. The main characteristic of this group is that most of the technologies are net zero technologies, including renewable energy, which is becoming increasingly popular. Specifically, mature renewable energy technologies such as solar power generation and wind power generation fall into this category, and agriculture related technologies can also be found. Water electrolysis equipment was also moved to this group after a review by external experts raised its TRL.

It should be emphasized once again that even in the technologies included in this group, it is necessary to fully consider the potential and interaction of each technology.

Table 10.1: Candidate list of promising technological solutions

Type of technology (number of subjects)	Technological solution
Negative emission (1)	BECCS (bioenergy with carbon capture and storage)
Net zero emission (10)	Offshore wind power generation (fixed type), commercial solar power generation, onshore wind power generation, residential solar power generation, geothermal power generation, water electrolysis equipment, ZEH (for single houses), synthetic methane, small and medium hydroelectric power generation, carbon capture at waste disposal facilities
Low emission (3)	LNG fuelled ship, 3NOP, extension of mid-drying period for wet-rice cultivation

[B: Cost reduction required]

Although this group has already at the demonstration test level or higher, cost is considered to be the main bottleneck in implementation. This group has the largest number of applicable technologies and is consistent with the general theory that carbon neutral technologies are expensive.

For the technologies included in this group, development of technologies for cost reduction and consideration of mass production may bring them closer to social implementation. At present, 24 technologies are included in this group, which are characterized by a wide variety of negative emission, net zero emission, and low emission technologies.

Table 10.2: Candidate list of cost reduction required technological solutions

Type of technology (number of subjects)	Technological solution
Negative emission (3)	Carbon negative concrete, CO2 fixation by input of biochar in farmland, utilization of blue carbon in shallow coastal ecosystems
Net zero emission (11)	Hydrogen boiler, ZEB, ocean thermal energy conversion, tidal power generation, fuel conversion (utilization of biomass for the thermal source for the paper industry), wave-power generation, FC Bus, solar heat utilization, geothermal heat utilization, snow-and-ice cryogenic energy, development/introduction of crops with high CO2 fixation capabilities
Low emission (10)	Electric car, natural refrigerant, gas cogeneration, stationary fuel cell, waste power generation, fuel cell ship, electric vehicle (storage battery), changing in streetlights to LED, industrial heat pumps, change in livestock waste management methods

[C: Development promotion required]

This group is expected to have a certain level of cost potential, but has a low TRL.

The technologies included in this group are expected to contribute to the achievement of carbon neutrality in a more economical manner by prioritizing and promoting their technological development. At present, this group includes four technologies, most of which are related to alternative fuels.

Table 10.3: Candidate list of development promotion required technological solutions

Type of technology (number of subjects)	Technological solution
Negative emission (1)	Separation and compression of CO2 by membrane separation, chemical and physical absorption
Net zero emission (3)	High-temperature gas cooled reactor, co-firing of ammonia in thermal power generation by coal, biomass-sourced LP gas production

[D: Medium to long term]

This group is assumed to be difficult to implement in society at this point due to both cost and TRL.

For the technologies included in this group, It is assumed that it will be important to assess the development status from a medium-to long-term perspective, rather than considering social implementation on a short-term basis.

At present, this group includes three technologies, and further development and data release are expected.

Table 10.4: Candidate list of medium to long term technological solutions

Type of technology (number of subjects)	Technological solution
Net zero emission (3)	Synthetic fuels (alternative to gasoline), fast reactor, plastic raw material (olefin) by artificial photosynthesis

Analysis examples of the list of technologies (Advanced Natural Language Processing)

Analysis example (2): Visualization of the attention level of each technology using information retrieval algorithms

- **Outline**

The purpose of this analysis is to calculate the degree of attention paid to each technology in various news reports by applying a text mining (information extraction) algorithm, and to make a simple evaluation of the direction of investment and development.

The number or articles related to each technology in the news article data is considered here as a relative degree of attention to each technology. The list of technologies includes technologies with both low and high readiness. It is necessary to have data sources with excellent real-time and comprehensive information to grasp the trends of R&D and social implementation initiatives that change day by day. In light of this point, the analysis has utilized news article data as its data source, which is superior in terms of real-time information and comprehensiveness compared to conventionally used financial information, and has been increasingly utilized in recent years, especially for investments and loans in the financial sector.

While general news article data may be assigned tags such as country/region, industry, and category, there are no tags assigned in the classification and granularity as in this list of technologies, so text mining is necessary to extract article data related to each technology from a large amount of article data. In this analysis, we have set search keywords (queries) that characterize each technology, extracted articles highly related to the search keywords using text mining techniques, and visualized the degree of attention paid to each technology in Japan and foreign countries.

- **Analysis scope**

Of the total 50 technologies in the list of technologies, the following three were taken in account, resulting a total of 47 technologies.

- "Offshore wind power generation" and "onshore wind power generation" were unified as "wind power generation" due to the small number of articles that were limited to one or the other technology.
- "Renovation of existing buildings" and "changing in streetlights to LED" were excluded because their meanings are generic and appropriate search keywords could not be set.

- **How to analyze technologies**

Step 1: Define database

We have created a database by gathering 49,760 news articles and technical articles related to carbon neutrality and decarbonization in Japan and foreign countries. Since this data is unstructured data consisting of a list of character-type data, words were cut out (tokenized) for later analysis, and appropriate pre- processing was performed.

- Search keywords: low-carbon, decarbonization, and carbon-neutral
- Search period: January 1, 2018 to November 20, 2021
- Language: English
- Countries: All (Japan: 2,045 articles, foreign countries: 47,715 articles)

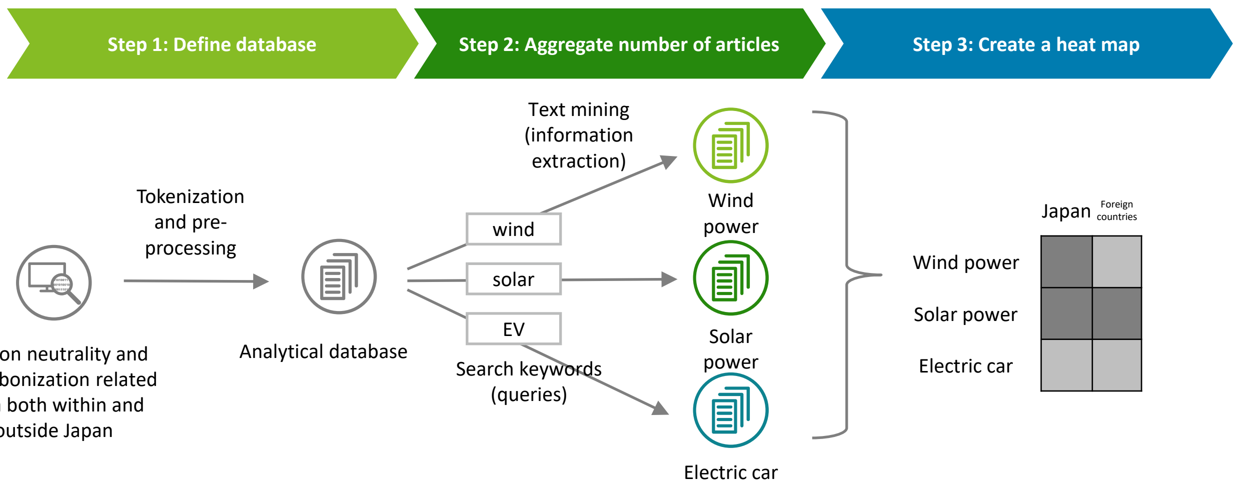
Step 2: Aggregate number of articles

The search keywords (queries) that characterize each technology were specified, and the relevance of the search keywords to the document data was determined using a search algorithm called Okapi BM25 (Best Matching 25) (hereinafter referred to as "BM25") [258]. BM25 is a method to retrieve documents related to a certain search keyword from document data, and can calculate a score (i.e., degree of relevance) considering the rarity and number of occurrences of the search keyword and the length of the sentences in which the search keyword appears. We performed clustering of the document data using the BM25 score calculated for each technology as a feature, and extracted document data with a certain level of relevance for each technology.

Step 3: Create a heat map

We calculated the cumulative number of articles related to each technology over the collection period, and normalized them to a maximum value of 1 and a minimum value of 0 so that we could compare the difference in the degree of attention paid to each technology between Japan and foreign countries. We then used the normalized data to create a heat map in ascending order of attention in Japan.

Figure 5: Analysis process flow



■ **Analysis results**

Table 11: Attention level to each technology in news articles

0-0.05	0.05-0.1	0.1-0.25	0.25-0.5	0.5-0.75	0.75-1.0

Group	Technology	Japan	Foreign countries
	Commercial solar power generation	1.00	1.00
1	Wind power generation (offshore/onshore)	0.94	0.67
	Electric passenger car	0.93	0.72
	ZEB	0.50	0.62
	Nuclear fusion	0.26	0.05
2	Hydrogen power generation	0.25	0.16
	Hydrogen production by renewable energy water electrolysis	0.22	0.09
1	Stationary fuel cell (for home use)	0.18	0.11
	ZEH	0.16	0.09
2	Co-firing of ammonia in thermal power generation by coal	0.10	0.05
	Bio-based plastics	0.10	0.05
1	CO2 separation and capture (CCS)	0.10	0.12
	Small modular reactor (SMR)	0.08	0.04
4	Geothermal power generation	0.07	0.03
	Green LPG	0.07	0.02
3	Decarbonization of paper industry	0.07	0.07
4	Hydrogen reduction ironmaking	0.06	0.04
	Synthetic fuels	0.06	0.08
3	Residential solar power generation	0.05	0.07
	High-temperature gas reactor	0.05	0.07
	Forests (e.g., proper thinning of artificial plantation, elite trees)	0.05	0.04
4	Carbon capture at waste disposal facilities	0.05	0.04
	Carbon neutralization on the demand side	0.03	0.09
	Alternative aviation fuel (SAF)	0.02	0.08

Technology	Japan	Foreign countries
Fast reactor	0.04	0.03
Ocean thermal energy conversion	0.03	0.02
Blue carbon using steel slag	0.03	0.01
Synthetic methane	0.03	0.02
FC Bus	0.03	0.00
Concrete/cement	0.03	0.03
Small and medium hydroelectric power generation	0.02	0.04
CO2 separation and capture (DAC)	0.02	0.04
Plastic raw material by artificial photosynthesis	0.02	0.01
Gas fuel ship (ammonia-fuelled ships)	0.01	0.00
CO2 separation and capture (microorganisms)	0.01	0.01
LNG fuelled ship	0.00	0.01
Wood (e.g., wood construction materials)	0.00	0.03
Waste power generation	0.00	0.00
Non-fluorocarbon refrigerant	0.00	0.01
Fuel cell ship	0.00	0.00
Electric vehicle	0.00	0.00
Farmland (e.g., bio-coal)	0.00	0.00
LLCM housing	0.00	0.00
Hydrogen cogeneration	0.00	0.00
Hydrogen boiler	0.00	0.00
Wave-power generation	0.00	0.01
Tidal power generation	0.00	0.00

[Consideration]
Table 11 shows that while there appears to be a certain degree of correlation between the attention level in Japan and foreign countries, there are technologies for which the attention level in both countries diverges.
We divide the technologies into the following four groups and briefly discuss them, but in the future, we would like to obtain further insights by reflecting this analysis result in the results list of technologies and integrating it with other analyses. For example, we would like to develop a unified evaluation index for each technology for Japanese investment players by combining the CO2 emission reduction potential, cost, TRL, and others, which have been researched so far.
The technologies on the right column of the table did not receive much attention in this analysis, but different results could be obtained depending on the source, time frame, and methodology of the analysis.

1. Technologies receiving high level of attention both in Japan and foreign countries (solar power generation, wind power generation, electric passenger car, ZEB, stationary fuel cell, and CCS)
Most of the technologies in this group are at or higher the demonstration test level of technology readiness and are expected to be demonstrated in terms of cost. Although there are concerns about the TRL and costs of CCS and stationary fuel cell at this point, there are high expectations for their high reduction potential.

2. Technologies receiving high level of attention in Japan than foreign countries (nuclear fusion, hydrogen power generation, hydrogen production, ZEH, thermal power, and plastic)
Since Japan’s energy self-sufficiency rate is low, technologies that are considered alternative energy sources are likely to be the focus of attention. It is also assumed that ZEH and bio-derived plastics, which are related to energy-saving technologies, are considered to be related to the growing policy and social demands in Japan.

3. Technologies of common interest (decarbonization of paper industry, synthetic fuel, residential solar power generation, and high-temperature gas cooled reactor)
The technologies included in this group have a certain amount of attention in common both in Japan and foreign countries. Since this group includes technologies that have attracted attention in the past, such as residential solar power generation, we assume that it will require detailed analysis on a time axis.

4. Other topical technologies (small modular reactor, geothermal power generation, green LPG, hydrogen reduction ironmaking, forests, carbon capture at waste disposal facilities, carbon neutralization on the demand side, and alternative aviation fuel)
Since these technologies are likely to be the focus of attention in Japan and foreign countries, further insights may be gained by conducting analysis in light of actual trends.

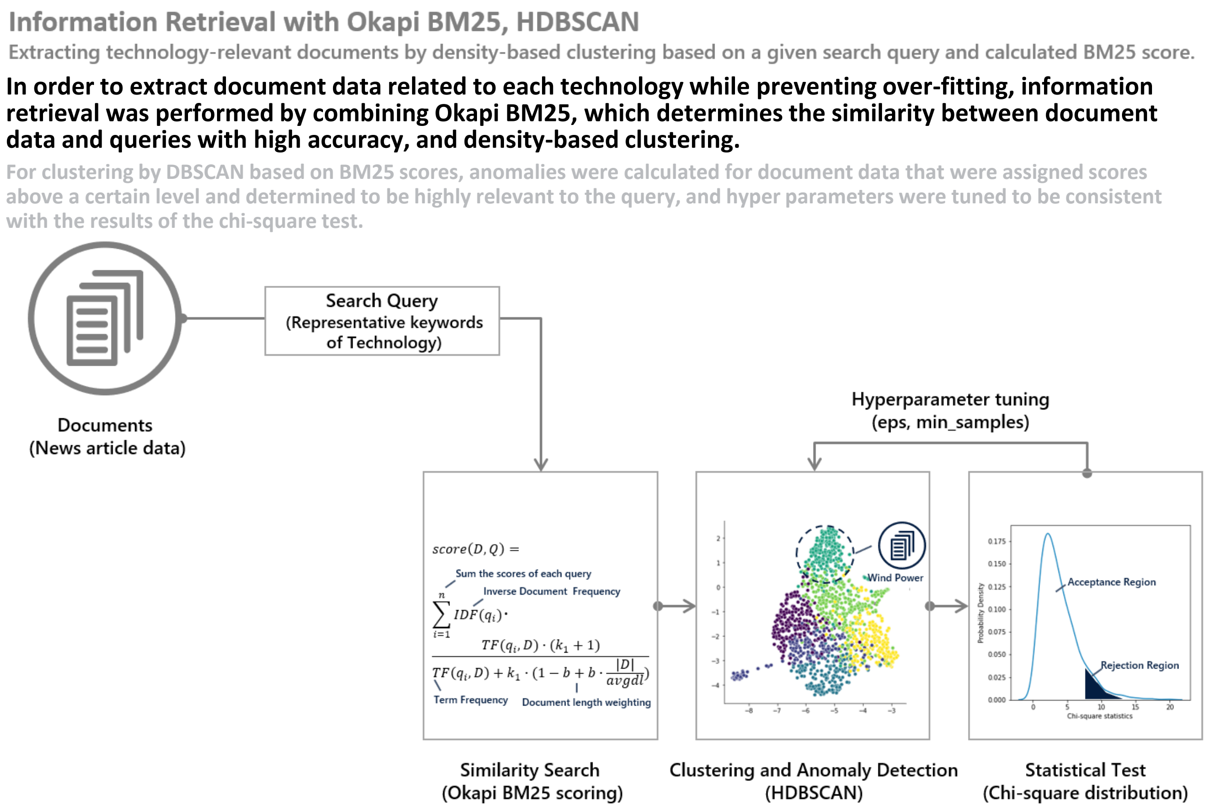
Issues and future directions for analysis

Finally, we summarize issues for future analysis from two perspectives: the data to be analyzed and the analysis methods.
This analysis used approximately four years of news article data from January 2018 to November 2021. However, in light of the recent momentum in efforts of policy and industry to address climate change, it is assumed that extending the data collection period to a more recent date would change the results. In addition, by using not only news article data but also data sources such as academic papers and trade journals, it would be possible to grasp the level of technological attention from the viewpoint of research and development. Moreover, although only English data was used in this analysis, it would be possible to compare the attention level to the technology from the perspectives of domestic and foreign media by using Japanese data as well.
Next, regarding the analysis method, in addition to the information extraction (text mining) method used in this analysis, it is possible to analyze the context in which the technology is discussed by classifying the content of articles related to each technology. For example, articles related to "small reactors for nuclear power generation" may include articles on corporate technological development, BCP measures, and legal regulations. By clarifying the differences in the context in which each technology is discussed, it will be possible to identify barriers to the diffusion and maturity of these technologies, which may lead to further suggestions.

Appendix: Text mining (information retrieval) algorithms

The simplest method for retrieving document data is simple matching of search keywords. However, this method may overestimate or underestimate the degree of conformity of document data, for example, conforming to document data that includes the search keyword but does not match the requested content contextually, or not conforming to the requested document data unless issues of distortion of the search keyword or synonyms and thesauruses are addressed. This is where the use of text mining (information retrieval) algorithms is necessary.
The Term frequency - inverse document frequency (hereinafter referred to as "Tf-idf") has been conventionally used as a model for calculating the goodness of fit of document data, but recently, BM25, which can obtain more accurate results, has been proposed.[*259] Both Tf-idf and BM25 are weighting methods that consider the frequency of occurrence of search keywords and the number of document data containing the search keywords, but BM25 has the advantage that it can also consider the number of characters in the document data containing the search keywords. In this study, we first set search keywords that characterize each technology in the list of technologies, and calculated scores that determine the goodness of fit with the document data using BM25.
Next, the BM25 scores were used to classify the document data. For the classification, we used Hierarchical Density-Based Spatial Clustering of Applications with Noise (hereinafter referred to as the "HDBSCAN"), a typical density-based clustering method.[*260] HDBSCAN is an algorithm that classifies closely spaced data into the same clusters and judges data in low-density areas as noise and has the advantage over the k-means algorithm in that the number of clusters need not be specified in advance. HDBSCAN uses two parameters, ε: distance from the data (radius) and minimum sample: the minimum number of data to form a cluster, and forms a cluster if there are more data than minimum sample data within the distance ε from a certain data.
The parameters of HDBSCAN were tuned by performing an anomaly test based on the Hotelling's theory.[*261] For the anomaly test, statistics using the mean and variance of the BM25 scores were used, and were assumed to follow a chi-square distribution. In this section, we evaluated the anomaly (i.e., whether the contents are peculiar) of documents that were given a score above a certain level by BM25 and judged to be highly relevant to other document data.
For the document data classified by the method described above, a heat map was created by counting the amount of data for Japan and non-Japan regions.

Figure 6: Flow of text mining (information retrieval)



Conclusion

Summary

This report (list of technologies) was intended to compile a list of carbon neutral technologies, as objectively as possible under common assumptions, and to organize and list the information on each technology. The list was compiled by DTST professionals with backgrounds in science and technology, who researched opensource information published by the government, universities, and companies, and made calculations based on this information. The following three points are currently suggested for the 63 technologies related to carbon neutrality summarized in this report.

1. **Negative emission technologies tend to have less readiness overall**
Negative emission technologies tended to have lower CO2 emission reductions, fewer patents, and higher CO2 emission reduction costs than net zero emission and low emission technologies. It is assumed that investment and research in this area are lagging behind at this time. However, negative emission technologies that collect and store CO2 emissions are indispensable to achieve virtually zero CO2 emissions, and development and promotion of such technologies from a medium- to long-term perspective are assumed to be necessary.

2. **Net zero emission technology has high potential for reducing CO2 emissions**
When focusing on CO2 emission reduction figures, we found that the values for technological solutions related to net zero emission technologies tend to be higher. It is assumed that this is because net zero emission technologies include many solutions related to energy generating sectors such as wind and solar power generation. In other words, the decarbonization of electricity can contribute significantly to CO2 emission reductions.
However, there is some duplication in the calculation of CO2 emission reductions among technologies in the current list of technologies, and the total of the values in the table does not simply represent the potential for CO2 emission reduction in Japan. In addition, it is necessary to fully consider that excessive introduction of renewable energy is a trade-off with stable electricity supply.

3. **Many of the low emission technologies are at a high TRL**
Low emission technologies tend to have a high level of readiness overall, and many of them, such as electric cars and gas cogeneration, are already being implemented in society. The main issue for further social implementation of these technologies is to lower the cost of CO2 emission reductions.

Issues identified by the research of technologies

The list of technologies is a prototype of the technologies to achieve carbon neutrality, organized from the viewpoints of CO2 emission reduction potential, CO2 emission reduction cost, number of patents, TRL, and text mining analysis. The following is a list of issues that we identified through the research of various technologies that contribute to carbon neutrality, from the two perspectives of quantity and quality of information.

- **Amount of information**
  - Expansion of technologies researched
    In the list of technologies of this report, we have researched 63 carbon neutral technologies. Since there are many technologies that are not included in this report, it is necessary to continue expanding the number of technologies to be included in the report in the future.
  - Gathering further information on the subject of the research
    The availability of data on CO2 emission reduction cost varies widely because the research was conducted based on opensource information for which there is little information available and the readiness level differs depending on the technology. For many values, calculations were made based on numerical assumptions. In the future, it will be necessary to collect more information and refine the values by collaborating with universities and companies that have such technologies and by promoting social implementation projects.
  - Consideration for listing technology players (universities and companies)
    At present, there is no list of universities and companies engaged in research and business related to each technology solution. We believe it is necessary to further advance efforts toward social implementation of technologies by listing universities and companies associated with each technology.
    However, at this point, we feel that there are challenges in terms of ensuring the objectivity and fairness of the information, and we are currently considering whether and how to disclose the information.

- **Quality of information**
  - Consideration of numerical duplication
    The current list of technologies does not take into account duplicated values, so it does not consider the effects of related technologies such as the introduction of one technology reducing the amount of the other technology that can be introduced.
    In the future, it will be necessary to consider the duplication and integration models.
  - Reconsideration of technological classification
    The technologies were identified from the June 18, 2021 version of the Ministry of Economy, Trade and Industry's "Green Growth Strategy Through Achieving Carbon Neutrality in 2050". In the current list of technologies, the granularity of technological solutions differs, and in fact, some technologies can be classified even more finely, so it is necessary to examine the appropriateness of the granularity of technologies.
  - Further input from experts
    In preparing the list of technologies, DTST professionals with backgrounds in science and technology conducted the research, and the entire document was reviewed by several professionals belonging to a different organization than the members of this working group within the Deloitte Tohmatsu Group.
    In this study, opinions of experts from universities, companies, and other organizations with technological knowledge were incorporated in some of the researched technologies and it is necessary to further increase the number of reviews in the future.

Steps for the future

In order to make the list of technologies useful for social implementation, we believe it is necessary to work toward solutions to the issues identified in the research of the technologies described in the previous section, and to consider feasibility priorities and multiple scenarios for carbon neutrality, taking into account such aspects as laws and regulations related to social implementation, social acceptance, maintaining and improving industry competitiveness, and long term technological development.
Therefore, it is necessary to research a wide variety of technologies other than those listed here and analyze them from a bird's eye view, and continue to update the list of technologies to make it more advanced by incorporating the knowledge of experts in each technology. In order to do so, collaboration is essential, not only between the members involved in the preparation of this report, but also between researchers, government, business, and other experts in various fields both inside and outside the Deloitte Tohmatsu Group.
By publicizing these activities and accelerating collaboration with various experts, we aim to promote the social implementation of important technologies and contribute to achieving carbon neutrality. We will also be
updating the list over the medium to long term by periodically re-examining
the contents of the list of technologies and conducting additional research of other new technologies, with the aim of releasing it as a priority list enabling an overall comparison and examination of each technology.

If you are interested in this initiative and would like to provide information on technologies for achieving carbon neutrality, or would like to discuss potential collaboration, please contact the Tohmatsu Science and Technology CN team at the email address listed at the end of the list of technologies

Acknowledgements

At the end

In closing, we would like to thank Kazuhiro Hikima, Assistant Professor of Toyohashi University of Technology; Etsushi Tsuji, Assistant Professor of Graduate school of Tottori University; Chapman Andrew John, Assistant Professor of International Institute for Carbon-Neutral Energy Research, Kyushu University; Tomohiro Kuwae, Head of Group of National Research and Development Agency, National Institute of Maritime, Port and Aviation Technology; Shunichi Hienuki, Research Scientist of Socio-Economic Research Center of Central Research Institute of Electric Power Industry; Masato Kouzu, Professor of Graduate School of Tokyo City University; and Shinji Kambara, Professor of Gifu University Faculty of Engineering and Graduate School of Engineering for their expert opinion and support in providing the latest information in the field, as well as the marketing team for their full support in making this web publication available to the public.

Reference materials

*1 首相官邸第二百三回国会における菅内閣総理大臣所信表明演説
<https://www.kantei.go.jp/jp/99_suga/statement/2020/1026shoshinhyomei.html>
(Referenced on 7/1/2021)

*2 環境省 2019 年度（令和元年度）の温室効果ガス排出量（確報値）について
<http://www.env.go.jp/earth/ondanka/ghg-mrv/emissions/results/material/honbun2019rev2.pdf>
(Referenced on 7/1/2021）

*3 経済産業省 2050年カーボンニュートラルに伴うグリーン成長戦略
<https://www.meti.go.jp/press/2021/06/20210618005/20210618005.html>
(Referenced on 7/1/2021)

*4 クラリベイト・アナリティクス Derwent Innovation
<https://clarivate.com/derwent/ja/solutions/derwent-innovation/>
(Referenced on 11/30/2021)

*5 国立研究開発法人産業技術総合研究所 令和元年度 研究評価委員会 （材料・化学領域）評価報告書
<https://unit.aist.go.jp/evaloo2020/R01research/R01research_zairyoukagaku.pdf> (Referenced on 5/31/2023)

6 国立研究開発法人産業技術総合研究所 技術成熟度
<https://unit.aist.go.jp/adperc/ci/research/outline3.html>
(Referenced on 11/30/2021)

*7 （国研）森林研究・整備機構森林総合研究所林木育種センター エリートツリーの開発・普及
<https://www.rinya.maff.go.jp/j/kanbatu/houkokusho/attach/pdf/souseiju2019-7.pdf>
(Referenced on 11/30/2021)

*8 （独）森林総合研究所 温暖化対応推進拠点 一般向け算定・報告解説（090130）
<https://www.ffpri.affrc.go.jp/research/dept/22climate/kyuushuuryou/documents/page1-2-per-a-tree.pdf>
(Referenced on 11/30/2021)

*9 林野庁 モデル地区における森林施業の考え方
<https://www.rinya.maff.go.jp/j/kokuyu_rinya/kakusyu_siryo/pdf/00271_3_h18_003.pdf>
(Referenced on 11/30/2021)

*10 林野庁 都道府県別森林率・人工林率（平成29年3月31日現在）
<https://www.rinya.maff.go.jp/j/keikaku/genkyou/h29/1.html>
(Referenced on 11/30/2021)

*11 農林水産省 みどりの食料システム戦略
<https://www.maff.go.jp/j/kanbo/kankyo/seisaku/midori/attach/pdf/index-7.pdf>
(Referenced on 11/30/2021)

*12 林野庁 森林・林業基本計画の概要
<https://www.rinya.maff.go.jp/j/press/kikaku/attach/pdf/210615-4.pdf>
(Referenced on 11/30/2021)

*13 （国研）森林研究・整備機構森林総合研究所林木育種センター エリートツリーの普及に向けた今後の課題について<https://www.ffpri.affrc.go.jp/ftbc/rinbokuikusyugijyutusenryakuiinkai/documents/konngonokadai.pdf>
(Referenced on 11/30/2021)

*14 大成建設株式会社 カーボンリサイクル・コンクリート「T-eConcrete®/Carbon-Recycle」を開発
<https://www.taisei.co.jp/about_us/wn/2021/210216_5079.html>
(Referenced on 6/3/2022)

*15 国土交通省 令和 2 年度 主要建設資材需要見通し
<https://www.mlit.go.jp/common/001370937.pdf>
(Referenced on 6/3/2022)

*16 會澤高圧コンクリート株式会社 コンクリートの比重
<https://concrete-mc.jp/specificgravity/>
(Referenced on 6/3/2022)

*17 国土交通省 生コン業界の現状と課題への取組みについて
<https://www.mlit.go.jp/road/ir/ir-council/douroshizai/pdf02/5.pdf>
(Referenced on 6/3/2022)

*18 立命館大学 HP
<https://www.ritsumeikan-carbon-minus.org/%E3%83%90%E3%82%A4%E3%82%AA%E7%82%AD%E3%81%AB%E3%81%A4%E3%81%84%E3%81%A6>
(Referenced on 6/3/2022)

*19 農林水産省 環境政策室 バイオ炭の農地施用を対象とした方法論について
<https://www.maff.go.jp/j/kanbo/kankyo/seisaku/climate/biochar/attach/pdf/top-4.pdf>
(Referenced on 6/3/2022)

*20 総務省統計局 統計データ（ 8- 3 耕地面積）
<https://www.stat.go.jp/data/nihon/08.html>
(Referenced on 6/3/2022)

*21 農林水産省 バイオ炭の施用量上限の目安について
<https://www.maff.go.jp/j/seisan/kankyo/ondanka/biochar01.html>
(Referenced on 6/3/2022)

*22 農林水産省 令和2年耕地面積（7月15日現在）
<https://www.maff.go.jp/j/tokei/kekka_gaiyou/sakumotu/menseki/r2/kouti/index.html>
(Referenced on 6/3/2022)

*23 J-クレジット 方法論 バイオ炭の農地施用
<https://japancredit.go.jp/pdf/methodology/AG-004_v1.0.pdf>
(Referenced on 6/3/2022)

*24 山形大学紀要 第18巻 第 2 号：57－84. 平成31年 2 月 木炭生産者の現状と森林資源管理の課題（P21）
<https://core.ac.uk/download/pdf/269026063.pdf>
(Referenced on 6/3/2022)

*25 農業・食品産業技術総合研究機構農業環境変動研究センター バイオ炭普及研究の今と、今後の展望（P14）
<https://www.maff.go.jp/j/kanbo/kankyo/seisaku/climate/visual/attach/pdf/r2_3-8.pdf>
(Referenced on 6/3/2022)

*26 IEA World Energy Outlook2019
<https://iea.blob.core.windows.net/assets/98909c1b-aabc-4797-9926-35307b418cdb/WEO2019-free.pdf>
(Referenced on 6/3/2022)

*27 国立研究開発法人科学技術振興機構 CCS（二酸化炭素回収貯留）の概要と展望（Vol.2）
<https://www.jst.go.jp/lcs/pdf/fy2016-pp-06.pdf>
(Referenced on 6/3/2022)

*28 J-STAGE 浅海生態系における年間二酸化炭素吸収量の全国推計
<https://www.jstage.jst.go.jp/article/kaigan/75/1/75_10/_pdf/-char/ja>
(Referenced on 6/3/2022)

*29 環境省 閉鎖性海域における水環境改善技術
<https://www.env.go.jp/policy/etv/pdf/list/h21/02_h_4%5B1%5D.pdf>
(Referenced on 6/3/2022)

*30 e-Gov 減価償却資産の耐用年数等に関する省令
<https://elaws.e-gov.go.jp/document?lawid=340M50000040015>
(Referenced on 6/3/2022)

*31 株式会社CO2資源化研究所 UCDI®Technology
<https://www.co2.co.jp/jp/technology>
(Referenced on 6/3/2022)

*32 一般財団法人 日本水産油脂協会 平成30年度事業報告書
<http://www.suisan.or.jp/html/file/h30report.pdf>
(Referenced on 6/3/2022)

*33 国立研究開発法人科学技術振興機構 低炭素社会戦略センター 二酸化炭素の Direct Air Capture（DAC）法のコストと評価
<https://www.jst.go.jp/lcs/pdf/fy2019-pp-07.pdf>
(Referenced on 6/3/2022)"

*34 日刊工業新聞社 工業団地インフォ
<https://estate.nikkan.co.jp/>
(Referenced on 6/3/2022)

*35 一般社団法人日本ガス協会 天然ガスの特徴・種類
<https://www.gas.or.jp/tokucho/>
(Referenced on 6/3/2022)

*36 株式会社富士経済プレスリリース CO2 分離・カーボンリサイクル関連市場
<https://www.fuji-keizai.co.jp/file.html?dir=press&file=20069.pdf&nocache>
(Referenced on 6/3/2022)

*37 産業競争懇談会 COCN【DAC（Direct Air Capture）研究会】
<http://www.cocn.jp/report/1c5b57152a8d0c5c739ccfee2693fe42bb1b792d.pdf>
(Referenced on 6/3/2022)

*38 一般財団法人新エネルギー財団 洋上風力発電の課題について
<https://www.nef.or.jp/keyword/ya/articles_yo_01_05.html>
(Referenced on 6/3/2022)

*39 電力中央研究所 日本における発電技術のライフサイクルCO2排出量総合評価
<https://criepi.denken.or.jp/hokokusho/pb/reportDownload?reportNoUkCode=Y06&tenpuTypeCode=30&seqNo=1&reportId=8713>
(Referenced on 6/3/2022)

*40 資源エネルギー庁 エネルギー白書2021
<https://www.enecho.meti.go.jp/about/whitepaper/2021/pdf/>
(Referenced on 6/3/2022)

*41 資源エネルギー庁 総合エネルギー調査会 発電コスト検証ワーキンググループ（第8回会合）資料3各電源の諸元一覧
<https://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/mitoshi/cost_wg/pdf/cost_wg_20210908_02.pdf>
(Referenced on 6/3/2022)

*42 環境省 令和元年度再生可能エネルギーに関するゾーニング基礎情報等の整備・公開等に関する委託業務報告書
<https://www.renewable-energy-potential.env.go.jp/RenewableEnergy/report/r01.html>
(Referenced on 6/3/2022)
*43 資源エネルギー庁 再生可能エネルギーとは
<https://www.enecho.meti.go.jp/category/saving_and_new/saiene/renewable/solar/index.html>
(Referenced on 6/3/2022)
*44 電力中央研究所 日本における発電技術のライフサイクルCO2排出量総合評価
<https://criepi.denken.or.jp/hokokusho/pb/reportDownload?reportNoUkCode=Y06&tenpuTypeCode=30&seqNo=1&reportId=8713>
(Referenced on 6/3/2022)
*45 NEDO 再生可能エネルギー技術白書
<https://www.nedo.go.jp/content/100544818.pdf>
(Referenced on 6/3/2022)
*46 資源エネルギー庁 総合エネルギー統計2019年度
<https://www.enecho.meti.go.jp/statistics/total_energy/results.html#headline1>
(Referenced on 6/3/2022)
*47 日本エネルギー経済研究所総合研究部環境グループ、電力グループ わが国における化石エネルギーに関するライフサイクル・インベントリー分析
<https://eneken.ieej.or.jp/data/old/pdf/enekei/lci.pdf>
(Referenced on 6/3/2022)
*48 京都フュージョニアリング 京都フュージョニアリング
<https://kyotofusioneering.com/company>
(Referenced on 6/3/2022)
*49 三菱重工 核融合エネルギー
<https://www.mhi.com/jp/products/energy/fusion_reactor.html>
(Referenced on 6/3/2022)
*50 東芝 核融合
<https://www.global.toshiba/jp/products-solutions/nuclearenergy/research/energy.html>
(Referenced on 6/3/2022)
*51 日立製作所 核融合・加速器
<https://www.hitachi.co.jp/products/energy/nuclear/accelerator/index.html>
(Referenced on 6/3/2022)
*52 笠田竜太（京都大学）他 若手による核融合炉実用化に向けた技術成熟度評価
<http://www.jspf.or.jp/Journal/PDF_JSPF/jspf2013_04/jspf2013_04-193.pdf>
(Referenced on 6/3/2022)
*53 上村聡志（名古屋大学）他 二酸化炭素排出量の計算による核融合炉の環境負荷評価
<https://www.jstage.jst.go.jp/article/taesj/8/1/8_J08.019/_pdf>
(Referenced on 6/3/2022)
*54 核融合会議開発戦略検討分科会 核融合エネルギーの技術的実現性計画の拡がりと裾野としての基礎研究に関する報告書
<http://www.aec.go.jp/jicst/NC/senmon/old/kakuyugo/siryo/siryo136/siryo213.htm>(Referenced on 6/3/2022)
*55 経済産業省 令和3年エネルギー基本計画の概要
<https://www.meti.go.jp/press/2021/10/20211022005/20211022005-2.pdf>
(Referenced on 6/3/2022)
*56 大野哲靖（名古屋大学） 工学実証段階にきた核融合発電研究の現状と課題
<https://www.chuden.co.jp/resource/seicho_kaihatsu/kaihatsu/kai_library/news/news_158_02.pdf>
(Referenced on 6/3/2022)
*57 田中知（東京大学） 核融合炉の安全規制と廃棄物処理
<http://www.jspf.or.jp/conference/fusion_energy02/pdf/2Q05.pdf>
(Referenced on 6/3/2022)
*58 経済産業省 第12回CO2フリー水素WG事務局提
<https://www.meti.go.jp/committee/kenkyukai/energy/suiso_nenryodenchi/co2free/pdf/012_01_00.pdf>
(Referenced on 6/3/2022)
*59 経済産業省 水素の製造、輸送・貯蔵について
<https://www.meti.go.jp/committee/kenkyukai/energy/suiso_nenryodenchi/suiso_nenryodenchi_wg/pdf/005_02_00.pdf>
(Referenced on 6/3/2022)
*60 日本原子力研究開発機構 商用高温ガス炉発電原価の再評価
<https://www.jstage.jst.go.jp/article/taesj/advpub/0/advpub_J21.005/_pdf/-char/ja>(Referenced on 6/3/2022)
*61 日本原子力研究開発機構 高温ガス炉による水素製造が実用化へ大きく前進
<https://www.jaea.go.jp/02/press2018/p19012502/>
(Referenced on 6/3/2022)

*62 日本原子力研究開発機構 高温ガス炉とは
<https://www.jaea.go.jp/04/o-arai/nhc/jp/faq/>
(Referenced on 6/3/2022)
*63 日本原子力研究開発機構 高温ガス炉による 水素製造技術の研究開発
<https://www.jaea.go.jp/jaea-houkoku14/shiryo/03.pdf>
(Referenced on 6/3/2022)
*64 岡本孝司（東京大学） 高温ガス炉の課題
<https://www.iae.or.jp/htgr/pdf/02_result/infomation/02result_20130903_04.pdf>
(Referenced on 6/3/2022)
*65 日本原子力研究開発機構 高温ガス炉タービンシステム（GTHTR300）の経済性評価
<https://www.jstage.jst.go.jp/article/taesj2002/5/2/5_2_109/_pdf/-char/ja>
(Referenced on 6/3/2022)
*66 環境エネルギー政策研究所 2020年の自然エネルギー電力の割合（暦年速報）
< https://www.isep.or.jp/archives/library >
(Referenced on 6/3/2022)
*67 日本原子力研究開発機構 高速炉サイクルの経済性評価ー炉の建設コストと燃料サイクルコストー
<https://www.jstage.jst.go.jp/article/jaesjb/61/1/61_43/_pdf>
(Referenced on 6/3/2022)
*68 中部電力 高速炉開発の現状と今後「もんじゅ」の廃止措置と高速炉の開発目標
<https://www.chuden.co.jp/resource/seicho_kaihatsu/kaihatsu/kai_library/news/news_158_22.pdf>
(Referenced on 6/3/2022)
*69 日本原子力研究開発機構 もんじゅ性能試験データを用いた高速炉技術に関する先端的研究
<https://www.nsystemkoubo.jp/result/h22/o17.html>
(Referenced on 6/3/2022)
*70 東京大学大学院工学系研究科原子力国際専攻 社会に受容される高速炉開発の進め方ー技術から人・社会への検討範囲拡大と高速炉開発意義の共有ー
<https://www.meti.go.jp/committee/kenkyukai/energy/fr/senryaku_wg/pdf/006_01_00.pdf>
(Referenced on 6/3/2022)
*71 九州大学 新型炉の国際協力の現状と今後の研究開発課題（イノベーションの創出）
<http://www.aesj.or.jp/division/ard/documents/AESJ-2019S-ARD-2.pdf>
(Referenced on 6/3/2022)
*72 EnergyShift 世界で注目を集めている小型原子炉は、本当に脱炭素の選択肢になるのか
<https://energy-shift.com/news/693065ca-965a-4f55-9fc3-550cf5f85cd1?page=4>
(Referenced on 6/3/2022)
*73 EnergyShift 世界で注目を集めている小型原子炉は、本当に脱炭素の選択肢になるのか
<https://energy-shift.com/news/693065ca-965a-4f55-9fc3-550cf5f85cd1>
(Referenced on 6/3/2022)
*74 時事通信社 脱炭素の切り札？次世代小型炉「ＳＭＲ」の課題と現状
<https://www.jiji.com/jc/v4?id=2022kogatagensiro0001>
(Referenced on 6/3/2022)
*75 (一般社団法人）海外電力調査会 世界の小型モジュール炉の開発動向
<http://www.aec.go.jp/jicst/NC/iinkai/teirei/siryo2021/siryo32/1_haifu.pdf>
(Referenced on 6/3/2022)

*76 三井住友DSアセットマネジメント株式会社 脱炭素の切り札か、安全で低コストな『小型原子炉』
<https://www.smd-am.co.jp/market/daily/keyword/2022/02/key220203gl/>
(Referenced on 6/3/2022)
*77 環境エネルギー政策研究所 2020年の自然エネルギー電力の割合（暦年速報）
< https://www.isep.or.jp/archives/library >
(Referenced on 6/3/2022)
*78 経済産業省　今後の水素政策の課題と対応の方向性 中間整理（案）
<https://www.meti.go.jp/shingikai/energy_environment/suiso_nenryo/pdf/025_01_00.pdf>
(Referenced on 6/3/2022)
*79 経済産業省　基本政策分科会に対する発電コスト検証に関する報告
<https://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/mitoshi/cost_wg/pdf/cost_wg_20210908_01.pdf>
(Referenced on 6/3/2022)
*80 神戸・関西圏水素利活用協議会 神戸・関西圏水素利活用協議会協議会レポート（2020年度）
<https://www.city.kobe.lg.jp/documents/51573/gairyakuban.pdf>
(Referenced on 6/3/2022)"
*81 三浦工業株式会社 統合報告書2021
<https://www.miuraz.co.jp/assets/pdf/ir/integrated/2021/view.pdf>
(Referenced on 6/3/2022)
*82 一般財団法人 ヒートポンプ・蓄熱センター　令和２年度ヒートポンプ普及見通し調査
<https://www.hptcj.or.jp/Portals/0/data0/press_topics/2020NewsRelease/news_release_siryo.pdf>
(Referenced on 6/3/2022)
*83 日刊工業新聞HP ボイラの市場動向と技術動向
<https://pub.nikkan.co.jp/uploads/book/pdf_file5859d23e856fd.pdf>
(Referenced on 6/3/2022)
*84 経済産業省（資源エネルギー庁）　標準発熱量・炭素排出係数（総合エネルギー統計）
<https://www.enecho.meti.go.jp/statistics/total_energy/carbon.html>
(Referenced on 6/3/2022)
*85 三浦工業株式会社 仕様リスト
<https://www.miuraz.co.jp/assets/doc/product/list_QA-17021-18_20200401.pdf>
(Referenced on 6/3/2022)
*86 三浦工業株式会社 令和３年度「先進的省エネルギー投資促進支援事業費補助金」様式７－１ 様式７－２「先進事業」における『先進設備・システム』応募申請書
<https://sii.or.jp/file/cutback_system_search_03/R3A-0042.pdf>
(Referenced on 6/3/2022)
*87 三浦工業株式会社 三浦工業の水素社会への取り組み
<https://www.meti.go.jp/shingikai/energy_environment/2050_gas_jigyo/pdf/004_06_00.pdf>
(Referenced on 6/3/2022)
*88 三浦工業株式会社 運転時CO2排出ゼロ、水素燃料の貫流蒸気ボイラをラインナップ
<https://www.miuraz.co.jp/news/newsrelease/2017/831.php>
(Referenced on 6/3/2022)
*89 合成燃料研究会 合成燃料研究会中間とりまとめ
<https://www.meti.go.jp/shingikai/energy_environment/gosei_nenryo/pdf/20210422_1.pdf>
(Referenced on 6/3/2022)

*90 トヨタ自動車株式会社、みずほ情報総研株式会社 輸送用燃料の Well-to-Wheel 評価（日本における輸送用燃料製造（Well-to-Tank）を中心とした温室効果ガス排出量に関する研究報告）p19
<https://www.mizuho-ir.co.jp/solution/improvement/csr/lca/pdf/jisseki02_wtwghg2004.pdf>
(Referenced on 6/3/2022)
*91 Audi 2018年3月12日プレスリリース
<https://www.audi-press.jp/press-releases/2018/b7rqqm000000lqor.html>
(Referenced on 6/3/2022)
*92 環境省 算定・報告・公表制度における算定方法・排出係数一覧
<https://ghg-santeikohyo.env.go.jp/calc>
(Referenced on 6/3/2022)
*93 資源エネルギー庁 エンジン車でも脱炭素？グリーンな液体燃料「合成燃料」とは
<https://www.enecho.meti.go.jp/about/special/johoteikyo/gosei_nenryo.html>
(Referenced on 6/3/2022)
*94 資源エネルギー庁 エネルギー白書2017
<https://www.enecho.meti.go.jp/category/electricity_and_gas/nuclear/001/pdf/001_02_003.pdf>
(Referenced on 6/3/2022)
*95 資源エネルギー庁 石炭火力検討ワーキンググループ中間取りまとめ概要
<https://www.meti.go.jp/shingikai/enecho/denryoku_gas/denryoku_gas/sekitan_karyoku_wg/pdf/20210423_1.pdf>
(Referenced on 6/3/2022)
*96 国立研究開発機構 アンモニア混焼技術　2020年度成果報告会
<https://www.nedo.go.jp/content/100932835.pdf>
(Referenced on 6/3/2022)
*97 環境省　水素社会実現に向けた経済産業省の取組
<https://www.env.go.jp/seisaku/list/ondanka_saisei/lowcarbon-h2-sc/events/PDF/shiryou06.pdf>
(Referenced on 6/3/2022)
*98 経済産業省 「大規模水素サプライチェーンの構築」プロジェクトに関する研究開発・社会実装計画
<https://www.meti.go.jp/press/2021/05/20210518003/20210518003-2.pdf>
(Referenced on 6/3/2022)
*99 環境省　電気事業者別排出係数（特定排出者の温室効果ガス排出量算定用）－R１年度実績－
<https://www.env.go.jp/press/files/jp/116530.pdf>
(Referenced on 6/3/2022)
*100 環境省 我が国の地熱発電の概要
<https://www.env.go.jp/nature/geothermal_power/conf/h2301/mat02.pdf>
(Referenced on 6/3/2022)
*101 日本地熱協会 地熱発電の現況と課題
<https://www.enaa.or.jp/?fname=gec_2021_1_14.pdf>
(Referenced on 6/3/2022)
*102 経済産業省　グリーンイノベーション基金事業「再エネ等由来の電力を活用した水電解による水素製造」プロジェクトに関する研究開発・社会実装計画
<https://www.meti.go.jp/policy/energy_environment/global_warming/gifund/pdf/gif_04_randd.pdf>
(Referenced on 6/3/2022)
*103 経済産業省　水素・燃料電池戦略ロードマップの達成状況（推移）
<https://www.meti.go.jp/shingikai/energy_environment/suiso_nenryo/roadmap_hyoka_wg/pdf/002_03_00.pdf>
(Referenced on 6/3/2022)
*104 経済産業省　水素社会実現に向けた社会実装モデルについて
<https://www.meti.go.jp/shingikai/energy_environment/suiso_nenryo/pdf/027_01_00.pdf>
(Referenced on 6/3/2022)
*105 国土交通省 ＺＥＨ（ネット・ゼロ・エネルギー・ハウス）、ＬＣＣＭ（ライフ・サイクル・カーボン・マイナス）住宅関連事業（補助金）について
<https://www.mlit.go.jp/jutakukentiku/house/jutakukentiku_house_tk4_000153.html>
(Referenced on 6/3/2022)
*106 総務省 住宅の規模
<https://www.stat.go.jp/data/jyutaku/2008/nihon/2_4.html>
(Referenced on 6/3/2022)
*107 環境省 LCCM住宅の展開
<https://www.env.go.jp/earth/house/conf/lcs01/mat03-3.pdf>
(Referenced on 6/3/2022)
*108 環境省 ZEHの普及促進に向けた政策動向と令和２年度の関連予算案<https://www.env.go.jp/earth/meti%20moe%20.pdf>
(Referenced on 6/3/2022)

*109 ARPChem 人工光合成PJ について
<https://www.meti.go.jp/committee/kenkyukai/energy_environment/jisedai_karyoku/pdf/002_02_05.pdf>
(Referenced on 6/3/2022)

*110 NEDO 世界初、人工光合成により100m2規模でソーラー水素を製造する実証試験に成功
<https://www.nedo.go.jp/news/press/AA5_101473.html>
(Referenced on 6/3/2022)

*111 新エネルギー・産業技術総合開発機構「二酸化炭素原料化基幹化学品製造プロセス技術開発」事業原簿【公開】
<https://www.nedo.go.jp/content/100899250.pdf>
(Referenced on 6/3/2022)

*112 内閣府「ボトルネック課題研究会」CO2 利用に当たってのボトルネック課題及び研究開発の方向性
<https://www8.cao.go.jp/cstp/stmain/houkousei.pdf>
(Referenced on 6/3/2022)

*113 株式会社東レリサーチセンター エネルギー・環境分野における有望技術の技術課題に関する包括的調査
<https://www8.cao.go.jp/cstp/stmain/houkokusho.pdf>
(Referenced on 6/3/2022)

*114 石油化学協会 石油化学製品の生産
<https://www.jpca.or.jp/statistics/annual/seisan.html>
(Referenced on 6/3/2022)

*115 NEDO「二酸化炭素原料化基幹化学品製造プロセス技術開発」（中間評価）
<https://www.nedo.go.jp/content/100899249.pdf>
(Referenced on 6/3/2022)

*116 newsclip タイ石化最大手PTTGC、オレフィンプラント新設　投資額10億ドル
<http://www.newsclip.be/article/2018/01/25/35289.html>
(Referenced on 6/3/2022)

*117 製造産業局 カーボンリサイクル関連プロジェクト（化学品分野）の研究開発・社会実装の方向性
<https://www.meti.go.jp/shingikai/sankoshin/green_innovation/energy_structure/pdf/004_04_00.pdf>
(Referenced on 6/3/2022)

*118 JCCCA　全国地球温暖化防止活動推進センター 日本の部門別二酸化炭素排出量(2019年度)
<https://www.jccca.org/download/13335>
(Referenced on 6/3/2022)

*119 太陽光発電導入ガイドライン ゼロエネルギー住宅（ZEH）仕様にするのに必要な費用の目安
<http://www.qool-shop.com/zeh/entry213.html>
(Referenced on 6/3/2022)

*120 国土交通省 建築物ストック統計の公表について
<https://www.mlit.go.jp/report/press/joho04_hh_000785.html>
(Referenced on 6/3/2022)

*121 一般財団法人エネルギー総合工学研究所 メタネーションによるカーボンニュートラル・メタン（CNメタン）の経済性評価の調査報告～CO2のコスト評価・排出量評価～
<https://www.iae.or.jp/wp/wp-content/uploads/2020/07/metanation_202003.pdf>
(Referenced on 6/3/2022)

*122 浜松ヒートテック株式会社 技術資料No.11　気体燃料の物性代表値
<http://www.heat-tech.co.jp/business/dm/HHT_DM_No.11.pdf>
(Referenced on 6/3/2022)

*123 European Union's Horizon 2020 research and innovation programme Report on the costs involved with PtG technologies and their potentials across the EU
<https://www.storeandgo.info/fileadmin/downloads/deliverables_2019/20190801-STOREandGO-D8.3-RUG-Report_on_the_costs_involved_with_PtG_technologies_and_their_potentials_across_the_EU.pdf>
(Referenced on 6/3/2022)

*124 資源エネルギー庁 今後のガス事業政策について
<https://www.meti.go.jp/shingikai/enecho/denryoku_gas/denryoku_gas/pdf/033_03_01.pdf>
(Referenced on 6/3/2022)

*125 NEDO 再生可能エネルギー白書第2版
<https://www.nedo.go.jp/content/100544823.pdf>
(Referenced on 6/3/2022)

*126 国土交通省 建築物ストック統計の公表について
<https://www.mlit.go.jp/common/001198960.pdf>
(Referenced on 6/3/2022)

*127 経済産業省 令和元年度　ZEB ロードマップフォローアップ委員会　とりまとめ
<https://www.enecho.meti.go.jp/category/saving_and_new/saving/enterprise/support/pdf/2004_followup_sammary.pdf>
(Referenced on 6/3/2022)

*128 国土交通省 住宅・建築物の省エネ・省ＣＯ２施策と支援事業の動向
<https://www.kenken.go.jp/shouco2/pdf/symposium/23/23-1v3_mlit.pdf>
(Referenced on 6/3/2022)

*129 経済産業省 省エネ普及促進コーナー（ZEB）ネット・ゼロ・エネルギー・ビルとは
<https://www.enecho.meti.go.jp/category/saving_and_new/saving/assets/pdf/enterprise/enex2019/shiryo5.pdf>
(Referenced on 6/3/2022)

*130 日系XTECH 水道光熱費はm2当たり年約5000円、REIT所有ビル
<https://xtech.nikkei.com/kn/article/building/news/20031027/113232/>
(Referenced on 6/3/2022)

*131 東洋エンジニアリング e-fuel・SAF
<https://www.toyo-eng.com/jp/ja/solution/e-fuel/>
(Referenced on 6/3/2022)

*132 経済産業省　CO2等を用いた燃料製造技術開発プロジェクトの研究開発・社会実装の方向性（案）
<https://www.meti.go.jp/shingikai/sankoshin/green_innovation/energy_structure/pdf/007_02_00.pdf>
(Referenced on 6/3/2022)

*133 経済産業省　令和元年度燃料安定供給対策に関する調査等（バイオ燃料等のライフサイクルＧＨＧ排出量算定に関する調査）報告書
<https://www.meti.go.jp/meti_lib/report/2019FY/000447.pdf>
(Referenced on 6/3/2022)"

*134 国土交通省 航空輸送統計年報（令 和 元 年（２ ０ １ ９ 年））
<https://www.mlit.go.jp/report/press/joho05_hh_000549.html>
(Referenced on 6/3/2022)

*135 石油連盟 統計情報
<https://www.paj.gr.jp/statis/kansan/>
(Referenced on 6/3/2022)

*136 国立研究開発法人産業技術総合研究所　2-1804 2050年の社会像を見据えた再生可能エネルギー利用拡大への道筋
<https://www.erca.go.jp/suishinhi/seika/pdf/seika_1_r03/seika/2-1804.pdf>
(Referenced on 6/3/2022)

*137 国立研究開発法人 平成 29 年度 海洋開発人材育成 海洋開発工学概論 海洋再生可能エネルギー開発編
<https://www.mlit.go.jp/common/001235504.pdf>
(Referenced on 6/3/2022)

*138 NEDO Pt. 再生可能エネルギー技術白書 7　海洋温度差発電の技術の現状とロードマップ
<https://www.nedo.go.jp/content/100107275.pdf>
(Referenced on 6/3/2022)

*139 NEDO H27年度報告書2. 海洋温度差発電システムの確立について
<https://www.pref.okinawa.jp/site/shoko/seisaku/kiban/oceanrenewableenergy/otec/houkokusyo/documents/h28hatsuden_03_2syou.pdf>
(Referenced on 6/3/2022)

*140 経済産業省 グリーンイノベーション基金事業に係る実施予定先一覧
<https://www.nedo.go.jp/content/100938629.pdf>
(Referenced on 6/3/2022)

*141 国土交通省「次世代船舶の開発」プロジェクトの研究開発・社会実装計画（案）
<https://www.meti.go.jp/shingikai/sankoshin/green_innovation/industrial_restructuring/pdf/002_04_00.pdf>
(Referenced on 6/3/2022)

*142 海上技術安全技術研究所 船舶へのＬＣＡの適用に関する調査研究
<https://www.nmri.go.jp/oldpages/env/lca/Paper/pdf/27.pdf>
(Referenced on 6/3/2022)

*143 日本船主協会 世界の商船船腹量の推移
<https://www.jsanet.or.jp/data/pdf/2020data10-1.pdf>
(Referenced on 6/3/2022)

*144 日本船主協会 日本籍船船腹量の推移
<https://www.jsanet.or.jp/data/pdf/2020data10-5.pdf>
(Referenced on 6/3/2022)

*145 経済産業省 次世代船舶の開発　事業概要
<https://www.nedo.go.jp/content/100938630.pdf>
(Referenced on 6/3/2022)

*146 国際海運GHGゼロエミッションプロジェクト 国際海運のゼロエミッションに向けたロードマップ<https://www.mlit.go.jp/common/001344866.pdf>
(Referenced on 6/3/2022)

*147 国際海運GHGゼロエミッションプロジェクト 国際海運のゼロエミッションに向けたロードマップ（PPT）
<https://www.mlit.go.jp/common/001377661.pdf>
(Referenced on 6/3/2022)

*148 国土技術政策総合研究所 総トン数（GT）と載貨重量トン数（DWT）
<http://www.nilim.go.jp/lab/bcg/siryou/rpn/rpn0028pdf/kh0028015.pdf>
(Referenced on 6/3/2022)
*149 日本船主協会 わが国外交商船隊
<https://www.jsanet.or.jp/data/pdf/2020data40-1.pdf>
(Referenced on 6/3/2022)
*150 資源エネルギー庁 総合資源エネルギー調査会長期エネルギー需給見通し小委員会（第6回会合）、平成27年4月
<https://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/mitoshi/006/pdf/006_06.pdf>
(Referenced on 6/3/2022)
*151 一般財団法人コージェネレーション・エネルギー高度利用センター コージェネの特徴
<https://www.ace.or.jp/web/chp/chp_0030.html>
(Referenced on 6/3/2022)
*152 環境省 サプライチェーンを通じた組織の温室効果ガス排出等の算定のための排出原単位データベース（Ver.3.1）
<https://www.env.go.jp/earth/ondanka/supply_chain/gvc/estimate_tool.html>
(Referenced on 6/3/2022)
*153 一般財団法人コージェネレーション・エネルギー高度利用センター 原動機種別導入状況
<https://www.ace.or.jp/web/works/works_0060.html>
(Referenced on 6/3/2022)
*154 環境省 電気事業者別排出係数一覧（令和4年提出用）
<https://ghg-santeikohyo.env.go.jp/files/calc/r04_coefficient_rev.pdf>
(Referenced on 6/3/2022)
*155 株式会社 日立パワーソリューションズHP ガスコージェネレーションシステム水素燃料への取り組み
<https://www.hitachi-power-solutions.com/energy/self-generation/engine/gas/hydrogen.html>
(Referenced on 6/3/2022)
*156 東邦ガス株式会社 プレスリリースコージェネレーションシステム用ガスエンジン商品機で都市ガス・水素混焼の試験運転に成功～水素混焼率35%での定格運転は国内初～
<https://www.tohogas.co.jp/corporate-n/press/1223638_1342.html>
(Referenced on 6/3/2022)"
*157 九電みらいエナジー「潮流発電技術実用化推進事業」発電機設置工事の開始について
<https://www.q-mirai.co.jp/news/archives/243>
(Referenced on 6/3/2022)
*158 IPCC 再生可能エネルギー源と気候変動緩和に関する特別報告書
<http://www.env.go.jp/earth/ipcc/special_reports/srren/pdf/SRREN_Ch06_ja.pdf>
(Referenced on 6/3/2022)
*159 国立研究開発法人科学技術振興機構 研究開発戦略センター 研究開発の俯瞰報告書　環境・エネルギー分野（2021年）
<https://www.jst.go.jp/crds/pdf/2020/FR/CRDS-FY2020-FR-01/CRDS-FY2020-FR-01_20107.pdf>
(Referenced on 6/3/2022)
*160 地球工学研究所・環境科学研究所 海洋エネルギー利用発電技術の現状と課題
<https://criepi.denken.or.jp/jp/env/outline/2010/report/pdf/67.pdf>
(Referenced on 6/3/2022)
*161 NEDO 再生可能エネルギー技術白書
<https://www.nedo.go.jp/content/100544821.pdf>
(Referenced on 6/3/2022)
*162 スマートジャパン 国内初の商用スケールの「大型潮流発電」を実証、九電みらいが長崎県五島沖で
<https://www.itmedia.co.jp/smartjapan/articles/2203/18/news063.html>
(Referenced on 6/3/2022)
*163 日本製紙連合会 産業構造審議会 第12回 製造産業分科会
<https://www.meti.go.jp/shingikai/sankoshin/seizo_sangyo/pdf/012_04_00.pdf>
(Referenced on 6/3/2022)
*164 日本製紙連合会 技術環境部 紙パルプ産業のエネルギー事情 2020 年度版（2019 年度実績）
<https://www.jpa.gr.jp/file/release/20210225034339-1.pdf>
(Referenced on 6/3/2022)
*165 環境省 温室効果ガス総排出量 算定方法ガイドライン
<https://www.env.go.jp/policy/local_keikaku/data/guideline.pdf>
(Referenced on 6/3/2022)
*166 日本製紙連合会 2021年度カーボンニュートラル行動計画（低炭素社会実行計画）フォローアップ調査結果(2020年度実績)
<https://www.meti.go.jp/shingikai/sankoshin/sangyo_gijutsu/chikyu_kankyo/seishi_wg/pdf/2021_001_05_01.pdf>
(Referenced on 6/3/2022)
*167 日本木質バイオマスエネルギー協会 国産材を活用した木質バイオマス発電におけるGHG排出量の試算について
<https://www.meti.go.jp/shingikai/enecho/shoene_shinene/shin_energy/biomass_sus_wg/pdf/012_03_00.pdf>
(Referenced on 6/3/2022)
*168 日本製紙連合会 製紙業界の「低炭素社会実行計画」（2020 年目標）
<https://www.meti.go.jp/shingikai/sankoshin/sangyo_gijutsu/chikyu_kankyo/seishi_wg/pdf/h29_001_04_02.pdf>
(Referenced on 6/3/2022)
*169 資源エネルギー庁 地熱発電・中小水力発電・バイオマス発電のコストデータ
<https://www.meti.go.jp/shingikai/santeii/pdf/050_02_00.pdf>
(Referenced on 6/3/2022)
*170 農林水産省 再生可能エネルギー事業の標準的な収支及びキャッシュフロー（農林水産省試算）
<https://www.env.go.jp/policy/%EF%BC%88%E6%9C%A8%E8%B3%AA%E3%83%90%E3%82%A4%E3%82%AA%E3%83%9E%E3%82%B9%EF%BC%89Ver1.1_%E7%A2%BA%E5%AE%9A%E7%89%88.pdf>
(Referenced on 6/3/2022)
*171 環境省大臣官房環境経済課 地域における再生可能エネルギー事業の事業性評価等に関する手引き（金融機関向け）Ver1.1 ～木質バイオマス発電事業編～
<https://www.maff.go.jp/j/shokusan/renewable/energy/pdf/syushi.pdf>
(Referenced on 6/3/2022)
*172 NEDO カーボンリサイクル実現を加速するバイオ由来製品生産技術の開発
<https://www.nedo.go.jp/activities/ZZJP_100170.html>
(Referenced on 6/3/2022)
*173 資源エネルギー庁 エネルギー白書2021
<https://www.enecho.meti.go.jp/about/whitepaper/>
(Referenced on 6/3/2022)
*174 日本プラスチック工業連盟 年次資料（2020年プラスチック製品生産実績、プラスチック製品生産実績）
<http://www.jpif.gr.jp/3toukei/toukei.htm>
(Referenced on 6/3/2022)
*175 経済産業省資料 表 1-3 プラスチック製容器包装の製造における CO2 排出原単位
<https://www.meti.go.jp/policy/recycle/main/data/research/h24fy/h2503-yourimri/h2503-yourimri-01.pdf>
(Referenced on 6/3/2022)
*176 Erwin T.H. Vink and Steve Davies Life Cycle Inventory and Impact Assessment Data for 2014 Ingeo™ Polylactide Production
<https://www.liebertpub.com/doi/full/10.1089/ind.2015.0003>
(Referenced on 6/3/2022)
*177 環境省廃棄物分科会 廃棄物分野における排出量の算定方法について
<https://www.env.go.jp/earth/ondanka/ghg-mrv/committee/h30/Waste_30.pdf>
(Referenced on 6/3/2022)
*178 NEDO 6 波力発電の技術の現状とロードマップ
<https://www.nedo.go.jp/content/100107274.pdf>
(Referenced on 6/3/2022)
*179 三井造船【事業名】小型で高効率な波力発電システムに関わる技術開発・実証事業（副題：大洗港における技術実証）
<https://www.env.go.jp/earth/ondanka/cpttv_funds/pdf/db/153.pdf>
(Referenced on 6/3/2022)
*180 電力中央研究所 発電プラントの温暖化影響分析（平成4年）
<https://criepi.denken.or.jp/hokokusho/pb/reportDownload?reportNoUkCode=Y91005&tenpuTypeCode=30&seqNo=1&reportId=3088>
(Referenced on 6/3/2022)
*181 日本鉄鋼連盟 用途別受注統計(2021年3月　累計）
<https://www.jisf.or.jp/data/yoto/index.html>
(Referenced on 6/3/2022)
*182 日鉄総研 日本鉄鋼連盟『ゼロカーボンスチールへの挑戦』実現に向けた課題（P11)
<https://www.esisyab.iis.u-tokyo.ac.jp/symposium/20210204/20210204-05.pdf>
(Referenced on 6/3/2022)
*183 環境省 廃棄物・資源循環分野における2050年温室効果ガス排出実質ゼロに向けた中長期シナリオ(案)
<http://www.env.go.jp/council/03recycle/y030-38b/mat01_1.pdf>
(Referenced on 6/3/2022)
*184 warecl ステーション 佐賀市はCO2分離回収の先駆け！ バイオマス産業で地域振興目指す
<https://wa-recl.net/article/a/189>
(Referenced on 6/3/2022)

*185 日本LPガス協会 グリーンLPガスの生産技術開発に向けた研究会　報告書(令和3年5月12日)
<https://www.j-lpgas.gr.jp/data/GreenLPG_Report_20120622.pdf>
(Referenced on 6/3/2022)
*186 日本LPガス協会 DME混合によるLPガスの低炭素化（令和3年3月25日）
<https://www.j-lpgas.gr.jp/data/GreenLPG_Presen_DME_20210325.pdf>
(Referenced on 6/3/2022)
*187 農林水産省　食料産業局 バイオマスの活用をめぐる状況
<https://www.maff.go.jp/j/shokusan/biomass/attach/pdf/index-110.pdf>
(Referenced on 6/3/2022)
*188 財団法人エンジニアリング振興協会地下開発利用研究センター バイオマス起源 DME を含むエネルギー貯蔵供給システムの開発に関する調査研究報告書
<https://hojo.keirin-autorace.or.jp/seikabutsu/seika/20nx_/bhu_/zp_/20-112koho-03.pdf>
(Referenced on 6/3/2022)
*189 日本LPガス団体協議会 LPガス読本
<http://www.nichidankyo.gr.jp/toku/>
(Referenced on 6/3/2022)
*190 一般財団法人日本自動車研究所 燃料電池自動車（FCV）のしくみ
<http://www.jari.or.jp/portals/0/jhfc/beginner/about_fcv/index.html>
(Referenced on 6/3/2022)
*191 公益社団法人日本バス協会 2020年度版（令和2年度）日本のバス事業
<https://www.bus.or.jp/about/pdf/2020_busjigyo.pdf>
(Referenced on 6/3/2022)
*192 日野自動車 日野自動車のFCバスへの取組と課題
<https://www.meti.go.jp/committee/kenkyukai/energy/suiso_nenryodenchi/suiso_nenryodenchi_wg/pdf/004_s01_00.pdf>
(Referenced on 6/3/2022)
*193 国土交通省 燃料電池バスの普及及び導入支援策について
<https://www.meti.go.jp/committee/kenkyukai/energy/nenryodenchi_fukyu/pdf/003_03_02.pdf>
(Referenced on 6/3/2022)
*194 国土交通省 自動車燃費一覧（令和2年3月）
<https://www.mlit.go.jp/jidosha/jidosha_fr10_000044.html>
(Referenced on 6/3/2022)
*195 資源エネルギー庁 水素・燃料電池戦略ロードマップの達成に向けた対応状況
<https://www.meti.go.jp/shingikai/energy_environment/suiso_nenryo/roadmap_hyoka_wg/pdf/002_01_00.pdf>
(Referenced on 6/3/2022)
*196 再生可能エネルギー・水素等関係閣僚会議 水素基本戦略
<https://www.cas.go.jp/jp/seisaku/saisei_energy/pdf/hydrogen_basic_strategy.pdf>
(Referenced on 6/3/2022)
*197 水素・燃料電池戦略協議会 水素・燃料電池戦略ロードマップ
<https://www.meti.go.jp/press/2018/03/20190312001/20190312001-1.pdf>
(Referenced on 6/3/2022)
*198 Ryuji Kawamoto, Hideo Mochizuki, Yoshihisa Moriguchi, Takahiro Nakano, Masayuki Motohashi, Yuji Sakai and Atsushi Inaba Estimation of CO2 Emissions of Internal Combustion Engine Vehicle and Battery Electric Vehicle Using LCA
<https://www.mdpi.com/2071-1050/11/9/2690>
(Referenced on 6/3/2022)
*199 環境省 次世代自動車ガイドブック2017-2018
<https://www.env.go.jp/air/car/vehicles2017-2018/LEV_chapter2-1.pdf>
(Referenced on 6/3/2022)
*200 石崎啓太、中野冠 内燃機関自動車，ハイブリッド自動車，電気自動車，燃料電池自動車における車内空調を考慮した量産車両 LCCO2排出量の比較分析
<https://www.jstage.jst.go.jp/article/transjsme/84/866/84_18-00050/_pdf/-char/ja>
(Referenced on 6/3/2022)
*201 国土交通省 自動車燃料消費量調査2020年度
<https://www.e-stat.go.jp/stat-search/files?page=1&layout=datalist&toukei=00600370&kikan=00600&tstat=000001051698&cycle=8&year=20201&month=0&result_back=1&result_page=1&tclass1val=0>
(Referenced on 6/3/2022)
*202 日産自動車 電気自動車総合サイト
<https://ev2.nissan.co.jp/BLOG/582/>
(Referenced on 6/3/2022)
*203 IEA World Energy Outlook 2020
<https://www.iea.org/reports/world-energy-outlook-2020>
(Referenced on 6/3/2022)
*204 東京電力エナジーパートナー ウェブサイト
<https://evdays.tepco.co.jp/entry/2021/10/12/000021>
(Referenced on 6/3/2022)
*205 一般社団法人日本自動車販売協会連合会 車種別販売台数
<http://www.jada.or.jp/data/year/y-r-hanbai/y-r-type/y-r-type-ns/>
(Referenced on 6/3/2022)
*206 パナソニックホールディングス株式会社 ノンフロン冷凍機システム
<https://panasonic.biz/appliance/cold_chain/refrigerator/cfcfree/>
(Referenced on 6/3/2022)
*207 三菱重工サーマルシステムズ株式会社 冷熱製品サイト
<https://www.mhi-mth.co.jp/business/engineering/c-puzzle/>
(Referenced on 6/3/2022)
*208 株式会社前川製作所 冷蔵倉庫向けノンフロン冷凍機
<http://www.mayekawa.co.jp/ja/about/natural_refrigerant/>
(Referenced on 6/3/2022)
*209 国立環境研究所　温室効果ガスインベントリオフィス 日本の温室効果ガス排出量データ
<https://www.nies.go.jp/gio/aboutghg/index.html>
(Referenced on 6/3/2022)
*210 経済産業省、環境省 代替フロンに関する状況と現行の取組について
<https://www.meti.go.jp/shingikai/sankoshin/seizo_sangyo/kagaku_busshitsu/flon_godo/pdf/010_01_00.pdf>
(Referenced on 6/3/2022)
*211 公益社団法人日本冷凍空調学会 次世代冷媒に関する調査委員会 次世代冷媒・冷凍空調技術の基本性能・最適化・評価手法および安全性・リスク評価
<https://www.jsrae.or.jp/committee/jisedai_R/2019_ProgressR_WG3.pdf>
(Referenced on 6/3/2022)
*212 日本経済新聞 2015年7月23日　三菱重工、サウジで大型ターボ冷凍機80台受注
<https://www.nikkei.com/article/DGXLASDZ23HLQ_T20C15A7TJC000/>
(Referenced on 6/3/2022)
*213 三菱重工 2015年7月23日　ニュースリリース
<https://www.mhi.com/jp/news/1507235663.html>
(Referenced on 6/3/2022)
*214 環境省 冷媒代替の現状と課題
<https://www.env.go.jp/council/06earth/y0612-01/mat02_3-2.pdf>
(Referenced on 6/3/2022)
*215 三菱重工サーマルシステムズ株式会社WEBカタログ 高性能ターボ冷凍機
<https://www.mhi-mth.co.jp/catalogue/index.php?mode=preview&contentsNumber=545&pvp=5>
(Referenced on 6/3/2022)
*216 東京電力エナジーパートナー株式会社 電気料金プラン（高圧電力）
<https://www.tepco.co.jp/ep/corporate/plan_h/plan10.html>
(Referenced on 6/3/2022)
*217 国税庁 耐用年数の適用等に関する取扱通達の付表
<https://www.nta.go.jp/law/tsutatsu/kobetsu/sonota/700525/fuhyou/10.htm>
(Referenced on 6/3/2022)
*218 環境省 サプライチェーンを通じた組織の温室効果ガス排出等の算定のための排出原単位データベースVer.3.2
<https://www.env.go.jp/earth/ondanka/supply_chain/gvc/estimate_tool.html#no02>
(Referenced on 6/3/2022)
*219 栃木県 天然ガスコージェネレーション設備の導入事例
<https://www.pref.tochigi.lg.jp/kankyoseisaku/home/keikaku/archive/shinenergy/pdf/8.pdf>
(Referenced on 6/3/2022)
*220 神奈川県 コージェネレーションシステムの魅力
<https://www.pref.kanagawa.jp/docs/e3g/cnt/f537516/index.html#cost>
(Referenced on 6/3/2022)
*221 資源エネルギー庁 ガス事業生産動態統計調査
<https://www.enecho.meti.go.jp/statistics/gas/ga001/results.html#headline2>
(Referenced on 6/3/2022)
*222 一般財団法人コージェネレーション・エネルギー高度利用センター コージェネ・廃熱利用機器メーカー情報-2
<https://www.ace.or.jp/web/chp/chp_0100.html>
(Referenced on 6/3/2022)
*223 国立研究開発法人新エネルギー・産業技術総合開発機構 環境調和型プロセス技術の開発/水素還元等プロセス技術の開発
<https://www.nedo.go.jp/content/100932842.pdf>
(Referenced on 6/3/2022)

*224 日本製鉄株式会社 鉄鋼業における水素利用
<https://www.meti.go.jp/shingikai/energy_environment/suiso_nenryo/pdf/020_05_00.pdf>
(Referenced on 6/3/2022)
*225 国立研究開発法人国立環境研究所 日本の温室効果ガス排出量データ(1990～2019年度)確報値
<https://www.nies.go.jp/gio/archive/ghgdata/index.html>
(Referenced on 6/3/2022)
*226 普通鋼電炉工業会 電炉鋼のシェア
<http://www.fudenkou.jp/about_03.html>
(Referenced on 6/3/2022)
*227 東京製鉄 環境報告書2020
<http://www.tokyosteel.co.jp/eco/achievement/pdf/Tokyo_Steel_Environmental_Report_2020.pdf>
(Referenced on 6/3/2022)
*228 経済産業省　水素・燃料電池戦略ロードマップ
<https://www.meti.go.jp/press/2018/03/20190312001/20190312001-1.>
(Referenced on 6/3/2022)
*229 東京ガス エネファームを導入するには
<https://home.tokyo-gas.co.jp/living/enefarm/introduction/new.html>
(Referenced on 6/3/2022)
*230 国立研究開発法人新エネルギー・産業技術総合開発機構 定置用燃料電池大規模実証研究事業報告書
<https://www.nedo.go.jp/content/100116229.pdf>
(Referenced on 6/3/2022)
*231 西部ガス 光熱費は、年間どのくらいお得になりますか？
<https://www.saibugas.co.jp/home/house/myhome_ene/farm/qa04.htm>
(Referenced on 6/3/2022)
*232 商船三井 船舶におけるLNG燃料としての現状と今後
<https://www.mol-service.com/ja/blog/lng-as-ships-fuel>
(Referenced on 6/3/2022)
*233 日本船舶技術研究協会 国際海運のゼロエミッションに向けた産学官公の総合戦略
<https://www.mlit.go.jp/policy/shingikai/content/001389406.pdf>
(Referenced on 6/3/2022)
*234 海上技術安全研究所 GHG削減船の実現に向けた検討
<https://www.nmri.go.jp/event/presentation/R3/lecture_13.pdf>
(Referenced on 6/3/2022)
*235 一般財団法人 運輸総合研究所 船舶の代替燃料としてのLNG の可能性に関する調査研究
<https://www.jttri.or.jp/docs/190207_houkokusho.pdf>
(Referenced on 6/3/2022)
*236 環境展望台　環境技術解説 廃棄物発電
<https://tenbou.nies.go.jp/science/description/detail.php?id=72#:~:text=%E5%BB%83%E6%A3%84%E7%89%A9%E7%99%BA%E9%9B%BB%E3%81%A8%E3%81%AF,%E3%82%92%E8%A1%8C%E3%81%86%E6%96%B9%E6%B3%95%E3%81%A7%E3%81%82%E3%82%8B%E3%80%82>
(Referenced on 6/3/2022)
*237 電力中央研究所 日本における発電技術のライフサイクルCO2排出量総合評価
<https://criepi.denken.or.jp/hokokusho/pb/reportDetail?reportNoUkCode=Y06>
(Referenced on 6/3/2022)
*238 環境省資料 廃棄物発電に係るコスト試算
<http://www.env.go.jp/recycle/waste/tool_gwd3r/h24_report03.pdf>
(Referenced on 6/3/2022)
*239 国立研究開発法人 海上・港湾・航空技術研究所 海上技術安全研究所 低・脱炭素燃料に対応する舶用動力システムに関する研究
<https://www.nmri.go.jp/event/presentation/R1/lecture_1.pdf>
(Referenced on 6/3/2022)
*240 国立研究開発法人 海上・港湾・航空技術研究所 船舶分野における燃料電池システムの展開
<https://www.nmri.go.jp/_src/7826/pnm2a170012-00.pdf>
(Referenced on 6/3/2022)
*241 国土交通省　海事局 内航海運のCO2排出量の現状及び取り巻く環境等について
<https://www.mlit.go.jp/maritime/content/001402855.pdf>
(Referenced on 6/3/2022)
*242 MONOist（出典：日本郵船） 海運もゼロエミッション、燃料電池で動く「日本初」の船舶が2024年竣工
<https://monoist.itmedia.co.jp/mn/articles/2009/09/news047_3.html>
(Referenced on 6/3/2022)

*243 一般財団法人日本船舶技術研究協会 欧州における電池推進船の動向調査
<https://www.jstra.jp/html/PDF/research2017_02.pdf>
(Referenced on 6/3/2022)
*244 国立研究開発法人 海上・港湾・航空技術研究所 内航船舶のカーボンニュートラル推進に向けた短期的取り組みの検討
<https://www.mlit.go.jp/maritime/content/001406937.pdf>
(Referenced on 6/3/2022)
*245 船主連絡協議会　貨物船部会 令和2年度　貨物船船舶経費見直しについて
<http://www.zenkaiun.or.jp/wp/wp-content/uploads/2020/11/20201119111429806.pdf>
(Referenced on 6/3/2022)
*246 日経ビジネス 商船三井や三菱商事が挑むEVタンカー、背景に海運業「2つの高齢化」
<https://business.nikkei.com/atcl/gen/19/00002/080700601/>
(Referenced on 6/3/2022)
*247 BBC Pining for cleaner air in the Norwegian fjords
<https://www.bbc.com/news/business-39478856>
(Referenced on 6/3/2022)
*248 富士電機 リチウムイオン電池を唯一の動力源とするゼロエミッション船の「電気推進システム」を提供
<https://www.fujielectric.co.jp/products/saveblue-solution/electricpropulsion.html>
(Referenced on 6/3/2022)
*249 国土交通省 運輸部門における二酸化炭素排出量
<https://www.mlit.go.jp/sogoseisaku/environment/sosei_environment_tk_000007.html>
(Referenced on 6/3/2022)
*250 三菱総合研究所 蓄電システムをめぐる現状認識
<https://www.meti.go.jp/shingikai/energy_environment/storage_system/pdf/001_05_00.pdf>
(Referenced on 6/3/2022)
*251 国際海運 GHG ゼロエミッションプロジェクト 国際海運のゼロエミッションに向けたロードマップ
<https://www.mlit.go.jp/common/001354532.pdf>
(Referenced on 6/3/2022)
*252 国土交通省 参考資料
<https://www.mlit.go.jp/policy/shingikai/content/001364129.pdf>
(Referenced on 6/3/2022)
*253 既存建築物省エネ化推進事業 既存建築物省エネ化推進事業
<https://hyoka-jimu.jp/kaishu/>
(Referenced on 6/3/2022)
*254 国土交通省 国土交通省における省エネ対策の概要
<https://www.meti.go.jp/shingikai/enecho/shoene_shinene/sho_energy/pdf/032_02_00.pdf>
(Referenced on 6/3/2022)
*255 株式会社野村総合研究所 既存建築物のＺＥＢ化推進に向けた調査報告書
<https://www.meti.go.jp/meti_lib/report/H30FY/000723.pdf>
(Referenced on 6/3/2022)
*256 国土交通省 現状の道路照明における課題・新たな道路照明に期待する効果
<https://www.mlit.go.jp/tec/content/001362070.pdf>
(Referenced on 6/3/2022)
*257 国土交通省 現状の道路照明における課題・新技術に期待する効果
<https://www.mlit.go.jp/tec/content/001312075.pdf>
(Referenced on 6/3/2022)
*258 Robertson, Stephen E. and Hugo Zaragoza. “The Probabilistic Relevance Framework: BM25 and Beyond.” *Found. Trends Inf. Retr.* 3 (2009):333-389.
<https://dl.acm.org/doi/10.1561/1500000019 >
(Referenced on 2/28/2023)
*259 Lv, Yuanhua and ChengXiang Zhai. ”Lower-bounding term frequency normalization.” *International Conference on Information and Knowledge Management* (2011).
<https://dl.acm.org/doi/10.1145/2063576.2063584 >
(Referenced on 2/28/2023)
*260 Campello, R.J.G.B., Moulavi, D., Sander, J. (2013). Density-Based Clustering Based on Hierarchical Density Estimates. In: Pei, J., Tseng, V.S., Cao, L., Motoda, H., Xu, G. (eds) Advances in Knowledge Discovery and Data Mining. PAKDD 2013. Lecture Notes in Computer Science(), vol 7819. Springer, Berlin, Heidelberg.
<https://link.springer.com/chapter/10.1007/978-3-642-37456-2_14>
(Referenced on 2/28/2023)
*261 M. Çelik, F. Dadaşer-Çelik and A. Ş. Dokuz, "Anomaly detection in temperature data using DBSCAN algorithm," *2011 International Symposium on Innovations in Intelligent Systems and Applications*, Istanbul, Turkey, 2011, pp. 91-95.”
<https://ieeexplore.ieee.org/document/5946052 >
(Referenced on 2/28/2023)

*262 国立環境研究所 ネガティブ・エミッションの達成にむけた全球炭素管理
<https://www.nies.go.jp/kanko/news/34/34-4/34-4-04.html>
(Referenced on 6/9/2023)
*263 資源エネルギー庁 エネルギー白書2021
<https://www.enecho.meti.go.jp/about/whitepaper/2021/html/2-1-4.html>
(Referenced on 6/9/2023)
*264 経済産業省産業技術環境局ネガティブエミッション技術について
<007_03_02.pdf (meti.go.jp)>
(Referenced on 6/9/2023)
*265 NEDO「2018年度～2019年度成果報告書　バイオマスエネルギーの地域自立システム化実証事業／地域自立システム化実証事業／栃木県におけるエリアンサスを含めたバイオマス資源を利活用した公共施設への地域自立システム化の事業性評価（FS）」
*266 林野庁 令和 3 年における木質粒状燃料（木質ペレット）の生産量等について
<https://www.rinya.maff.go.jp/j/riyou/biomass/attach/pdf/w_pellet-4.pdf>
(Referenced on 6/9/2023)
*267 港湾空港技術研究所 沿岸環境研究グループ 浅海生態系における年間二酸化炭素吸収量の全国推計
<https://www.jstage.jst.go.jp/article/kaigan/75/1/75_10/_pdf/-char/ja>
(Referenced on 6/9/2023)
*268 経済産業省ホームページ 2050年カーボンニュートラルに伴うグリーン成長戦略
<https://www.meti.go.jp/press/2021/06/20210618005/20210618005.html>
(Referenced on 6/9/2023)
*269 経済産業省資源エネルギー庁 太陽熱利用システム
<https://www.enecho.meti.go.jp/category/saving_and_new/attaka_eco/system/index.html>
(Referenced on 6/9/2023)
*270 iPROS 太陽熱温水器 - 企業5社の製品一覧とランキング
<https://www.ipros.jp/cg2/%E5%A4%AA%E9%99%BD%E7%86%B1%E6%B8%A9%E6%B0%B4%E5%99%A8/>
(Referenced on 6/9/2023)
*271 門倉宏子、本藤祐樹 家庭用太陽熱給湯機のエネルギー収支とライフサイクルCO2排出量
<https://www.jstage.jst.go.jp/article/lca/12/2/12_97/_pdf/-char/ja>
(Referenced on 6/9/2023)
*272 総務省 平成30年住宅土地統計調査住宅及び世帯に関する基本集計
<https://www.stat.go.jp/data/jyutaku/2018/pdf/kouzou_gaiyou.pdf>
(Referenced on 6/9/2023)
*273 総務省 平成 25 年住宅・土地統計調査結果による住宅に関する主な指標（確報値）
<https://www.stat.go.jp/data/jyutaku/topics/pdf/topics86_2.pdf>
(Referenced on 6/9/2023)
*274 リフォームLab. 太陽熱温水器の価格と費用対効果
<https://standard-project.net/smarthouse/water-heater/solar-powered_cost.html>
(Referenced on 6/9/2023)
*275 リフォームLab. 給湯器の交換　費用や光熱費を徹底比較
<https://standard-project.net/smarthouse/water-heater/#2>
(Referenced on 6/9/2023)
*276 NEDO TSC Foresight Vol.41
<https://www.nedo.go.jp/content/100928248.pdf>
(Referenced on 6/9/2023)
*277 吉永美香、城出浩作 住宅用太陽熱利用給湯システムの評価及び効果予測シミュレーションに関する研究
<https://www.jstage.jst.go.jp/article/shasetaikai/2018.10/0/2018.10_105/_pdf/-char/ja>
(Referenced on 6/9/2023)
*278 港湾空港技術研究所 沿岸環境研究グループ 浅海生態系における年間二酸化炭素吸収量の全国推計
<https://www.jstage.jst.go.jp/article/kaigan/75/1/75_10/_pdf/-char/ja>
(Referenced on 6/9/2023)
*279 経済産業省ホームページ 2050年カーボンニュートラルに伴うグリーン成長戦略
<https://www.meti.go.jp/press/2021/06/20210618005/20210618005.html>
(Referenced on 6/9/2023)
*280 経済産業省資源エネルギー庁 再生可能エネルギーとは
<https://www.enecho.meti.go.jp/category/saving_and_new/saiene/renewable/underground/index.html>
(Referenced on 6/9/2023)
*281 阪田義隆、葛隆生等 地中熱利用ヒートポンプシステム導入によるCO2排出量削減の全国評価：戸建住宅への暖房利用を例として
<https://www.jstage.jst.go.jp/article/jscejer/74/5/74_I_359/_pdf/-char/ja>
(Referenced on 6/9/2023)
*282 岡田浩一、山崎智雄等 ライフサイクルCO2排出量による地中熱利用事業および小水力発電事業の評価
<http://library.jsce.or.jp/jsce/open/00519/2013/21-0043.pdf>
(Referenced on 6/9/2023)
*283 NEDO TSC Foresight Vol.41
<https://www.nedo.go.jp/content/100928248.pdf>
(Referenced on 6/9/2023)
*284 小原隆、守山久子 地中熱ヒートポンプで省エネ化
<https://xtech.nikkei.com/atcl/nxt/column/18/00119/>
(Referenced on 6/9/2023)
*285 阪田義隆、葛隆生等 ライフサイクルに基づく地中熱交換器規模の算定と地下水流れがもたらす削減効果の分析：戸建て住宅を例として
<https://www.jstage.jst.go.jp/article/jagh/60/4/60_483/_pdf/-char/ja>
(Referenced on 6/9/2023)
*286 阪田義隆、長野克則等 地中熱利用における課題と地下水学からのアプローチ
<https://www.jstage.jst.go.jp/article/jagh/62/4/62_515/_pdf/-char/ja>
(Referenced on 6/9/2023)
*287 新潟県地中熱利用研究会 地中熱利用ヒートポンプ
<http://ngeoh.jp/example/>
(Referenced on 6/9/2023)
*288 国土交通省 雪冷熱エネルギーの活用促進
<https://www.milt.go.jp/policy/shingikai/content/001319591.pdf>
(Referenced on 6/9/2023)
*289 資源エネルギー庁 再生可能エネルギーとは＞雪氷熱利用
<https://www.enecho.meti.go.jp/category/saving_and_new/saiene/renewable/snow/index.html>
(Referenced on 6/9/2023)
*290 NEDO 再生可能エネルギー白書 8その他の再生可能エネルギー等の技術の現状
<https://www.nedo.go.jp/content/100116325.pdf>
(Referenced on 6/9/2023)
*291 ニセコ町 雪氷熱エネルギー実証実験
<https://www.town.niseko.lg.jp/resources/output/contents/file/release/1498/13917/21midoribunkenhokoku09.pdf>
(Referenced on 6/9/2023)
*292 NEDO/三菱UFJリサーチ＆コンサルティング株式会社(委託) 再生可能エネルギー熱利用技術開発 再生可能エネルギー熱利用システムの普及に向けた技術開発に関する調査
<https://www.nedo.go.jp/koubo/FF3_100257.html>
(Referenced on 6/9/2023)
*293 炭素繊維協会 航空機・自動車・風車LCA
<https://www.carbonfiber.gr.jp/pdf/lca.pdf>
(Referenced on 6/9/2023)
*294 一般社団法人日本自動車工業会 2021年の車種別新車販売台数と構成比
<https://www.jama.or.jp/statistics/facts/four_wheeled/index.html>
(Referenced on 6/9/2023)
*295 炭素繊維協会 航空機・自動車・風車LCA
<https://www.carbonfiber.gr.jp/pdf/lca.pdf>
(Referenced on 6/9/2023)
*296 一般財団法人 日本航空機開発協会 民間航空機に関する市場予測
<174_ext_01_0.pdf (jadc.jp)>
(Referenced on 6/9/2023)
*297 一般財団法人ヒートポンプ・蓄熱センター一般社団法人日本 エレクトロヒートセンター 令和4年度　電化普及見通し調査報告書
<https://www.hptcj.or.jp/Portals/0/data0/press_topics/%E4%BB%A4%E5%92%8C%EF%BC%94%E5%B9%B4%E5%B9%B4%E5%BA%A6/R4Houkokusyo.pdf>
(Referenced on 6/9/2023)
*298 国立社会保障・人口問題研究所 日本の将来推計人口（平成30年度推計）結果報告書
<https://www.ipss.go.jp/pp-ajsetai/j/HPRJ2018/t-page.asp>
(Referenced on 6/9/2023)
*299 資源エネルギー庁 空調機器のエネルギー消費割合
<https://www.enecho.meti.go.jp/category/saving_and_new/saving/general/what/>
(Referenced on 6/9/2023)

*300 国立環境研究所 ネガティブ・エミッションの達成にむけた全球炭素管理
<https://www.nies.go.jp/kanko/news/34/34-4/34-4-04.html>
(Referenced on 6/9/2023)
*301 国立社会保障・人口問題研究所 日本の将来推計人口（平成29年度推計）結果報告書
<https://www.ipss.go.jp/pp-zenkoku/j/zenkoku2017/pp29_Report3.pdf>
(Referenced on 6/9/2023)
*302 資源エネルギー庁 ホームページ第二節　部門別エネルギー消費の動向
<https://www.enecho.meti.go.jp/about/whitepaper/2020html/2-1-2.html>
(Referenced on 6/9/2023)
*303 国立研究開発法人　新エネルギー・産業技術総合開発機構（NEDO） 脱炭素社会実現に向けた 省エネルギー技術の研究開発・社会実装促進 プログラムの概要
<https://www.nedo.go.jp/content/100931519.pdf>
(Referenced on 6/9/2023)
*304 国立研究開発法人　新エネルギー・産業技術総合開発機構（NEDO） 未利用熱エネルギーの革新的活用技術研究開発
<https://www.nedo.go.jp/activities/ZZJP_100097.html>
(Referenced on 6/9/2023)
*305 国立研究開発法人　新エネルギー・産業技術総合開発機構（NEDO） 省エネ化・低温室効果を達成できる次世代冷媒・冷凍空調技術及び評価手法の開発
<https://www.nedo.go.jp/activities/ZZJP_100140.html>
(Referenced on 6/9/2023)
*306 環境省 地球温暖化対策計画（令和３年10月22日閣議決定）
<https://www.env.go.jp/earth/ondanka/keikaku/211022.html>
(Referenced on 6/9/2023)
*307 資源エネルギー庁 2030年度におけるエネルギー需給の見通し （関連資料）
<https://www.meti.go.jp/press/2021/10/20211022005/20211022005-3.pdf>
(Referenced on 6/9/2023)
*308 産業技術環境局・資源エネルギー庁 クリーンエネルギー戦略 中間整理
<https://www.meti.go.jp/shingikai/sankoshin/sangyo_gijutsu/green_transformation/pdf/008_01_00.pdf>
(Referenced on 6/9/2023)
*309 環境省 <第6-1-3表>暖房使用状況別-月別エネルギー種別エネルギー消費量2019
<https://www.e-stat.go.jp/stat-search/files?page=1&layout=datalist&toukei=00650408&kikan=00650&tstat=000001149406&cycle=8&tclass1=000001149407&result_page=1&tclass2val=0>
(Referenced on 6/9/2023)
*310 資源エネルギー庁 トップランナー基準の現状等について
<https://www.meti.go.jp/committee/summary/0004310/017_s01_00.pdf>
(Referenced on 6/9/2023)
*311 神奈川県LPガス協会 販売事業者向け業界最新情報
<https://www.kanagawalpg.or.jp/050211.html>
(Referenced on 6/9/2023)
*312 一般財団法人ヒートポンプ・蓄熱センター 家庭部門のエネルギー消費について
<https://www.hptcj.or.jp/individual/tabid/158/Default.aspx>
(Referenced on 6/9/2023)
*313 資源エネルギー庁 令和２年度エネルギー消費統計調査
<https://www.enecho.meti.go.jp/statistics/energy_consumption/ec001/2020_01/>
(Referenced on 6/9/2023)
*314（一社）日本冷凍空調工業会 自主統計
<https://www.jraia.or.jp/statistic/detail.html?ca=0&ca2=0>
(Referenced on 6/9/2023)
*315 日立製作所 業務用エコキュート ｜ 価格・部品適用表
<https://kadenfan.hitachi.co.jp/biz_hp/pdf/price.pdf>
(Referenced on 6/9/2023)
*316 マイクロ波化学（株） 公式ホームページ
<https://mwcc.jp/>
(Referenced on 6/9/2023)
*317 NEDO GaN増幅器モジュールを加熱源とする産業用マイクロ波加熱装置を開発
<https://www.nedo.go.jp/news/press/AA5_100519.html>
(Referenced on 6/9/2023)
*318 国立研究開発法人量子科学技術研究開発機構 マイクロ波加熱を用いた省エネ・CO_2削減精製技術によりベリリウム鉱石の溶解に成功―汎用性の高い精製法として社会実装により、核融合発電の実現を加速―
<https://www.qst.go.jp/site/press/20230330.html>
(Referenced on 6/9/2023)
*319 国立研究開発法人量子科学技術研究開発機構 マイクロ波加熱を用いる省エネ・CO_2削減精製技術でリチウム実鉱石の溶解に成功 ―社会実装に向け加速―
<https://www.qst.go.jp/site/press/20220713.html>
(Referenced on 6/9/2023)
*320 国立社会保障・人口問題研究所 日本の将来推計人口（平成29年度推計）結果報告書
<https://www.ipss.go.jp/pp-zenkoku/j/zenkoku2017/pp29_Report3.pdf>
(Referenced on 6/9/2023)
*321 資源エネルギー庁 総合エネルギー統計2019
<https://www.enecho.meti.go.jp/statistics/total_energy/results.html#headline7>
(Referenced on 6/9/2023)
*322 （一社）日本エレクトロヒートセンター 産業用ヒートポンプ.com
<https://sangyo-hp.jeh-center.org/>
(Referenced on 6/9/2023)
*323 日本経済新聞 日経Xtech マイクロ波加熱で炭素繊維を短時間・低コストで製造、三井化学ら実証へ
<https://xtech.nikkei.com/atcl/nxt/news/18/14168/>
(Referenced on 6/9/2023)
*324 農研機構 カシューナッツ殻液は乾乳牛のメタンを大幅に抑制できる
<https://www.naro.go.jp/project/results/laboratory/nilgs/2012/210c0_03_08.html>
(Referenced on 6/9/2023)
*325 国立環境研究所 日本国温室効果ガスインベントリ報告書（2022年）
<NIR-JPN-2022-v3.0_J_GIOweb.pdf (nies.go.jp)>
(Referenced on 6/9/2023)
*326 株式会社エス・ディー・エスバイオテック ルミナップP
<https://www.sdsbio.co.jp/products/anim/rumi_p.html>
(Referenced on 6/9/2023)
*327 農林水産省 畜産統計（乳用牛　飼養戸数・頭数）
<https://www.e-stat.go.jp/stat-search/files?page=1&layout=datalist&lid=000001304956&toukei=00500222&tstat=000001015614&tclass1=000001020206&tclass2=000001171886&cycle=7&year=20220&month=0&tclass3val=0&stat_infid=000032256893>
(Referenced on 6/9/2023)
*328 農林水産省 畜産統計（肉用牛　飼養戸数・頭数）
<https://www.e-stat.go.jp/stat-search/files?page=1&layout=datalist&lid=000001304956&toukei=00500222&tstat=000001015614&tclass1=000001020206&tclass2=000001171886&cycle=7&year=20220&month=0&tclass3val=0&stat_infid=000032256921>
(Referenced on 6/9/2023)
*329 農業協同組合新聞 カシューナッツ殻液配合鶏用飼料発売　出光興産
<https://www.jacom.or.jp/niku/news/2015/10/151019-28305.php>
(Referenced on 6/9/2023)
*330 日本農業新聞 牛のげっぷ中メタン抑制へ　飼料添加物の基準策定　農水省
<https://www.agrinews.co.jp/farming/index/106558>
(Referenced on 6/9/2023)
*331 帯広畜産大学 微細藻類ユーグレナと海藻のカギケノリの組み合わせが反芻家畜のメタン排出を軽減することを確認メタン排出抑制効果を有する反芻家畜用の飼料原料としての可能性
<https://www.obihiro.ac.jp/wp/wp-content/uploads/2023/04/press20230412.pdf>
(Referenced on 6/9/2023)
*332 国立環境研究所 日本国温室効果ガスインベントリ報告書（2022年）
<NIR-JPN-2022-v3.0_J_GIOweb.pdf (nies.go.jp)>
(Referenced on 6/9/2023)
*333 ABC News How feed additives could cut methane emissions from livestock by 90 per cent
<N/A>
(Referenced on 6/9/2023)
*334 J-クレジット　方法論 水稲栽培における中干し期間の延長
<https://japancredit.go.jp/pdf/methodology/AG-005_v1.0.pdf>
(Referenced on 6/9/2023)
*335 日本国温室効果ガスインベントリ報告書2023 年 5.4. 稲作（3.C.）
<https://www.nies.go.jp/gio/archive/nir/jqjm1000001v3c7t-att/NIR-JPN-2023-v3.0_J_gioweb.pdf>
(Referenced on 6/9/2023)
*336 須藤 重人 水田の中干し延長で温暖化対策
<https://www.naro.affrc.go.jp/archive/niaes/sinfo/publish/niaesnews/096/09603.pdf>
(Referenced on 6/9/2023)

*337 農業環境技術研究所（現農研機構） 水田メタン発生抑制のための新たな水管理技術マニュアル
<https://www.naro.affrc.go.jp/archive/niaes/techdoc/methane_manual.pdf>
(Referenced on 6/9/2023)
*338 農林水産省 令和4年度農業由来のメタン等排出削減対策に係る国際調査等委託事業
<https://www.maff.go.jp/j/kanbo/kankyo/seisaku/climate/methane_report.html>
(Referenced on 6/9/2023)
*339 DSM Bovaer
<Bovaer® (dsm.com)>
(Referenced on 6/9/2023)
*340 PR TIMES DSMの新たな飼料添加物、オランダでの試験で乳牛の温室効果ガス排出を大幅に削減 <N/A>
(Referenced on 6/9/2023)
*341 J-クレジット　方法論 家畜排せつ物管理方法の変更
<https://japancredit.go.jp/pdf/methodology/AG-002_v1.2.pdf>
(Referenced on 6/9/2023)
*342 国立環境研究所 日本国温室効果ガスインベントリ報告書（2022年）
<NIR-JPN-2022-v3.0_J_GIOweb.pdf (nies.go.jp)>
(Referenced on 6/9/2023)
*343 農林水産省 家畜排せつ物処理状況等調査結果（平成31年４月１日現在）
<https://www.maff.go.jp/j/chikusan/kankyo/taisaku/pdf/H31_syori-joukyou.pdf>
(Referenced on 6/9/2023)
*344 畜産環境技術研究所 固液分離機
<https://www.chikusan-kankyo.jp/kkg/kkg/kkg_5_5_1-8.pdf>
(Referenced on 6/9/2023)
*345 丸紅株式会社 畜産業界におけるJ-クレジット制度への登録について
<https://www.marubeni.com/jp/news/2022/release/00067.html>
(Referenced on 6/9/2023)
*346 J-クレジット　方法論 牛・豚・ブロイラーへのアミノ酸バランス改善飼料の給餌
<https://japancredit.go.jp/pdf/methodology/AG-001_v3.0.pdf>
(Referenced on 6/9/2023)
*347 農林水産省 畜産統計（豚　飼養戸数・頭数）
<https://www.e-stat.go.jp/stat-search/files?page=1&layout=datalist&lid=000001304956&toukei=00500222&tstat=000001015614&tclass1=000001020206&tclass2=000001171886&cycle=7&year=20220&month=0&tclass3val=0&stat_infid=000032256951>
(Referenced on 6/9/2023)
*348 農林水産省 畜産統計（ブロイラー　飼養戸数・羽数）
<https://www.e-stat.go.jp/stat-search/files?page=1&layout=datalist&lid=000001304956&toukei=00500222&tstat=000001015614&tclass1=000001020206&tclass2=000001171886&cycle=7&year=20220&month=0&tclass3val=0&stat_infid=000032256971>
(Referenced on 6/9/2023)
*349 農研機構 肥育牛のアミノ酸バランス飼料の給与事例紹介
<https://www.maff.go.jp/j/chikusan/kankyo/taisaku/attach/pdf/sympo-3.pdfhttps://www.affrc.maff.go.jp/docs/press/attach/pdf/211223-3.pdf>
(Referenced on 6/9/2023)
*350 J-クレジット 第29回 J －クレジット制度運営委員会資料
<https://japancredit.go.jp/steering_committee/data/haihu_230301/1_inkai_shiryo.pdf>
(Referenced on 6/9/2023)

Deloitte Tohmatsu Science and Technology CN Team list of authors

Kotaro Saito
Managing Director
Operational Risk
Risk Advisory
Deloitte Touche Tohmatsu LLC

Naoki Sakaguchi
Director
Deloitte Touche Tohmatsu LLC

Hao Zhao
Manager
ESG&IR Advisory
Risk Advisory
Deloitte Touche Tohmatsu LLC

Yoshiki Akimoto
Manager
GRC Operational Risk
Risk Advisory
Deloitte Touche Tohmatsu LLC

Takashi Sugiyama
Manager
Public Sector
Deloitte Tohmatsu Consulting LLC

Junichi Ominami
Public Sector
Deloitte Tohmatsu Consulting LLC

Akihiro Urata
Deloitte Tohmatsu Consulting LLC

Shohei Takata
OGCMM Corporate Strategy
Deloitte Tohmatsu Financial Advisory LLC

Kohei Akashi
PSHC
Auditing & Attestation
Deloitte Touche Tohmatsu LLC

Kazuki Tomonari
GRC Operational Risk
Risk Advisory
Deloitte Touche Tohmatsu LLC

Nao Sekiguchi
GAU general
Risk Advisory
Deloitte Touche Tohmatsu LLC

Tomoya Sakunai
GAU general
Risk Advisory
Deloitte Touche Tohmatsu LLC

Hiroki Toyoda
GAU general
Risk Advisory
Deloitte Touche Tohmatsu LLC

Hisanaga Oba
Senior Manager
Deloitte Analytics
Risk Advisory
Deloitte Touche Tohmatsu LLC

Ken Mohri
Senior analyst
Deloitte Analytics
Risk Advisory
Deloitte Touche Tohmatsu LLC

Zhe Wang
GRC Operational Risk
Risk Advisory
Deloitte Touche Tohmatsu LLC

Takashi Yamamoto
Deloitte Analytics
Risk Advisory
Deloitte Touche Tohmatsu LLC

Deloitte Tohmatsu Science and Technology CN Team

Mail dtst_carbon_neutral@tohmatsu.co.jp