SUSTAINABLE FINANCE

PROGRAMME

SMITH SCHOOL OF ENTERPRISE AND THE ENVIRONMENT

UNIVERSITY OF OXFORD

Stranded Assets and Thermal Coal in Japan:

An analysis of environment-related risk exposure

Working Paper

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About the Sustainable Finance Programme

The Sustainable Finance Programme at the University of Oxford's Smith School of Enterprise and the Environment was established in 2012 (originally as the Stranded Assets Programme) to understand how finance and investment intersects with the environment and sustainability.

We seek to understand the requirements, challenges, and opportunities associated with a reallocation of capital towards investments aligned with global environmental sustainability. We seek to understand environment-related risk and opportunity, both in different sectors and systemically; how such factors are emerging and how they positively or negatively affect asset values; how such factors might be interrelated or correlated; their materiality (in terms of scale, impact, timing, and likelihood); who will be affected; and what affected groups can do to pre-emptively manage risk.

We recognise that the production of high-quality research on environment-related factors is a necessary, though insufficient, condition for these factors to be successfully integrated into decision-making. Consequently, we also research the barriers that might prevent integration, whether in financial institutions, companies, governments, or regulators, and develop responses to address them. We also develop the data, analytics, frameworks, and models required to enable the integration of this information into decision-making.

The Programme is based in a world leading university with a global reach and reputation. We work with leading practitioners from across the investment chain (including actuaries, asset owners, asset managers, accountants, banks, data providers, investment consultants, lawyers, ratings agencies, stock exchanges), with firms and their management, and with experts from a wide range of related subject areas (including finance, economics, management, geography, anthropology, climate science, law, area studies, psychology) within the University of Oxford and beyond.

Since 2012 we have conducted pioneering research on stranded assets and remain the only academic institution conducting work in a significant and coordinated way on the topic. We have created the Stranded Assets Research Network, which brings together researchers, research institutions, and practitioners working on these and related issues internationally to share expertise. We have also created the Stranded Assets Forums, which are a series of private workshops to explore the issues involved.

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About the Authors

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Key findings

- The future for Japan's power generators is highly uncertain, particularly for heavily polluting thermal generators such as coal. Factors including climate change policy and renewables subsidies, the prospect of nuclear restarts, energy efficiency, and macroeconomic factors like low levels of population and GDP growth, will all affect power demand and supply in ways that would likely harm the economics of coal-fired power stations in Japan.

- Despite the highly uncertain context for coal-fired generation, the government has encouraged a major expansion of coal-fired generating capacity. As a result, the number of coal plants under development has increased rapidly in the past few years. Although there are currently four coal plants under construction with a combined capacity of 1.9 GW, there are now 49 planned plants comprising a significant 28 GW at various stages of planning.

- The amount of planned and under construction coal-fired generating capacity greatly exceeds the capacity required to replace the retiring fleet - by 191%. This may result in overcapacity and combined with competition from other forms of generation capacity with lower marginal costs (e.g. nuclear and renewables), lead to significant asset stranding of coal generation assets.

- To examine the scale of potential stranded coal assets in Japan, we used three illustrative scenarios where existing and planned coal-fired power stations are stranded over 5-year, 10-year, and 15-year periods. We selected these three periods to reflect the different speeds and scales at which the risk factors identified in this report could realistically materialise. While highly illustrative, these scenarios highlight the potential impact of stranded coal assets on the utility sector in Japan, particularly from coal-fired power plants that are planned, but not currently under construction.

- We find that stranded coal assets could be ¥6,857bn - ¥8,924bn ($61.6bn - $80.2bn), equivalent to 22.6% - 29.4% of the current market capitalization, and 4.5%-5.9% of total assets, of Japan's power utilities. This highlights the risks of continuing to proceed with the planning and development of new coal-fired power plants in Japan.

- In the 5-year scenario, where coal-fired power stations become stranded assets by 2021, the total value of stranded coal assets are estimated to be ¥8,453 billion ($76bn). In the 10-year scenario, where coal-fired power stations become stranded assets by 2026, the total value of stranded coal assets are estimated to be ¥8,924 billion ($80.2bn), of which ¥6,223 billion ($55.9bn) are plants built after 2016. Finally, in the 15-year scenario where coal-fired power stations become stranded assets by 2031, the total value of stranded coal assets are estimated to be ¥6,857 billion ($61.6bn), of which ¥5,307 billion ($47.69bn) are plants built after 2016.

- We judge that the five-year, ten-year, and 15-year scenarios are a suitable time horizon to consider given the pace of change in the global energy system. Renewables deployment has increased from 10% of global capacity to 15%in the last five years,[1] the cost of onshore wind and solar PV has fallen by 39% and 41% respectively over the same period, and sales of electric vehicles have grown by 1,031%.[2] Disruption appears to be accelerating as tipping points are reached and the idea that

[1] BNEF (2015) 'global trends in renewable energy investment 2015'
[2] Office of Energy Efficiency & Renewable Energy (2016) 'Fact #918: march 28, 2016 global plug-in light vehicle sales increased by about 80% in 2015' [Online] Available at: http://energy.gov/eere/vehicles/fact-918-march-28-2016-global-plug-light-vehicle-sales-increased-about-80-2015

the power sector will remain relatively static and 'safe' for new thermal coal assets is counter to the evidence we see internationally across the G20.

- At the company-level, we prepared five case studies of selected utilities. These were for: 1) J-Power; 2) Tokyo Electric Power Co; 3) Chubu Electric Power Co Inc; 4) Kyushu Electric Power Co; and 5) Kansai Electric Power Co. In these case studies we examine the sensitivity of these companies to the risks outlined in this report, and estimate potential scale of asset stranding specifically attributable to them.

- We find that Tokyo Electric Power Co has the highest exposure to asset stranding in absolute value for the five-year, ten-year, and 15-year scenarios of the five comparator companies. Tokyo Electric Power Co also has some of the highest exposure to environment-related risk, especially for planned or under construction power stations. J-Power has the most exposure to asset stranding relative to total assets (>20%).

- Given significant proposed coal expansion on the one hand and growing environment-related risks on the other, companies, investors, and policymakers should examine the exposure of Japan's existing and proposed coal-fired power plants to the risk of asset stranding. Stranded coal assets would affect utility returns for investors; impair the ability of utilities to service outstanding debt obligations; and create stranded assets that have to be absorbed by taxpayers and ratepayers. Moreover, new coal-fired power stations will generate significant negative externalities for the duration of their shorter than anticipated lives, particularly in terms of carbon emissions that cause climate change, as well as air pollution that harms human health.

Executive summary

To our knowledge this is the most up-to-date and comprehensive analysis of the exposure of coal-fired power stations in Japan to environment-related risks that can create 'stranded assets'. Stranded assets are assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities.[3] The environment-related risks facing coal-fired power stations are substantial and could be significant drivers of asset stranding. They span physical environmental impacts, the societal responses to such environmental impacts (for example, new policies and technological change), and new legal liabilities that may arise from either of the former.

By examining the environment-related risks facing coal-fired power stations, creating appropriate measures to differentiate the exposure of different assets to these risks, and linking this analysis to company ownership, debt issuance, and capital expenditure plans, our research is designed to help inform decision-making in relation to Japan's power sector. In particular, our research can help to inform specific investor actions related to risk management, screening, voting, engagement, and disinvestment. The datasets that underpin our analysis, as well as the analysis itself, also enable new lines of academic research and inquiry.

The Tohoku Earthquake and associated Fukushima Daiichi disaster caused a dramatic shift in Japanese energy policy. As a result of the nuclear meltdowns at Fukushima, public confidence in nuclear power dissolved rapidly, causing the government to shut down all of Japan's nuclear reactors pending significant safety reviews. Gas, oil, and coal-fired power stations compensated for the drop in supply, while the rapid rise of renewables, particularly solar PV, has been ongoing since the disaster. Consequently, the future for Japan's power generators is highly uncertain, particularly for heavily polluting thermal generators such as coal. Factors including climate change policy and renewables subsidies, the prospect of nuclear restarts, energy efficiency, and macroeconomic factors like low levels of population and GDP growth, will all affect power demand and supply in ways that would likely harm the economics of coal-fired power stations in Japan.

Despite this highly uncertain context for coal-fired generation – the government has encouraged a major expansion of coal-fired generating capacity. As recently as 2013, Japan had only four new coal plants planned.[4] However the new Basic Energy Plan decided by Cabinet Council in April 2014 re-evaluated coal and saw it having a much more important role for baseload power generation. Utilities have since been rushing to develop new coal-fired power plants with the government's approval and support.

As a result, the number of coal plants under development has increased rapidly in the past few years. Although there are currently four coal plants under construction with a combined capacity of 1.9GW, there are now 49 planned plants comprising a significant 28GW at various stages of planning. By contrast gas-fired plants have 16GW under construction and 21GW planned. Since Japan's coal fleet is the youngest of all types of thermal generation and is on average five years *younger* than gas, this represents a very significant push to increase coal's share in Japan's generation mix.[5]

[3] See Caldecott, B., et al. (2013). *Stranded Assets in Agriculture: Protecting Value from Environment-Related Risks.*
[4] See Guay, J., 'Fukushima and the Japanese Coal Myth', *Huffington Post*, 2013.
[5] see Figure 5.

Table 1: Replacement of retiring capacity by fuel type

[GW]	'Retiring Capacity' through 2026, estimate	Under Construction and Planned Capacity, actual	Replacement Ratio
Coal	10.3	30.0	291%
Gas	37.1	37.1	100%

To better understand how significant this extra coal capacity is, we compared the amount of coal and gas generating capacity currently under construction or in planning with the amount of capacity required to maintain total capacity at current levels (see Table 1). The amount of planned and under construction coal-fired generating capacity greatly exceeds the capacity required to replace the retiring fleet – by 191%. This may result in overcapacity and combined with competition from other forms of generation capacity with lower marginal costs (e.g. nuclear and renewables), lead to significant asset stranding of coal generation assets.

Given significant proposed coal expansion on the one hand and growing environment-related risks on the other, companies, investors, and policymakers should examine the exposure of Japan's existing and proposed coal-fired power plants to the risk of asset stranding. Stranded coal assets would affect utility returns for investors; impair the ability of utilities to service outstanding debt obligations; and create stranded assets that have to be absorbed by taxpayers and ratepayers. Moreover, new coal-fired power stations will generate significant negative externalities for the duration of their shorter than anticipated lives, particularly in terms of carbon emissions that cause climate change, as well as air pollution that harms human health.

Methodology

The approach we have used here is based on the methods pioneered in a previous report of the Sustainable Finance Programme of the University of Oxford's Smith School of Enterprise and the Environment (the 'Oxford Smith School') from March 2015, entitled *Stranded Assets and Subcritical Coal: the risk to companies and investors.*[6] This methodology was significantly expanded in the landmark publication *Stranded Assets and Thermal Coal: An analysis of environment-related risks*[7], published by the Oxford Smith School in February 2016. This report uses similar data and methods to provide a high-resolution examination of the environment-related risks facing Japan's thermal coal assets.

Understanding how environment-related factors interact and affect a company requires a detailed examination of the company's specific asset base. For all of Japan's utilities, we have analysed the attributes of their coal-fired power stations and integrated and cross-referenced this data with indicators of environment-related risk to develop asset-specific analyses of risk exposure. We then aggregate these analyses to the company level to provide company-wide assessments of environment-related risk exposure. We also integrate capital expenditure pipeline and company debt issuance into these analyses to identify companies with the most significant risk exposure in their capex pipeline. The datasets used to underpin our analysis are described in Appendix A.

Our approach requires us to take a view on what the environment-related risks facing coal-fired power stations could be and how they could affect asset values. We call these Local Risk Hypotheses (LRHs) or National Risk Hypotheses (NRHs) based on whether the risk factor in question affects all assets in Japan in a similar way, or if risk exposure is specific to the local environment. Water stress, for example, varies

[6] See Caldecott, B., Dericks, G., & Mitchell, J. (2015). *Stranded Assets and Subcritical Coal: the Risk to Companies and Investors.*

[7] See Caldecott, B., Kruitwagen, L., Dericks, G., et al. (2016). *Stranded Assets and Thermal Coal: an Analysis of Environment-Related Risk Exposure.*

across the country and so is an LRH, whereas country-wide changes to renewables policy support is an NRH. The list of these LRHs and NRHs can be found below in Table 2 with a brief description.

Table 2: Local Risk Hypotheses (LRHs) and National Risk Hypotheses (NRHs)

#	NAME	SOURCE
Coal-Fired Power Utilities		
LRH-1	Carbon Intensity	CARMA/CoalSwarm/Oxford Smith School
LRH-2	Plant Age	CARMA/CoalSwarm/WEPP
LRH-3	Local Air Pollution	Boys et al. (2015)/NASA's SEDAC
LRH-4	Water Stress	WRI's Aqueduct
LRH-5	CCS Retrofitability	CARMA/CoalSwarm/WEPP/Geogreen
LRH-6	Future Heat Stress	IPCC AR5
LRH-7	Nuclear Restart Risk	CoalSwarm/WEPP
NRH-1	Future Electricity Demand	Oxford Smith School
NRH-2	Renewables Resource	Oxford Smith School
NRH-3	Renewables Policy Support	EY's Renewables Attractiveness Index
NRH-4	Decentralised Renewables and the 'Utility Death Spiral'	Oxford Smith School
NRH-5	Growth of Utility-Scale Renewables Generation	BP/REN21
NRH-6	Growth of Gas-Fired Generation	IEA
NRH-7	Falling Utilisation Rates	Oxford Smith School
NRH-8	Regulatory Water Stress	WRI's Aqueduct
NRH-9	CCS Legal Environment	Global CCS Institute
NRH-10	Nuclear Restarts	Oxford Smith School

Utility exposure to LRHs

The Local Risk Hypotheses we apply and measure Japan's coal-fired power stations against are outlined here:

LRH-1: Carbon Intensity

The more carbon intensive a coal-fired power station, the more likely it is to be negatively impacted by climate policy, whether carbon pricing, emissions performance standards, or other similar measures. More carbon-intensive power stations are more exposed to transitional risk from climate change mitigation policy. Carbon intensity is assessed for each power station in kg.CO_2/MWh.

LRH-2: Plant Age

Older power stations create risks for owners in a number of ways. First, ageing power stations are more vulnerable to regulations that might force their closure. Second, utilities with significant ageing generation portfolios have a higher risk of being required to cover site remediation costs after power station closures and outstanding worker liabilities (i.e. pension costs). Finally, older power stations are more susceptible to unplanned shutdowns and maintenance needs, resulting in the costs of repairs and secondary losses or opportunity costs of underperformance on contracted power delivery. Plant age is taken as the year of completed construction.

LRH-3: Local Air Pollution

Coal-fired power stations in locations with high population density and serious local air pollution are more at risk of being regulated and required to either install emission abatement technologies or cease operation. Thus, owners of assets in areas of high population density and high local pollution will have a greater risk of bearing the financial impacts of such possibilities. Local air pollution is assessed using $PM_{2.5}$ as a proxy and is measured in $\mu g/m^3$.

LRH-4: Water Stress

The hypothesis is that power stations located in areas with higher physical baseline water stress or in areas with water conflict or regulatory uncertainty are at higher risk of being forced to reduce or cease operation, of losing licence to operate, or of having profits impaired by water pricing. These risks can be mitigated to an extent by the use of closed-cycle, hybrid, or dry cooling technology. Water stress is the fraction of extracted renewable water resources in a given water basin.

LRH-5: CCS Retrofitability

Coal-fired power stations not suitable for the retrofit of carbon capture and storage (CCS) technology may be at more risk of premature closure. These power stations do not have the option of CCS retrofit in the case of strong GHG mitigation requirements on coal-fired power utilities, enforced either by targeted policy or carbon pricing. CCS retrofitability is assessed based on a number of criteria given in Section 2.2.1.

LRH-6: Future Heat Stress

The hypothesis is that physical climate change will exacerbate heat stress on power stations. Higher ambient local temperatures decrease power station efficiency and exacerbate water stress, which causes physical risks, such as forced closure or reduced operation, and social risks, such as unrest and increased potential for regulation. Future heat stress is measured in ^{o}C in 2035 above preindustrial levels.

LRH-7: Regional Nuclear Restart Capacity

Nuclear restarts and new builds pose a significant risk for Japan's utility companies. This risk is especially concerning for coal-fired power stations built primarily to replace lost nuclear capacity. New coal-fired power stations in regions that have the greatest potential nuclear capacity are more likely to be affected by an expansion of nuclear restarts. Nuclear restart capacity is measured in MW of regional restartable nuclear capacity.

Table 3 Summary of financial and environment-related risk exposure

SUMMARY OF RISK EXPOSURE	COAL-FIRED GENERATION	COAL-FIRED CAPACITY			DEBT / EQUITE	CURRENT RATIO	(EBITDA-CAPEX) / INTEREST	LRH-1: CARBON INTENSITY	LRH-2: PLANT AGE	LRH-#: LOCAL AIR POLLUTION	LRH-4: WATER STRESS	LRH-5: CCS RETROFITABILITY	LRH-6: FUTURE HEAT STRESS	LRH-7: NUCLEAR RESTARTS
		OPR	CON	PLN										
	[GWh]	[MW]	[MW]	[MW]				RANK*						
J-POWER	60,352	8,414	84	4,020	2.48	1.17	0.63	6	24	7	3	1	13	26
TOKYO ELECTRIC POWER CO	25,360	5,900	540	5,357	3.34	1.21	3.77	24	27	22	9	40	36	15
TOHOKU ELECTRIC POWER CO	36,273	4,901	0	600	3.97	0.73	2.47	37	6	11	16	1	34	26
CHUGOKU ELECTRIC POWER CO	23,106	4,208	84	1,445	3.14	0.86	0.41	38	6	8	15	1	13	26
CHUBU ELECTRIC POWER CO INC	30,610	4,100	0	2,030	1.95	0.83	2.36	1	2	37	33	1	2	21
KYUSHU ELECTRIC POWER CO	17,231	3,646	1,000	667	7.41	1.03	NA	31	15	28	9	1	9	15
HOKURIKU ELECTRIC POWER CO	18,492	2,903	0	0	2.54	1.23	NA	1	12	10	23	1	7	1
HOKKAIDO ELECTRIC POWER CO INC	15,868	2,500	0	0	6.89	0.70	NA	22	18	27	31	31	28	24
KANSAI ELECTRIC POWER CO	5,507	1,800	0	3,462	4.07	0.63	NA	39	29	39	37	40	1	21
KOBE STEEL LTD	8,753	1,475	0	1,300	0.83	1.22	7.19	23	9	38	18	1	2	21
NIPPON STEEL & SUMITOMO METAL	6,739	1,443	0	320	0.56	1.38	17.80	17	15	12	29	33	15	13
SUMITOMO CORP	7,994	1,395	0	0	1.73	1.59	1.35	15	21	9	29	26	16	14
SHIKOKU ELECTRIC POWER CO	7,040	1,106	0	500	2.37	0.91	3.58	21	21	23	13	34	9	40
TOKUYAMA CORP	1,730	883	0	0	1.67	2.08	1.24	9	38	14	38	40	17	7
OKINAWA ELECTRIC POWER CO	4,912	754	0	0	1.56	0.72	5.38	1	15	25	26	1	9	40
NIPPON PAPER INDUSTRIES CO LTD	2,473	680	100	508	1.49	1.02	3.76	20	13	13	26	27	24	29
TOSOH CORP	3,474	667	0	0	0.85	1.35	17.91	14	24	33	25	1	8	5
KASHIMA-KITA ELEC POWER CORP	789	647	0	0	NA	NA	NA	13	1	1	40	1	26	7
MITSUBISHI CORP	1,700	406	0	292	1.06	1.53	NA	16	29	19	19	25	33	19
OJI PAPER CO LTD	1,415	283	0	0	1.08	0.89	4.57	19	32	21	9	40	36	15
TAIHEIYO CEMENT CORP	1,689	281	0	0	1.21	0.87	10.54	33	39	34	4	40	9	40
MIIKE THERMAL POWER CO	1,659	175	0	0	NA	NA	NA	1	9	30	5	1	28	29
MITSUI & CO LTD	721	170	0	0	1.09	1.67	2.46	39	40	18	17	1	28	24
OSAKA GAS CO LTD	870	149	110	500	0.69	1.89	9.83	11	6	36	13	1	4	4
TOKAI KYODO ELEC POWER CO	822	149	0	0	NA	NA	NA	27	18	5	35	29	23	7
JFE STEEL CORP	652	124	0	333	0.75	1.54	12.24	8	9	2	24	1	17	7
SHOWA DENKO KK	438	78	0	124	1.19	1.01	5.69	32	34	16	2	1	17	29
IDEMITSU KOSAN CO LTD	416	76	0	667	1.60	0.96	NA	34	13	24	39	1	36	15
ITOCHU ENEX CO LTD	344	61	0	0	0.46	1.06	12.99	35	35	29	8	40	36	40
ASAHI KASEI GROUP	364	50	0	120	0.25	1.76	55.68	30	23	35	26	1	6	1
CHUETSU PULP INDUSTRY CO LTD	267	50	0	0	1.00	0.85	6.15	18	5	17	1	1	35	35
TOSHIBA CORP	279	48	0	0	0.86	1.15	4.96	1	3	31	5	1	28	29
MAZDA	206	39	0	0	0.79	1.45	10.83	6	37	3	22	1	17	7
TEIJIN LTD	25	32	0	70	1.01	1.68	18.12	25	18	15	19	28	27	20
HOKUREN NOKYO RENGOKAI	8	26	0	0	NA	NA	NA	28	32	26	33	1	5	3
NIPPON MINING HOLDINGS CO LTD	143	24	0	0	1.09	0.98	NA	12	3	4	21	1	17	7
KURARAY COMPANY LTD	74	17	0	0	0.12	3.11	92.65	29	26	6	32	1	17	29
MATSUSHIMA COAL MINING CO LTD	33	9	0	0	0.37	2.51	3.46	26	29	40	12	30	40	40
DAICEL CHEMICAL INDUSTRIES CO	33	9	0	0	0.24	2.49	34.36	36	28	32	5	1	28	29
TOKYO GAS	1	0	0	1,500	0.67	1.51	10.24	10	35	20	36	32	25	6
UBE INDUSTRIES	0	0	0	400	0.83	1.18	6.14	NA	NA	NA	NA	NA	NA	NA
MARUBENI CORP	0	0	0	750	2.03	1.19	NA	NA	NA	NA	NA	NA	NA	NA
ORIX CORP	0	0	0	390	1.85	2.59	NA	NA	NA	NA	NA	NA	NA	NA
ABL CO LTD.	0	0	0	110	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
AIR WATER INC.	0	0	0	56	0.64	1.20	22.35	NA	NA	NA	NA	NA	NA	NA
CHIBA PREFECTURE	0	0	0	500	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
HIROSHIMA GAS	0	0	0	56	1.00	0.95	9.04	NA	NA	NA	NA	NA	NA	NA
HOKUZAI TRANSPORT	0	0	0	56	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
IDI INFRASTRUCTURES F-POWER	0	0	0	100	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
JAPAN ENERGY PARTNERS	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
JOBAN JOINT POWER CO	0	0	0	180	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MAEDA CORPORATION	0	0	0	1,100	0.51	1.34	6.68	NA	NA	NA	NA	NA	NA	NA
MEIKO TRANS	0	0	0	15	0.00	3.92	NA	NA	NA	NA	NA	NA	NA	NA
SEIKA CORPORATION	0	0	0	15	0.30	1.39	34.43	NA	NA	NA	NA	NA	NA	NA
TONEN GENERAL SEKIYU	0	0	0	500	1.43	0.83	2.80	NA	NA	NA	NA	NA	NA	NA

***Rank indicates relative exposure to risk, with 1 being the most exposed.**

Table 4: Units of measurement of LRHs

	Hypothesis	Unit
LRH-1	Carbon intensity of generated electricity	[kg.CO_2/MWh]
LRH-2	Plant age, year constructed	[year]
LRH-3	Local air pollution exposure with $PM_{2.5}$ as a proxy	[$\mu g_{PM2.5}/m^3$]
LRH-4	Fraction of extracted renewable water resources	[Percentage]
LRH-5	CCS Retrofitability described by criteria in Section 2.2.1	[1 = Retrofitable; 0 = Not retrofitable]
LRH-6	Average temperature change in 2035 above preindustrial levels	[Δ^oC]
LRH-7	Regional restartable nuclear generation capacity	[MW]

There is little variation in average coal generation CO2 intensity across the 11 major Japanese utilities, all of which average close to the threshold for supercritical efficiency (880 kg CO2/MWh); but industrial users have consistently higher CO2 intensity.

There is also little variation among the top 11 utilities with respect to average coal plant age - which were built on average in the 1990s - with the exception of Kansai EPC which has a single plant built in 2007. Air pollution, measured as atmospheric particulate matter of less than 2.5 µm (PM 2.5), is also low especially when compared with some of Japan's neighbouring countries, although 16 companies have power stations located where local air pollution is in excess of the WHO annual limit of 10 $\mu g/m^3$.

Average Water Stress (i.e. the percentage of annual recovered renewable water resources) is substantially less than 100% for most Japanese utilities, with the exception of Show Denko (89%) and Tokuyama Corp (100%).

As can been from Figure 20, with regard to the potential for CCS suitability Japan is split around the Shizuoka area, with coastal areas south of this location generally possessing the potential to be suitable for CCS, and locations north of this generally unsuitable. Furthermore, inland locations do not have the potential for CCS. The potential CCS suitability of Japanese utilities reflects this combined north-south and coastal-inland division.

Heat stress also shows a geographic divide, with utilities operating in northern areas such as Hokkaido EPC taking on the largest 2035 temperature increases. However, within Japan this variation is small, with the biggest difference between utilities at less than half a degree C (0.45).

Utilities with major operations in the Tohoku and Hokuriku regions bearing the most nuclear restart risk, and more moderate risks for utilities on the island of Kyushu and Chubu on the south coast of Honshu.

In sum, a distinct north-south divide seems to be at work in Japan with respect to LRH's, with utilities focused in northern regions fairing worse than utilities in central and to a lesser extent southern Honshu Island.

Utility exposure to NRHs

The hypotheses below affect all coal-fired generating assets in Japan. A simple traffic-light method has been used to conduct analysis for these risk hypotheses. Criteria are developed below for each hypothesis, with conclusions as to whether coal-fired utilities are at high risk (red), medium risk (yellow) or low risk (blank). Based on each of these criteria, an aggregate risk outlook is given after scoring each (+2 for high risk criteria, +1 for medium risk criteria). Comparator countries are also given based on the analysis conducted in *Stranded Assets and Thermal Coal: An analysis of environment-related risks*. These comparisons are important for contextualising risk exposure in Japan. For investors who have a global universe of investment opportunities understanding how Japan's utilities compare to utilities in other countries with regards to environment-related risk exposure is eminently relevant. Table 5 provides a summary of all NRHs for Japan's coal-fired power utilities and those in comparator countries, where directly comparable.

Table 5: Summary of National Risk Hypotheses

	Japan	Australia	China	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
NRH-1: Future Electricity Demand	Red	Yellow	Green	Red	Green	Green	Red	Yellow	Red	Yellow
NRH-2: Renewables Resource	Green	Red	Green	Green	Yellow	Yellow	Yellow	Red	Yellow	Yellow
NRH-3: Renewables Policy Support	Red	Yellow	Red	Red	Green	Red	Green	Yellow	Yellow	Red
NRH-4: Growth of Decentralised Renewables	Red					N/A				
NRH-5: Growth of Utility-Scale Renewables	Green					N/A				
NRH-6: Growth of Gas-Fired Power	Yellow	Yellow	Red	Green	Red	Yellow	Green	Green	Green	Red
NRH-7: Falling Utilisation Rates	Yellow	Yellow	Red	Green	Yellow	Red	Yellow	Red	Yellow	Yellow
NRH-8: Regulatory Water Stress	Green	Green	Yellow	Green	Red	Yellow	Green	Yellow	Green	Green
NRH-9: CCS Regulatory Env.	Yellow	Green	Red	Yellow	Red	Red	Yellow	Red	Green	Green
NRH-10: Nuclear Restarts	Yellow					N/A				
TOTAL*	50%	60%	60%	50%	40%	45%	40%	55%	45%	60%

*Higher percentage equates to a worse risk outlook. Total for Japan based on this publication. Total for comparator countries based on *Stranded Assets and Thermal Coal*.

The National Risk Hypotheses we apply and measure Japan's coal-fired power stations against are outlined here:

NRH-1: Future Electricity Demand Outlook

The hypothesis is that the greater the growth in demand for electricity, the less likely other forms for generation (e.g. solar, wind, gas, and nuclear) are to displace coal-fired power. Growth in overall electricity demand might allow coal-fired generators to maintain or increase their current share of power generation.

NRH-2: Renewables Resource

The hypothesis is that the availability of strong renewable resources is a key determinant of the competiveness of renewables relative to conventional generation. Countries with larger renewables resources could see larger and faster rates of deployment. This would result in coal-fired power stations being more likely to face lower wholesale electricity prices and other forms of power sector disruption.

NRH-3: Renewables Policy Support

This hypothesis examines the Japanese government's policy support for renewable power generation. The hypothesis is that countries with robust regimes for supporting renewables will see greater renewables deployment. This would result in coal-fired power stations being more likely to face lower wholesale electricity prices and other forms of power sector disruption.

NRH-4: Growth of Decentralised Renewables and the Utility Death Spiral

The hypotheses are that the growth of decentralised renewables might affect coal-fired power differently than centralised renewables by leading to a 'utility death spiral' and the rapid, unforeseen erosion of a coal-fired utility's business model. In Japan, decentralised renewables are almost exclusively small-scale solar PV installations. The utility death spiral is the disruption to conventional power utility companies as a result of a virtuous cycle where distributed energy resources (e.g. rooftop solar PV) are eroding the distribution network business model of the central utility, which in turn raises retail electricity prices making distributed energy resources even more competitive.[8]

NRH-5: Growth of Utility-Scale Renewables

The hypothesis is that rapid renewables deployment would result in coal-fired power stations being more likely to face lower wholesale electricity prices and other forms of power sector disruption. Since 2008, half the world's added electric generating capacity has been renewable.[9] The Japanese Government wants to increase renewables from 10% of its energy mix to 24% by 2030, reducing its reliance on gas, coal and nuclear.

NRH-6: Growth of Gas-Fired Generation

The hypothesis is that the growth of gas-fired generation, particularly in markets where electricity demand growth is lower or negative, could harm the economics of coal-fired generation and result in coal-to-gas switching.

NRH-7: Falling Utilisation Rates

The hypothesis is that under-utilised coal-fired power stations will be financially vulnerable and more prone to stranding. The entrance of new generating options may reduce the utilisation rates of coal-fired generating assets. Competition on marginal costs, or must-run regulation for renewables, can displace coal-fired generation, reducing utilisation rates. Generating stations with falling utilisation rates are less able to cover fixed costs with operating profit.

NRH-8: Regulatory Water Stress

The hypothesis is that coal-fired power stations in countries that have strict water use requirements and an awareness of water issues are more likely to be affected by water scarcity through direct or indirect water pricing.

NRH-9: CCS Regulatory Environment

The hypothesis is that CCS could be a way for coal-fired power stations to keep running under stricter carbon constraints, but CCS will not happen without a supportive legal framework. Such uncertainties can present barriers to the development of CCS projects, which in turn present a risk to coal-fired utilities which may not have CCS as an option for future GHG mitigation.

NRH-10: Nuclear Restarts

The hypothesis is that nuclear restarts in Japan would disrupt the economics of coal-fired power stations.

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[8] CTI (2015). *Coal: Caught in the EU Utility Death Spiral*. London, UK.; Graffy, E. and Kihm, S. (2014) 'Does disruptive competition mean a death spiral for electric utilities', Energy LJ, HeinOnline, 35, p. 1.; Costello, K. W. and Hemphill, R. C. (2014) 'Electric Utilities' "Death Spiral": Hyperbole or Reality?', The Electricity Journal, 27(10), pp. 7–26

[9] Lovins, A. 'How Opposite Energy Policies Turned the Fukushima Disaster into a Loss for Japan and a win for Germany', *Forbes,* 2014.

Scale of potential asset stranding

To examine the scale of potential stranded coal assets in Japan, we used three illustrative scenarios where existing and planned coal-fired power stations are stranded over five-year, ten-year, and 15-year periods. We selected these three periods to reflect the different speeds and scales at which the environment-related risks identified in this report could realistically materialise. The five-year scenario represents the very rapid emergence of factors such as falling electricity demand (NRH-1), rapid growth in renewables (NRH-4 and NRH-5), and nuclear restarts (LRH-10). The ten-year and 15-year scenarios represent the emergence of these factors more slowly or less forcefully.

In all three scenarios the start date is 2016 and the known installed capacity of coal-fired generation is 48.3GW (including capacity planned for 2016). We extract capacity data from the Platts World Electric Power Plants (WEPP) Database for Q1 2016. For our sample of 55 Japanese companies, we extract all the capacities of all coal-fired generation assets in MW. To avoid double-counting jointly-owned capacity, we separate capacity among joint-owners. We delineate the capacities into existing and planned (or currently under construction). We assume a total installation cost of ¥250,000,000/MW (US$2.25m/MW[10]), which is generous given that there are higher cost estimates for new build and the costs of new coal-fired power stations have been increasing globally.[11] We include all sunk costs – such as fees and contingency, engineering, procurement and construction services, and any additional owner costs[12] - as these represent losses in the case of asset stranding. For each asset, we depreciate the asset over an assumed useful life of 40 years since the date (or planned date) of build, congruent with Pfeiffer et al. (2015).[13] We assume a salvage value of zero. As the last planned generating plant is scheduled for 2035, our total time series covers 2016 to 2076 including 40 years depreciation.

In the five-year scenario, where coal-fired power stations become stranded assets by 2021, the total value of stranded coal assets are estimated to be ¥8,453 billion ($75bn). In the 10-year scenario, where coal-fired power stations become stranded assets by 2026, the total value of stranded coal assets are estimated to be ¥8,924 billion ($80.2bn), of which ¥6,223 billion ($56bn) are plants built after 2016. Finally, in the 15-year scenario where coal-fired power stations become stranded assets by 2031, the total value of stranded coal assets are estimated to be ¥6,857 billion ($61.6bn), of which ¥5,307 billion ($47.7bn) are plants built after 2016.

While highly illustrative, these scenarios highlight the potential impact of stranded coal assets on the utility sector in Japan, particularly from coal-fired power plants that are planned, but not currently under construction. Stranded coal assets would represent 22.6%-29.4% of the current market capitalization, and 4.5%-5.9% of total assets, of Japan's power utilities. This highlights the risks of continuing to proceed with the planning and development of new coal-fired power plants in Japan.

We judge that the five-year, ten-year, and 15-year scenarios are a suitable time horizon to consider given the pace of change in the global energy system. Renewables deployment has increased from 10% of global capacity to 15%in the last five years,[14] the cost of onshore wind and solar PV has fallen by 39% and 41% respectively over the same period, and sales of electric vehicles have grown by 1,031%.[15] Disruption

[10] Assuming ¥111.28/$1, April 27th 2016 exchange rate. This exchange rate is used in all currency conversions below.
[11] METI (26th May 2015) 各電源の諸元一覧.
[12] Rong and Victor
[13] Pfeiffer, A., Millar, R., Hepburn, C. and Beinhocker, E. (2015) The '2oC capital stock' for electricity generation: Cumulative committed carbon emissions and climate change,.
[14] BNEF, 'global trends in renewable energy investment 2015', 2015.
[15] Office of Energy Efficiency & Renewable Energy (2016) 'Fact #918: march 28, 2016 global plug-in light vehicle sales increased by about 80% in 2015' [Online] Available at: http://energy.gov/eere/vehicles/fact-918-march-28-2016-global-plug-light-vehicle-sales-increased-about-80-2015

appears to be accelerating as tipping points are reached and the idea that the power sector will remain relatively static and 'safe' for new thermal coal assets is counter to the evidence we see internationally across the G20.

Figure 1: Estimated scale of asset stranding for existing and new build coal generators

NB: The difference between the value on the y-axis and zero represents estimated stranded assets charge.
Letters in the chart correspond to the labels in Table 6.

Table 6: Estimates of total stranded assets (¥ billion/US$)

Coal Offline in:	Existing Assets	Planned and Under Construction	Total
2021 (5 years)	**[A]** ¥4,005 ($35.99)	**[B]** ¥4,447 ($39.96)	**[A + B]** ¥8,453 ($75.96)
2026 (10 years)	**[C]** ¥2,700 ($24.26)	**[D]** ¥6,223 ($55.92)	**[C+ D]** ¥8,924 ($80.19)
2031 (15 years)	**[E]** ¥1,550 ($13.93)	**[F]** ¥5,307 ($47.69)	**[E + F]** ¥6,857 ($61.62)

Utility case studies

At the company-level, we prepared five case studies of selected utilities. These were for: 1) J-Power; 2) Tokyo Electric Power Co; 3) Chubu Electric Power Co Inc; 4) Kyushu Electric Power Co; and 5) Kansai Electric Power Co. In these case studies we examine the sensitivity of these companies to the risks outlined in this report, and estimate potential scale of asset stranding specifically attributable to them.

Table 7: Breakdown of the five utilities' operating, under construction, and planned coal capacity

Rank	Company	Coal Generating Capacity* [MW]			
		OPR	CON	PLN	Total
1	J-POWER	8,414	84	4,020	12,518
2	TOKYO ELECTRIC POWER CO	5,900	540	5,357	11,797
5	CHUBU ELECTRIC POWER CO	4,100	NA	2,030	6,130
6	KYUSHU ELECTRIC POWER CO	3,646	1,000	667	5,313
7	KANSAI ELECTRIC POWER CO	1,800	NA	3,462	5,262

Table 8: Selected utility estimates of total stranded assets(¥billion)

	Ratio Analysis[i]				Env.-Related Risks[i]							Stranded Assets[ii]		
	DEBT / EQUITY	CURRENT RATIO	(EBITDA - CAPEX)/ INTEREST	OPR / PLN[iii]	LRH-1	LRH-2	LRH-3	LRH-4	LRH-5	LRH-6	LRH-7	2021 (5 year)	20 26 (10 year)	2031 (15 year)
J-POWER	84%	56%	94%	**OPR**	40%	58%	88%	55%	32%	53%	53%	¥586.2 (23%)	¥406.3 (16%)	¥237.5 (9%)
				PLN	44%	44%	68%	88%	41%	56%	6%	¥608.2 (24%)	¥904.9 (35%)	¥773.3 (30%)
TEPCO	91%	47%	66%	**OPR**	32%	22%	22%	20%	100%	12%	95%	¥730.1 (5%)	¥541.0 (4%)	¥351.9 (3%)
				PLN	47%	44%	68%	79%	53%	65%	76%	¥1,309.3 (9%)	¥1,136.3 (8%)	¥963.3 (7%)
CHUBU EPCO	78%	87%	86%	**OPR**	42%	35%	60%	80%	15%	30%	65%	¥384.6 (7%)	¥253.2 (5%)	¥121.7 (2%)
				PLN	26%	6%	76%	91%	38%	68%	74%	¥114.1 (2%)	¥339.5 (6%)	¥290.4 (5%)
KYUSHU EPCO	100%	62%	ND	**OPR**	35%	58%	88%	15%	30%	17%	85%	¥248.2 (5%)	¥145.7 (3%)	¥83.6 (2%)
				PLN	94%	62%	35%	50%	29%	15%	44%	¥406.0 (9%)	¥353.0 (8%)	¥299.2 (6%)
KANSAI EPCO	96%	98%	ND	**OPR**	20%	5%	30%	95%	15%	88%	12%	¥288.5 (4%)	¥230.8 (3%)	¥173.1 (2%)
				PLN	53%	18%	68%	74%	44%	59%	65%	¥439.2 (6%)	¥661.3 (9%)	¥566.4 (8%)

i) Ratio and environment-related risk presented as a percentile relative to Japan utility peer group, with a higher percentage indicating higher risk:
$N_{D/E}$, $N_{Current\ Ratio}$ = 45; $N_{(EBITDA\text{-}CAPEX)/INT}$ = 35; N_{OPR} = 40; N_{PLN} = 34;
ii) Stranded Assets expressed in bn¥ and as a fraction of total utility assets
iii) OPR: Operating plants; PLN: Planned and under construction plants;

Table 9 describes the units which are used to evaluate exposure to environment-related risks at the asset level. Examples of these calculations are shown in the five case studies. In most cases, aggregate company exposure is evaluated on a MW-weighted basis of the units of measurement in Table 9.

Table 9: Units of measurement of LRHs

	Hypothesis	Unit
LRH-1	Carbon intensity of generated electricity	[kg.CO_2/MWh]
LRH-2	Plant age, year constructed	[year]
LRH-3	Local air pollution exposure with $PM_{2.5}$ as a proxy	[$\mu g_{PM2.5}/m^3$]
LRH-4	Fraction of extracted renewable water resources	[Percentage]
LRH-5	CCS Retrofitability described by criteria in Section 2.2.1	[1 = Retrofitable; 0 = not retrofitable]
LRH-6	Average temperature change in 2035 above preindustrial levels	[$\Delta^o C$]
LRH-7	Regional restartable nuclear generation capacity	[MW]

Each of the five companies will be subject to stranded assets if we assume coal must be removed from the system in line with our five-year, ten-year and 15-year scenarios. Table 8 shows that both existing and planned capacities are at risk of stranded assets in each of three scenarios. We briefly evaluate each company below on the basis of i) their existing coal-fired power station portfolio, ii) the coal-fired generation capacity they are constructing or planning to construct and iii) the extent their existing and planned portfolios are exposed to environment-related risks. Table 9 provides guidance on the interpretation of LRH exposure.

Table 8 shows selected indicators of risk for the five case study utilities. For the ratio analyses and environment-related risk exposures, the performance of the utilities is shown by their percentile relative to the entire peer population of Japan's utility companies, where a higher percentage indicates a higher risk. Potential stranded assets under the five, ten, and 15-year scenarios are shown both in their absolute value and as a portion of total company assets. In the Appendix tables, the MW-weighted average risk exposure is given in the units in Table 9, but in the summary tables in this report, the companies are compared to each other either with by percentile or ranking.

J-Power

J-Power has the most coal generation (8.4GW) of all utilities in Japan, and coal comprises almost half of J-Power's total generation (17.5GW). In addition, over 90% of planned generation capacity is coal (4GW out of 4.3GW), and only TEPCO has more planned coal generation (5.9GW). J-Power has the largest combined existing and planned coal plant capacity of all Japanese utilities (12.5GW), with two-thirds of this (8.2 GW) is already operating.

Notably it has the lowest planned coal plant exposure to nuclear restarts of any of the major Japanese utilities at only 704MW on average (2,465MW existing). According to our analyses we classify J-Power as having a high exposure to asset stranding for existing coal capacity but less exposure for its planned coal-capacity. Across the existing and planned capacities, it is estimated stranded assets in the five-year, ten-year, and 15-year scenarios are second only to TEPCO. This is because most of J-Power's existing capacity was built between 1980 and 2000 and thus has already depreciated significantly.

Table 10: Environment-related risk exposure of J-Power operating plants

PLANT	CAPACITY[ii] [MW]	GENERATION[ii] [GWH]	UR[iii]	LRH-1: CARBON INTENSITY [kg.CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLL'N [µgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: CCS RETROFITABILITY [1=RETROFITABLE]	LRH-6: FUTRE HEAT STRESS [ΔoC]	LRH-7: REGIONAL NUC. RESTARTS [MW]
MATSUSHIMA	1,002	6,730	77%	922	1980	11.8	0%	0	0.90	4,699
MATSUURA	2,000	15,633	89%	887	1993	11.9	19%	0	0.90	4,699
ISHIKAWA	312	2,134	78%	880	1986	4.2	100%	0	0.68	0
TAKEHARA	1,300	8,136	71%	913	1978	8.6	05%	0	0.88	820
TAKASAGO	500	3,761	86%	928	1969	8.3	35%	0	0.88	0
TACHIBANAWAN	2,100	16,182	88%	823	2001	8.5	10%	1	0.88	2,022
SHIN ISOGO	1,200	7,367	70%	786	2006	10.4	89%	1	0.92	1,100
TOTAL[i]	**8,414**	**59,943**	**81%**	**867**	**1991**	**9.8**	**26%**	**39%**	**0.89**	**2,465**

i. MW-weighted for LRHs and UR; ii. Capacity and generation only for owned portion; iii. UR: Utilisation Rate

Table 11: Environment-related risk exposure of J-Power planned plants

PLANT	CON/ PLN	CAPACITY[ii] [MW]	LRH-1	LRH-2	LRH-3	LRH-4	LRH-5	LRH-6	LRH-7
TAKEHARA	PLN	600	766	2020	8.6	05%	0	0.88	820
TAKASAGO	PLN	1,200	759	2024	8.3	35%	1	0.88	0
NISHIOKINOYAMA	PLN	400	872	2023	10.8	15%	0	0.90	820
OSAKI COOLGEN	CON	84	692	2017	8.9	04%	0	0.88	820
KASHIMA POWER	PLN	320	767	2020	10.1	30%	0	0.88	1,100
YOKOHAMA	PLN	500	900	2020	10.4	89%	1	0.92	1,100
SHIN YOKOSUKA	PLN	500	767	2020	10.2	89%	1	0.92	1,100
YOKOSUKA	PLN	500	807	2020	10.2	89%	1	0.92	1,100
TOTAL[i]		**4,104**	**794**	**2021**	**9.5**	**47%**	**66%**	**0.90**	**704**

i. MW-weighted for LRHs; ii. Capacity only for owned portion;

Tokyo Electric Power Company

Like Kansai EPC, Tokyo Electric Power Company (TEPCO) is notable in that its planned coal generation capacity (5.4GW) is high relative to its current operating capacity (5.9GW). This planned coal capacity (5.4GW) represents 36% of TEPCO's total planned generation (14.7GW). TEPCO has 54GW of existing generation in total, of which currently only 11% (5.9GW) is coal.

On a MW-weighted basis, TEPCO's existing coal-plants in Tokyo and Tohuku regions may need to compete with 11,784MW of shutdown nuclear power. TEPCO also has planned or under construction coal-fired power in regions which may nuclear power be restored to generating a MW-weighted average of 10,130MW. The potential for CCS retrofitability is also poor for TEPCO's existing coal fleet at 0%, and only 26% for planned plants.

TEPCO's existing and planned coal capacity is highly exposed to asset stranding. Of TEPCO's 5.9GW of existing coal capacity, 3.2GW was recently built in 2008-09 and therefore has incurred little depreciation. Further, Tokyo Electric has 5.4GW of planned capacity between 2017 and 2035, where most is planned for pre-2020. We find that TEPCO has the highest exposure to asset stranding of all five companies analysed in each of the three scenarios.

Table 12: Environment-related risk exposure of TEPCO operating plants

PLANT	CAPACITY[ii] [MW]	GENERATION[ii] [GWH]	UR[iii]	LRH-1: CARBON INTENSITY [kg.CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLL'N [μgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: CCS RETROFITABILITY [1=RETROFITABLE]	LRH-6: FUTRE HEAT STRESS [Δ°C]	LRH-7: REGIONAL NUC. RESTARTS [MW]
SHINCHI	1,000	7,104	81%	857	1995	7.7	15%	0	0.95	17,263
HIRONO	1,200	3,352	32%	773	2009	7.4	15%	0	0.88	17,263
NAKOSO	1,700	8,802	59%	926	1992	7.6	15%	0	0.88	17,263
HITACHINAKA	2,000	6,103	35%	846	2008	8.8	16%	0	0.88	1,100
TOTAL[i]	**5,900**	**25,361**	**49%**	**856**	**2001**	**8.0**	**15%**	**0%**	**0.89**	**11,784**

i. MW-weighted for LRHs and UR; ii. Capacity and generation only for owned portion; iii. UR: Utilisation Rate

Table 13: Environment-related risk exposure of TEPCO planned plants

PLANT	CON/ PLN	CAPACITY[ii] [MW]	LRH-1	LRH-2	LRH-3	LRH-4	LRH-5	LRH-6	LRH-7
HIRONO 'CGAS'	CON	540	652	2020	7.3	00%	0	0.88	17,263
SHINCHI	PLN	500	835	2035	7.7	15%	0	0.95	17,263
SOMA CORE	PLN	112	849	2017	7.7	15%	0	0.95	17,263
HIRONO	PLN	540	652	2020	7.4	15%	0	0.88	17,263
HIRONO	PLN	1,200	765	2020	7.4	15%	0	0.88	17,263
NAKOSO	PLN	180	652	2021	7.6	15%	0	0.88	17,263
HITACHINAKA	PLN	325	768	2021	8.8	16%	0	0.88	1,100
KITAKYUSHU	PLN	1,000	900	2019	11.4	18%	0	0.90	4,699
YOKOHAMA	PLN	500	900	2020	10.4	89%	1	0.92	1,100
SHIN YOKOSUKA	PLN	500	767	2020	10.2	89%	1	0.92	1,100
YOKOSUKA	PLN	500	807	2020	10.2	89%	1	0.92	1,100
TOTAL[i]		**5,897**	**787**	**2021**	**8.9**	**33%**	**25%**	**0.90**	**10,130**

i. MW-weighted for LRHs; ii. Capacity only for owned portion;

Chubu Electric Power Company

Although Chubu Electric Power Co has 30.3GW of operating capacity, only 4.1GW (or 14%) is coal-fired. Yet of its 2.33 GW of total planned generation, 2GW or 88% is coal. With regard to the risk of nuclear restart, Chubu EPC's planned coal plants can be considered to have medium exposure with an average of 7,619MW of potential nuclear capacity located in the same region as its planned coal plants, whereas its existing coal plants are only exposed on average to 3,617MW.

Table 14: Environment-related risk exposure of Chubu EPCO operating plants

PLANT	CAPACITY[ii] [MW]	GENERATION[ii] [GWH]	UR[iii]	LRH-1: CARBON INTENSITY [kg.CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLL'N [µgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: CCS RETROFITABILITY [1=RETROFITABLE]	LRH-6: FUTRE HEAT STRESS [Δ°C]	LRH-7: REGIONAL NUC. RESTARTS [MW]
HEKINAN	4,100	30,610	85%	869	1997	9.0	53%	1	0.84	3,617
TOTAL[i]	**4,100**	**30,610**	**85%**	**869**	**1997**	**9.0**	**53%**	**1**	**0.84**	**3,617**

i. MW-weighted for LRHs and UR; ii. Capacity and generation only for owned portion; iii. UR: Utilisation Rate

Table 15: Environment-related risk exposure of Chubu EPCO planned plants

PLANT	CON/ PLN	CAPACITY[ii] [MW]	LRH-1	LRH-2	LRH-3	LRH-4	LRH-5	LRH-6	LRH-7
SHINCHI	PLN	500	835	2035	7.7	15%	0	0.95	17,263
HITACHINAKA	PLN	325	NA[iii]	2021	NA	NA	0	NA	NA
TAKETOYO	PLN	1,070	763	2022	9.0	53%	1	0.84	3,617
TOYOHASHI AKEMI	PLN	135	780	2020	8.6	23%	1	0.84	3,617
TOTAL[i]		**2,030**	**785**	**2025**	**8.6**	**39%**	**59%**	**0.87**	**7,619**

i. MW-weighted for LRHs; ii. Capacity only for owned portion; iii: ND: No Data, omitted in MW weighting

Kyushu Electric Power Company

Kyushu EPC is the sole regional utility based on the island of Kyushu. Although Kyushu EPC has 3.6GW of existing coal capacity (23% of total existing capacity: 15.5GW), it only has plans for another 0.7GW of coal generation. However, almost 100% of total planned generation (0.7GW) is expected to be derived from coal. Kyushu EPC is sole owner of the Matsuura coal plant, which is the largest coal plant (1.0GW) currently under construction in Japan, and joint owner of the planned 2.0GW Sodegaura power plant.

Kyushu EPC's existing coal plants are all in the Kyushu region, where there are 4,699MW of restartable nuclear power capacity, a medium risk level relative to the other utilities. Its planned coal plant (Sodegaura) is in the Tokyo region where there is less restartable nuclear capacity, 1,100MW. Its existing power plants also have relatively low potential CCS retrofitability at only 46%.

Our analysis shows that Kyushu Electric Power Co has low exposure to asset stranding. Kyushu has 3.64GW of existing capacity which was built between 1964 and 2001. Most of the capacity has already significantly depreciated. Only 0.67GW of new capacity is planned for 2020. This low amount of planned capacity reduces the level of asset stranding in later years.

Table 16: Environment-related risk exposure of Kyushu EPCO operating plants

PLANT	CAPACITY[ii] [MW]	GENERATION[ii] [GWH]	UR[iii]	LRH-1: CARBON INTENSITY [kg.CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLL'N [µgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: CCS RETROFITABILITY [1=RETROFITABLE]	LRH-6: FUTRE HEAT STRESS [ΔoC]	LRH-7: REGIONAL NUC. RESTARTS [MW]
REIHOKU	1,400	7,369	60%	874	1999	11.8	0%	1	0.90	4,699
MATSUURA KYUDEN	700	4,982	81%	861	1989	11.9	19%	0	0.90	4,699
KANDA	740	2,132	33%	896	1986	11.4	18%	0	0.90	4,699
KARITA PBFC	360	850	27%	911	2001	11.4	18%	1	0.90	4,699
TOBATA	446	1,198	31%	744	1979	11.5	18%	0	0.90	4,699
TOTAL[i]	**3,646**	**16,531**	**52%**	**864**	**1992**	**11.7**	**11%**	**48%**	**0.90**	**4,699**

i. MW-weighted for LRHs and UR; ii. Capacity and generation only for owned portion; iii. UR: Utilisation Rate

Table 17: Environment-related risk exposure of Kyushu EPCO planned plants

PLANT	CON/ PLN	CAPACITY[ii] [MW]	LRH-1	LRH-2	LRH-3	LRH-4	LRH-5	LRH-6	LRH-7
MATSUURA KYUDEN	CON	1,000	767	2020	11.9	19%	1	0.90	4,699
SODEGAURA	PLN	667	900	2020	11.0	35%	1	0.88	1,100
TOTAL[i]		**1,667**	**820**	**2020**	**11.5**	**25%**	**100%**	**0.89**	**3,259**

i. MW-weighted for LRHs; ii. Capacity only for owned portion;

Kansai Electric Power Company

Kansai EPC is notable in that, should all its planned plants be built, the total coal capacity of Kansai will almost triple from 1.8GW to 5.3 GW. This planned increase of 3.5 GW in coal generation represents 82% of Kansai EPC's total planned capacity (4.2GW). Kansai EPC's coal fleet also has the youngest average age of all major Japanese utilities at just nine years (2007 average).

Although Kansai EPC's single existing coal plant (Maizuru, 1.8GW) has no exposure to nuclear restart, we classify its planned coal plants as having a medium risk of nuclear restart with 4,276 MW on average in the same region. Japan generally has ample access to water resources, but certain areas (particularly cities) have high water stress. Kansai EPC's Maizuru coal plant is noteworthy in that it has a relatively high level of water stress, at 77% of renewable water resources recovered and used. Many Japanese power plants utilise seawater for cooling and Maizuru is no exception. At the same time, while Maizuru power is potentially CCS retrofitable, only 53% of Kansai EPC's planned coal plants have that possibility as well.

Kansai Electric Power Co has low exposure to asset stranding for existing capacity, but a medium risk for planned capacity. Kansai plans to build an additional 3.5GW of capacity between 2017 and 2035. The large additional capacity expected to come online in the 2020s increases Kansai's risk of asset stranding over time.

Table 18: Environment-related risk exposure of Kansai EPCO operating plants

PLANT	CAPACITY[ii] [MW]	GENERATION[ii] [GWH]	UR[iii]	LRH-1: CARBON INTENSITY [kg.CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLL'N [µgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: CCS RETROFITABILITY [1=RETROFITABLE]	LRH-6: FUTRE HEAT STRESS [Δ°C]	LRH-7: REGIONAL NUC. RESTARTS [MW]
MAIZURU	1,800	5,507	35%	806	2007	8.1	77%	1	0.93	0
TOTAL[i]	**1,800**	**5,507**	**35%**	**806**	**2007**	**8.1**	**77%**	**1**	**0.93**	**0**

i. MW-weighted for LRHs and UR; ii. Capacity and generation only for owned portion; iii. UR: Utilisation Rate

Table 19: Environment-related risk exposure of Kansai EPCO planned plants

PLANT	CON/ PLN	CAPACITY[ii] [MW]	LRH-1	LRH-2	LRH-3	LRH-4	LRH-5	LRH-6	LRH-7
SENDAI PORT	PLN	112	900	2017	7.3	37%	0	0.95	17,263
AKITA	PLN	650	807	2025	8.6	13%	1	0.92	17,263
AKO	PLN	1,200	800	2020	8.5	40%	1	0.88	0
ICHIHARA	PLN	500	807	2025	11.0	35%	0	0.88	1,100
KANSAI ELECTRIC POWER CHIBA PREF.	PLN	500	743	2035	11.0	35%	0	0.88	1,100
KEPCO CHIBA	PLN	500	839	2020	10.9	35%	0	0.88	1,100
TOTAL[i]		**3,462**	**803**	**2024**	**9.5**	**33%**	**53%**	**0.89**	**4,276**

i. MW-weighted for LRHs; ii. Capacity only for owned portion;

1 Introduction

The principal aim of this report is to conduct a comprehensive analysis of the exposure of coal-fired power stations in Japan to environment-related risks that can create 'stranded assets'. Stranded assets are assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities.[16] By examining the environment-related risks facing coal-fired power stations, creating appropriate measures to differentiate the exposure of different assets to these risks, and linking this analysis to company ownership, debt issuance, and capital expenditure plans, our research can help inform decision-making in relation to Japan's power sector by investors, policymakers, and civil society. The datasets that underpin our analysis, as well as the analysis itself, also enables new lines of academic research and inquiry. The typology of environment-related risks is described in Table 20.

Table 20: Typology of environment-related risks

Set	Subset
Environmental Change	Climate change; natural capital depletion and degradation; biodiversity loss and decreasing species richness; air, land, and water contamination; habitat loss; and freshwater availability.
Resource Landscapes	Price and availability of different resources such as oil, gas, coal and other minerals and metals (e.g. shale gas revolution, phosphate availability, and rare earth metals).
Government Regulations	Carbon pricing (via taxes and trading schemes); subsidy regimes (e.g. for fossil fuels and renewables); air pollution regulation; voluntary and compulsory disclosure requirements; changing liability regimes and stricter licence conditions for operation; the 'carbon bubble' and international climate policy.
Technology Change	Falling clean technology costs (e.g. solar PV, onshore wind); disruptive technologies; GMO; and electric vehicles.
Social Norms and Consumer Behaviour	Fossil fuel divestment campaign; product labelling and certification schemes; and changing consumer preferences.
Litigation and Statutory Interpretations	Carbon liability; litigation; damages; and changes in the way existing laws are applied or interpreted.

The approach used in this report is based on the methods pioneered in a previous report of the Sustainable Finance Programme of the University of Oxford's Smith School of Enterprise and the Environment (the 'Oxford Smith School') from March 2015, entitled *Stranded Assets and Subcritical Coal: the risk to companies and investors.*[17] This methodology was significantly expanded in the landmark publication *Stranded Assets and Thermal Coal: An analysis of environment-related risks,*[18] also published by the Oxford Smith School in February 2016. This report uses similar data and methods to provide a high-resolution examination of environment-related risk to Japanese thermal coal assets.

[16] See Ben Caldecott, Nicholas Howarth, and Patrick McSharry, "Stranded Assets in Agriculture : Protecting Value from Environment-Related Risks," *Stranded Assets Programme, SSEE, University of Oxford*, 2013, http://www.smithschool.ox.ac.uk/research-programmes/stranded-assets/Stranded Assets Agriculture Report Final.pdf.
[17] Ben Caldecott, Gerard Dericks, and James Mitchell, "Stranded Assets and Subcritical Coal: The Risk to Companies and Investors," *Stranded Assets Programme, SSEE, University of Oxford*, 2015, 1–78.
[18] Ben Caldecott et al., "Stranded Assets and Thermal Coal: An Analysis of Environment-Related Risk Exposure," *Stranded Assets Programme, SSEE, University of Oxford*, 2016, 1–188.

The Tohoku Earthquake and associated Fukushima Daiichi disaster caused a dramatic shift in Japanese energy policy. As a result of the nuclear meltdowns at Fukushima, public confidence in nuclear power dissolved rapidly, causing the government to shut down all of Japan's nuclear reactors pending significant safety reviews. Gas, oil, and coal-fired power stations compensated for the drop in supply, however an explosion of renewables, particularly solar photovoltaic (PV), has been ongoing since the disaster. The future of Japanese electricity supply is now substantially uncertain, with fundamental drivers like climate change policies and renewables subsidies, commodity prices, the prospect of nuclear restarts, and macroeconomic factors like population and GDP growth all likely to affect demand for power and its supply.

Understanding how these and other environment-related factors interact and affect companies requires a detailed examination of the company's specific asset base. For Japanese utilities, we analyse the attributes of their coal-fired generating stations and integrate and cross-reference this data with indicators of environment-related risk to develop asset-specific analyses of risk exposure. We then aggregate these analyses to the company level to provide company-wide assessments of environment-related risk. We also integrate capital expenditure pipeline and company debt issuance into these analyses to identify companies with the most significant risk exposure.

This approach requires us to take a view on what the environment-related risks facing thermal coal assets could be and how they could affect asset values. The environment-related risks facing the thermal coal value chain are substantial and span physical environmental impacts, the transition risks of policy and technology responding to environmental pressures, and new legal liabilities that may arise from either of the former. From this horizon-scanning exercise we develop risk hypotheses. The hypotheses are categorised into Local Risk Hypotheses (LRHs) and National Risk Hypotheses (NRHs) based on whether the risk factor in question affects all assets in a particular country in a similar way or not. For example, water stress has variable impacts within a country and so is an LRH, whereas a country-wide carbon price is an NRH. In this report, we apply this bottom up, asset-specific approach to Japanese coal-fired power stations.

The remainder of Section 1 introduces the Japanese power market and the use of coal-fired power in Japan. Section 2 presents analysis of environment-related risk exposure of Japanese coal-fired power stations and their utility owners. Section 3 examines stranding risks to Japanese coal-fired power plants across three decommissioning scenarios and provides breakdowns of these risks for five major utilities. Section 4 concludes.

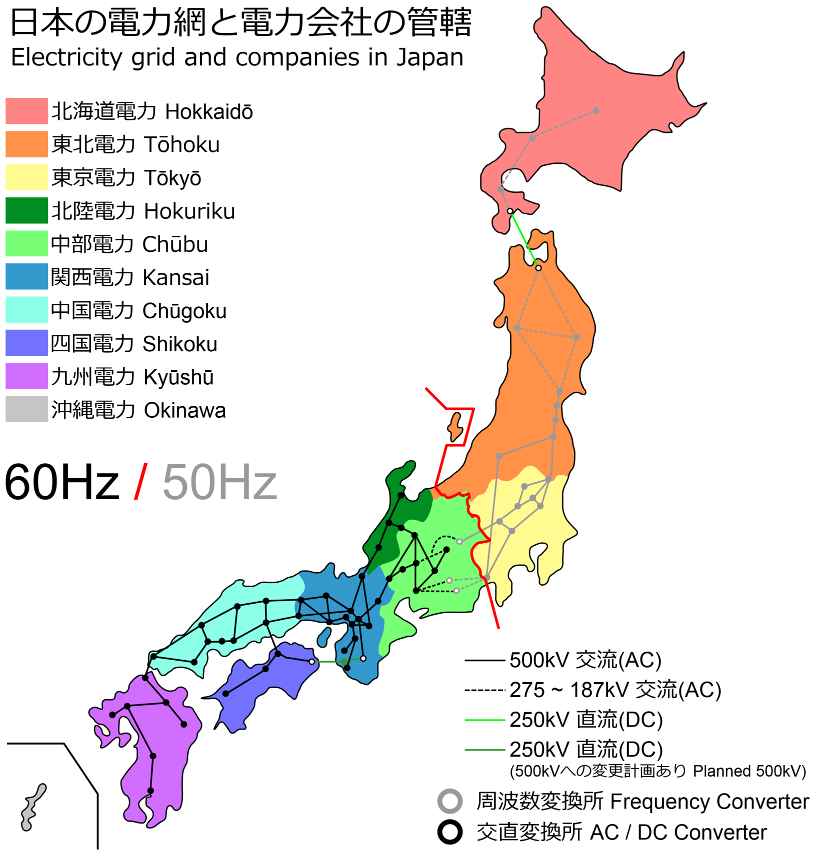
1.1 Japanese Electricity Market Structure

Japan has the second largest electricity market in the OECD.[19] This market is dominated by ten vertically integrated regional monopolies and the former national electricity development company (now called J-Power) which owns plants in every region but is not involved in distribution. This framework was created from the breakup of the former national electricity monopoly following WWII. These 11 companies control the generation, transmission, and distribution of electricity across Japan. As a result, the utilities can decide whom they will allow to compete against their own assets. In addition, the wholesale power market comprises only 1.6% of total power, the remainder being locked up in long-term contracts. Today Japan has 255GW of generation capacity in total, of which these 11 companies control 76%.[20]

[19] Louis du Plessis, "Japan's Biomass Market," *JETRO*, 2015, https://www.jetro.go.jp/ext_images/_Events/ldn/Japan_biomass_market_overview.pdf.
[20] According to WEPP, these 11 companies own 194 GW in Japanese generation capacity.

While the main island of Honshu is divided between six regional companies, the three other major islands and Okinawa have sole providers. Notably, Japan is the only country in the world which uses two different electricity frequencies to transmit power, with the eastern half of the country (including Tokyo) operating at 50Hz and the western half at 60Hz. Expensive transformers are therefore required to exchange power between Japan's eastern and western grids, and at present only 1.2GW in total can be transferred at three conversion locations. In practice this setup isolates the electrical grids of each half of the country. Furthermore, within the eastern and western frequency zones connections between regions are also weak.[21] This disjointed grid structure effectively blunts policy aimed at increasing market competition and compromises national energy security.

Figure 2: Japanese regional monopolies and electricity grid[22]



[21] James Topham, "Japan's Power Failure: Bid to Forge National Grid Stumbles," *Reuters*, 2014, http://www.reuters.com/article/us-japan-electricity-grid-idUSKCN0IA2JX20141021.
[22] Source: Callum Aitchison, "The Power Grid of Japan," 2012, https://commons.wikimedia.org/w/index.php?curid=19075661.

1.2 Market Reform

In spite of the dominance of the ten regional monopolists and J-Power, Japan's electricity market has been undergoing a process of gradual deregulation. Deregulation is of concern as empirical evidence from the EU has shown that liberalization (deregulation) and environmental objectives have had a material impact on the financial returns of European energy utilities.[23] Beginning in December 1995 Japan's independent power producers (IPP) were allowed to provide wholesale electricity services, and in March 2000 electricity retail supply for extra-high voltage users (demand exceeding 2MW) was liberalised. The scope of retail liberalisation was then expanded in April 2004 to users of more than 500kW, to users of more than 50kW in 2005, and since April 2016 Japan has had full retail competition across all users. The Revised Electricity Business Act 2015 will require legal separation of generation from transmission and distribution by April 2020. In order to effect these changes the Organisation for Cross-Regional Coordination of Transmission Operators (OCCTO) was set up in 2015 to function as a national transmission system operator (TSO). Its remit is to develop interconnections among present utility networks and increase the frequency converter capacity across the 50-60 Hz east-west divide from 1.2 to 3GW by 2021. These changes are expected to loosen the price control held by regional monopolies and open a ¥10tn ($82.8bn) market to competition.[24] In order to do so, OCCTO is expected to invest about ¥300bn (US $2.8 bn).[25]

1.3 Japan's generating options and the Tohoku Earthquake

The 9.0 magnitude Tohoku earthquake of March 2011 was the largest earthquake ever recorded in Japan. It triggered enormous tsunami waves which caused wholesale destruction along the Northeast coast of the main island and the meltdown of three reactors at the Fukushima Daiichi nuclear plant: one of the world's worst-ever nuclear accidents. In the wake of this disaster public sentiment towards nuclear power soured and the government ordered the shutdown of all 54 operating nuclear plants (comprising 49GW) until such time as safety reviews could be carried out.[26] Prior to the shutdown nuclear had generated 30 per cent of Japan's electricity and Japan had been the world's third biggest generator behind the US and France.[27]

[23] Daniel J Tulloch, Ivan Diaz-Rainey, and I.M. Premachandra, "The Impact of Liberalization and Environmental Policy on the Financial Returns of European Energy Utilities," *The Energy Journal* 38, no. 2 (2017): 77–106, doi:http://dx.doi.org/10.5547/01956574.38.2.dtul.

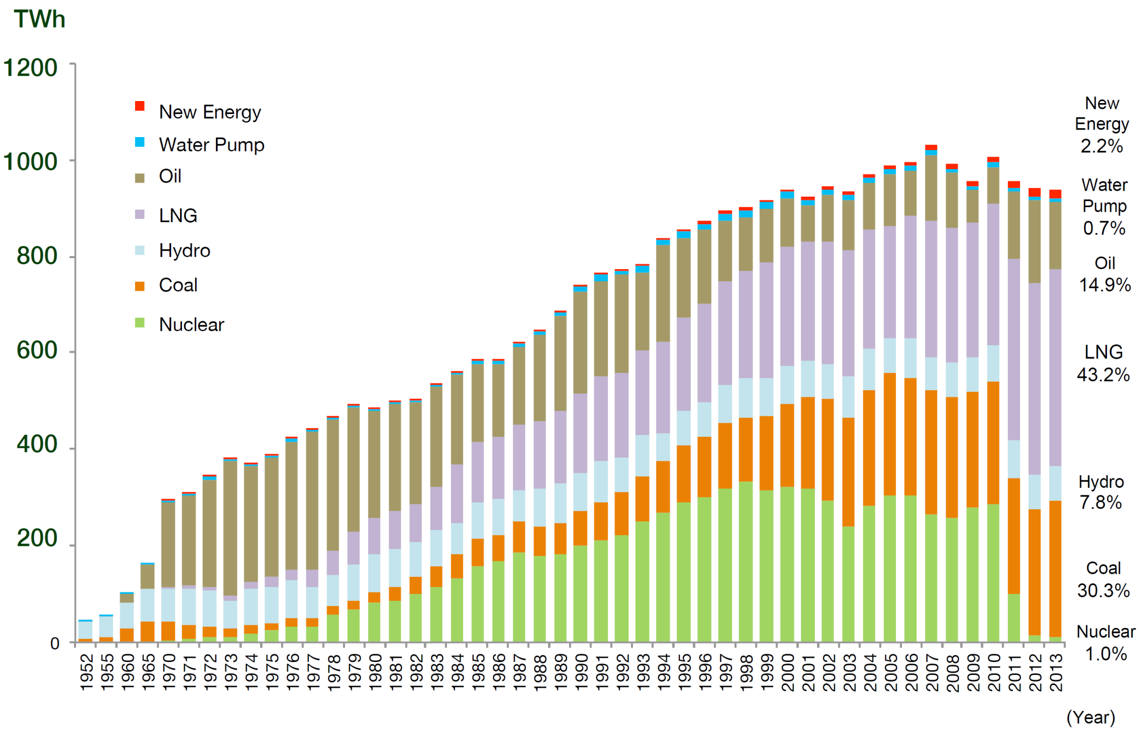
[24] Hirofumi Matsuo, "Energy Deregulation Threatens to Break up Japanese Monopolies," *The Financial Times*, 2015, http://www.ft.com/cms/s/2/ac713e7a-cbd1-11e4-beca-00144feab7de.html#axzz45zVvNX8X.

[25] Ibid.

[26] World Nuclear Association, "Nuclear Power in Japan," 2016, http://www.world-nuclear.org/information-library/country-profiles/countries-g-n/japan-nuclear-power.aspx.

[27] Ibid.

Figure 3: Electricity mix by generation 1952-2013

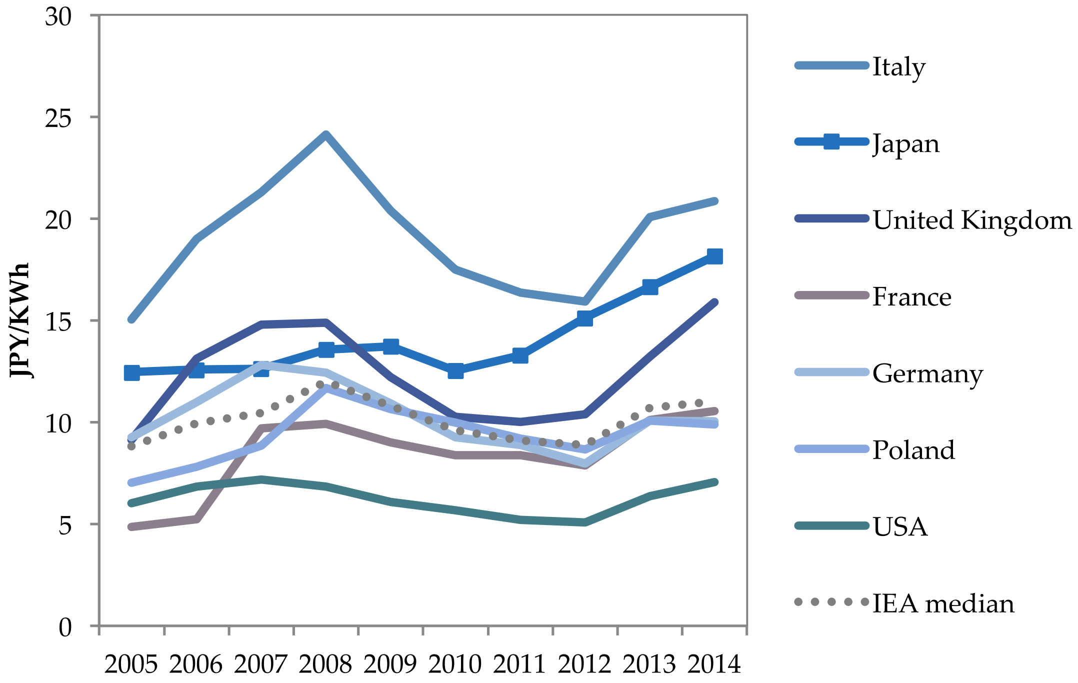


Derived from "Energy Balance Sheet" Ministry of Economy Trade and Industry

This shutdown crippled the grid in the eastern half of the country, and although western Japan had excess generation capacity little could be transferred. In combination with the shutdowns the government imposed a dramatic programme of energy conservation measures and called upon industry and citizens to abstain from unnecessary power consumption. This policy caused total and peak electricity demand to fall in 2011 by 12% and 18% respectively.[28] After years of stagnation, in 2011 electricity prices rose 20 per cent for households and 30 per cent for industry and are now the fourth highest among the IEA's 29 members.[29,30]

[28] Nick Butler, "Japan Returns to Nuclear Power," *The Financial Times*, 2015, http://blogs.ft.com/nick-butler/2015/06/22/japan-returns-to-nuclear-power/.
[29] Matsuo, "Energy Deregulation Threatens to Break up Japanese Monopolies."
[30] Italy, Ireland, and Slovakia have higher electricity prices.

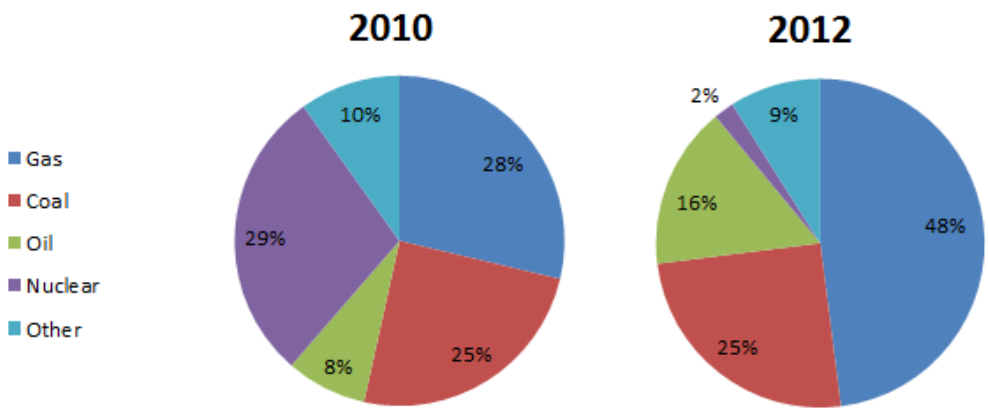
Figure 4: IEA member country industrial electricity prices



Source: Derived from the International Energy Agency publication, Energy Prices and Taxes

In order to compensate for the electricity supply lost due to the nuclear shutdown, existing oil, gas, and coal plants expanded output by increasing their utilisation rates. However, the primary substitution came from gas, as gas-fired power plants have greater output flexibility than coal and are cheaper to run than oil. By contrast between 2010 and 2012 coal's share of the energy mix did not increase.[31] Whereas demand for gas increased by a third in Japan from 70 million tons to 90 million tons, which effectively doubled the import price of gas and increased expenditure from ¥3.5tn per year to ¥6tn.[32]

Figure 5: 2010 to 2012 change in Japanese generation mix



Source: http://www.nbr.org/downloads/pdfs/eta/PES_2013_handout_kihara.pdf

[31] Coal capacity is less flexible than gas.
[32] The National Bureau of Asian Research, "Energy Mix in Japan - Before and after Fukushima," 2013, http://www.nbr.org/downloads/pdfs/eta/PES_2013_handout_kihara.pdf.

At present Japanese generation capacity consists primarily of gas (30%), followed by coal (19%) and oil (17%). Although Japan has excellent access to various forms of renewable energy, these are comparatively underdeveloped. However, since 2014 solar capacity, particularly small-scale solar, has tripled from 10 to 30GW, and now represents 13% of generation capacity. Whereas there are currently 43 serviceable nuclear reactors comprising 42.5GW (eight from the Fukushima Daiichi plant are no longer usable and three others have since been retired due to age), only one Japanese reactor is currently operating.

In the short term Japan will see an additional 5.3GW of gas-fired and 1.9GW of coal-fired capacity come online (plants currently under construction), but coal now comprises more than half of total planned generation capacity (plants at any stage of the planning process) at 28.0GW, and this is almost double the planned new capacity of gas (14.9GW). In the coming years there is also expected to be large increases in small-scale and residential solar.[33] And in spite of the current political difficulty in restarting nuclear reactors, the construction of Ohma power plant is continuing (slated to open in 2021), and an additional two reactors at Tsuruga power plant are in the planning stages. Other forms of generation in the pipeline are negligible.

Table 21: Japanese generating capacity and pipeline as of Q1 2016

	Operational			Construction		Planned		Shutdown
	MW	Percent of Total	Average age (MW weighted)	MW	Percent of Total	MW	Percent of Total	MW
Gas	78,111	31%	1989	5,345	49%	14,946	29%	83
Coal	47,803	19%	1994	1,917	18%	28,044	55%	462
Oil	43,016	17%	1981	0	0%	176	0%	5,988
Nuclear	2,360	1%	1992†	1,383	13%	3,400	7%	40,114
Solar	32,700	13%	2014	764	7%	1,493	3%	0
Water	27,953	11%	1974	571	5%	183	0%	0
Wind	3,028	1%	2009	43	0%	1,174	2%	0
Geothermal	539	0%	1988	0	0%	350	1%	0
Other	19,525	8%	1986	811	7%	1,265	2%	477
Total	**255,035**	**100%**	**1995**	**10,834**	**100%**	**51,031**	**100%**	**47,124**

a – WEPP coverage of small scale wind and PV 'plants' is not comprehensive. For operational renewable capacity, estimates from official sources are placed in parenthesis.
b - http://www.enecho.meti.go.jp/category/electricity_and_gas/electric/hydroelectric/database/energy_japan002/
†One observation: Ohi power plant reactors 3&4.

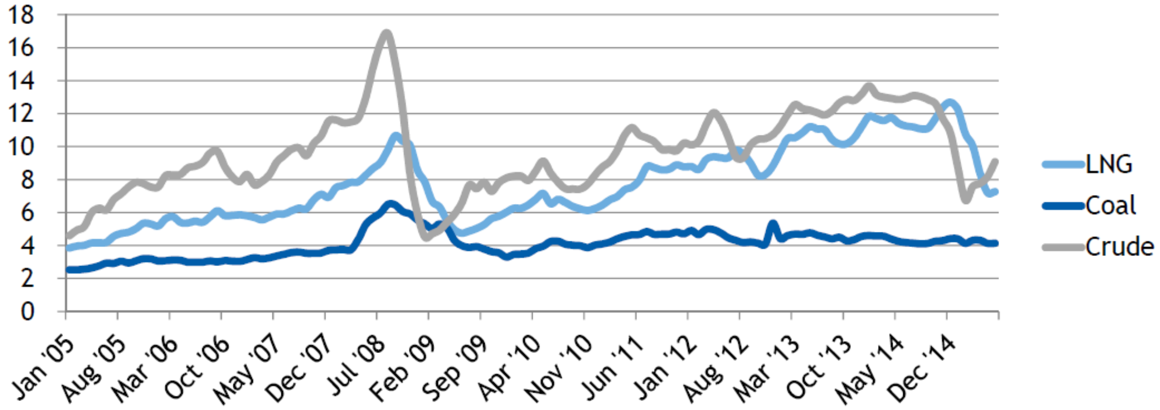
1.4 Coal-Fired Power in Japan

As recently as 2013, Japan had only 3.2GW of new coal capacity planned from four plants, and half of this was not expected to be brought online until the next decade.[34] However a new Basic Energy Plan was decided by the Cabinet Council in April 2014, and it re-evaluated coal as an important fuel for baseload power. Although coal-based power generation emits highly toxic air pollutants, is at least twice as CO_2 intensive as other fuels, and can less easily adjust output to match demand, coal was viewed to possess certain advantages. Among major fuels, coal has the most stable supplies (lowest geopolitical risk), and the

[33] The data in
Table 21 does not include 'under construction' and 'planned' small scale solar, but does include operational small scale solar.
[34] Justin Guay, "Fukushima and the Japanese Coal Myth," *Huffington Post*, 2013, http://www.huffingtonpost.com/justin-guay/fukushima-and-the-japanes_b_3062522.html.

greatest economic efficiency (the lowest price per unit of heat energy).[35] With the government's approval[36], coal prices in secular decline, and deregulation threatening their business, power suppliers have been rushing to develop new coal power plants.

Figure 6: Japanese fuel costs (¥/KWh)



Source: Argus Media (2015) Coal serves as long-term replacement for nuclear?

As a result, the number of coal development plans has increased rapidly in the past few years. Although there are now only four coal plants under construction with a combined capacity of 1.9GW, there are also 49 planned plants comprising a significant 28GW at various planning stages. By contrast gas-fired plants have 16GW under construction and 21GW planned. Since Japan's coal fleet is the youngest of all types of thermal generation and is on average five years *younger* than gas, this represents a very significant push to increase coal's share in Japan's generation mix.

To better understand how significant this extra coal capacity is, we compare the amount of coal and gas generating capacity currently under construction or in planning with the amount of capacity required to maintain total capacity at current levels. By assuming a plant operating life of 40 years, the amount of capacity retiring in the next ten years can be estimated (i.e. the sum of capacity constructed before 1986). Assuming the under construction or in planning plants capture a ten-year development horizon, the amount of new capacity can be directly compared to the amount of capacity estimated to be retiring, see

Figure 7.

Figure 7: Replacement of retiring capacity by fuel type

[GW]	'Retiring Capacity' through 2026, estimate	Under Construction and Planned Capacity, actual	Replacement Ratio
Coal	10.3	30.0	291%
Gas	37.1	37.1	100%

The amount of planned and under construction coal-fired generating capacity greatly exceeds the capacity required to replace the retiring fleet, by 191%. This may lead to conditions of oversupply exacerbated by environment-related risks, leading to significant asset stranding. Strikingly, the amount of planned and under construction gas capacity is precisely equal to the amount of capacity estimated to be retiring in the next ten years.

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[35] Anthony Fensom, "Japan: An Industry Saviour?," *World Coal*, 2015, http://www.worldcoal.com/special-reports/13052015/Japan-coal-demand-what-does-the-future-hold-coal2265/.
[36] Certain elements within the government do strongly oppose additional coal capacity such as the Ministry of the Environment (MOEJ).

2 Investment Risk Hypotheses

In this section, a comprehensive analysis of the environment-related risk exposure facing Japan's coal-fired utilities is completed. This analysis is divided between two sub-sections: the first sub-section is a financial analysis that considers Japan's utilities in aggregate to explore the sector's financial health, and provides insight into its potential vulnerability (or resilience) to environment-related risks; the second is our assessment of the potential environment-related risks facing coal-fired power stations in Japan and how they could affect asset values.

Table 22 shows there are 55 companies which own coal plants that are either operating, under construction, or planned. These companies own 51GW of generating capacity, generating 289TWh of electricity per year. Five new coal-fired power stations are under construction for an additional 1.9GW generating capacity, and 49 plants with a total of 28GW capacity are in the planning phase.

2.1 Financial Analysis

This section provides an in-depth look at the financial structure and market value of Japanese utilities over time. A thorough examination of the financial structure helps determine the performance, stability and health of the utility companies. In this section, we examine the market capitalisation of the sample to examine how market values of these firms have evolved over time. Second, we examine common financial ratios, including: debt, leverage, profitability, coverage, liquidity and capital expenditure. These latter ratios help identify investors' exposure to financial risk in the sector. Understanding the financial structure provides insight in Japan's ability to finance both RES and thermal future generating capacity, as investors also seek this information to determine their expected rates of return on utility investments. Utilities in good financial health may be able to adapt to changes in operating environment, such as demand destruction, population decline and adapting to a market with a large proportion of renewables. If the sample is found to be under considerable financial stress, investors may consider the sector non-investment grade and be hesitant to commit capital or demand higher rates of return on their investment. Access to this private capital is crucial to facilitate investment in Japan's energy infrastructure and generating assets.

2.1.1 Market Capitalisation and Book Value of the Sector

The following section presents the evolution of the market and book values of the 55 companies in our sample. Figure 8 shows a 13-fold increase in total market capitalisation of the sample between 1995 and 2007, from ¥4.53 trillion to a peak of ¥60.45 trillion. From July 2007 to April 2009, the height of the Global Financial Crisis (GFC), the sample saw a -55% decrease in value. It is argued that Japan was not affected materially by the GFC, but rather through negative terms of trade shocks and sharp increases in energy and other commodity prices (Kawai and Takagi, 2009). The time period also experienced negative economic growth, compounding the issue. Total market capitalisation of the sector also declined post-Fukushima, but it had already been on a downwards trajectory post-GFC. The sector experienced a recovery in market capitalisation from late 2012 onwards.

Table 22: The 55 Companies owning; operating, under construction, and planned coal plants

Rank	Company	Coal Generating Capacity* [MW]			
		OPR	CON	PLN	Total
1	J-POWER	8,414	84	4,020	12,518
2	TOKYO ELECTRIC POWER CO	5,900	540	5,357	10,947
3	CHUGOKU ELECTRIC POWER CO	5,164	84	1,445	6,693
4	TOHOKU ELECTRIC POWER CO	5,751	NA	600	6,351
5	CHUBU ELECTRIC POWER CO	4,100	NA	2,030	5,878
6	KYUSHU ELECTRIC POWER CO	3,646	1,000	667	5,313
7	KANSAI ELECTRIC POWER CO	1,800	NA	3,462	5,262
8	HOKURIKU ELECTRIC POWER CO	2,903	NA	NA	2,903
9	KOBE STEEL	1,475	NA	1,300	2,775
10	NIPPON STEEL & SUMITOMO METAL	1,950	NA	320	2,270
11	HOKKAIDO ELECTRIC POWER CO	2,250	NA	NA	2,250
12	SHIKOKU ELECTRIC POWER CO	1,106	NA	500	1,606
13	TOKYO GAS	0	NA	1,500	1,500
14	NIPPON PAPER INDUSTRIES CO	680	100	508	1,288
15	Maeda Corporation	NA	NA	1,100	1,100
16	SUMITOMO CORP	888	NA	NA	888
17	TOKUYAMA CORP	883	NA	NA	883
18	OSAKA GAS	149	110	500	759
19	OKINAWA ELECTRIC POWER CO	754	NA	NA	754
20	MARUBENI CORP	NA	NA	750	750
21	IDEMITSU KOSAN CO	76	NA	667	743
22	MITSUBISHI CORP	406	NA	292	698
23	TOSOH CORP	667	NA	NA	667
24	KASHIMA-KITA ELEC POWER CORP	647	NA	NA	647
25	Tonen General Sekiyu	NA	NA	500	500
26	Chiba Prefecture	NA	NA	500	500
27	JFE STEEL CORP	124	NA	333	457
28	Ube Industries	NA	NA	400	400
29	ORIX CORP	NA	NA	390	390
30	OJI PAPER CO	283	NA	NA	283
31	TAIHEIYO CEMENT CORP	281	NA	NA	281
32	SHOWA DENKO KK	78	NA	124	202
33	Joban Joint Power Co	NA	NA	180	180
34	MIIKE THERMAL POWER CO	175	NA	NA	175
35	ASAHI KASEI GROUP	50	NA	120	170
36	MITSUI & CO	170	NA	NA	170
37	TOKAI KYODO ELEC POWER CO	149	NA	NA	149
38	ABL Co Ltd.	NA	NA	110	110
39	TEIJIN LTD	32	NA	70	102
40	IDI infrastructures F-Power	NA	NA	100	100
41	ITOCHU ENEX CO	61	NA	NA	61
42	Air Water Inc.	NA	NA	56	56
43	Hiroshima Gas	NA	NA	56	56
44	Hokuzai Transport	NA	NA	56	56
45	CHUETSU PULP INDUSTRY CO	50	NA	NA	50
46	TOSHIBA CORP	48	NA	NA	48
47	MAZDA	39	NA	NA	39
48	HOKUREN NOKYO RENGOKAI	26	NA	NA	26
49	NIPPON MINING HOLDINGS CO	24	NA	NA	24
50	KURARAY COMPANY	17	NA	NA	17
51	Meiko Trans	NA	NA	15	15
52	Seika Corporation	NA	NA	15	15
53	MATSUSHIMA COAL MINING CO	9	NA	NA	9
54	DAICEL CHEMICAL INDUSTRIES CO	9	NA	NA	9
55	Japan Energy Partners	NA	NA	0.16	0

*OPR: Operating; CON: Under Construction; PLN: Planned

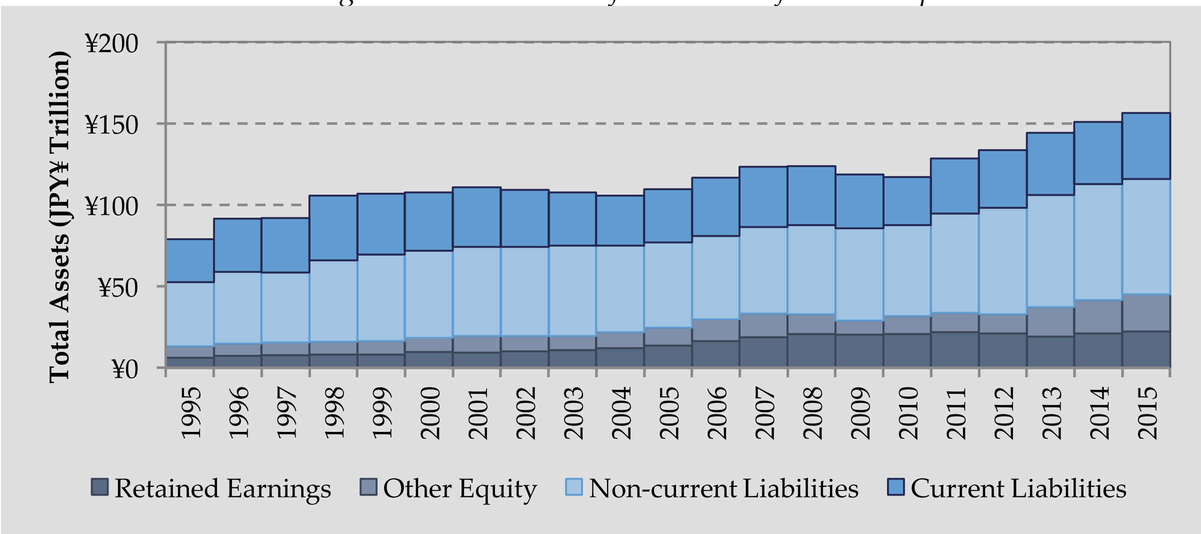
Figure 8: Aggregate market capitalisation for the Japanese sample

This figure illustrates the monthly sum of market capitalisations across the 54 companies in the Japanese sample. Data between January 1995 and March 2016. Source: Data from S&P Capital IQ.

Between 1995 and 2015, Figure 9 shows that our sample companies began to increase total equity in the sector at a greater rate than increasing debt. The majority of growth came from retained earnings – reinvesting a larger proportion of net income into the company. Total retained earnings in the sector increased by 261.69% between 1995 and 2015 – from ¥6.17 trillion to ¥22.31 trillion. As shown Figure 9, there was little change in retained earnings at the sector-level post-Fukushima; between 2011 and 2015 retained earnings totalled ¥21.83 trillion and ¥22.31 trillion, respectively. Simultaneously, total equity (less retained earnings) also increased by 226.56% over the same period, from ¥6.98 trillion to ¥22.78 trillion. This increase in equity can include book value of: preferred stock, paid-up capital, and common stock. Post-Fukushima, the book value of 'other equity' more than doubled, from ¥11.92 trillion in 2011 to ¥22.78 trillion in 2015.

In absolute terms, the total value of debt is greater than equity. However, between 1995 and 2015, the total liabilities of the companies grew at a slower rate than equity. Current liabilities grew by 53.20% between 1995 and 2015, from ¥26.49 trillion to ¥40.58 trillion. Of this value, ¥6.78 trillion was issued post-Fukushima. Non-current liabilities also grew by 80.03% between 1995 and 2015, from ¥39.31 trillion in 1995 to ¥70.77 trillion in 2015; where ¥9.93 trillion was issued post-Fukushima. Overall, non-current liabilities represent the largest entry on the balance sheets. The implications of the results above are that a large portion of the companies' total value was issued post-Fukushima; primarily from other equity and non-current liabilities.

Figure 9: Delineation of total assets for the sample



This figure presents the aggregate total assets for the sample. The data is delineated into: Retained Earnings, Other Equity (total equity less retained earnings), Current Liabilities, and Non-current Liabilities (Total liabilities less current liabilities).

2.1.2 *Bond Issuances*

Exposure to high levels of debt increases risk for both debt and equity holders of companies as the priority of either is further diluted in the event of the company's insolvency.

To build a general picture of the future direction for bond issuances, fixed-income securities are examined through ratio analysis. A number of financial ratios are examined, including those related to profitability, capital expenditure, liquidity, leverage, debt coverage, and the ability for utilities to service existing debt. The analyses are conducted between 1995 and 2015 to represent the last 21 (inclusive) years of data.[37] Of the 55 companies in the sample, fixed-income data was available for 41. Thus, the analysis only includes securities which could be publicly traded. Figure 10 presents the median ratios, with 25th and 75th percentiles to illustrate the distribution of observed ratios: 50% of companies will fall within the two percentile bands.

The first two ratios examined report general profitability and capital expenditure in the thermal coal mining industry, which are both relevant to the industry's ability to service its debt commitments. Profit margins, shown in Figure 10 Chart (A), have been volatile since 2003. The most profitable years of operations occurred in 2006-07, where the median profit margins were 4.03-4.24%. However, operations were particularly difficult for many companies in 2009 and 2013, with negative profit margins.

Capital expenditure represents the funds required to acquire, maintain, or upgrade existing physical assets. Capital expenditure is scaled by revenue to show how aggressively the company is re-investing its revenue back into productive assets. A high ratio can be perceived either positively or negatively, depending on how the capital is spent and how effectively it uses the assets to generate income. Chart (B) shows that a large proportion of revenue was re-invested in companies between 1996 and 2003, with the median reaching 11.42% at its peak (1999). Post-2003, the ratio remains relatively stable.

The current ratio and quick ratio are used as proxies for liquidity in the industry. The former measures the ability to service current liabilities using current assets, the latter measures the ability to service current liabilities using cash, near-cash equivalents, or short-term investments. Charts (C) and (D) show both liquidity ratios have increased through time. Both ratios show increasing liquidity over the entire series.

[37] Data were extracted from S&P Capital IQ (11 April 2016).

The current ratio increases from 0.84 in 1995 to 1.20 in 2015, whereas the quick ratio increases from 0.65 in 1995 to 0.77 in 2015. Chart (C) shows that firms' holdings of current assets are currently in excess of their current liabilities, being able to service their short-term liabilities. Chart (D) shows that the firms are holding a greater proportion of cash, near-cash equivalents, or short-term investments to service current liabilities. Overall, the sample's liquidity has increased during the period.

Two financial leverage ratios are examined: the Debt/Equity ratio in Chart (I) and the Debt/Assets ratio in Chart (J). Both ratios have increased over time, suggesting the industry is financing its growth with debt and/or may be retiring equity. Both ratios suggest leverage ratios are declining across time. The Debt/Equity ratio decreases from 231% in 1995, with a wide range of observations, to 108% in 2015. Similarly, the Debt/Capital ratio also declines over the same period. Combined with Figure 9, these decreasing leverage ratios are primarily driven by a greater value of Total Equity on the balance sheet, as opposed to decreasing total debt. The increase in total equity is a combination of greater retained earnings and now issuances. Overall, the industry has made efforts to reduce its leverage, which can translate to lower financial risk.

Coverage ratios measure the industry's ability to meet its financial obligations. Three ratios are considered: 1) EBIT/interest, 2) EBITDA/interest, and 3) (EBITDA-CAPEX)/interest. All three ratios are positive, suggesting the sample is able to cover interest expenses and its ability to pay increases through time. The EBIT/interest ratio in Chart (K) shows that the operating income of the industry is typically between 1.60 and 6.82 times. The increasing median ratio suggests that the average company can pay its interest expenses many times over. Chart (L) considers EBITDA which accounts for large depreciation and amortisation on assets. Consequently, the EBITDA/interest ratios ranging from 2.29 to 14.29 times interest expense, suggest the costs of intangible and tangible assets are large. Chart (M) considers the impact of capital expenditures on the industry's ability to cover interest expenses. The deduction of CAPEX allows comparison across capital-intensive companies. When deducting annual CAPEX, the ratios range from 1.85 to 6.15 times interest cover. Across the three ratios, the range of observations widens through time, suggesting a divergence of practices among companies.

The final four ratios represent the industry's ability to retire incurred debt. The ratios can be broadly interpreted as the amount of time needed to pay off all debt, ignoring interest, tax, depreciation and amortisation. The ratios are divided into two groups: group 1 considers the numerators: 'total debt' and 'net debt', where the latter subtracts cash and near-cash equivalents for total debt; group 2 considers the denominators: EBITDA and (EBITDA-CAPEX), where the latter controls for capital expenditures.

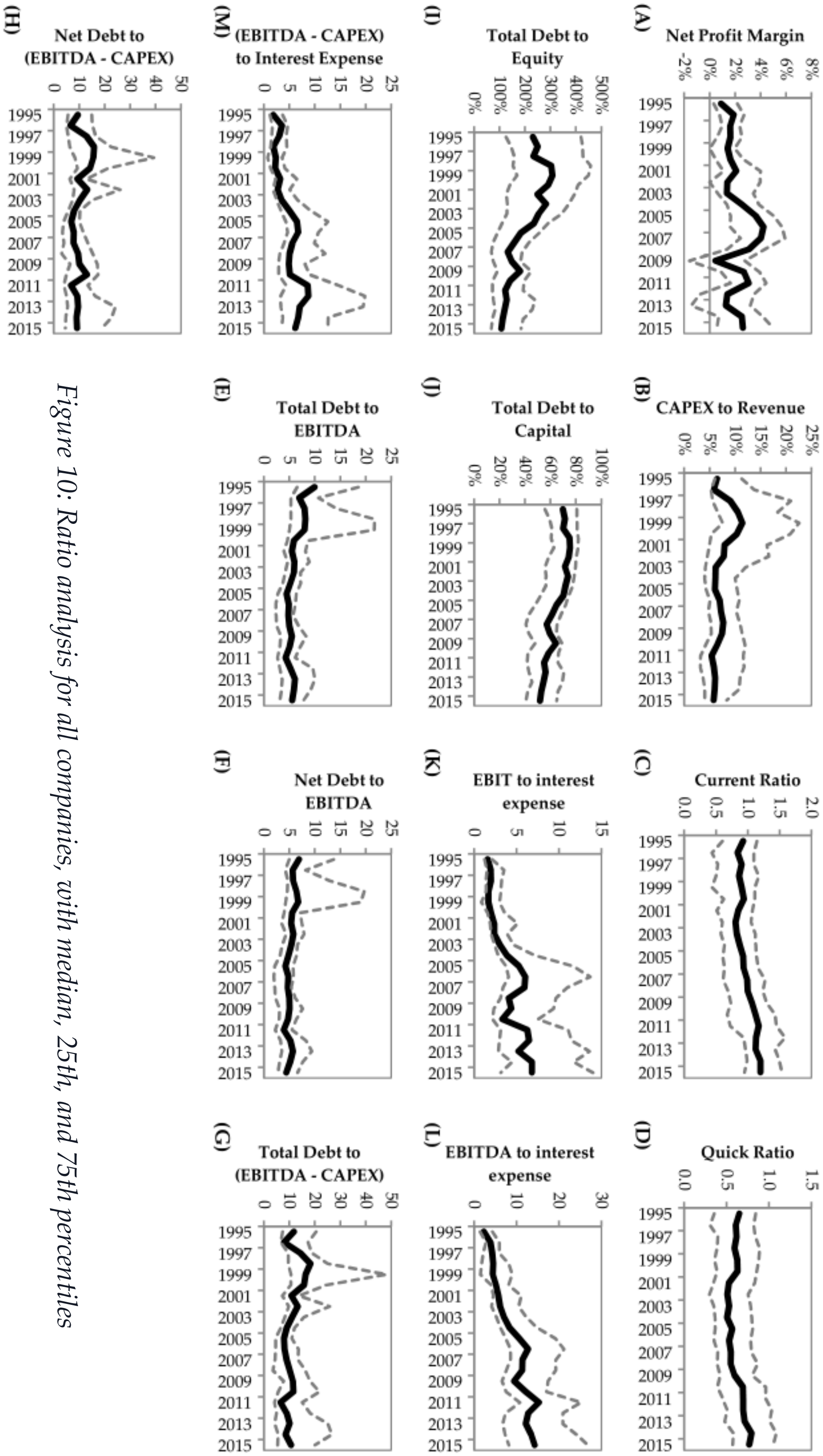


Figure 10: Ratio analysis for all companies, with median, 25th, and 75th percentiles

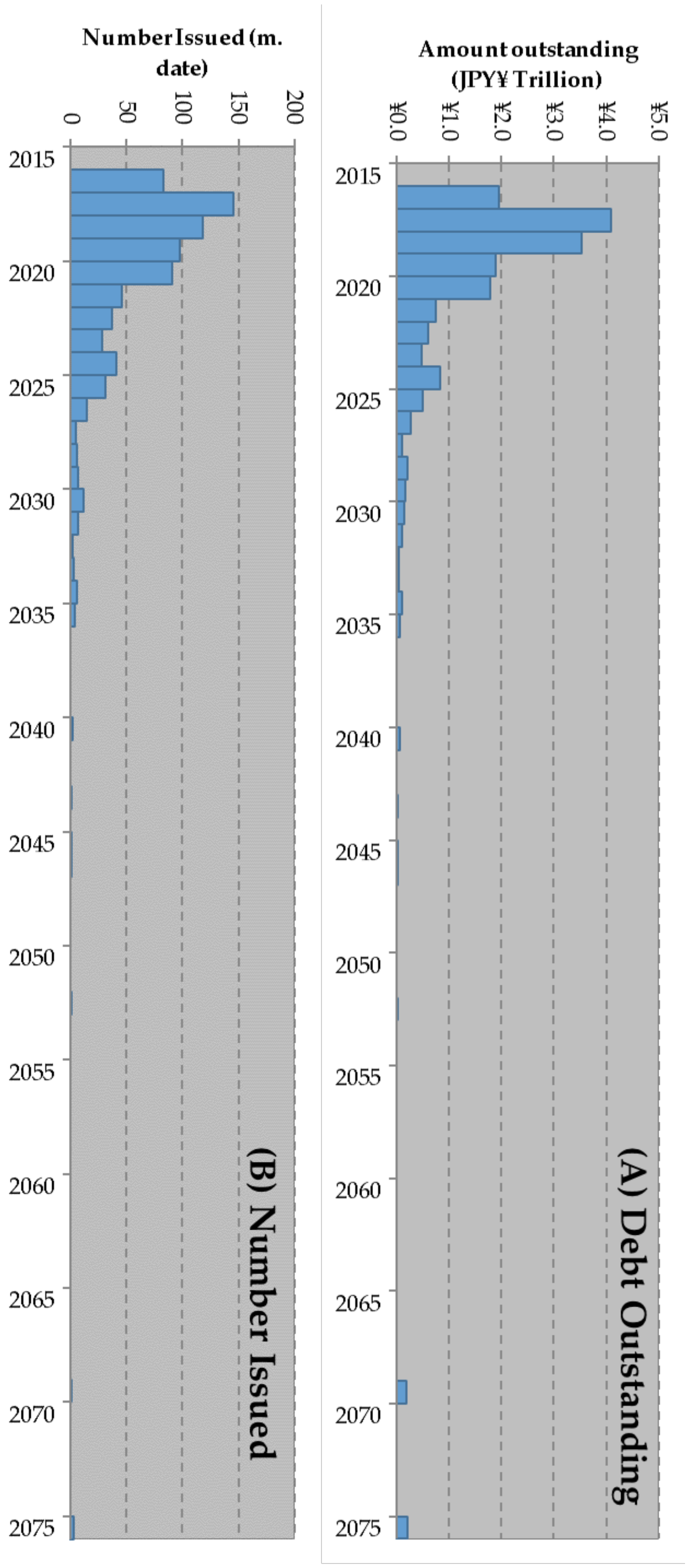
All four ratios suggest the ability to retire debt has been relatively stable over the past 21 years, typically fluctuating in the region of four to ten years using EBITDA, and six to 19 years after subtracting CAPEX. The latter suggests that CAPEX is a major factor in the sample's ability to retire debt. Considering Charts (E) and (F), the number of years taken to retire debt, assuming constant income, has been declining over time. In 1995, it took ten years to retire total debt and seven years to retire net debt after utilising near-cash equivalents. By 2015, total debt could be retired in 5.6 years while net debt could be retired in 4.4 years.[38] When deducting CAPEX, these ratios increase. In 1995, total debt took 11.8 years to retire while net debt took 9.5 years. 1997 to 2000 represent particularly capital intensive years, where both debt ratios increase dramatically. This is consistent with the CAPEX ratios in Chart (B), which showed high capital intensity over a similar period. In conclusion, all four ratios indicate that the sample is making advances in its ability to retire debt.

Figure 11 illustrates the maturity schedule for the total debt outstanding for the sample. The fixed-income data was available for 41 of the 55 companies. The schedule is divided into total amount outstanding (¥ Trillion) and the maturity dates of various contracts.

Plot A of Figure 11 shows that the majority (73.5%) of all outstanding debt obligation is due between 2016 and 2020, indicating the sample shows a preference for debt which matures within five years or less. The most expensive years for retiring debt will be 2017 and 2018, with ¥4.09 trillion and ¥3.54 trillion due, respectively. There is some appetite for longer maturities; some contracts extend to 2035 and a few contracts extend to 2075. In the sample, only one company reported perpetual debt: Nippon Steel & Sumitomo Metal Corporation issued perpetual debt worth ¥273.86bn.

[38] Much of this decline has been due to the fall in Japanese interest rates since 1990.

Figure 11: Bond maturity schedule and number of contracts issued



2.2 Environment-Related Risk Hypotheses

In this section, we examine the environment-related risks facing coal-fired power stations and how they could affect asset values. We call these Local Risk Hypotheses (LRHs) or National Risk Hypotheses (NRHs) based on whether the risk factor in question affects all assets in Japan in a similar way, or if risk exposure is specific to the local environment. Water stress, for example, varies across the country and so is an LRH, whereas a country-wide 'utility death spiral' is an NRH. The hypotheses are coded for easier reference. For example, LRH-1 refers to carbon intensity of coal-fired power stations and NRH-1 refers to the overall demand outlook for electricity.

Hypotheses for different environment-related risks have been developed through an informal process. We produced an initial long list of possible LRHs and NRHs. This list was reduced to the more manageable number of LRHs and NRHs contained in this report. We excluded potential LRHs and NRHs based on two criteria. First, we received feedback from investors and other researchers in meetings, roundtables, and through correspondence, on the soundness, relevance, and practicality of each hypothesis. Second, we assessed the data needs and analytical effort required to link the hypotheses with relevant, up-to-date, and where possible, non-proprietary, datasets.

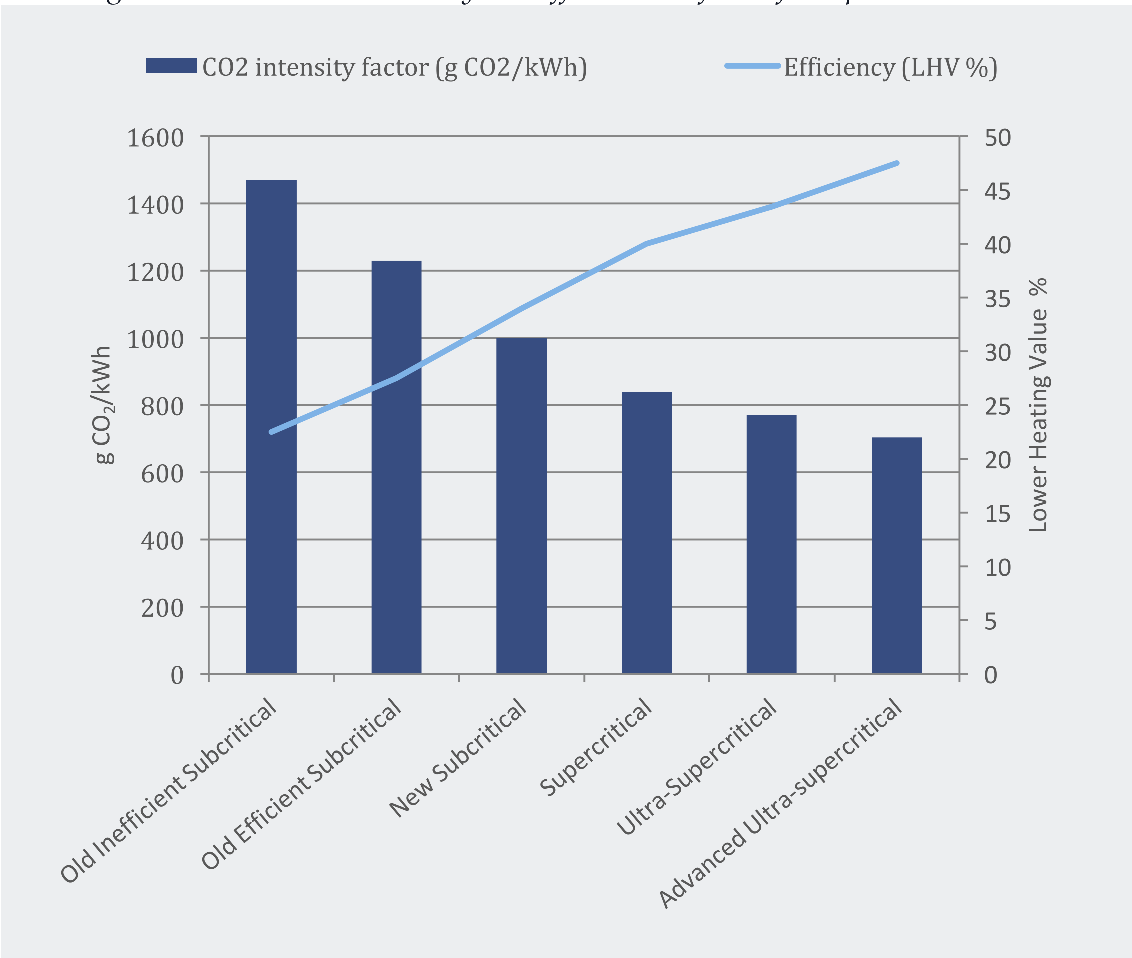
The current list of hypotheses and the datasets used to measure asset exposure to them are in draft form. Other datasets may have better correlations and serve as more accurate proxies for the issues we examine. Important factors may not be represented in our current hypotheses. We are aware of these potential shortcomings and in subsequent research intend to expand the number of hypotheses we have, as well as improve the approaches we have used to analyse them.

2.2.1 Local Risk Hypotheses

LRH-1: Carbon Intensity

The hypothesis is that the more carbon intensive a coal-fired power station is, the more likely it is to be negatively impacted by climate policy: whether carbon pricing, emissions performance standards, or other similar measures. Carbon intensity is directly dependent on power station efficiency, see Figure 12.

Figure 12: Emissions intensity and efficiencies of coal-fired power stations[39]



The carbon intensity of power stations can vary widely based on the efficiency of the boiler technology used. Power stations with lower thermal efficiencies are more vulnerable to carbon policies because such policies will more heavily impact inefficient power stations relative to other power stations.[40] This is highly relevant to coal-fired power generation because it is the most emissions-intensive form of centralised generation.[41] Inefficient coal-fired power stations, such as subcritical coal-fired power stations (SCPSs), are the most vulnerable to such policies. Although Japan has one of the world's least carbon intensive coal fleets, there are plants within it that are relatively inefficient, particularly small plants built for industrial use.

To identify carbon intensity risks, the emissions intensity of each power station globally is identified in kg.CO_2/MWh using data from CoalSwarm's Global Coal Plant Tracker database, the Kiko Network, and the Carbon Monitoring for Action (CARMA) database. Within our population of power utilities, CO_2 intensities for 3% of all power plants and 10% of coal-fired power stations was not available. CO_2 intensity for these missing data points was estimated from coefficients derived from a log-log regression of matched data, using fuel type, MW capacity, age, and a country or regional dummy[42] as regressors. This functional

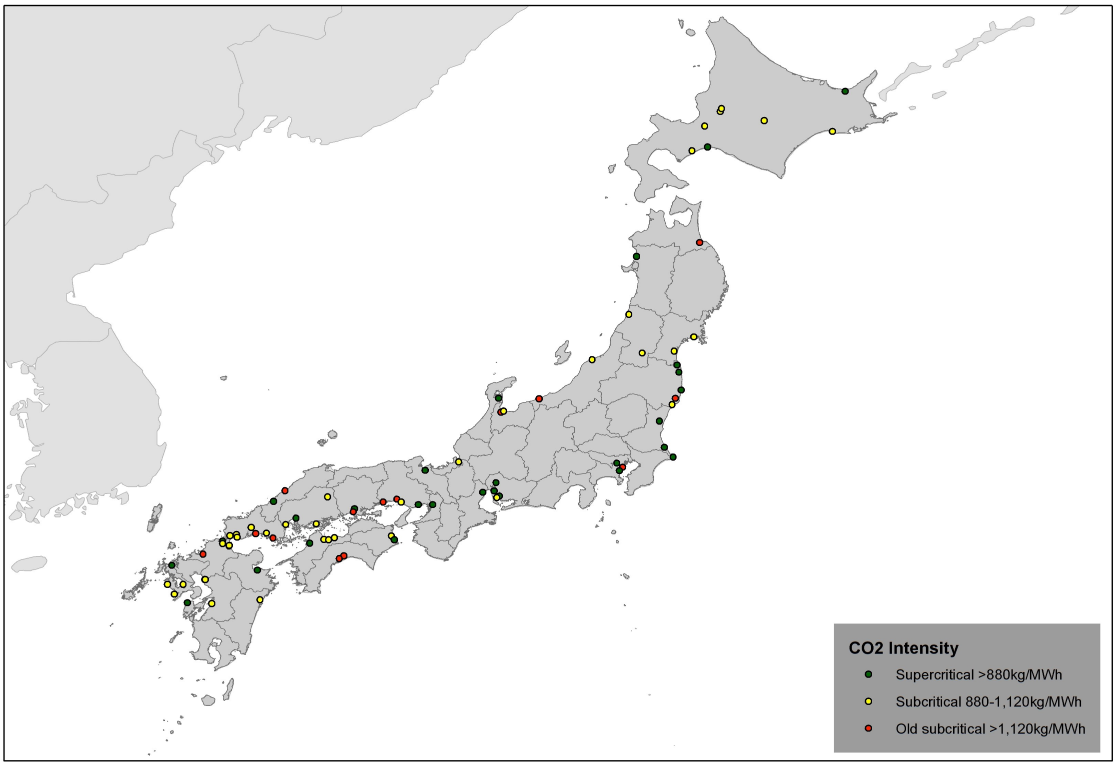
[39] Taken from IEA, "Energy Technology Perspectives 2013", (Paris, France, 2013).
[40] Ben Caldecott and James Mitchell, "Premature Retirement of Sub-Critical Coal Assets: The Potential Role of Compensation and the Implications for International Climate Policy," *Seton Hall Journal of Diplomacy and International Relations* 16, no. 1 (2014): 59–70.
[41] W Moomaw et al., "Annex II: Methodology," *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*, 2011, 982.
[42] Regional dummies are employed where there are fewer than 30 observations of plants in a given country.

form was chosen as it allows for proportional rather than absolute coefficient values, thereby corresponding more closely with the way in which our regressors should affect CO_2 intensity in practice.

Annual generation data (in MWh) was unavailable for 48% of all power stations owned by our 55 companies (all fuel sources) and 32% of coal-fired power stations. This data and plant utilisation rates (in MWh/MW) for missing data points were similarly estimated from coefficients derived from a log-log regression. The regressors employed were fuel type, plant age, and country or region.[43] Similar to CO_2 intensity, this functional form was chosen as it should correspond more closely with the way in which our regressors are likely to affect MWh of generation in practice.

Power stations were then aggregated by utility and weighted by MW to determine the average carbon intensity of both all the power stations and only the coal-fired power stations of the 55 companies in our sample.

Figure 13: Operational coal-fired power station CO2 emissions intensities



LRH-2: Plant Age

The hypothesis is that older power stations creates risks for owners in two ways. First, ageing power stations are more vulnerable to regulations that might force their closure, since it is financially and politically simpler to regulate the closure of ageing power stations. Power stations typically have a technical life of 40 years and recover their capital costs after 35 years[44]. Once power stations have recovered capital costs and have exceeded their technical lives, the financial need to compensate is greatly reduced or eliminated[45]. Second, utilities with significant ageing generation portfolios have a higher risk

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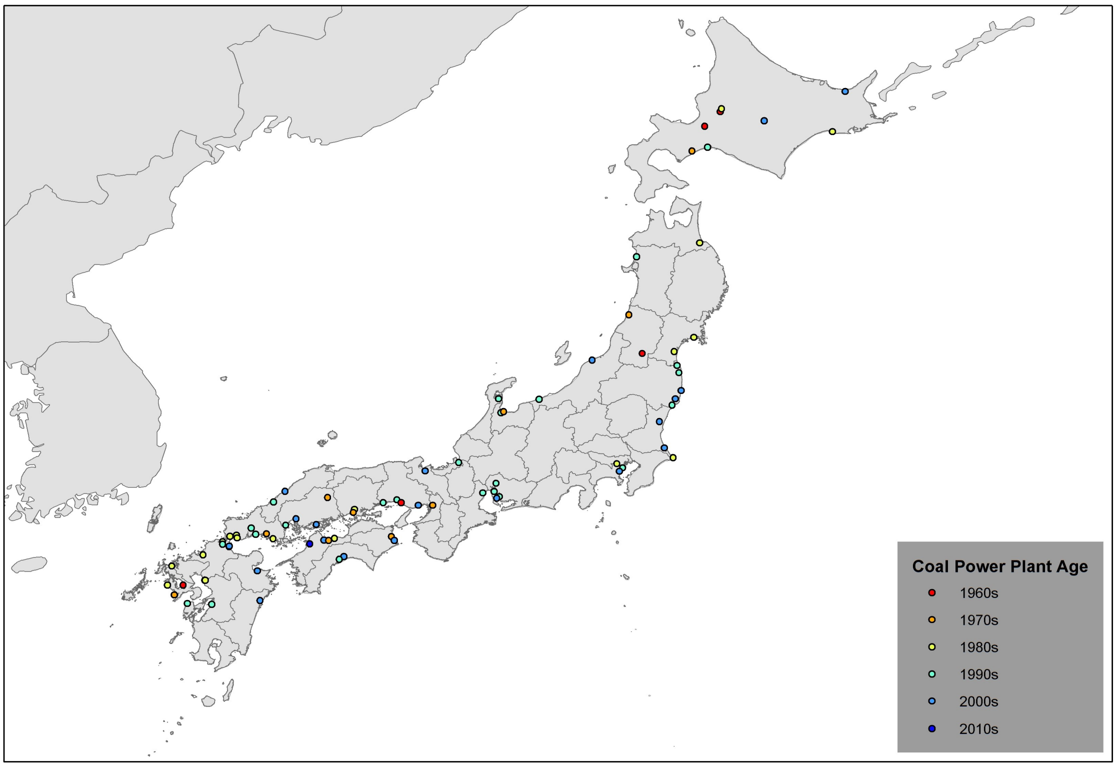
[43] Regional dummies are employed where there are fewer than 30 observations of plants in a given country.
[44] IEA, "Energy, Climate Change and Environment" (Paris, France, 2014).
[45] Caldecott and Mitchell, "Premature Retirement of Sub-Critical Coal Assets: The Potential Role of Compensation and the Implications for International Climate Policy."

of being required to cover site remediation costs after power station closures and outstanding worker liabilities (i.e. pension costs). Finally, older power stations are more susceptible to unplanned shutdowns and maintenance needs, resulting in the costs of repairs and secondary losses or opportunity costs of underperformance on contracted power delivery.

The age of each generating unit within each power station is identified using CoalSwarm, the World Electric Power Plant (WEPP) database, Kiko Network coal plant data, and CARMA. These are then aggregated to the plant level by weighting the MW capacity of each generating unit. For power stations that lack age data (4% in total, 7% for coal), the average age of stations with the same fuel type across the complete dataset is used. Power stations are then further aggregated by utility company to determine the average age of their complete and coal-fired only power generation portfolios.

Figure 14: Operational coal-fired power station ages



LRH-3: Local Air Pollution

The hypothesis is that coal-fired power stations in locations with serious local air pollution are at greater risk of being regulated and required to either install emission abatement technologies or cease operation. Thus, owners of assets in areas of high local pollution will have a greater risk of bearing the financial impacts of such possibilities.

There is strong evidence to support this hypothesis from China, the EU, and the US. In China, a number of non-GHG emission policies are forcing the closure of coal-fired power generation in the heavily polluted eastern provinces.[46]

Power stations without abatement technologies (e.g. flue gas desulphurisation units and electrostatic precipitators) installed are more at risk of being stranded by having to make large capital expenditures to

[46] Caldecott, Dericks, and Mitchell, "Stranded Assets and Subcritical Coal: The Risk to Companies and Investors."

fit emission abatement technologies. This risk is exacerbated by power station age because investments are harder to justify closer to the end of a power station's technical life.

This is illustrated by the effects of the Mercury and Air Toxics Standards in the United States. Implemented under the 1990 Clean Air Act amendments, MATS limit emissions of mercury, toxic metals, and acidic gases. 70% of coal-fired power stations are compliant with the regulations. While 6% have plans to comply with the regulation, 16% plan to cease operation instead of comply and another 8% are undecided. The EIA attributes this to the capital expenditure necessary to comply as well as competition from renewables and gas.[47]

The following approach is taken to identify risks to utilities that may be created by the co-location of coal-fired power stations with serious local air pollution.

- All coal-fired power stations are mapped against a geospatial dataset of global $PM_{2.5}$ pollution. $PM_{2.5}$ data is taken from the analysis of Boys, Martin et al. (2015), and consists of annual ground-level $PM_{2.5}$ averages between 2012 and 2014 derived from satellite observation.
- Average $PM_{2.5}$ pollution within a radius of 100km of each power station is identified.

In this hypothesis, $PM_{2.5}$ is used as a proxy for the other conventional air pollutants. Mercury has toxic neurological impacts on humans and ecosystems, but $PM_{2.5}$ is responsible for a more significant range of respiratory and cardiac health impacts associated with coal-fired power.[48] NO_x and SO_x form additional PM pollution once suspended in the atmosphere, and so are included in an evaluation of exposure to $PM_{2.5}$ alone. Figure 15, Figure 16, Figure 17, and Figure 18 show conventional air pollutant concentrations in Japan.

[47] Elias Johnson, "Planned Coal-Fired Power Plant Retirements Continue to Increase," *EIA*, 2014, https://www.eia.gov/todayinenergy/detail.cfm?id=15491.
[48] Alan H Lockwood et al., "Coal's Assault on Human Health," *Physicians for Social Responsibility Report*, 2009.

Figure 15: Average $PM_{2.5}$ concentrations, 2012-2014[49]

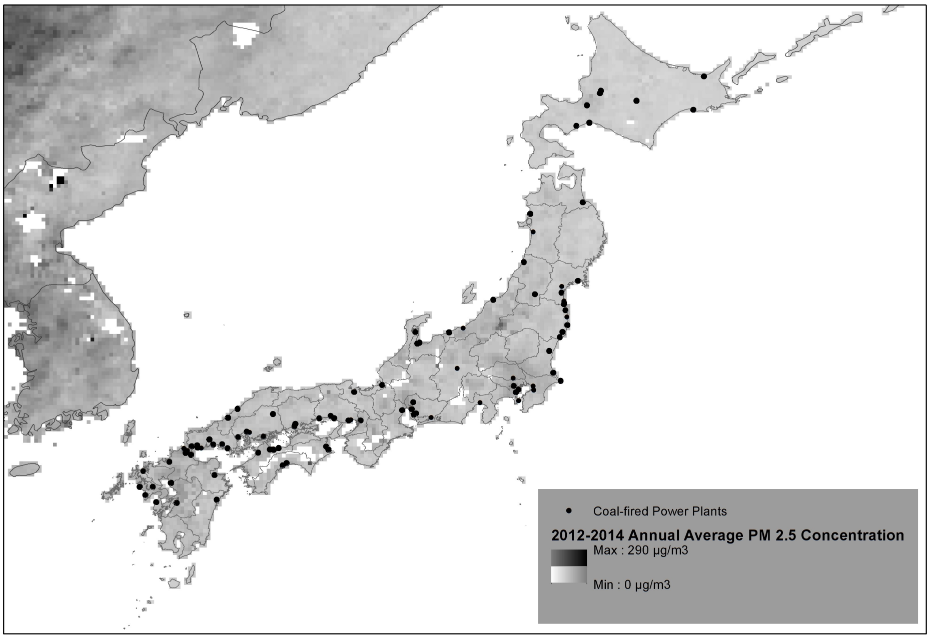
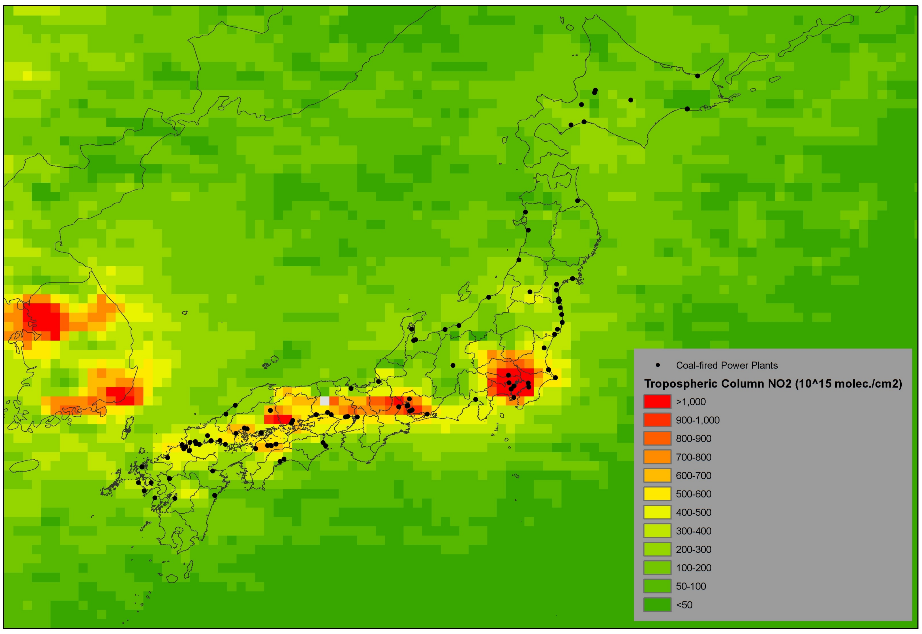


Figure 16: Average NO_2 concentrations, 2015[50]



[49] B L Boys et al., "Fifteen-Year Global Time Series of Satellite-Derived Fine Particulate Matter," *Environmental Science & Technology* 48, no. 19 (2014): 11109–18.
[50] K F Boersma et al., "An Improved Tropospheric NO2 Column Retrieval Algorithm for the Ozone Monitoring Instrument," *Atmos. Meas. Tech.* 4, no. 9 (September 16, 2011): 1905–28, doi:10.5194/amt-4-1905-2011.

Figure 17: Average SO_2 concentrations, 2011-14[51]

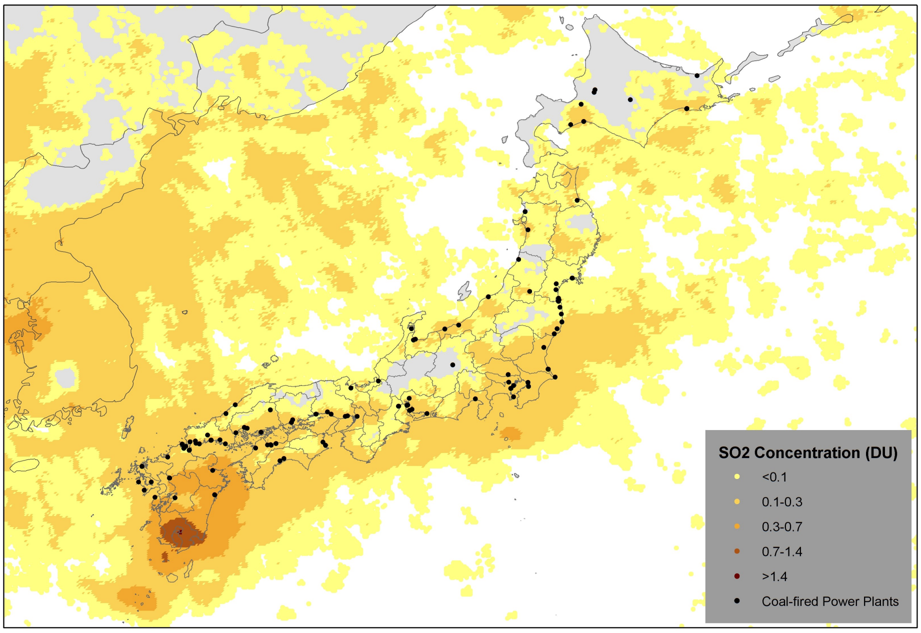
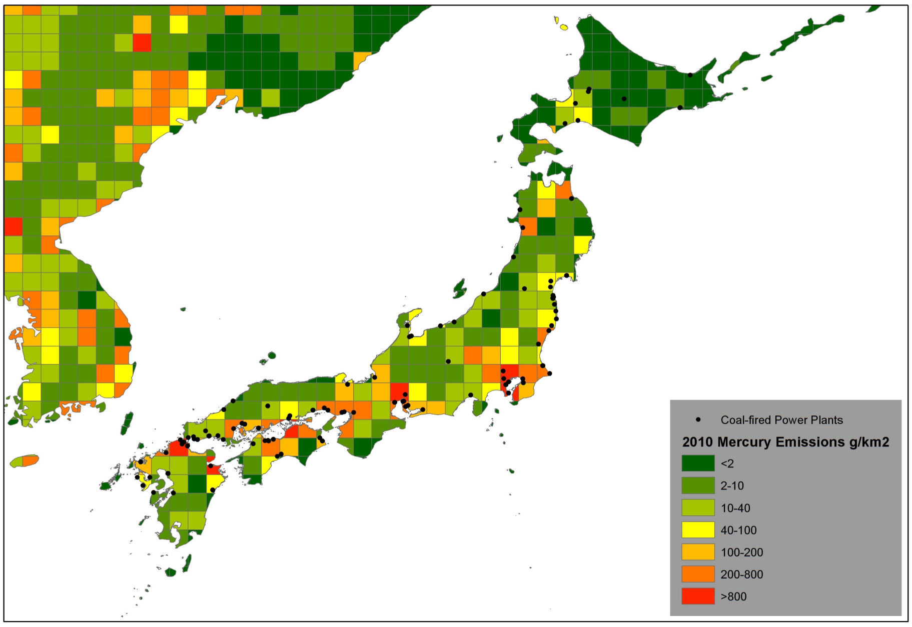


Figure 18: Average mercury emissions, 2010[52]



LRH-4: Water Stress

The hypothesis is that power stations located in areas with higher physical baseline water stress or in areas with water conflict or regulatory uncertainty are at higher risk of being forced to reduce or cease

[51] N A Krotkov et al., "Aura OMI Observations of Regional SO2 and NO2 Pollution Changes from 2005 to 2015," *Atmos. Chem. Phys.* 16, no. 7 (April 13, 2016): 4605–29, doi:10.5194/acp-16-4605-2016.
[52] AMAP/UNEP, "AMAP/UNEP Geospatially Distributed Mercury Emissions Dataset 2010v1," 2013, http://www.amap.no/mercury-emissions/datasets.

operation, of losing licence to operate, or of having profits impaired by water pricing. These risks can be mitigated to an extent by the use of closed-cycle, hybrid, or dry cooling technology.

These risks can be exacerbated by policy in two ways. First, water-use hierarchies that give residential or agricultural water use precedence over industrial use might worsen impacts of physical scarcity on power generation. Second, areas with high water stress and low industrial water pricing are more vulnerable to policy change.

Coal-fired Rankine-cycle (steam) power stations are second only to nuclear power stations in water use. Cooling is by far the largest use of water in these power stations. The largest factor in determining the water-efficiency of stations is the type of cooling system installed. Secondary factors are the ambient temperature and station efficiency.[53]

Table 23: Water use in electric power generation[54]

Fuel-Type	Cooling Technology			
	Once-Through	Closed-Cycle (Wet)	Hybrid (Wet/Dry)	Dry Cooling
Coal	95,000-171,000	2,090-3,040	1,045-2,755	~0
Gas	76,000-133,000	1,900-2,660	950-2,470	~0
Oil	76,000-133,000	1,900-2,660	950-2,470	~0
Nuclear	133,000-190,000	2,850-3,420	Applicability[1]	Applicability[1]

Previous research shows that there is strong evidence to suggest that unavailability of water resources is a legitimate concern to the profitability of power stations.[55] In India, coal-water risks have forced nationwide blackouts and water shortages that restrict plants from operating at full capacity and have been shown to quickly erode the profitability of Indian power stations.[56] In China, attempts to abate local air pollution in eastern provinces have pushed coal-fired power generation into western provinces, where there is extreme water scarcity and shortages are expected.[57]

The following approach is taken to identify risks to utilities that may be created by physical water stress as well as social or regulatory water risks. The Baseline Water Stress geospatial dataset from WRI's Aqueduct is used to assess physical water stress-related risks. Social and regulatory risks are assessed at the national level in NRH-U8. Power station cooling technology is taken from the WEPP database and visual inspection. It was not possible to identify the cooling technology of 29% of coal plants.

The measure for water stress used in this report is Baseline Water Stress (BWS) from Aqueduct created by the World Resources Institute (WRI). BWS is defined as total annual water withdrawals (municipal, industrial, and agricultural) expressed as a percentage of the total annual available flow within a given watershed. Higher values indicate greater competition for water among users. Extremely high water stress areas are determined by WRI as watersheds with >80% withdrawal to available flow ratios, 80-40% as high water stress, 40-20% as high to medium, 20-10% as medium to low, and <10% as low.[58]

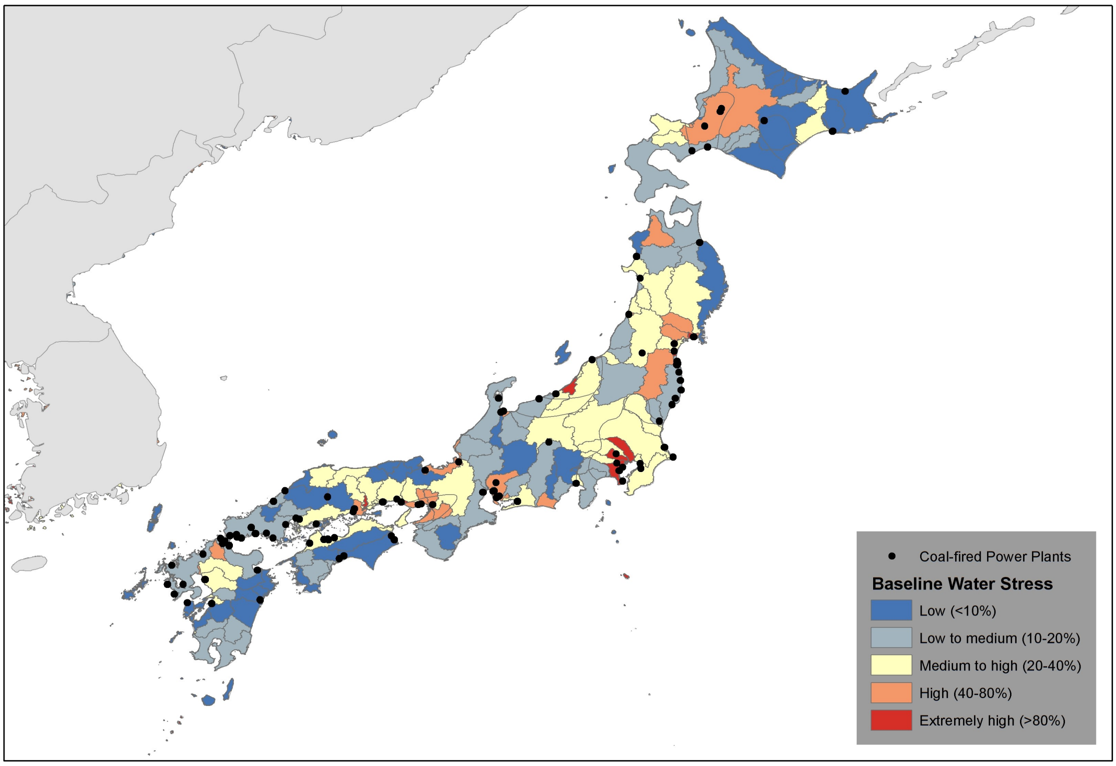
All coal-fired power stations are mapped against the Aqueduct Baseline Water Stress geospatial dataset. Those power stations that are in watersheds that have 'extremely high water risk'[59] for baseline water

[53] Caldecott, Dericks, and Mitchell, "Stranded Assets and Subcritical Coal: The Risk to Companies and Investors."
[54] EPRI, "Water Use for Electric Power Generation" (Palo Alto, CA, 2008).
[55] Ibid.
[56] IEA, "World Energy Outlook 2012", 2012.
[57] CTI, "Coal Financial Trends", 2014.
[58] Francis Gassert et al., "Aqueduct Global Maps 2.1: Constructing Decision-Relevant Global Water Risk Indicators" (Working Paper. Washington, DC: World Resources Institute. Available online at: http://www. wri. org/publication/aqueductglobalmaps-21-indicators, 2014).
[59] Baseline water stress measures the ratio of total annual water withdrawals to total available annual renewable supply, accounting for upstream consumptive use. Extremely high water risk signifies that >80% of renewable supply is withdrawn.

stress are identified as 'at risk'. If a power station uses dry cooling technology, it is reclassified as 'not at risk'.

Power stations are then aggregated by utility to identify the percentage of capacity that is 'at risk'. Figure 19 shows global baseline water stress.

Figure 19: Baseline water stress, Data from WRI Aqueduct 2015



LRH-5: CCS Retrofitability

Coal-fired power stations not suitable for the retrofit of carbon capture and storage (CCS) technology may be at more risk of premature closure. These power stations do not have the option of CCS retrofit in the case of strong GHG mitigation requirements on coal-fired power utilities, enforced either by targeted policy or carbon pricing. Because CCS plays a large part in in the IPCC and IEA's 2°C scenarios[60] (IPCC AR5 2DS) as well as the IEA's 2°C scenarios (IEA ETP, IEA WEO 450S), it is necessary to evaluate the retrofitability of power stations to assess the resilience of utilities' generation portfolio to policies aiming to align power generation emissions with a 2DS.

In post-Fukushima Japan, thermal power became key energy policy in tandem with government plans to increase efficiency in new coal power stations and reduce the cost of CCS projects to curb its CO2 emissions by 2030 (See following sections). Although there are few demonstration CCS projects in Japan, the government supports cutting down the carbon capture cost from US$40/t in 2015 to US$10/t in 2025 in order to accelerate its commercialization.[61] A geological CO2 storage in Japan can be achieved in deep saline aquifers, which makes offshore seabed suitable for CCS projects. A 2012 survey by Research Institute of Innovation Technology for the Earth suggests that the potential geological storage capacity on

[60] Refers specifically to the IPCC AR5 430-480PPM, IEA ETP 2DS, and IEA WEO 450S.

[61] Kawasaki, T., Harada, M. (2015). Current Situation of Japan's Post-combustion Capture and CCS. Japan Coal Energy Center, September 8-9.

Japan's offshore areas shallower than 200 meters is 146.1 billion ton, and a further survey is being conducted for areas deeper than 200 meters.[62]

No dataset exists for CCS retrofitability.[63] Instead, this is defined as a function of power station size, where only boilers larger than 100MW are economic to retrofit;[64][65] age, where only power stations <20 years old are worth making significant investments in[66,67], and location, where power stations that are within 40km of geologically suitable areas are economically suitable.[68]

The following approach is taken to identify the percentage of utilities' coal-fired power generation portfolios that may be suitable for CCS retrofits. CCS policy support is considered separately as a national-level risk indicator.

Power stations with generators larger than 100MW, that are younger than 20 years, are deemed technically suitable for CCS retrofit, and are then mapped against the Global CCS Suitability geospatial dataset to determine whether they are within 40km of areas suitable for CCS, and therefore geographically suitable. Power stations that are both technically and geographically suitable are aggregated by utility to identify the percentage of utilities' generation portfolio that is 'suitable' for CCS retrofit.

Figure 20 depicts global CCS geological suitability and is taken from Geogreen. As we can see from this figure, with the exception of western coasts of Aomori, Akita, and Yamagata prefectures and the outer elbow of the Noto peninsula, there are few suitable CCS locations that are known in Japan. Whereas CCS may be viable in many coastal regions south of Shizuoka, the areas around northern Honshu and Hokkaido are less certain.

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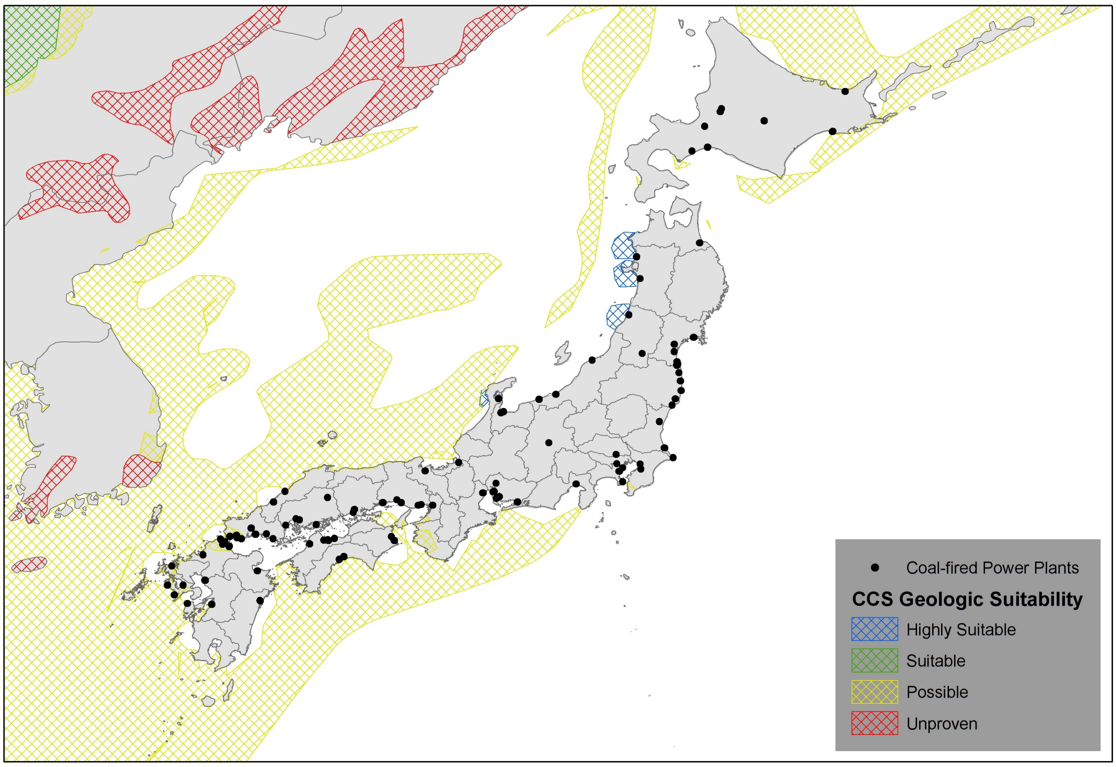
[62] Kawasaki, T. (2015). Op. Cit.
[63] IEA, "CCS Retrofit", 2012.
[64] National Energy Technology Laboratory, "Coal-Fired Power Plants in the United States: Examination of the Costs of Retrofitting with CO2 Capture Technology" (Washington, US, 2011), http://www.netl.doe.gov/energy-analyses/pubs/GIS_CCS_retrofit.pdf.
[65] Although MITei suggests that 300MW is the threshold for power stations generally, 100MW is taken as a conservative case. See MITei, "Retrofitting of Coal-fired Power Plants for CO2 Emission Reductions", 2009.
[66] Ibid.
[67] This is the central scenario of the OECD CCS retrofit study.
[68] 40km has been suggested as the distance to assess proximity to geological reservoirs, see NETL (2011).

Figure 20: CCS geological suitability[69]



CCS map data provided by Geogreen

LRH-6: Future Heat Stress

The hypothesis is that physical climate change will exacerbate heat stress on power stations. Higher ambient local temperatures decrease power station efficiency and exacerbate water stress, which causes physical risks, such as forced closure or reduced operation, and social risks, such as unrest and increased potential for regulation.

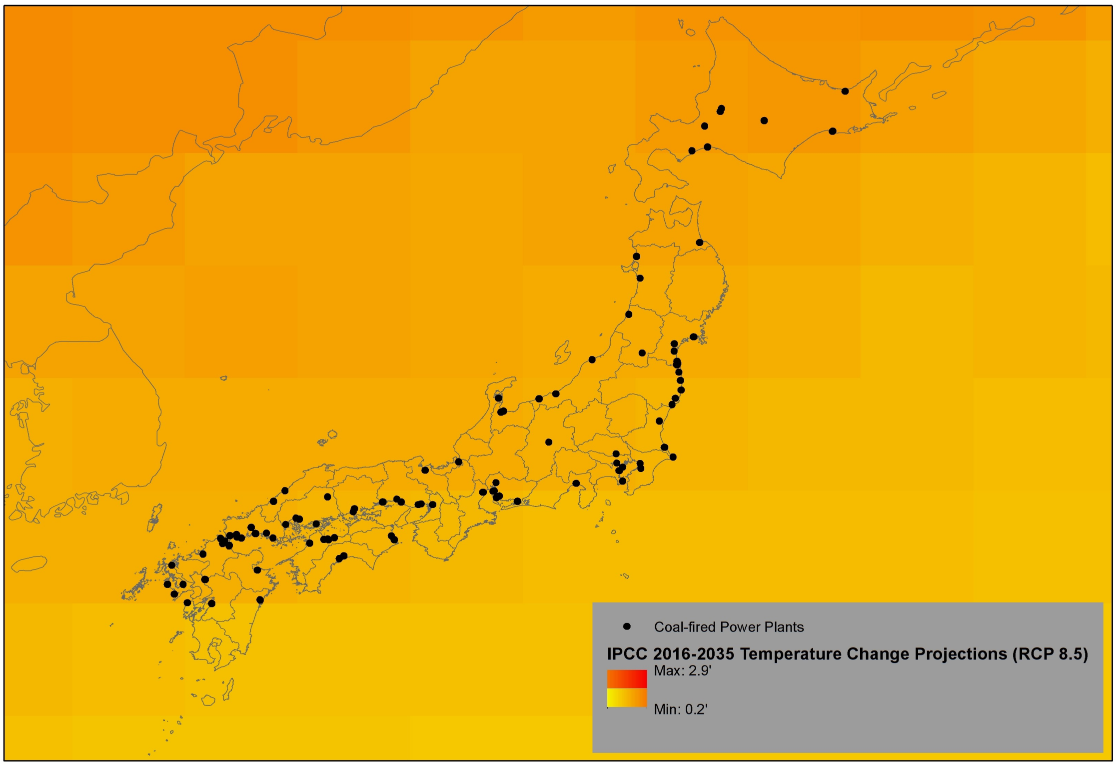
There is strong evidence that warming risks should be taken into account. In Australia, there is evidence that climate change poses direct water-related risks to Australian coal-fired power generation. During a heat wave in the 2014 Australian summer, electricity demand increased in tandem with water temperatures. Loy Yang power station's generating ability was greatly reduced because it could not cool itself effectively.[70] This caused the spot price to surge to near the market cap price.[71] Inability to produce power at peak demand times has the capacity to significantly impact power stations' profits in competitive energy markets.

To assess vulnerability of power stations to climate change-related temperature increases, the Intergovernmental Panel on Climate Change's AR5 2035 geospatial dataset is used. This dataset gives a spatial representation of expected temperature change by 2035.

[69] Reproduced with permission of IEA GHG and Geogreen
[70] AEMO, "Heatwave 13 to 17 January 2014," *American Energy Market Operator*, 2014, http://www.aemo.com.au/News-and-Events/News/2014-Media-Releases/Heatwave-13-to-17-January-2014.
[71] Brian Robins, "Electricity Market: Heatwave Generates Interest in Power," *The Sydney Morning Herald*, 2014, http://www.smh.com.au/business/electricity-market-heatwave-generates-interest-in-power-20140117-310d2.html.

Average temperature change within a 50km radius is calculated for each power station globally. Power stations are then ranked globally. Those power stations in the top quintile of temperature change are identified as 'at risk'. Power stations are then aggregated by utility to identify the percentage of capacity at risk from heat stress induced by climate change. Figure 21 shows global near-term future temperature changes.

Figure 21: Projected 2016-35 temperature change[72]



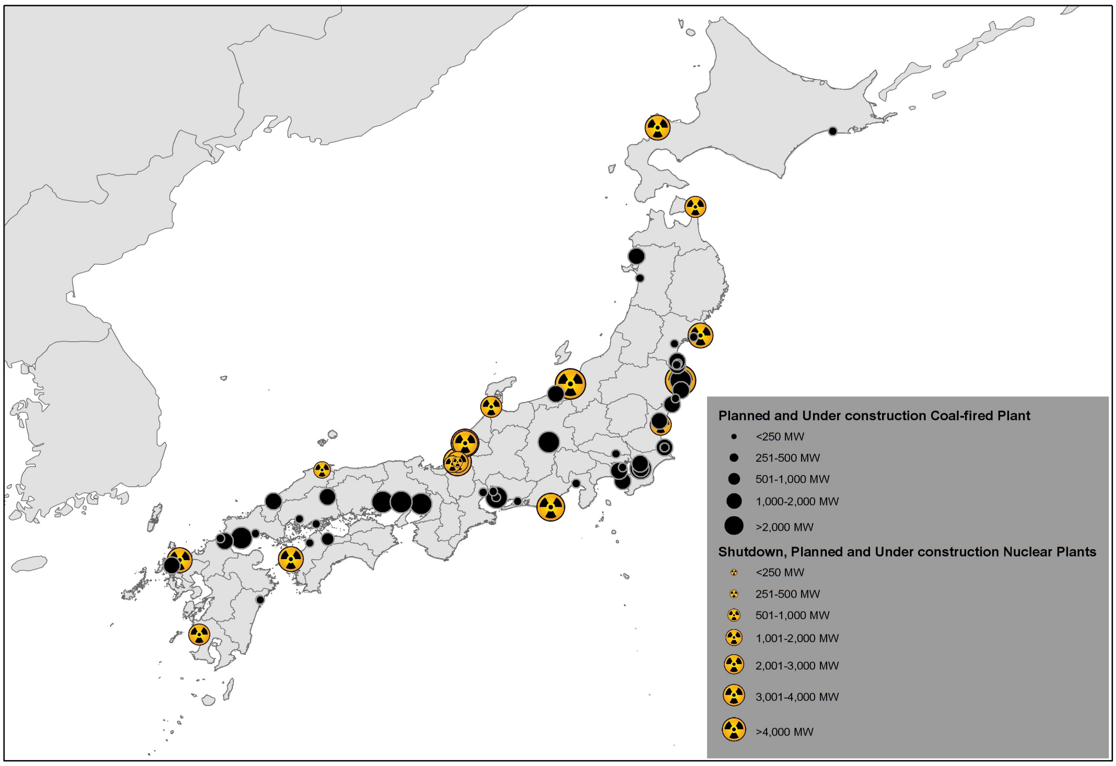
LRH-7: Regional Nuclear Restart Capacity

With almost all nuclear plants in Japan now shutdown, nuclear restarts and new nuclear construction pose a significant risk for power plants in Japan's development pipeline. This risk is especially concerning for coal plants built primarily to replace lost nuclear capacity. Existing and planned coal plants are evaluated with regard to the nuclear capacity which exists in their regions that could be restarted; or nuclear capacity which if now planned, could be developed. This is done because inter-regional electric connections in Japan are weak, and therefore electrical grids are relatively compartmentalised by region.[73] New coal plants in regions that have the greatest potential nuclear capacity are more likely to suffer lower demand by an expansion of nuclear restarts.

Nuclear restarts and new builds pose a significant risk for Japan's utility companies. This risk is especially concerning for coal plants built primarily to replace lost nuclear capacity. Indeed, Figure 22 shows that both the location and size of shutdown and new build nuclear plants are highly correlated with the location and size choices of the coal plants now in the development pipeline. It is clear from this figure that a number of planned coal plants are being strategically positioned to replace lost nuclear capacity.

[72] Data from RCP8.5, P50 of IPCC, "Climate Change 2014: Mitigation of Climate Change", 2014.
[73] Note that coal capacity owned by one company is still threatened by nuclear from the same company. This is because, if restarted, the nuclear plant will still cannibalise demand from that coal plant.

Figure 22: Planned and under construction coal plants; and shutdown, planned and under construction nuclear plants



Note that all shutdown nuclear capacity has new coal plants of a similar size being built within the same city, and therefore each nuclear plant is underlaid by a size-equivalent coal plant marker.

The magnitude of nuclear restart risk to new coal plants will depend upon both the probability that a nuclear plant restarts and the grid proximity of that nuclear plant to new coal. We do not explicitly address the probability of individual nuclear restarts here as this is a political question with great uncertainty(all operable plants are treated identically), but instead focus on the problem of grid proximity.

The ability of a power plant to compete with another is dependent on the grid network and complex interlinkages that are difficult to model even with ideal data. With an adequate distribution network, it is possible for power plants that are many hundreds of kilometres distant to compete with one another. Rather than attempt to model the electrical network explicitly, we instead draw upon the fact that inter-regional linkages in Japan are known to be weak.[74] We have therefore chosen to assume that each nuclear plant and new coal plant can effectively provide power (and therefore compete) throughout the same region[75], but that these plants are effectively isolated from capacity in other regions. As such, we take the amount of shutdown (but operable), planned, and under construction nuclear capacity within each region as an approximation for the risk of nuclear restart to new coal power plants within that region.

When aggregating this risk up to the level of the utility, we take an average of the restartable nuclear capacity in each region, weighted by the generating capacity of the utility's coal-fired power stations in each region. We can see from Table 24 that the regions of Tohoku, Hokuriku and the island of Kyushu

[74] Topham, "Japan's Power Failure: Bid to Forge National Grid Stumbles."
[75] We define these regions by geographical divisions of the 10 regional monopolists. There are therefore 10 such regions.

have the greatest potential nuclear capacity, and therefore new coal plants in these regions are likely to be among the most affected by an expansion of nuclear restarts.

Table 24: Potential regional nuclear capacity (shutdown, under construction and planned)

Region	MW
Tohoku	17,263
Hokuriku	13,306
Kyushu	4,699
Chubu	3,617
Hokkaido	2,070
Shikoku	2,022
Tokyo	1,100
Chugoku	820
Kansai	0
Okinawa	0

2.2.2 National Risk Hypotheses

The hypotheses below affect all generating assets in Japan. A simple traffic light method has been used to conduct analysis for these risk hypotheses. Traffic-light methods are well suited to complex situations where more formal analysis is unavailable or unnecessary, and are particular prevalent in environmental and sustainability analysis, e.g. DEFRA[76], the World Bank[77]. The hypotheses developed below draw on the IEA NPS as a conservative scenario and add extra evidence to give a more complete policy outlook for coal-fired utilities. The time horizon for these risk indicators is near to mid-term, using the IEA's 2020 projections where appropriate.

An effective traffic-light method clearly describes threshold values or criteria for each colour that are testable by analysis or experiment.[78] Criteria are developed below for each hypothesis, with conclusions as to whether coal-fired utilities are at high risk (red), medium risk (yellow) or low risk (blank). Based on each of these criteria, an aggregate risk outlook is given after scoring each (+2 for high risk criteria, +1 for medium risk criteria). These scores can be used for an aggregate risk outlook for coal-fired power generation in Japan. Comparator countries are also given based on the analysis conducted in *Stranded Assets and Thermal Coal: An analysis of environment-related risks*. Particularly with the traffic-light methodology, these comparisons are important for contextualising risk exposure in Japan. For investors who have a global universe of investment opportunities understanding how Japan's utilities compare to utilities in other countries with regards to environment-related risk exposure is eminently relevant.

The analysis of NRHs below has been expanded and updated since *Stranded Assets and Thermal Coal*. Changes in opinion of risk exposure are noted where appropriate. Table 25 provides a summary of all NRHs for Japan's coal-fired power utilities and their peers in comparator countries, where directly comparable. Since *Stranded Assets and Thermal Coal* our opinion of risk exposure for Japan has worsened with the additional of NRH-10: Nuclear Restarts.

[76] Department for Food, Environment & Rural Affairs, "Sustainable Development Indicators," 2013.
[77] The World Bank, "RISE Scoring Methodology," 2016, http://rise.worldbank.org/Methodology/Scoring-methodology.
[78] R G Halliday, L P Fanning, and R K Mohn, "Use of the Traffic Light Method in Fisheries Management Planning," *Marine Fish Division, Scotia-Fundy Region, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmount, NS, Canada*, 2001.

Table 25: Summary of National Risk Hypotheses

	Japan	Australia	China	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
NRH-1: Future Electricity Demand	Red	Yellow	Green	Red	Green	Green	Red	Yellow	Red	Yellow
NRH-2: Renewables Resource	Green	Red	Green	Green	Yellow	Yellow	Yellow	Red	Yellow	Yellow
NRH-3: Renewables Policy Support	Red	Yellow	Red	Red	Green	Red	Green	Yellow	Yellow	Red
NRH-4: Growth of Decentralised Renewables	Red	N/A								
NRH-5: Growth of Utility-Scale Renewables	Green	N/A								
NRH-6: Growth of Gas-Fired Power	Yellow	Yellow	Red	Green	Red	Yellow	Green	Green	Green	Red
NRH-7: Falling Utilisation Rates	Yellow	Yellow	Red	Green	Yellow	Red	Yellow	Red	Yellow	Yellow
NRH-8: Regulatory Water Stress	Green	Green	Yellow	Green	Red	Yellow	Green	Yellow	Green	Green
NRH-9: CCS Regulatory Env.	Yellow	Green	Red	Yellow	Red	Red	Yellow	Red	Green	Green
NRH-10: Nuclear Restarts	Yellow	N/A								
TOTAL*	50%	60%	60%	50%	40%	45%	40%	55%	45%	60%

*Higher percentage equates to a worse risk outlook. Total for Japan based on this publication. Total for comparator countries based on *Stranded Assets and Thermal Coal*.

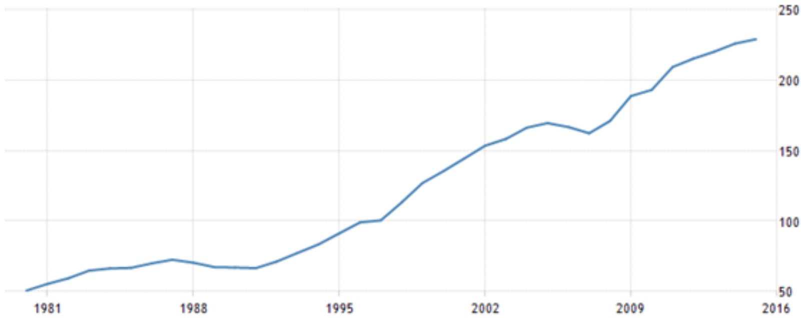
NRH-1: Future Electricity Demand Outlook

The hypothesis is that the greater the growth in demand for electricity, the less likely other forms for generation (e.g. solar, wind, gas, and nuclear) are to displace coal-fired power. Growth in overall electricity demand might allow coal-fired generators to maintain or increase their current share of power generation.

Change in electricity demand is driven by macroeconomic conditions and technology deployment. Japan faces severe economic challenges as a result of its crushing debt load and now falling population. The economic problems began in 1990 when Japan experienced the collapse of one of the largest financial bubbles the world had ever seen. During the ensuing 25 years Japan experienced practically no economic growth combined with no inflation and massive government spending. This had the predictable effect of ballooning government debt from 67 per cent of GDP in 1990 to 229 per cent in 2015. Over the past decade this debt has continued to grow at an average of rate of about 7 per cent per year.[79] These unsustainable liabilities have forced Japan's hand to pursue an extremely risky policy of monetising this debt and other forms of money printing such as Quantitative Easing which create economic distortions and have the potential to cause hyperinflation. However, the Japanese economy is now dependent upon this financial manipulation, and any attempts to remove it would prove equally disastrous. As a result, the Japanese economy is locked in a fragile state. Since fluctuations in economic output are a key determinant of electricity demand, Japanese energy producers have reason to be cautious about the future.

[79] By comparison much in the news Greece has a lower debt to GDP ratio of 179% which has been stable over the last three years.

Figure 23: Japanese government debt to GDP ratio 1980-2015

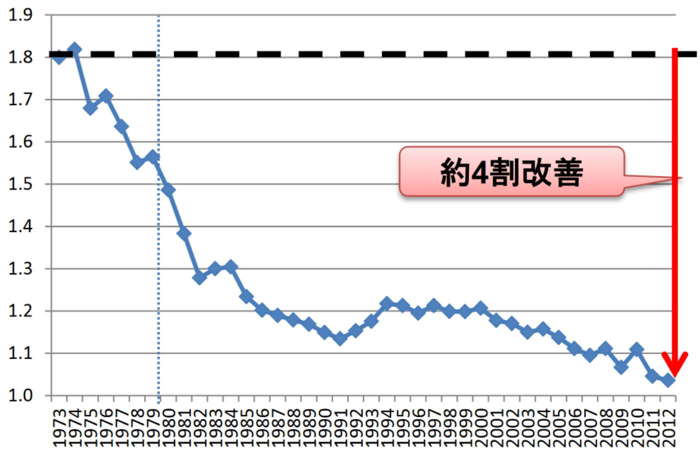


Source: www.tradingeconomics.com, Ministry of Finance Japan

Against this already threatening economic backdrop, projections by the Japanese government indicate that the population will also decline by 8 per cent from its current 127 million to 117 million by 2030, or 0.5% per year; and then accelerate to 0.85% per cent per year until 2050 to 97 million.[80] Meanwhile the working age population is expected to fall even faster at 0.9 per cent per year to 2030. This decline is significant given the long time-scale over which power plants operate (typically 40 years).[81] Absent radical increases in workforce participation rates or productivity, this smaller population will slash economic output and further undermine the solvency of Japan's financial system.

Energy producers must also dodge a third bullet in the form of increasing energy efficiency. Although most of the increase in Japanese energy efficiency took place prior to 1990, in the last four years increased energy efficiency has caused electricity demand to fall by 10%.[82]

Figure 24: Japanese energy efficiency per unit of real GDP (Mtoe/¥100 bn)



Source: METI 省エネルギーに関する情勢及び 取組の状況について

A struggling economy, declining population, and increasing energy efficiency should lead to falling electricity demand. Curiously this is not what the Japanese government is forecasting. According to METI the government expects electricity demand to increase from 967 TWh in 2013 to 981 TWh in 2030. By contrast, using more realistic assumptions BNEF estimates 2030 demand to fall 3.5% to 946 TWh. Figure 25 shows projections of Japan's electricity generating mix in 2030. BNEF takes a much more pessimistic view of nuclear restarts than the Japanese Government. BNEF and both the IEA's NPS and 450S project larger

[80] BNEF, "Japan's Likely 2030 Energy Mix: More Gas and Solar," *Bloomberg New Energy Finance*, 2015, http://about.bnef.com/content/uploads/sites/4/2015/06/BNEF_White_Paper_Japan_Outlook_EN_FINAL.pdf.
[81] John Mauldin and Jonathan Tepper, *Code Red: How to Protect Your Savings from the Coming Crisis* (John Wiley & Sons, 2013).
[82] Christine Sheerer et al., "Boom and Bust 2016: Tracking the Global Coal Plant Pipeline," 2016, http://sierraclub.org/sites/www.sierraclub.org/files/uploads-wysiwig/final boom and bust 2017 %283-27-16%29.pdf.

penetration of renewables than the Japanese Government. In all scenarios, the IEA projects a strong return of nuclear power to the Japanese generating mix.

Figure 25: 2030 projections of Japan's electricity mix[83,84,85,86]

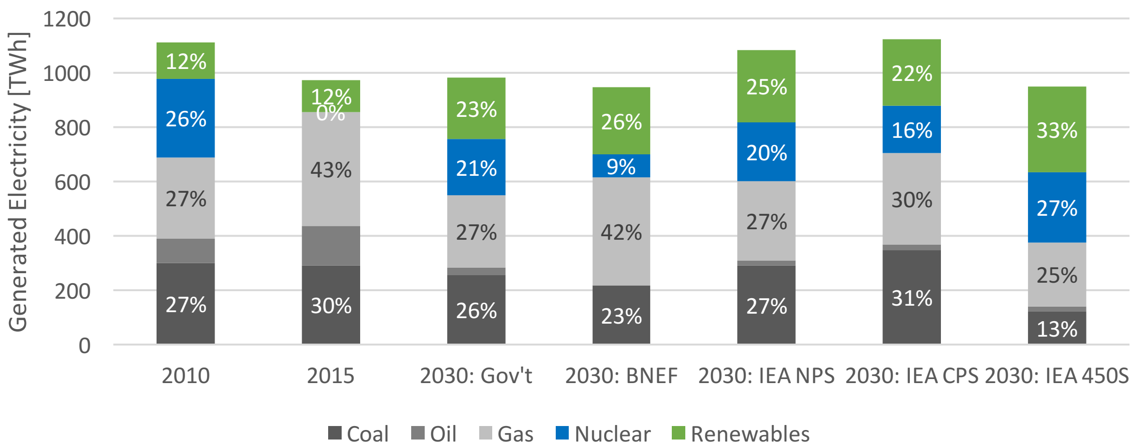


Table 26 shows the compound annual growth rates in GDP, population, and electricity and final energy demand, and ratios thereof for several published projections. The government of Japan projects substantial GDP growth simultaneous with large gains in efficiency, demonstrated by rapidly diminishing final energy demand and power generation relative to GDP. The IEA also expects electricity as a portion of total final energy demand to grow quicker than the government projects, indicating the electrification of final energy uses like transport and heat.

Table 26: Japan future energy demand assumptions and indicators

2013-2030 CAGR	GDP	POP	ELEC	TFED	ELEC/GDP	ELEC/POP	TFED/GDP	TFED/POP	ELEC/TFED
Government of Japan[87]	1.7%	-0.7%	0.1%	-0.6%	-1.6%	0.8%	-2.3%	0.1%	0.7%
BNEF[88]	1.0%	-0.5%	-0.1%	N/A	-1.1%	0.4%	NA	NA	NA
IEA: NPS[89]	0.8%	-0.4%	0.3%	-0.7%	-0.5%	0.6%	-1.7%	-0.2%	1.0%
IEA: CPS	0.8%	-0.4%	0.5%	-0.6%	-0.3%	0.8%	-1.6%	-0.1%	1.0%
IEA: 450S	0.8%	-0.4%	-0.5%	-1.4%	-1.3%	-0.2%	-2.3%	-0.9%	0.9%

ELEC: Total electricity generation (i.e. in TWh)
POP: Population
TFED: Total Final Energy Demand (i.e. in EJ of electricity, heat, light, mobility, etc.)

For the purposes of evaluating risk exposure in this hypothesis, future electricity demand is considered in the medium term. Medium-term electricity demand outlook is obtained from IEA WEO 2015. The WEO's NPS scenario is chosen as a conservative outlook. Japan's outlook is compared in Table 26 with the other scope countries from *Stranded Assets and Thermal Coal: An analysis of environment-related risk exposure.*

[83] BNEF, "Japan's Likely 2030 Energy Mix: More Gas and Solar.", 2015.
[84] IEA, "World Energy Outlook," 2015.
[85] Mari Iwata and Henry Hoenig, "Japan Struggles to Find Balanced Energy Strategy," *The Wall Street Journal*, 2015, http://www.wsj.com/articles/japan-struggles-to-find-balanced-energy-strategy-1431545581.
[86] Reuters, "CORRECTED-UPDATE 2-As Japan's Oil, Gas, Power Use Stalls, Coal Imports Hit New Record," *Reuters*, 2016, http://www.reuters.com/article/japan-energy-demand-idUSL3N15900U.
[87] METI, "Long-Term Energy Supply and Demand Outlook (Provisional Translation)," *Ministry of Economy, Trade and Industry*, 2015, http://www.meti.go.jp/english/press/2015/pdf/0716_01a.pdf.
[88] BNEF, "Japan's Likely 2030 Energy Mix: More Gas and Solar.", 2015.
[89] IEA, "World Energy Outlook."

Countries which have 0% projected electricity demand growth between 2013 and 2020 are considered ‘high risk’. Countries with 1% or 2% growth are considered ‘medium risk’. Countries with >2% growth are considered ‘low risk’. Japan is considered ‘high risk’.

Table 27: 2013-20 electricity demand outlook from IEA WEO 2015 NPS[90]

2013 - 2020	**Japan**	Other OECD Pacific	China	India	Other SE Asia	South Africa	EU	US
CAGR	0%	2%	4%	6%	4%	1%	0%	1%
Risk	Red	Yellow	Green	Green	Green	Yellow	Red	Yellow

NRH-2: Renewables Resource

The hypothesis is that the availability of strong renewable resources is a key determinant of the competiveness of renewables relative to conventional generation. Countries with larger renewable resources could see larger and faster rates of deployment. This would result in coal-fired power stations being more likely to face lower wholesale electricity prices and other forms of power sector disruption.

Wind resource potential is drawn from Lu et al. (2009) and is normalised by 2014 total electricity generation. Solar resource potential is drawn from McKinsey & Company and SolarGIS. Where either solar resource exceeds 1400 kWh/kW$_P$ or wind resource exceeds – ten times the annual electricity demand of the country, coal-fired power generation in the country is considered at ‘medium risk’ of displacement by renewables. Where both exceed these thresholds, coal-fired power is considered at ‘high risk’.

Despite Japan’s abundance of wind resource, the available capacity normalised by Japan’s total power consumption does not appear threatening to Japan’s conventional generators. Similarly, despite massive build-outs of solar PV generation, Japan’s underlying solar resource is not naturally compelling.

Table 28: Renewables resources

	Japan	Australia	China	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
Wind resource [TWh/TWh] [91,92]	**3.8**	405.0	7.8	6.5	4.4	3.3	22.0	31.7	29.8	20.5
Solar resource [kWh/kW$_P$][93,94]	**1,175**	1,425	1,300	950	1,400	1,450	~950	1,500	875	1,250
RISK	Green	Red	Green	Green	Yellow	Yellow	Yellow	Red	Yellow	Yellow

NRH-3: Renewables Policy Support

This hypothesis examines the Japanese government’s policy support for renewable power generation. The hypothesis is that countries with robust regimes for supporting renewables will see greater renewables deployment. This would result in coal-fired power stations being more likely to face lower wholesale electricity prices and other forms of power sector disruption.

[90] Ibid.
[91] Xi Lu, Michael B McElroy, and Juha Kiviluoma, 'Global Potential for Wind-Generated Electricity', *Proceedings of the National Academy of Sciences* 106, no. 27 (2009): 10933–38.
[92] BP, “Statistical Review of World Energy 2015”, 2015.
[93] SolarGIS, “SolarGIS: Free Solar Radiation Maps Download Page,” 2016, http://solargis.info/doc/free-solar-radiation-maps-GHI.
[94] David Frankel, Kenneth Ostrowski, and Dickon Pinner, “The Disruptive Potential of Solar Power,” *McKinsey Quarterly* 4 (2014).

Climate and Energy Policy in Japan

Prior to the Fukushima disaster, nuclear power was the Japanese government's preferred technology for the provision of low-carbon energy. In the Ministry of Economy, Trade, and Industry's (METI's) 2008 Cool Earth-Innovative Technology Plan, the Japan Atomic Energy Agency (JAEA) anticipated a 54% reduction in CO2 emissions (from 2000 levels) by 2050, increasing to a 90% reduction by 2100. 60% of primary energy needs would be supplied by nuclear energy in 2100 (compared with 10% in 2008), 10% from renewables (from 5%) and 30% fossil fuels (from 85%). The adoption of nuclear power would contribute a 51% reduction in emissions: 38% from power generation and 13% from hydrogen production and process heat.

In post-Fukushima Japan, coal-fired power has displaced shut-down nuclear plants at the expense of carbon emissions. Japan's CO_2 emissions were about 1.31 billion tons in 2013, and about 270 million tons were derived from coal-fired power generation.[95] Although Japan's coal-fired power generation has the world's highest level of efficiency, it still emits about twice the amount of CO_2 as compared to gas-fired power generation. During the UN climate talks in Warsaw in 2013, Japan faced international criticism for abandoning its 2020 emission reduction target plans by slashing it from 25% to 3.8% on 1990 figures.[96] In 2012, the Japanese government announced that its new energy policy, where nuclear made up 15% of Japanese electricity generation and eventually planned to be phased out, would lead to 9% decrease in its emissions.[97] In fact, abandoning climate targets came at a time when the Japanese government did not want any carbon constraint on its coal-driven economic recovery. .[98]

In the lead up to the Paris talks, Japan committed to reducing greenhouse gas emissions by 26% below 2013 figures by 2030 in its Intended National Determined Contributions (INDC).[99] As put by Climate Action Tracker, Japan's INDC is inadequate for a low carbon transition given the potential of coal to grow up by 2030.[100] Despite a 2015 agreement between G7 members for decarbonisation of the global economy, Japan is the only G7 member projecting to increase its coal generating capacity. Japan's INDC includes the addition of 54 coal-fired generating stations.[101]

The Japanese Government proposes to get accounting credits from land use, land use change and forestry to reduce its target to 23.3% below 2030 levels of greenhouse gases from fossil fuel industry.[102] Japan also has two regional cap-and-trade systems in Tokyo and Saitama[103] and a carbon tax on liquid fuels, LPG, gas, and coal.[104] Finally the government intends to use the Joint Crediting Mechanism (JCM), which includes obtaining overseas credits from bilateral offsetting programmes by installing efficient coal power stations in developing countries, and therefore generates a concern over countering decarbonisation of the energy systems.[105]

Renewables Support Policy

The main renewables support scheme in Japan is the feed-in-tariff (FIT), first introduced in 2012. The FIT scheme provided ¥42/kWh ($0.34/kWh) for 20 years when first introduced. Table 29 illustrates the range of tariffs available for renewables. The government introduced the feed-in tariff system to promote development of renewable energy power generation. Under the system, power utilities are required to purchase electricity from renewable energy sources for a certain amount of time at a fixed price. The price

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95 Coaltrans Japan , "Japan's Coal Policy", 2015.
96 John Vidal and Terry Macalister, "Japan under Fire for Scaling Back Plans to Cut Greenhouse Gases," *The Guardian*, 2013, http://www.theguardian.com/global-development/2013/nov/15/japan-scaling-back-cut-greenhouse-gases.
97 Carbon Brief, "Japan's Nuclear Rollback Doesn't Fully Explain Why It's Relaxing Climate Targets," *Carbon Brief*, 2013, http://www.carbonbrief.org/japans-nuclear-rollback-doesnt-fully-explain-why-its-relaxing-climate-targets.
98 Ibid.
99 Government of Japan, "Submission of Japan's Intended Nationally Determined Contribution", 2015.
100 Climate Action Tracker, "Japan - Climate Action Tracker," *Climate Action Tracker*, 2015, http://climateactiontracker.org/countries/japan.html.
101 Carbon Brief, "Japan's Nuclear Rollback Doesn't Fully Explain Why It's Relaxing Climate Targets."
102 Climate Action Tracker, "Japan - Climate Action Tracker."
103 Worldbank Group, "Tokyo's Emissions Trading System", *Directions in Urban Development,* 2013.
104 IEA, "World Energy Outlook 2015", 2015.
105 Ibid.

has been set high to encourage more businesses and households to install renewable energy power generation systems. For businesses, the tariff will remain in effect for 20 years. For households, the duration is only ten years.[106]

Table 29: The range of Japan's feed-in-tariffs[107]

			Purchase price (JPY/kWh) (tax excluded)					Purchase period
			FY2012	FY2013	FY2014	FY2015 (1)[a]	FY2015 (2)[a]	
Solar		Less than 10 kW	42	38	37	33[b]		10 years
		10 kW or more	40	36	32	29	27	20 years
	Double generation system[c] (Less than 10 kW)		34	31	30	27[d]		10 years
Wind	Onshore	Less than 20 kW	55	55	55	55		20 years
		20 kW or more	22	22	22	22		
	Offshore				36	36		
Geothermal		Less than 15,000 kW	40	40	40	40		15 years
		15,000 kW or more	26	26	26	26		
Hydro	Fully new facilities	Less than 200 kW	34	34	34	34		20 years
		200-1,000 kW	29	29	29	29		
		1,000-30,000 kW	24	24	24	24		
	Utilize existing headraces	Less than 200 kW			25	25		
		200-1,000 kW			21	21		
		1,000-30,000 kW			14	14		
Biogas			39	39	39	39		20 years
Biomass	Wood (forest thinning)	Less than 2,000 kW	32	32	32	40		
		2,000 kW or more				32		
	Wood (others), Crop residue		24	24	24	24		
	Wood (recycled waste materials of buildings)		13	13	13	13		
	Waste materials		17	17	17	17		

[a] FY2015 (1): from April 1 to June 30, (2): from July 1
[b] When generators are required to install output control equipment, 35 JPY/kWh
[c] Photovoltaic generation + storage battery or fuel cell
[d] When generators are required to install output control equipment, 29 JPY/kWh

Source: METI

In the past two-and-a-half years the FIT, combined with high retail prices, caused applications for renewables to skyrocket and led to a rapid expansion of solar PV capacity. Installation applications have exceeded 1.2 million, where solar has been the main beneficiary of the FIT reboot.

Overwhelmed by applications from solar power operators for grid connection and concerned about integrating the pipeline of approved projects into the grid, five of the EPCOs stopped accepting applications in 2014. Kyushu Electric Power, which supplies electricity to nine million households in Japan's sunny south, was the first to do so in September of 2014 after 72,000 solar-power producers rushed to beat the deadline for a cut in the guaranteed tariff to ¥32 a kWh. It is accepting no new applications to the grid until it has settled concerns about the reliability of supply from the new producers.[108] Dubbed the 'Kyushu electric shock', other power companies across Japan followed its lead.[109] The process was only restarted after METI agreed a rule change which allows EPCOs to curtail variable renewables at times of peak supply or low demand.[110]

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[106] Nikkei, "Japan's Solar Power Feed-in Tariff to Fall 20% or More in 3 Years," *Nikkei*, 2016, http://asia.nikkei.com/Politics-Economy/Policy-Politics/Japan-s-solar-power-feed-in-tariff-to-fall-20-or-more-in-3-years.
[107] IEA, "Feed-in Tariff for Electricity Generated from Renewable Energy," *International Energy Agency*, 2016, http://www.iea.org/policiesandmeasures/pams/japan/name-30660-en.php.
[108] David McNeill, "Japan's Feed-in Tariff Program Becomes a Solar Shambles," *Japan Today*, 2015, http://www.japantoday.com/category/opinions/view/japans-feed-in-tariff-program-becomes-a-solar-shambles.
[109] James Simms, "Outlook Cloudy for Japan's Renewable Energy Drive," *The Financial Times*, 2015, http://www.ft.com/cms/s/0/dae47c8c-d927-11e4-b907-00144feab7de.html#axzz459PztpkK.
[110] Rachel Parkes, "Japan: Land of the Rising Sun?," *Renewable Energy Focus*, 2015, http://www.renewableenergyfocus.com/view/43409/japan-land-of-the-rising-sun/.

Japan's utilities, backed by influential business and industry groups, have campaigned aggressively against the use of renewables. Combined with public opposition to the recommissioning of nuclear plants, the failure to deploy either nuclear or renewable power capacity could result in a large share of fossil fuel power, more even than current government forecasts. Japan's electricity companies have proposed voluntary reductions in carbon intensity in the period to 2030, but these have been criticised as insufficient by the Ministry of the Environment.[111]

The generous FITs which led to the solar boom are now under revision. The Ministry of Economy, Trade and Industry aims to reduce the FITs for both systems by ¥2-3 per year until fiscal 2019. This will lower the rate for the larger systems to around ¥17-18 per KWh by that year, bringing it in line with typical utility rates for factories and other volume users. The rate for the smaller setups will fall to around ¥24 per KWh, which is almost identical to the current power rate for the typical household. The ministry aims to keep the rates at high levels for geothermal, biomass and small-scale hydroelectric power, since they are still poorly utilised. But rates for wind power may also be lowered because the current rates are roughly double those in Germany and France.[112]

In order for this hypothesis to produce comparable, testable results, a consistent measure must be used to evaluate renewables policy support. EY's Renewable Energy Attractiveness Indicator (RECAI) provides a country-specific measure of renewables support. This measure is also useful in that it allows peer comparison of what constitutes 'strong' policy support. Where EY's aggregate ranking is above 60, the countries are considered 'high risk'. Where over 50 they are considered 'medium risk'. Despite the decrease in FIT rates and the obstruction of the utility companies, the Japanese government remains a strong supporter of renewables relative to peer countries and EY's recent RECAI update[113] call Japan a 'mature and steady' market for renewables, the third-largest in the world.

Table 30: Renewables policy support[114]

	Japan	Australia	China	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
EY: RECAI	64.5	56.0	75.6	66.3	41.8	62.2	45.8	53.2	58.5	73.3
RISK	Red	Yellow	Red	Red	Green	Red	Green	Yellow	Yellow	Red

NRH-4: Growth of Decentralised Renewables and the Utility Death Spiral

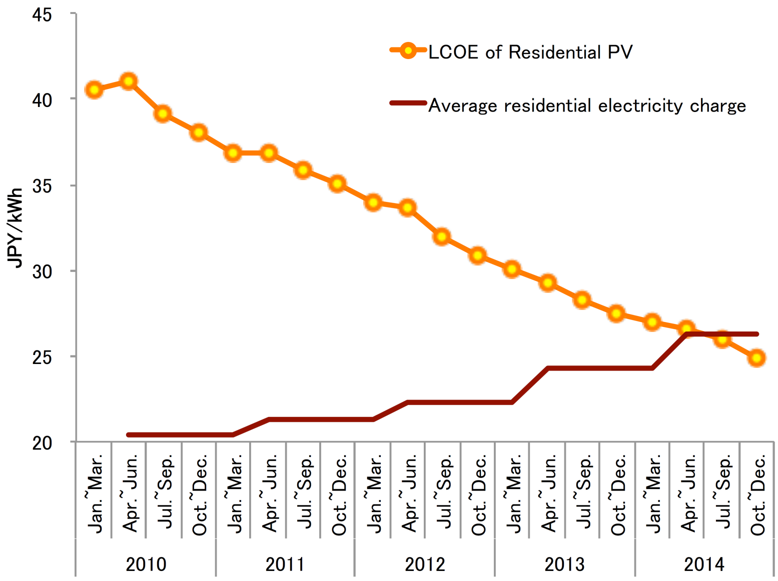
NRH-4 and NRH-5 examine the growth of renewables in Japan's power supply. The hypotheses are that the growth of decentralised renewables might affect coal-fired power differently from centralised renewables by leading to a 'utility death spiral' and the rapid, unforeseen erosion of a coal-fired utility's business model. In Japan, decentralised renewables are almost exclusively small-scale solar PV installations. Until recently, grid-scale generation has not included solar PV installations. NRH-4 and NRH-5 reflect this technological separation; however the growing role of solar PV is identified in NRH-5.

The 'utility death spiral' is the disruption to conventional power utility companies as a result of a virtuous cycle of distributed energy resources (e.g. rooftop solar PV) eroding the distribution network business model of the central utility, which in turn raises retail electricity prices making distributed energy

111 EDF, "The World's Carbon Markets: Japan", 2013.
112 Nikkei, "Japan's Solar Power Feed-in Tariff to Fall 20% or More in 3 Years."
113 EY, "RECAI: Renewable Energy Country Attractiveness Index," 2016, http://www.ey.com/Publication/vwLUAssets/EY-RECAI-46-Feb-2016/$FILE/EY-RECAI-46-Feb-2016.pdf.
114 EY, "RECAI: Renewable Energy Country Attractiveness Index," 2015, http://www.ey.com/Publication/vwLUAssets/Renewable_Energy_Country_Attractiveness_Index_43/$FILE/RECAI 43_March 2015.pdf.

resources even more competitive.[115] Figure 26 shows the levelised cost of electricity (LCOE) for residential PV and the average residential electricity tariff. The intersection of these two prices – where self-generated PV electricity becomes as cheap as grid power, i.e. grid parity – is one of the tipping points of the utility death spiral. Figure 26 suggests Japan reached this point in 2014.

Figure 26: The levelised cost of electricity for residential PV and retail electricity prices



Source: Renewable Energy Institute (Apr 2016) Recent renewable energy situation in Japan

Solar PV

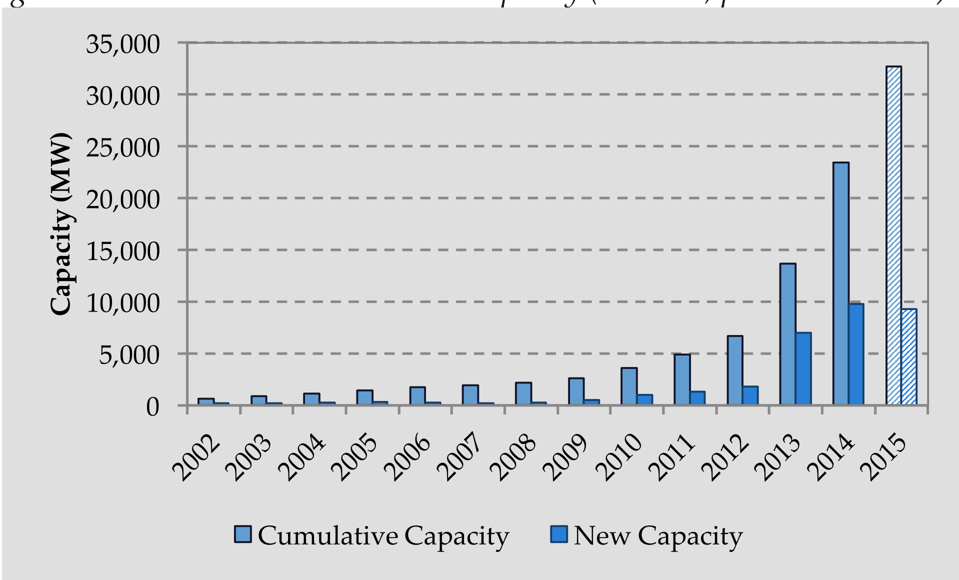
Solar power has been one of Japan's most successful renewables. There has been rapid growth in cumulative and new installations of solar PV capacity in Japan (see

Figure 27). In 2002, solar installation totalled 19 MW, total installation passed 2GW by 2008, and had grown to over 23.4GW in 2014. Provisional 2015 data[116] suggests an additional 9.76 GW of solar capacity has been installed, increasing cumulative capacity to 32.7 GW.[117] 96.6% of this capacity is distributed, see

[115] Matthew Gray, "Coal: Caught in the EU Utility Death Spiral," *Carbon Tracker. Http://www. Carbontracker. Org/wp-content/uploads/2015/06/CTI-EU-Utilities-Report-v6-080615. Pdf*, 2015; Elisabeth Graffy and Steven Kihm, "Does Disruptive Competition Mean a Death Spiral for Electric Utilities," *Energy LJ* 35 (2014): 1; Kenneth W Costello and Ross C Hemphill, "Electric Utilities' 'Death Spiral': Hyperbole or Reality?," *The Electricity Journal* 27, no. 10 (December 2014): 7–26, doi:http://dx.doi.org/10.1016/j.tej.2014.09.011.
[116] Japan Renewable Energy Foundation Database derived from METI data.
[117] Ibid.

Figure 27. Japan's solar growth finally slowed in Q2 2015, however it will remain one of the largest PV markets in the world[118] and Japan still has more ambitious solar targets for the future. By 2030, the country wants to more than double its solar capacity to 53.3 GW and generate 22% to 24% of its power from renewable energy sources.[119] Solar power is to contribute 7% under this goal.

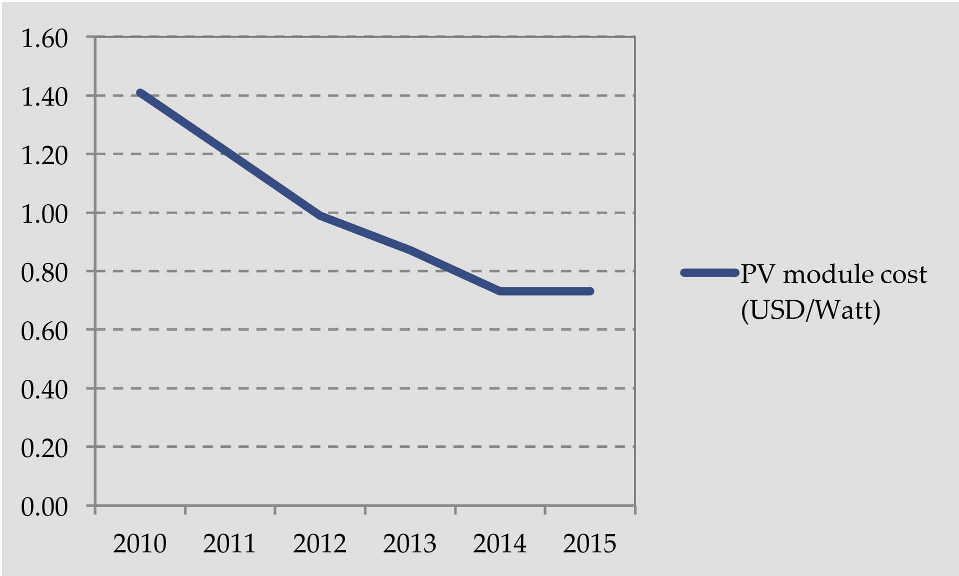
Figure 27: Cumulative and new solar capacity (2002-14, provisional 2015)[120]



The rapid expansion of solar PV capacity is due to the post-Fukushima feed-in tariffs and the rapidly falling costs of PV panels. The combination of European demand and Chinese investment has slashed the cost of solar panels by about two-thirds since 2006. Much of the price decline also occurred post-Fukushima, where the cost of solar PV modules has fallen by approximately 50% (see Figure 28).

Figure 28: The cost of solar PV

[118] Chisaki Watanabe, "Solar Shipments in Japan Drop First Time Since 2012 Incentives," *Bloomberg Technology*, 2015, http://www.bloomberg.com/news/articles/2015-08-31/solar-shipments-in-japan-drop-first-time-since-2012-incentives.
[119] Parkes, "Japan: Land of the Rising Sun?"
[120] IEA (2015). Survey report of selected IEA countries between 1992 and 2014: Photovoltaic power systems programme.



Source: IRENA (2012) Renewable energy technologies: cost analysis series, vol 4/5.

Table 31: Breakdown of solar PV installation in Japan (MW)

	Stand-alone (Domestic)	Stand-alone (Non-domestic)	Grid-connected (distributed)	Grid-connected (centralized)	Total
2002	0.96	71.69	561.30	2.90	636.84
	(0.15%)	(11.26%)	(88.14%)	(0.46%)	
2003	1.10	77.79	777.83	2.90	859.62
	(0.13%)	(9.05%)	(90.49%)	(0.34%)	
2004	1.14	83.11	1,044.85	2.90	1,131.99
	(0.10%)	(7.34%)	(92.30%)	(0.26%)	
2005	1.15	85.91	1,331.95	2.90	1,421.91
	(0.08%)	(6.04%)	(93.67%)	(0.20%)	
2006	1.21	87.38	1,617.01	29.00	1,734.60
	(0.07%)	(5.04%)	(93.22%)	(1.67%)	
2007	1.88	88.27	1,823.24	5.50	1,918.89
	(0.10%)	(4.60%)	(95.02%)	(0.29%)	
2008	1.92	88.89	2,044.08	9.30	2,144.19
	(0.09%)	(4.15%)	(95.33%)	(0.43%)	
2009	2.64	92.00	2,521.79	10.74	2,627.17
	(0.10%)	(3.50%)	(95.99%)	(0.41%)	
2010	3.37	95.42	3,496.02	23.33	3,618.14
	(0.09%)	(2.64%)	(96.62%)	(0.64%)	
2011	5.55	97.73	4,741.46	69.21	4,913.95
	(0.11%)	(1.99%)	(96.49%)	(1.41%)	
2012	8.82	100.53	6,522.32*		6,631.67
	(0.13%)	(1.52%)	(98.35%)		
2013	8.82	114.62	13,475.73*		13,599.17
	(0.06%)	(0.84%)	(99.09%)		
2014	8.82	116.00	23,214.26*		23,339.08
	(0.04%)	(0.50%)	(99.47%)		

Notes: * denotes that there is no longer a distinction between *distributed* and *centralised* generation.
Source: IEA PVPS (2014)

By 2020, renewable energy would account for 20% of Japan's power mix, up from 10% in 2010, almost fully accounting for the 27% contribution nuclear made pre-Fukushima. Moreover, the country's feed-in tariff regime, at that time limited to solar PV, would have to be overhauled, boosted and expanded to include all technologies.

Hypothesis

This hypothesis assesses whether the growth of decentralised power exposes Japan's utility companies to conditions of the utility death spiral. The rapid penetration of small-scale solar PV into Japan's electricity market indicates that Japan's utilities are significantly exposed to the growth of distributed renewables and the utility death spiral. Japan is compared to the other countries in the comparison group from *Stranded Assets and Thermal Coal: An analysis of environment-related risks* in Table 32.

Table 32: Countries showing evidence of the utility death spiral

Country	Reference	RISK
Japan	**Strong evidence of the utility death spiral**[121]	Red
Australia	Strong evidence of the utility death spiral[122]	Red
China	No evidence of the utility death spiral	Green
Germany	Strong evidence of the utility death spiral[123]	Red
Indonesia	No evidence of the utility death spiral	Green
India	No evidence of the utility death spiral	Green
Poland	No evidence of the utility death spiral	Green
South Africa	No evidence of the utility death spiral	Green
United Kingdom	Low evidence of the utility death spiral[124]	Yellow
United States	Strong evidence of the utility death spiral[125]	Red

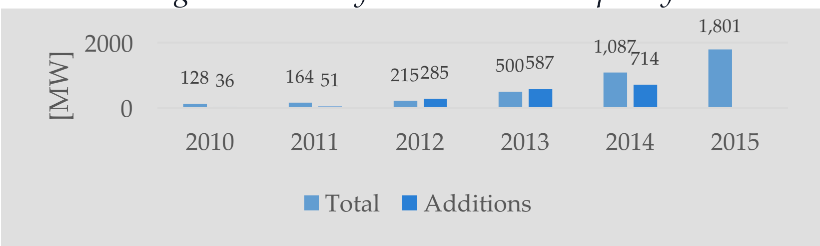
NRH-5: Growth of Utility-Scale Renewables

The hypothesis is that rapid renewables deployment would result in coal-fired power stations being more likely to face lower wholesale electricity prices and other forms of power sector disruption. Since 2008, half the world's added electric generating capacity has been renewable.[126] The Japanese Government wants to increase renewables from 10 per cent of its energy mix to 24 per cent by 2030, reducing its reliance on gas, coal and nuclear. The following sections outline the current and future state of grid-scale renewables in Japan, separated by technology. Distributed renewables, exclusively small-scale solar PV, were considered in NHR-4.

Solar PV

Recent years have seen the growth of utility-scale solar PV installations as well as the massive residential and distributed installations discussed in NRH-4. Utility-scale solar generating capacity taken from the dataset of the Oxford Smith School is shown in
Figure 29. METI will begin auctioning utility-scale solar PV contracts in 2017, which reflects a shift from distributed solar PV systems to distributed PV-storage systems and centralised utility-scale solar PV generation.[127]

Figure 29 Utility-scale solar PV capacity

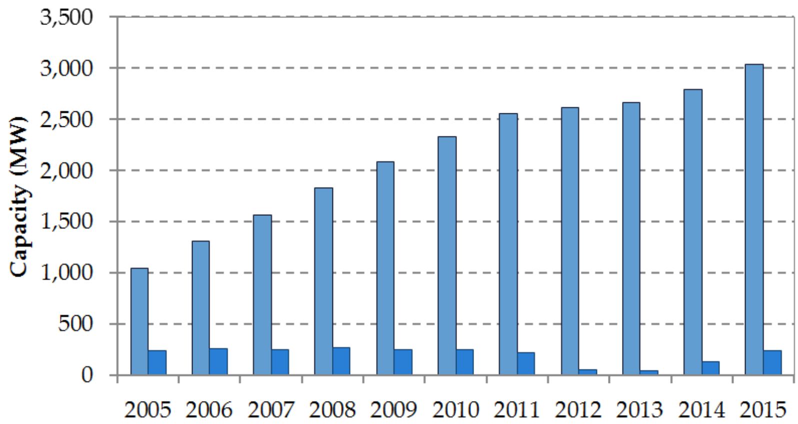


[121] Rising rates and falling costs leading to grid parity for solar PV, see Keiji Kimura, "Grid Parity – Solar PV Has Caught Up with Japan's Grid Electricity," *Renewable Energy Institute*, 2015, http://www.renewable-ei.org/en/column/column_20150730_02.php.
[122] AER, "State of the Energy Market 2014", 2014.
[123] Stephen Lacey, "This Is What the Utility Death Spiral Looks Like," *Greentech Media, March* 4 (2014).
[124] Costello, M. & Jamison, S. "Is the utility death spiral inevitable for energy companies?", *UtilityWeek*, 2014.
[125] Moody's Investors Service, "Moody's: Warnings of a Utility 'Death Spiral' from Distributed Generation Premature," *Moody's*, 2014, https://www.moodys.com/research/Moodys-Warnings-of-a-utility-death-spiral-from-distributed-generation--PR_312101.
[126] Amory B. Lovins, "How Opposite Energy Policies Turned The Fukushima Disaster Into A Loss For Japan And A Win For Germany," *Forbes*, 2014, http://www.forbes.com/sites/amorylovins/2014/06/28/how-opposite-energy-policies-turned-the-fukushima-disaster-into-a-loss-for-japan-and-a-win-for-germany.
[127] Jason Deign, "Japan Market Shift Looks Good for Larger Projects," *Solar Plaza*, 2016, http://www.solarplaza.com/channels/markets/11473/japan-market-shift-looks-good-larger-projects/.

Wind

There is increased interest in wind in the energy system. Since 2005, Japan's wind capacity as tripled, from 1.05GW to 3.04GW (see Figure 30). The growth in new capacity was relatively stable until Fukushima, where there was a decline in installed wind power between 2012 and 2014. The decline in wind installation is likely due to the rapid uptake of solar installations instead.

Figure 30: Cumulative and Installed Capacity in Japan (2005-15)[128]



Wind power has considerable potential in Japan. Over a whole power system, wind speeds tend to moderate fairly slowly; it takes hours, or in the very worst case many minutes, for wind power production to drop from high to low levels. To a large extent, wind speeds are predictable by detailed weather forecasts. This reduces the variability of electricity produced by wind farms and allows wind generators to contribute to base-load capacity. Further, the predictable wind speeds allow standing reserve to be used to cover production during periods of low wind generation, which contributes to Japan's overall security of energy supply. The standing generation fleet can be ranked by different response times to cover varying shortfalls; from plants which can ramp-up in a few minutes, such as diesel generators, to longer periods of scarcity, such as open-cycle and combined-cycle gas turbines.

Two major obstacles prevent the rapid uptake of wind energy. The first obstacle is regulatory, where environmental rules and onerous approval processes slows progress. Offshore wind has emerged as a potential avenue for wind generation in Japan. Onshore wind potential in Japan is estimated at 280GW, whereas its offshore wind potential is 1,570GW.[129] Japan's Wind Power Association has set national targets of 37GW of offshore wind by 2050.[130] Near-shore turbines (within 10km) will represent the majority of offshore wind, but Japan faces the physical challenge that its waters are relatively deep close to its shores. In the long term, Japan will need to address how and where to install wind farms in deep-water at low cost. Floating turbines have been suggested as a potential solution. However, floating turbines are very much in their infancy; only 7MWs of turbines are complete, with another 10MW planned.[131] Floating turbines are also relatively expensive to install compared to other wind technology and induce many technological challenges, such as ensuring enough cable flexibility for a mobile platform. Carbon Trust estimates there is a reasonable chance that Japan can achieve its 2050 target of 37GW using 19GW of fixed turbines and 18GW of floating turbines.[132]

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[128] Source: Japan Wind Power Association, "Wind Power Installed Capacity (by Year)," 2015, http://jwpa.jp/pdf/JapanWindPowerInstallation2015.pdf.
[129] Al-Karim Covindji, Rhodri James, and Adriana Cavallo, "Appraisal of the Offshore Wind Industry in Japan" (London, 2014), https://www.carbontrust.com/media/566323/ctc834-detailed-appraisal-of-the-offshore-wind-industry-in-japan.pdf.
[130] Ibid.
[131] Robin Harding, "Renewable Energy Poses Challenge for Tokyo," *The Financial Times*, 2015, http://www.ft.com/cms/s/0/86bbc5a4-290c-11e5-8613-e7aedbb7bdb7.html?siteedition=uk#axzz47DpFjeKy.
[132] Covindji, James, and Cavallo, "Appraisal of the Offshore Wind Industry in Japan."

The second is outright rejection by utility monopolists. As stated, the Japanese energy system contains regional monopolies, where vertically integrated utilities own both generating assets and transmission lines. Typically only about 1% of electricity is traded, thus the system has little competition. These vertically integrated utilities can bar competitors from their regional grids.

Given the historical installations, wind power is expected to remain relatively constant in the near future and, at present, there are few indications that there will be changes in support to encourage more installations, which will also depend on technological advances in deep-water wind generation.

Hydroelectric

Japan has an ample supply of water resources, but hydropower generation has remained between 19-21GW since 1990.[133] The major obstacles to the increased use of hydropower are both physical and regulatory. For the physical challenges, most of the country's 2,700 irrigation and flood control dams lack hydro-turbines and do not generate any electricity. Regulatory challenges for Japan include obtaining rights to use water - for power, irrigation or flood control - are fixed and difficult to change.[134]

At present, about 9% of Japan's generation is hydroelectric and there are no clear indications that capacity or generation will change in the near future. Simply adding generators to the existing dams could cover an additional 4% of Japan's electricity needs with clean, reliable, low-cost power. However, new hydro proposals always lead to disputes regarding who profits from the dam.

Geothermal

Geothermal power is a renewable, almost carbon-free, and sustainable source of energy. The volatile tectonics of Japan mean geothermal power is a viable option, with geothermal potential estimated to be 20GW.[135]

Geothermal capacity in Japan stagnated almost unchanged in recent years. In 2000 and 2015, installed capacities were respectively 546MW[136] to 519MW[137]. Overall, geothermal produces a tiny fraction of Japan's electricity and analysts are not optimistic that it will ever provide much more as much of the potential geothermal power is located in national parks. What is more any hint of using them produces a fierce backlash from hot spring resorts who think power stations will steal their hot water.

After a 20-year lull and in the wake of the Fukushima incident, government has restarted an incentive scheme for development and mitigation of constraints in national parks.[138] The purpose is to encourage and incentivise geothermal resource exploration and to build small binary systems. Approximately 40 new geothermal plants are under construction. Idemitsu Kosan is adding 5MW of geothermal capacity at an existing plant in Kyushu, while a consortium headed by J-Power is building a new 42MW geothermal facility in the northern province of Akita. [139] The success of the resource exploration and realised geothermal capacity will determine the extent to which geothermal can outbid conventional generators.

Risk Hypothesis

We use the growth in installed renewables capacity (GW) and the growth in the proportion of renewable power generation to estimate risk exposure to year-on-year renewables growth. Where the CAGR in renewable power generation as a portion of total generation exceeds 10%, and where CAGR in renewable power capacity exceeds 10%, the country is considered 'high risk'. Where only one exceeds 10%, the country is 'medium risk'. Table 33 and Table 34 shows the risk assessment for Japan's utilities and the risk

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[133] J-Power, "Hydro and Geothermal Development in Japan," *IEA*, 2013, https://www.iea.org/media/workshops/2013/scalingupfinancingtoexpandrenewables/7JPOWER.pdf.
[134] Harding, "Renewable Energy Poses Challenge for Tokyo."
[135] Ruggero Bertani, "Geothermal Power Generation in the World 2010–2014 Update Report," *Geothermics* 60 (2016): 31–43.
[136] Ruggero Bertani, "World Geothermal Generation in 2007," *GHC Bulletin* 7 (2007): 19.
[137] Bertani, "Geothermal Power Generation in the World 2010–2014 Update Report."
[138] Ibid.
[139] Harding, "Renewable Energy Poses Challenge for Tokyo."

assessments of comparator countries from *Stranded Assets and Thermal Coal: An analysis of environment-related risks.*

This hypothesis does not include the growth in distributed renewables, and Japan has long had substantial hydropower capacity, so Japan shows little growth in renewables capacity in this hypothesis. Because this methodology is different from *Stranded Assets and Thermal Coal*, the comparator countries are shown separately.

Table 33: Year-on-Year growth of utility-scale renewables capacity and generation

2010 - 2015 CAGR	Japan
Utility-Scale Renewables Capacity	**2%**
Utility-Scale Renewables Generation	**1.3%**
RISK	🟢

Table 34: Year-on-Year growth of all renewables capacity and generation

2010 - 2014 CAGR	Australia	China	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
All Renewables Capacity	11%	13%	14%	2%	7%	15%	14%	23%	8%
All Renewables Generation	8%	6%	12%	-8%	1%	16%	25%	30%	7%
RISK	🟡	🟡	🔴	🟢	🟢	🔴	🔴	🔴	🟢

NRH-6: Growth of Gas-Fired Generation

The hypothesis is that the growth of gas-fired generation, particularly in markets where electricity demand growth is lower or negative, could harm the economics of coal-fired generation and result in coal-to-gas switching.

While the growth of renewables and the restart of nuclear power stations are expected to displace fossil fuel-fired power, gas-fired generating stations are unlikely to be the first affected. Oil-fired and coal-fired power will be the first to be displaced by renewables and gas, see NRH-1. The IEA WEO is chosen as a central, conservative, and comparable scenario for use in this hypothesis. If either historic or projected CAGR of gas-fired power generation is positive, then the outlook for coal-fired power in that country is considered 'medium risk'. If both are positive, then the outlook is considered 'high risk' Table 35 shows the outlook for Japan and comparator countries.

Table 35: Natural gas-fired power generation outlook[140]

CAGR	Japan	Australia	China	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
2010-13 Historic	10%	11%	10%	-13%	2%	-18%	-13%	N/A	-13%	4%
2013-20 NPS	-4%	0%	17%	0%	2%	6%	0%		0%	2%
RISK	🟡	🟡	🔴	🟢	🔴	🟡	🟢	🟢	🟢	🔴

NRH-7: Falling Utilisation Rates

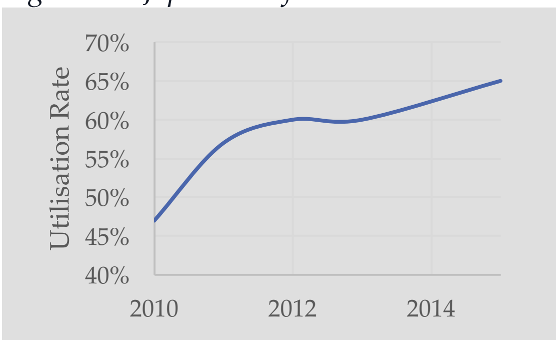
The hypothesis is that under-utilised coal-fired power stations will be financially vulnerable and more prone to stranding. The entrance of new generating options may reduce the utilisation rates of coal-fired generating assets. The utilisation rate of a power generating asset is the ratio of its actual annual output to

140 Harding, "Renewable Energy Poses Challenge for Tokyo."

its maximum potential annual output according to its nameplate capacity. Competition on marginal costs, or must-run regulation for renewables, can displace coal-fired generation, reducing utilisation rates. Generating stations with falling utilisation rates are less able to cover fixed costs with operating profit.

Utilisation rates have been identified for Japan in Figure 31. Post-Fukushima, a power supply crisis caused utilisation rates to jump above 60%. However the Institute for Energy Economics and Financial Analysis (IEEFA) finds[141] that although historic utilisation rates have been high since the crisis, falling electricity demand and a rapid build-out of coal-fired capacity will soon lead to an oversupply of coal-fired power.

Figure 31: Japan coal-fired utilisation rates



Following the methodology of *Stranded Assets and Thermal Coal: An analysis of environment-related risks,* where historic utilisation rates have been decreasing, we find this to be 'at risk'. We combine this with research on future utilisation rates. If they are expected to decrease, this is also 'at risk'. If both are 'at risk' then we assign a 'high risk' opinion. If only one is, then we assign a 'medium risk' opinion.

Japan's historic utilisation rate has been increasing, indicating low risk exposure. Based on the analysis by the IEEFA however, we find the future utilisation rate of Japan's coal-fired power stations to be 'at risk' – that is, that utilisation rates are likely to fall in the future. Combined, these two perspectives give a 'medium risk' evaluation. Table 36 shows the risk hypotheses of Japan and the comparator countries from *Stranded Assets and Thermal Coal.*

Table 36: Utilisation rate risk hypothesis

	Japan	Australia	China	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
Utilisation rate - Historic	Green	Green	Yellow	Green	Yellow	Yellow	Green	Yellow	Green	Green
Utilisation rate - Outlook	Yellow	Yellow	Yellow	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow
RISK	Yellow	Yellow	Red	Green	Yellow	Red	Yellow	Red	Yellow	Yellow

NRH-8: Regulatory Water Stress

The hypothesis is that coal-fired power stations in countries that have strict water use requirements and an awareness of water issues are more likely to be affected by water scarcity through direct or indirect water pricing. Coal-fired power generation has a substantial water footprint, described in hypothesis LRH-4: Water Stress. This water footprint exposes coal-fired power utilities to regulatory risks, as policymakers may take action to restrict or price a utility's access to water. Public opinion on the water footprint of

[141] IEEFA, "IEEFA: Japan Briefing: Japan's Energy Transformation," 2016, http://ieefa.org/wp-content/uploads/2016/03/Japan-Energy-Brief.pdf.

power generation may also put pressure on policymakers to restrict water use, exposing utilities to a reputational risk as well.

The World Resources Institute (WRI) maintains the Aqueduct Water Risk Indicator maps. The WRI's Regulatory & Reputational Risk indicator aggregates indicators from the World Health Organization (WHO) concerning water access, the International Union for Conservation of Nature (IUCN) for threatened amphibians, and Google keyword searches for water supply media coverage.[142] With few exceptions, this indicator is provided at the national level. WRI provides an indicator in five groupings, with low risk in group 1 and very high risk in group 5. In this report, WRI groups 1 and 2 will be considered 'low risk', group 3 will be considered 'medium risk' and groups 4 and 5 'high risk'.

Japan has very low exposure to regulatory water stress despite moderate levels of actual underlying water stress (see LRH-4). The Water Pollution Control Law protects all of Japan's freshwater resources, regulating industrial effluents either by concentration or volume. Japan's well-managed water system keeps water out of the news and thus unforeseen regulation of water is not a major cause for concern for Japan's utilities. Table 37 shows regulatory water stress exposure of Japan and its comparator countries.

Table 37: Regulatory water stress[143]

	Japan	Australia	China	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
Risk grouping	1	1	3	1	4	3	2	3	2	1
RISK	Green	Green	Yellow	Green	Red	Yellow	Green	Yellow	Green	Green

NRH-9: CCS Regulatory Environment

The hypothesis is that CCS could be a way for coal-fired power stations to keep running under stricter carbon constraints, but CCS will not happen without a supportive legal framework.

CCS in Japan faces substantial uncertainty with regards to current and future liabilities for the unique aspects of a CCS project. These uncertainties can present barriers to the development of CCS projects, which in turn present a risk to coal-fired utilities which may not have CCS as an option for future GHG mitigation. Box 1 reproduces our opinion on CCS from *Stranded Assets and Thermal Coal: an analysis of environment-related risks*. See *Stranded Assets and Thermal Coal* for more details and references.

In 2012, METI commissioned a large-scale CCS demonstration project in Tomakomai (south-west Hakkaido) with the aim of verifying the total CCS system and storage capacity. Japan CCS Co., Ltd (JCSS), established by 35 Japanese companies promoting CCS, is responsible for implementation and demonstration of viability of the Tomakomai CCS Project that is expected store 100,000 tonnes of CO2 per year in saline aquifers under offshore seabed.[144] On March 18, 2016, the Tomakomai CCS Project, being the first integrated CCS project in Japan, began operating and expected to be operational until 2020.[145] The planned CO2 injection will take place for the period between 2016-2018, and there will be two more years of environmental monitoring after the injection is completed.[146]

[142] Gassert et al., "Aqueduct Global Maps 2.1: Constructing Decision-Relevant Global Water Risk Indicators."
[143] IEA, "World Energy Outlook."
[144] Tanaka, Y., Abe, M., Sawada, U., Tanase, D., Ito, T., Kasukawa, T. (2014). Tomakomai CCS Demonstration Project in Japan, 2014 Update. *Energy Procedia* 63: 6111—6119.
[145] Global CCS Institute (2016). Tomakomai CCS Project showcases Japanese technology leadership. March 18, Melbourne, Australia.
[146] Global CCS Institute (2016). Tomakomai CCS Demonstration Project. March 17.

Box 1: Opinion on CCS from Stranded Assets and Thermal Coal

Several additional factors may prevent the scale adoption of CCS as a mitigation technology. First, CCS is not currently developing at the pace necessary to meet the 2oC scenarios of the IEA and the IPCC. Second, other mitigation substitutes are becoming cost-competitive much more quickly than CCS. Third, a technology pathway which necessarily includes enhanced oil recovery is subject to additional economic and reputational risks.

By 2040, in the IEA's 450S, CCS is deployed to store 4000 MtCO2 per year (Mtpa). The 15 currently operating projects are anticipated to store 28.4 Mtpa. The 30 additional projects planned to operate before 2025 will bring the total storage to 80 Mtpa, an annual growth rate of 11%. To reach 4000 Mtpa by 2040 will require a 48% growth rate from the 2025 planned fleet, or 22% growth from the operating fleet this year. This growth rate is unrealistic given the current state of deployment and technical progress.

The IEA foresees substantial deployment of CCS under the 450S only if policy supports CCS to become more affordable. As a mitigation technology for power generation, CCS will need to compete with falling prices of wind and solar power, and widespread efforts to improve grid flexibility. McKinsey estimates that by 2030, the abatement cost of solar and high-penetration wind power will be €18.0 and €21.0 per tCO2 respectively, while CCS coal retrofits, new builds, and gas new builds will be €41.3, €42.9, and €66.6 per tCO2 respectively. Bloomberg New Energy Finance (BNEF) estimates that the global average LCOE for onshore wind power is US$83/MWh, $122 for crystalline solar PV, and $174 for offshore wind , while the Global CCS Institute estimates the US levelised cost of electricity (LCOE) for coal with CCS is US$115/MWh to $160, and $82 to $93 for CCS-equipped gas-fired power . For markets and policymakers seeking abatement options in the context of finite public funds, CCS may remain a low priority for support.

The IEA suggests that the technology development pathway for power generation with CCS begins with collocating the power station with EOR projects to enable commercial viability. The IEA admits that the public are already 'sceptical of end-of-pipe solutions apparently promoted by the same industries they hold responsible for the problem' . When co-located with EOR the stored carbon is used to extract additional hydrocarbons. Critics would argue any purported climate change merit of these projects is greenwashing – a reputational risk for the companies involved. Moreover, dependence on EOR also exposes power stations with CCS to oil price commodity risks. If the price of oil falls, then the profitability of EOR falls, and the profitability of the power station is reduced.

In conclusion, CCS is unlikely to be significant in mitigating power sector emissions. Deployment of CCS has already been too slow to match IEA and IPCC scenarios. CCS compares unfavourably with other power sector mitigation options, especially considering that CCS also reduces plant efficiency, exacerbating existing merit-order challenges for conventional generators. CCS should remain an attractive option for industrial and process emitters that have few other mitigation options, and may be significant as a long-term option for delivering negative emissions with BECCS.

In 2014, Japanese Ministry of Environment (MOE) called for an additional Yen 1.25 billion plan to accelerate the CCS implementation in Japan with the aim of reducing GHG emissions by 80% by 2050.[147] The Ministry of Economy, Trade and Industry (METI) started considering new CCS projects by doing geological surveys for large-scale implementation, including storage in seabed in offshore areas.[148] Since FY2014, Japanese government has been supporting new initiatives for transportation of CO2 from power

[147] Global CCS Institute (2014). Japan's FY2014 draft budget and CCS-related actions explained. February 26, Chiyoda.
[148] Global CCS Institute (2014). Op. Cit. February 26.

stations to storage sites, which could accelerate the CCS implementation at low cost in Japan.[149] The Shuttle Ship Initiative, a concept developed by the Global CCS Institute in 2011 and now engaged by Chiyoda Corporation, aims to transport CO2 by shuttle ship for storage in seabed offshore.[150] Overall, prominent Japanese companies supported by the government, have been active participants in these demonstration projects which could help commercialization of CCS technologies in Japan.

The development of a robust hypothesis of risk exposure requires a repeatable, testable measure. Certain countries have been proactive in developing policy and law specifically for CCS. The Global CCS Institute periodically evaluates their progress and publishes an indexed indicator. The institute groups countries into three performance bands, which are used here as an indicator for CCS liability risk. Band A, the most CCS-ready, is considered 'low risk', Band B 'medium risk', and Band C 'high risk'. Japan, in Band B, is acknowledged for its progress in preliminary development of marine permitting models.

Table 38: CCS legal environment indicator[151]

	Japan	Australia	China	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
Band	B	A	C	B	C	C	B	C	A	A
RISK	● (yellow)	● (green)	● (red)	● (yellow)	● (red)	● (red)	● (yellow)	● (red)	● (green)	● (green)

NRH-10: Nuclear Restarts

The hypothesis is that nuclear restarts in Japan would disrupt the economics of new coal-fired power stations: many of which are ostensibly being built to replace lost nuclear capacity, and hurt existing coal plants now accustomed to higher levels of demand. This section examines the possibility of nuclear restarts from a political, social and technical standpoint.

Japan's first commercial nuclear power reactor began operating in 1966, and nuclear energy has been a national strategic priority since 1973. Nuclear power came under intense scrutiny following the Fukushima disaster, and in consequence all of Japan's nuclear plants were shut down by May 2012.[152] Prior to the accident, the country's 54 then existing reactors provided some 30% of its electricity and this share was expected to increase to at least 40% by 2017, and 50% by 2030.

Figure 32 shows the share of nuclear in both power capacity and generation by utility company prior to the earthquake.

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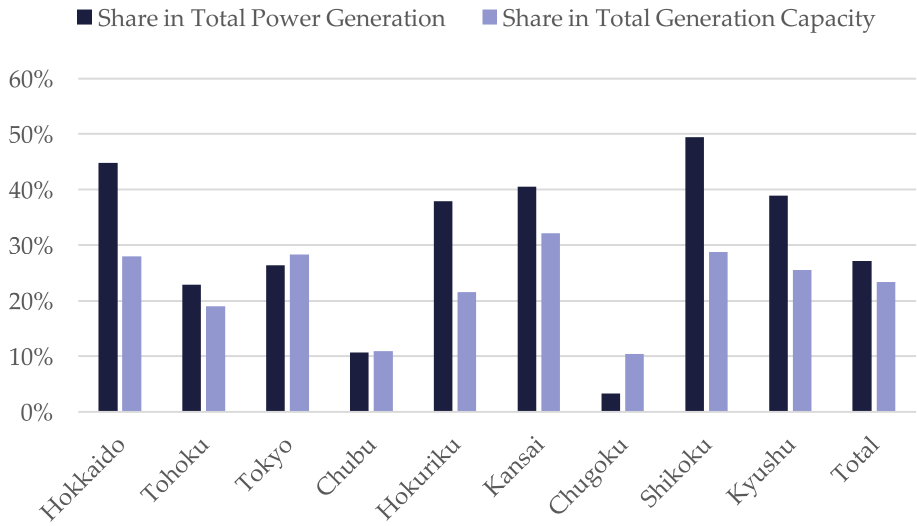
[149] Kawasaki, T., Harada, M. (2015). Op. Cit.
[150] Global CCS Institute (2014). Japan's Energy Market Post Fukushima and its Companies Involved in CCS. July 04.
[151] Global CCS Institute "CCS Legal and Regulatory Indicator", 2015.
[152] David Batty, "Japan Shuts down Last Working Nuclear Reactor," *The Guardian*, 2012, http://www.theguardian.com/world/2012/may/05/japan-shuts-down-last-nuclear-reactor.

Figure 32: Share of nuclear power plant capacity and its generation by region in 2010 [%][153]



Japan now has 43 operable nuclear reactors. Of these, 42 reactors across 17 plant sites with a total generation capacity of 40GW are currently shut down. The Sendai nuclear power plant was restarted in August 2015.[154] Oi nuclear power plant had been initially restarted in July 2012 but was then taken offline for a second time in September 2013 due to political opposition. No power plant has been retired as a result of the Fukushima meltdown[155] however the six reactors at Fukushima Daiichi are being decommissioned and several plants have been retired due to their age.

Political position

From a national security point of view, it is likely that Japan will restart more of its reactors. Enrichment capacity provides cover against any weakening of the US security umbrella, and supports a stronger negotiating position within it.

Japan's dependence on imported energy has been a drag on the 'Abenomics' growth-boosting programme (named after Japan's Prime Minister Shinzō Abe), and higher electricity prices have dented the business confidence of thousands of smaller manufacturers. He has promised restarts after regulators approve their safety and called nuclear power an important source of baseload electricity. His Liberal Democratic party (LDP), which has ruled Japan for most of the postwar period, has heavily pushed nuclear power to promote energy security and, more recently, to curtail greenhouse gas emissions.[156]

Accordingly, the power mix targets in the Fourth Basic Energy Plan, unveiled by the government in April 2015, included a target for nuclear power to produce 20-22% of Japan's electricity by 2020. The renewables

[153] Reproduced from Nobuhiro Hosoe, "Nuclear Power Plant Shutdown and Alternative Power Plant Installation scenarios–A Nine-Region Spatial Equilibrium Analysis of the Electric Power Market in Japan," *Energy Policy* 86 (2015): 416–32.
[154] Simms, "Outlook Cloudy for Japan's Renewable Energy Drive."
[155] Five reactors have since been retired however as a result of reaching the end of their normal operating lives (Genkai Unit 1, Mihama Units 1 and 2, Shimane Unit 1, and Tsuruga Unit 1)
[156] Ibid.

target remains at 20% (with hydro producing 10%, and solar producing 5%), despite the Ministry of Environment's assertion that Japan could achieve as much as 35% renewables penetration in the power mix.[157] The replacement of all nuclear plants with gas turbines would raise the price of power by ¥0.5-1.5 per kWh[158]. Table 39 shows the levelised costs of electricity (LCOE) of Japan's generating options.

Table 39: LCOE of Japan's generating options[159]

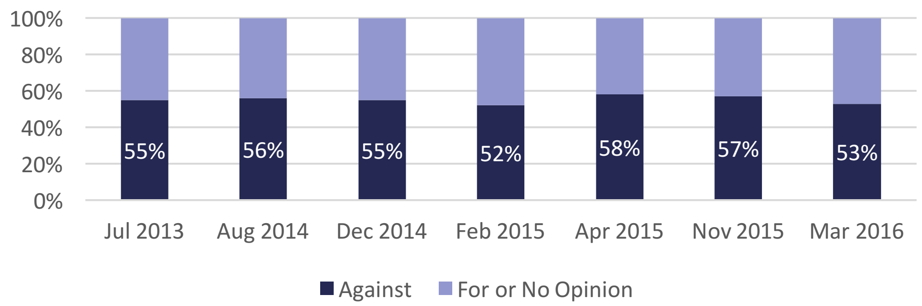
	Nuclear	Coal	Gas	Wind	Geo	Water	Biomass	Oil	Solar	CCGT
[Yen/KWh]	10.1	12.3	13.7	21.6	16.9	11.0	29.7	30.6	24.2	13.8

Public Sentiment

Even before the meltdowns at Fukushima, public acceptance of nuclear power was fragile due to numerous previous accidents and blatant cover-ups by utilities and authorities.[160] However the Fukushima meltdowns caused a public confidence crisis in nuclear technology and triggered a supply crisis as all of Japan's nuclear reactors were shut down.

Surveys from Japan's media outlets (e.g. NHK and *Mainichi*) continue to show that more people are against nuclear restarts than for them. Attitudes have been shifting over time. They are affected by a range of factors, one of which is that electricity bills are significantly higher than they were – and not just because of the nuclear shut-downs. Also significant are the perceived prospects for alternatives to nuclear power.[161] Due to a series of accidents between 1997 and 2007, public resistance has meant only five reactors have been built since 2000. Figure 33 shows public opposition to nuclear restarts since 2013.

Figure 33: Opposition to nuclear restarts in Japan[162,163]



Local opposition to nuclear power can have a substantial impact on the operations of utility companies. In March 2016, Kansai Electric was forced to shut down two of its nuclear reactors at Takahama over fears of insufficient earthquake protection. The court injunction caused Kansai shares to drop 15% the following day.[164] Nomura, an investment broker, has also dropped its buy recommendation. The injunction followed

[157] Parkes, "Japan: Land of the Rising Sun?"
[158] Hosoe, "Nuclear Power Plant Shutdown and Alternative Power Plant Installation scenarios–A Nine-Region Spatial Equilibrium Analysis of the Electric Power Market in Japan."
[159] METI, Cost Working Group. Available at http://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/mitoshi/cost_wg/pdf/cost_wg_01.pdf.
[160] For instance, in 2007 a magnitude 6.8 earthquake caused the Kashiwaszaki-Kariwa plant in Niigata to leak radioactive cooling water into the sea.
[161] Alex Forbes, "Back to a Nuclear Future: The Abe Government Restarts Japan's Energy Policy," *Energy Post*, 2015, http://www.energypost.eu/back-nuclear-future-abe-government-restarts-japans-energy-policy/.
[162] The Mainichi, "Many Feel Less Interest in 2011 Quake Disaster Hit Areas: Survey," *The Mainichi*, 2016, http://mainichi.jp/english/articles/20160308/p2a/00m/0na/006000c.
[163] Forbes, "Back to a Nuclear Future: The Abe Government Restarts Japan's Energy Policy."
[164] The Financial Times, "Kansai Electric Plunges after Reactor Halt," *The Financial Times*, 2016, http://www.ft.com/fastft/2016/03/10/kansai-electric-plunges-after-reactor-halt/.

a previous injunction in April 2015 which delayed the restart of two other reactors in the Fukui prefecture.[165] The plaintiffs in both cases were groups of concerned local residents.

Restart Feasibility

Of the 43 operable reactors, 24 are currently in the process of restart approvals. They are supported by powerful industrial lobbies such as the Kaidanren and the Keizai Doyukai and have the cooperation of the Japanese government.[166] The first two restarted in August and October 2015.[167] Fewer than a third, and at most about two-thirds, of the reactors will pass today's more stringent safety checks and clear the other seismological, economic, logistical and political hurdles needed to restart, a Reuters analysis shows.[168]

The reactor restarts are facing significant implementation costs ranging from US$700 million to US$1 billion per unit, regardless of reactor size or age. In March 2014 the cost was put at $12.3 billion so far. A key bottleneck is the level of expertise and the number of staff that the NRA is able to deploy to conduct the complex and time-consuming engineering studies required for safety reviews and approvals. [169] The Nuclear Regulation Authority (NRA) is working to increase its relicensing staff to about 100 people, which could potentially shorten the currently envisaged six-month review timeline. Under a high case scenario developed by Itochu, about ten reactors could be added every year and a total of up to 35 reactors back online within five years.[170]

The restart of all the nuclear plants is marred by substantial uncertainty. The government has made it clear that it will not force restarts, and has left it to the NRA to set safety rules and dictate the ability of utilities to restart their nuclear fleets. Decision making has ultimately been delegated to the local communities and local politicians may have the final say in whether a plant is restarted. Some of the front-runners have local governments strongly behind nuclear power and the wealth it brings to communities through jobs and government subsidies.

The NRA has fast-tracked two reactors at the Sendai plant in southern Japan after operator Kyushu Electric Power Co broke ranks with its peers and said it would provision for far greater seismic shocks to the plant. Three reactors in southern Japan are considered next in line, among 11 pressurised-water reactors at five plants run by Shikoku Electric, Kansai Electric and Hokkaido Electric being actively vetted by the regulator.

Hokkaido Electric Power Co, facing a third year of financial losses, is seeking a capital infusion from a state-owned lender, which would make it the second utility, after Fukushima operator Tokyo Electric Power Co, to get a government bailout since the March 2011 disaster.

Tepco's Kashiwazaki Kariwa plant on the Japan Sea coast north of Tokyo, the world's biggest nuclear station by output capacity, faces a politically fraught process. Although two of the seven reactors look likely to restart on technical grounds, the head of the local prefecture has accused the operator of 'institutionalized lying' and says Tepco cannot be trusted to operate another facility.

Chubu Electric Power Co's Hamaoka plant on the Pacific coast 190km southwest of Tokyo has been branded by one Japanese seismologist as the country's most dangerous nuclear facility as it is located in an

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[165] Kana Inagaki, "Japan Court Blocks Restart of Two Nuclear Reactors," *The Financial Times*, 2015, http://www.ft.com/cms/s/0/deaf7bde-e28a-11e4-ba33-00144feab7de.html#axzz42adPbRGg.
[166] Butler, "Japan Returns to Nuclear Power."
[167] World Nuclear Association, "Nuclear Power in Japan."
[168] Mari Saito, Aaron Sheldrick, and Kentaro Hamada, "Japan May Only Be Able to Restart One-Third of Its Nuclear Reactors," *Reuters*, 2014, http://www.reuters.com/article/us-japan-nuclear-restarts-insight-idUSBREA3020020140401. The Reuters analysis is based on questionnaires and interviews with more than a dozen experts and input from the 10 nuclear operators. It takes into account such factors as the age of the plants, nearby seismic faults, additional work needed to address safety concerns, evacuation plans and local political opposition.
[169] Forbes, "Back to a Nuclear Future: The Abe Government Restarts Japan's Energy Policy."
[170] Source: World Nuclear Association, "Nuclear Power in Japan."

area where four major tectonic plates meet. Any restart would face significant opposition from local legislators even in Mr Abe's own party, and the prefectural governor supports a referendum on the issue.

Tepco's Fukushima Daini station is well within the Daiichi plant evacuation zone and faces near-universal opposition from a traumatised local population. Also highly unlikely to switch back on is Japan Atomic Power Co's Tsuruga plant west of Tokyo. It sits on an active fault, according to experts commissioned by the NRA. Twelve reactors will reach or exceed the standard life expectancy of 40 years within the next five years, probably sealing their fate in the new, harsher regulatory climate. These include reactor No. 1 at Shikoku Electri''s Ikata power station.

'I think the government is incredibly clever by doing the restarts in the most modern, advanced places that have the most local support and are yet far from centres of political activity,' said Jeff Kingston, director of Asian Studies at Temple University's Japan campus. 'Then you use that to create momentum for the agenda of restarting as many reactors as possible.'

Table 40 shows the status of reactor restarts in Japan.

Table 40: Status of restart applications and safety reviews[171]

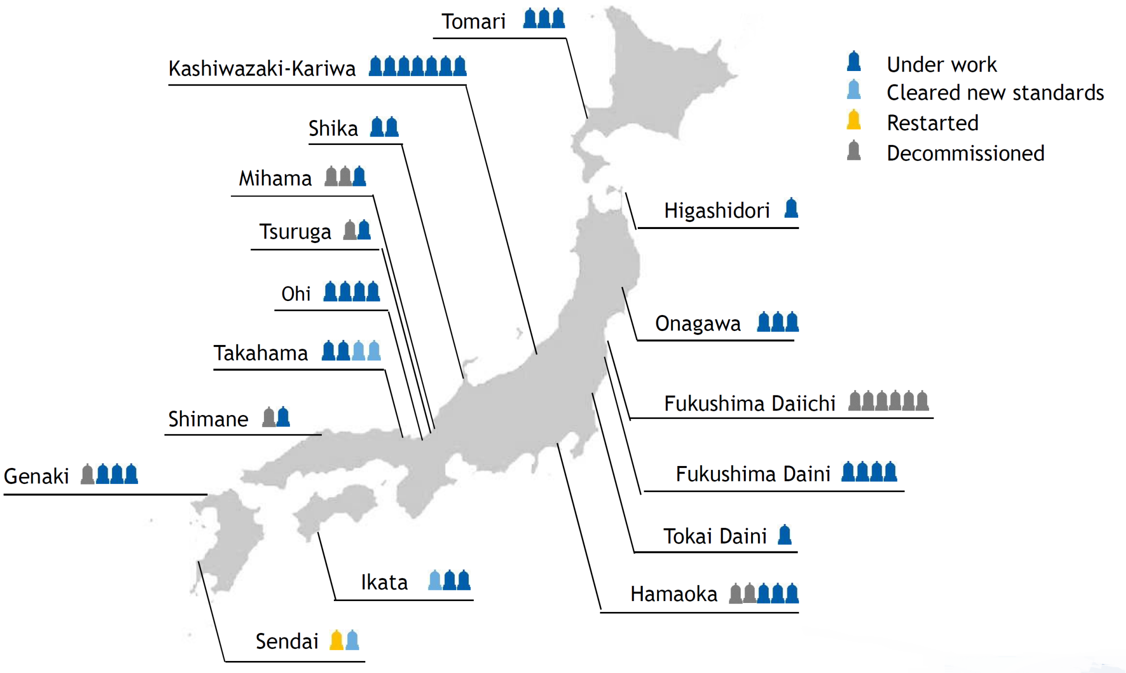
Reactors	Total Capacity [MW]	Age	Utility Company	Applied	Status	Notes
Sendai 1&2	1,780	1984 1985	Kyushu	Jul-13	Operational	Unit 1 connected to grid August 2015, unit 2 October 2015
Takahama 3&4	1,652	1985 1985	Kansai	Oct-14	Shutdown (court)	After NRA final approval and local gov approval, unit 3 grid connection 1/2/16. Unit 4 restarted end Feb. Both then shut down due to court injunction.
Ikata 3	890	1995	Shikoku	Mar-16	Scheduled restart	Upgrade plan approved by NRA, unanimous local gov approval, expect operation in August
Ohi 3&4	2,360	1991 1993	Kansai	Jul-13	Shutdown (court)	Restarted July 2012 and shutdown Sept 2013. Quake & tsunami scenarios complete, but court injunction issued
Genkai 3&4	2,360	1994 1997	Kyushu	Jul-13	Shutdown	Quake & tsunami scenarios complete
Tomari 1-3	2,070	1989 1991 2009	Hokkaido	Jul-13	Shutdown	Quake scenarios pending
Mihama 3	826	1976	Kansai	Mar-15	Shutdown	NRA reviewing (requires licence extension)
Takahama 1&2	1,652	1974 1975	Kansai	Mar-15	Shutdown	NRA doing inspection
Tsuruga 2	1,160	1987	JAPC*	Nov-15	Shutdown	NRA has identified seismic problem
Kashiwazaki Kariwa 6&7	2,706	1996 1997	Tepco	Sep-13	Shutdown	NRA doing inspection
Ohma 1	1,383	2021	JAPC*	Dec-14	Under construction	NRA reviewing
Shimane 2	820	1989	Chugoku	Dec-13	Shutdown	NRA reviewing
Onagawa 2	825	1995	Tohoku	Dec-13	Shutdown	NRA reviewing, start possible after April 2017
Hamaoka 4	1,137	1993	Chubu	Feb-14	Shutdown	NRA reviewing, start possible after Sept 2016
Tokai 2	1,100	1978	JAPC	May-14	Shutdown	NRA reviewing
Higashidori 1	1,100	2005	Tohoku	Jun-14	Shutdown	Question re faults nearby, start possible after April 2017
Shika 2	1,358	2006	Hokuriku	Aug-14	Shutdown	Safety engineering work to March 2017, NRA review under way but concern re seismic fault
Hamaoka 3	1,100	1987	Chubu	Jun-15	Shutdown	Start possible after Sept 2017

*JAPC is jointly owned by TEPCO (28.23%), Kansai (18.54%), Chubu (15.12%), Hokuriku (13.05%), Tohoku (6.12%), and J-Power (5.37%)

The six reactors at Fukushima Daiichi have been slated for permanent decommissioning, the first four in the immediate aftermath of the Tohoku earthquake and the last two in 2014. Decommisioning is expected to take at least 40 years[172] and will remove 2719MW from Tepco's generation capacity. Figure 34 shows the status of all Japan's nuclear reactors.

[171] Ibid.
[172] Robin Harding, "Chief Optimistic Tepco Earnings Can Cover Fukushima Plant Clean-Up," *The Financial Times*, 2016, http://www.ft.com/cms/s/0/af09b686-cd7d-11e5-92a1-c5e23ef99c77.html#axzz42adPbRGg.

Figure 34: Nuclear units shut for new safety standards[173]



There are nuclear plants still under construction – Oma nuclear power plant in Aomori Prefecture (northernmost prefecture on Honshu) is scheduled to startup in 2021. What's more, this plant will use a plutonium-uranium mixture (MOX) as fuel, which is only available from reprocessed spent uranium fuel. In effect it is designed to recycle spent uranium fuel. This plant relies therefore, not only on the ability to start in this region, but also on the fact that nuclear plants will be restarted around Japan as a whole. Work on the facility began in 2008, was halted following the Tohoku earthquake, and resumed in October 2012.

Although they do not take a definitive view, energy consultant Wood Mackenzie's base case future energy scenario for Japan has its nuclear power plants gradually returning to operation over the next several years.[174] New nuclear power stations, most of which have local political support, are expected to continue with construction and commissioning without challenge. In some cases there is local opposition but it is likely that up to ten nuclear plants will be operational again within 18 months.

Assessment of risk exposure

Due to Japan's unique circumstance post-Fukushima, an assessment with comparator countries is impossible. It is almost certain that Japan's nuclear fleet will continue to be returned to service. It is uncertain as to whether those restarts will fall short, meet, or exceed the government's targets, although given the challenges articulated above and analysis by BNEF,[175] a shortfall seems more likely. The impact on coal-fired generating stations, however, depends also on the future of gas-fired generation and renewables. Taking all other things to be equal, we find it 'medium risk' that nuclear restarts will disrupt coal-fired generating stations.

173 Source: Argus Media "Coal serves as long-term replacement for nuclear?", 2015.
174 Wood Mackenzie "Global thermal coal price forecast: How far will coal prices rise in 2015-2016?" 2015.
175 BNEF, "Japan's Likely 2030 Energy Mix: More Gas and Solar.", 2015.

Table 41: Risk exposure from nuclear restarts

	Justification	RISK
Japan	• Short to medium-term horizon limits the amount of nuclear able to be restarted • Nuclear restarts put pressure on total share of coal-fired power, although not as much as government projections • Nuclear power has lower marginal cost of electricity, depressing market prices • An overbuild of coal-fired power post-Fukushima will cause further supply competition	(yellow)

2.3 Summary of Companies Owning Operating, Under Construction, and Planned Coal Plants

Table 42 aggregates data on the *operating* capacity of all generation and coal generation only across each of our 55 companies. This table is ordered according to total coal generation capacity.

It is interesting to note that even though Tohoku EPC has less coal capacity than TEPCO, it has greater MWh of generation; perhaps replacing greater lost nuclear capacity. Another point that stands out from the data is that a number of steelmakers and conglomerates have coal generation capacity in excess of some regional monopolies.

Table 42: Summary of financial and environment-related risk exposure

SUMMARY OF RISK EXPOSYRE	COAL-FIRED GENERATION	COAL-FIRED CAPACITY			DEBT/EQUITY	CURRENT RATIO	(EBITDA-CAPEX) / INTEREST	LRH-1: CARBON INTENSITY	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLLUTION	LRH-4: WATER STRESS	LRH-5: CCS RETROFITABILITY	LRH-6: FUTURE HEAT STRESS	LRH-7: REGIONAL NUCLEAR RESTARTS
		OPR	CON	PLN										
	[GWH]	[MW]	[MW]	[MW]				RANK*						
Electric Power Development Co., Ltd.	60,352	8,414	84	4,020	2.48	1.17	0.6	6	24	7	3	1	13	26
Tokyo Electric Power Company	25,360	5,900	540	5,357	3.34	1.21	3.8	24	27	22	9	40	36	15
Tohoku Electric Power Co. Inc.	36,273	4,901	NA	600	3.97	0.73	2.5	37	6	11	16	1	34	26
Chugoku Electric Power Co.,Inc.	23,106	4,208	84	1,445	3.14	0.86	0.4	38	6	8	15	1	13	26
Chubu Electric Power Company,	30,610	4,100	NA	2,030	1.95	0.83	2.4	1	2	37	33	1	2	21
Kyushu Electric Power Company,	17,231	3,646	1,000	667	7.41	1.03	NA	31	15	28	9	1	9	15
Hokuriku Electric Power Company	18,492	2,903	NA	NA	2.54	1.23	NA	1	12	10	23	1	7	1
Hokkaido Electric Power Co. Inc.	15,868	2,500	NA	NA	6.89	0.70	NA	22	18	27	31	31	28	24
Kansai Electric Power Company,	5,507	1,800	NA	3,462	4.07	0.63	NA	39	29	39	37	40	1	21
Kobe Steel Ltd.	8,753	1,475	NA	1,300	0.83	1.22	7.2	23	9	38	18	1	2	21
NIPPON STEEL & SUMITOMO	6,739	1,443	NA	320	0.56	1.38	17.8	17	15	12	29	33	15	13
Sumitomo Corporation	7,994	1,395	NA	NA	1.73	1.59	1.3	15	21	9	29	26	16	14
Shikoku Electric Power Co. Inc.	7,040	1,106	NA	500	2.37	0.91	3.6	21	21	23	13	34	9	40
Tokuyama Corp.	1,730	883	NA	NA	1.67	2.08	1.2	9	38	14	38	40	17	7
The Okinawa Electric Power Company,	4,912	754	NA	NA	1.56	0.72	5.4	1	15	25	26	1	9	40
Nippon Paper Industries Co., Ltd.	2,473	680	100	508	1.49	1.02	3.8	20	13	13	26	27	24	29
Tosoh Corporation	3,474	667	NA	NA	0.85	1.35	17.9	14	24	33	25	1	8	5
Kashima-Kita Electric Power	789	647	NA	NA	NA	NA	NA	13	1	1	40	1	26	7
Mitsubishi Corporation	1,700	406	NA	292	1.06	1.53		16	29	19	19	25	33	19
Oji Holdings Corporation	1,415	283	NA	NA	1.08	0.89	4.6	19	32	21	9	40	36	15
Taiheiyo Cement Corp.	1,689	281	NA	NA	1.21	0.87	10.5	33	39	34	4	40	9	40
NC Miike Co., Ltd	1,659	175	NA	NA	NA	NA	NA	1	9	30	5	1	28	29
Mitsui & Co. Ltd.	721	170	NA	NA	1.09	1.67	2.5	39	40	18	17	1	28	24
Osaka Gas Co., Ltd.	870	149	110	500	0.69	1.89	9.8	11	6	36	13	1	4	4
Tokai Kyodo Hatsuden K.K.	822	149	NA	NA	NA	NA	NA	27	18	5	35	29	23	7
JFE Holdings, Inc.	652	124	NA	333	0.75	1.54	12.2	8	9	2	24	1	17	7
Showa Denko K.K.	438	78	NA	124	1.19	1.01	5.7	32	34	16	2	1	17	29
Idemitsu Kosan Co. Ltd.	416	76	NA	667	1.60	0.96		34	13	24	39	1	36	15
Itochu Enex Co. Ltd.	344	61	NA	NA	0.46	1.06	13.0	35	35	29	8	40	36	40
Asahi Kasei Corporation	364	50	NA	120	0.25	1.76	55.7	30	23	35	26	1	6	1
Chuetsu Pulp & Paper Co., Ltd.	267	50	NA	NA	1.00	0.85	6.1	18	5	17	1	1	35	35
Toshiba Corporation	279	48	NA	NA	0.86	1.15	5.0	1	3	31	5	1	28	29
Mazda Motor Corporation	206	39	NA	NA	0.79	1.45	10.8	6	37	3	22	1	17	7
Teijin Ltd.	25	32	NA	70	1.01	1.68	18.1	25	18	15	19	28	27	20
Hokuren Federation of Agricultural	8	26	NA	NA	NA	NA	NA	28	32	26	33	1	5	3
JX Holdings, Inc.	143	24	NA	NA	1.09	0.98		12	3	4	21	1	17	7
Kuraray Co. Ltd.	74	17	NA	NA	0.12	3.11	92.7	29	26	6	32	1	17	29
Mitsui Matsushima Co., Ltd.	33	9	NA	NA	0.37	2.51	3.5	26	29	40	12	30	40	40
Daicel Corporation	33	9	NA	NA	0.24	2.49	34.4	36	28	32	5	1	28	29
Tokyo Gas Co. Ltd.	1	0	NA	1,500	0.67	1.51	10.2	10	35	20	36	32	25	6
Ube Industries, Ltd.	NA	NA	NA	400	0.83	1.18	6.1	NA	NA	NA	NA	NA	NA	NA
Marubeni Corporation	NA	NA	NA	750	2.03	1.19	NA	NA	NA	NA	NA	NA	NA	NA
ORIX Corporation	NA	NA	NA	390	1.85	2.59	NA	NA	NA	NA	NA	NA	NA	NA
Abl Co.,Ltd.	NA	NA	NA	110	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Air Water Inc.	NA	NA	NA	56	0.64	1.20	22.3	NA	NA	NA	NA	NA	NA	NA
Chiba Prefecture	NA	NA	NA	500	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
HIROSHIMA GAS Co.,Ltd.	NA	NA	NA	56	1.00	0.95	9.0	NA	NA	NA	NA	NA	NA	NA
Hokuzai Transport Co.,Ltd.	NA	NA	NA	56	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
New Frontier Capital Management	NA	NA	NA	100	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Seika Corporation	NA	NA	NA	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Joban Joint Power Co., Ltd.	NA	NA	NA	180	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Maeda Corp.	NA	NA	NA	1,100	0.51	1.34	6.7	NA	NA	NA	NA	NA	NA	NA
Meiko Trans Co., Ltd.	NA	NA	NA	15	0.00	3.92		NA	NA	NA	NA	NA	NA	NA
Japan Energy Partners*	NA	NA	NA	15	0.30	1.39	34.4	NA	NA	NA	NA	NA	NA	NA
TonenGeneral Sekiyu k.k.	NA	NA	NA	500	1.43	0.83	2.8	NA	NA	NA	NA	NA	NA	NA

For LRHs, companies are ranked by exposure, with '1' being the most exposed
For more details, see tables in Appendix C.

3 Potential scale of stranded assets facing coal-fired power stations in Japan

Stranded assets are assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities and they can be caused by a variety of risks. Increasingly risk factors related to the environment are stranding assets and this trend is accelerating, potentially representing a discontinuity able to profoundly alter asset values across a wide range of sectors.[176] The following section examines the potential scale of stranded assets facing Japanese coal-fired utilities.

To calculate potential asset stranding charges, we extract capacity data from the Platts World Electric Power Plants (WEPP) Database for Q1 2016. For our sample of 55 Japanese companies, we extract the capacities of all coal-fired generation assets in MW. To avoid double-counting jointly-owned capacity, we divide capacity among joint-owners. We delineate the capacities into existing and planned (or currently under construction). We assume a total installation cost of ¥250,000,000/MW (US$2.25m/MW[177]).[178] We include all sunk costs – such as fees and contingency, engineering, procurement and construction services, and any additional owner costs[179] - as these represent losses in the case of asset stranding. For each asset, we depreciate the asset using the straight-line method over an assumed useful life of 40 years since the date (or planned date) of build, congruent with Pfeiffer et al. (2015).[180] We assume a salvage value of zero. As the last planned generating plant is scheduled for 2035, our total time series covers 2016 to 2076 including 40 years depreciation. The series plot, for each year, the total estimated asset stranding charge if the value of the generating assets declines unexpectedly.

In addition to the estimated asset stranding charges, we overlay three pathways to remove coal-fired generation from the energy system: five years, ten years, and 15 years. We select these three scenarios as they are compatible with the impact of factors chosen previously, such as: population growth and forecast electricity demand (NRH-1), targets for renewables policy support and generation outlook (NRH-4 and NRH-5), and nuclear restarts (LRH-7). In all three scenarios the start date is 2016 and the known installed capacity is 48.265 GW (including capacity planned for 2016). The three scenarios assume inaction in the early years and accelerated action in later years. This is primarily due to poor disclosure of marginally profitable assets by firms, regardless of technology, and the fact that many firms will forward-hedge future generation to protect profits.[181] Thus, the impact may not materialise for the first few years.

The results show that all generation assets, new and existing, will require some asset stranding regardless of the three scenarios. In the baseline scenario - the most extreme case where coal is decommissioned now, the total impairment charges would be ¥5,494 billion[182] ($49.37bn), with the existing generation assets being the most affected [¥5,416 billion ($48.67bn)]. Importantly, this baseline assumes that much of the planned assets are not built – especially the large amount of capacity planned in 2020. If the planned generation units are built, the asset stranding charges will be considerably higher depending on the value of sunk-costs.

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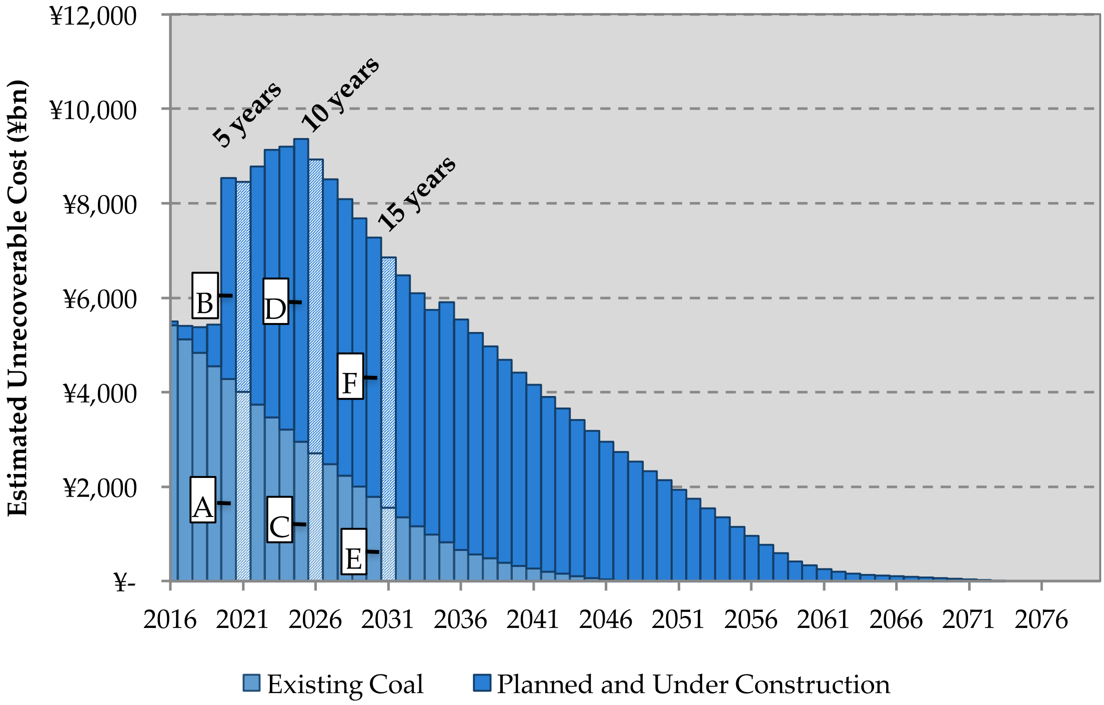
[176] Atif Ansar, Ben Caldecott, and James Tibury, "Stranded Assets and the Fossil Fuel Divestment Campaign: What Does Divestment Mean for the Valuation of Fossil Fuel Assets?," *Stranded Assets Programme, SSEE, University of Oxford*, no. October (2013): 1–81, doi:10.1177/0149206309337896.
[177] Assuming ¥111.28/$1, April 27th 2016 exchange rate. This exchange rate is used in all currency conversions below.
[178] METI, "All Power Plant Specifications List (各電源の諸元一覧)," 2016, http://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/mitoshi/cost_wg/001/pdf/001_11.pdf..
[179] Fang Rong and David G. Victor, "What Does It Cost to Build a Power Plant?," *ILAR Working Paper*, vol. 17, 2012.
[180] Alexander Pfeiffer et al., "The '2°C Capital Stock' for Electricity Generation: Committed Cumulative Carbon Emissions from the Electricity Generation Sector and the Transition to a Green Economy," *Applied Energy* (In Press) (2016), doi:http://dx.doi.org/10.1016/j.apenergy.2016.02.093.
[181] Ben Caldecott and Jeremy McDaniels, "Stranded Generation Assets : Implications for European Capacity Mechanisms , Energy Markets and Climate Policy," *Stranded Assets Programme, SSEE, University of Oxford*, 2014, 1–62.
[182] Note all asset stranding charges represent total and not annual charges.

For the five, ten, and 15-year scenarios, the total asset stranding new-capacity is estimated using known planned capacity and capacity currently under construction. Therefore, the charge represents the *lower* estimate bound, as any additional planned capacity over the upcoming years will also increase this estimate. In the 5-year scenario, total asset stranding charges are ¥8,453 billion ($75.96bn). The asset stranding charges are marginally weighted towards the planned capacity. The ten-year scenario is the most expensive overall, with total asset stranding charges of ¥8,924 billion ($80.19bn), of which ¥6,223 billion ($55.92bn) falls on the new-build capacity only. Finally, the 15-year scenario estimates total asset stranding charges to be ¥6,857 billion ($61.62bn), of which ¥5,307 billion ($47.69bn) falls on the new build.

Figure 35: Estimated scale of asset stranding for existing and new build coal generators



NB: The difference between the value on the y-axis and zero represents estimated stranded assets charge.
Letters in the chart correspond to the labels in Table 43.

Table 43: Estimates of total asset stranding charges (¥bn/US$)

Coal Offline in:	Existing Assets	Planned and Under Construction	Total
2021 (5 years)	**[A]** ¥4,005 ($35.99)	**[B]** ¥4,447 ($39.96)	**[A + B]** ¥8,453 ($75.96)
2026 (10 years)	**[C]** ¥2,700 ($24.26)	**[D]** ¥6,223 ($55.92)	**[C+ D]** ¥8,924 ($80.19)
2031 (15 years)	**[E]** ¥1,550 ($13.93)	**[F]** ¥5,307 ($47.69)	**[E + F]** ¥6,857 ($61.62)

Our conclusion from the preceding analysis is that asset stranding will impact both existing and planned generating capacity. For existing capacity, the impact is highest in the short-term – within five years. For planned capacity, the impact is highest after five years. Further, the impact for planned capacity will increase pending any additional capacity applications in the near future. Therefore, although total potential impairment charges in our analysis decline beyond ten years, if additional planned capacity is constructed within this time period then future stranded assets could continue to rise. It will be increasingly difficult to convince investors to commit capital to these projects if there is a high likelihood that assets will become stranded. Accordingly, planned capacity may be increasingly expensive to finance.

3.1 Utility Case Studies

At the company-level, we prepared five case studies of selected utilities. These were for: 1) J-Power; 2) Tokyo Electric Power Co; 3) Chubu Electric Power Co Inc; 4) Kyushu Electric Power Co; and 5) Kansai Electric Power Co. In these case studies we examine the sensitivity of these companies to the risks outlined in this report, and estimate potential scale of asset stranding specifically attributable to them following the methodology used earlier in this section.

Table 44: Breakdown of the five utilities' operating, under construction, and planned coal capacity

Rank	Company	Coal Generating Capacity* [MW]			
		OPR	CON	PLN	Total
1	J-POWER	8,414	84	4,020	12,518
2	TOKYO ELECTRIC POWER CO	5,900	540	5,357	11,797
5	CHUBU ELECTRIC POWER CO	4,100	NA	2,030	6,130
6	KYUSHU ELECTRIC POWER CO	3,646	1,000	667	5,313
7	KANSAI ELECTRIC POWER CO	1,800	NA	3,462	5,262

Table 45: Estimates of total asset stranding (¥bn)

	Ratio Analysis[i]				Env.-Related Risks[i]							Stranded Assets[ii]		
	DEBT / EQUITY	CURRENT RATIO	(EBITDA - CAPEX) / INTEREST	OPR / PLN[iii]	LRH-1	LRH-2	LRH-3	LRH-4	LRH-5	LRH-6	LRH-7	2021 (5 year)	20 26 (10 year)	2031 (15 year)
J-POWER	84%	56%	94%	OPR	40%	58%	88%	55%	32%	53%	53%	¥586.2 (23%)	¥406.3 (16%)	¥237.5 (9%)
				PLN	44%	44%	68%	88%	41%	56%	6%	¥608.2 (24%)	¥904.9 (35%)	¥773.3 (30%)
TEPCO	91%	47%	66%	OPR	32%	22%	22%	20%	100%	12%	95%	¥730.1 (5%)	¥541.0 (4%)	¥351.9 (3%)
				PLN	47%	44%	68%	79%	53%	65%	76%	¥1,309.3 (9%)	¥1,136.3 (8%)	¥963.3 (7%)
CHUBU EPCO	78%	87%	86%	OPR	42%	35%	60%	80%	15%	30%	65%	¥384.6 (7%)	¥253.2 (5%)	¥121.7 (2%)
				PLN	26%	6%	76%	91%	38%	68%	74%	¥114.1 (2%)	¥339.5 (6%)	¥290.4 (5%)
KYUSHU EPCO	100%	62%	ND	OPR	35%	58%	88%	15%	30%	17%	85%	¥248.2 (5%)	¥145.7 (3%)	¥83.6 (2%)
				PLN	94%	62%	35%	50%	29%	15%	44%	¥406.0 (9%)	¥353.0 (8%)	¥299.2 (6%)
KANSAI EPCO	96%	98%	ND	OPR	20%	5%	30%	95%	15%	88%	12%	¥288.5 (4%)	¥230.8 (3%)	¥173.1 (2%)
				PLN	53%	18%	68%	74%	44%	59%	65%	¥439.2 (6%)	¥661.3 (9%)	¥566.4 (8%)

i) Ratio and Environment-related risk presented as a percentile relative to Japan utility peer group:
$N_{D/E}$, $N_{Current\ Ratio} = 45$; $N_{(EBITDA-CAPEX)/INT} = 35$; $N_{OPR} = 40$; $N_{PLN} = 34$;
ii) Stranded Assets expressed in bn¥ and as a fraction of total utility assets
iii) OPR: Operating plants; PLN: Planned and under construction plants;

Overall, the five companies will be subject to some asset stranding charges if we assume all coal must be removed from the system in line with various transition scenarios. Table 45 shows that both existing and planned capacities are at risk of stranded assets in the baseline (now), five, ten, and 15-year cases. We evaluate each company below.

3.1.1 J-Power

J-Power has the most coal generation (8.41GW) of all utilities in Japan, and coal comprises almost half of J-Power's total generation (17.47GW). In addition, over 90% of planned generation capacity is coal (4.02 of 4.34 of GW), and only TEPCO has more planned coal generation (5.90GW).

Notably 67% of its planned coal fleet is potentially CCS retrofitable (39% existing) and it has the lowest planned coal plant exposure to nuclear restarts of any of the major Japanese utilities at only 702 MW on average (2,483 MW existing).

J-Power has the largest combined existing and planned coal plant capacity of all Japanese utilities (12.52 GW), but two-thirds of this (8.18 GW) is already operating. According to our analyses we classify J-Power as having a high exposure to asset stranding for both its existing coal capacity but only medium exposure to its planned coal-capacity. Across the existing and planned capacities, its estimated asset stranding charges in the 5, 10, and 15 year scenarios is second only to TEPCO. This is because although J-Power has 8.18 GW of existing capacity, most was built between 1980 and 2000 and thus has already depreciated significantly.

Table 46: Environment-related risk exposure of J-Power operating plants

PLANT	CAPACITY[ii] [MW]	GENERATION[ii] [GWH]	UR[iii]	LRH-1: CARBON INTENSITY [kg CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLL'N [ugPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: CCS RETROFITABILITY [1 = RETROFITABLE]	LRH-6: FUTRE HEAT STRESS [Δ°C]	LRH-7: REGIONAL NUC. RESTARTS [MW]
MATSUSHIMA	1,002	6,730	77%	922	1980	11.8	0%	0	0.90	4,699
MATSUURA	2,000	15,633	89%	887	1993	11.9	19%	0	0.90	4,699
ISHIKAWA	312	2,134	78%	880	1986	4.2	100%	0	0.68	0
TAKEHARA	1,300	8,136	71%	913	1978	8.6	05%	0	0.88	820
TAKASAGO	500	3,761	86%	928	1969	8.3	35%	0	0.88	0
TACHIBANAWAN	2,100	16,182	88%	823	2001	8.5	10%	1	0.88	2,022
SHIN ISOGO	1,200	7,367	70%	786	2006	10.4	89%	1	0.92	1,100
TOTAL[i]	**8,414**	**59,943**	**81%**	**867**	**1991**	**9.8**	**26%**	**39%**	**0.89**	**2,465**

i. MW-weighted for LRHs and UR; ii. Capacity and generation only for owned portion; iii. UR: Utilisation Rate

Table 47: Environment-related risk exposure of J-Power planned plants

PLANT	CON/ PLN	CAPACITY[ii] [MW]	LRH-1	LRH-2	LRH-3	LRH-4	LRH-5	LRH-6	LRH-7
TAKEHARA	PLN	600	766	2020	8.6	05%	0	0.88	820
TAKASAGO	PLN	1,200	759	2024	8.3	35%	1	0.88	0
NISHIOKINOYAMA	PLN	400	872	2023	10.8	15%	0	0.90	820
OSAKI COOLGEN	CON	84	692	2017	8.9	04%	0	0.88	820
KASHIMA POWER	PLN	320	767	2020	10.1	30%	0	0.88	1,100
YOKOHAMA	PLN	500	900	2020	10.4	89%	1	0.92	1,100
SHIN YOKOSUKA	PLN	500	767	2020	10.2	89%	1	0.92	1,100
YOKOSUKA	PLN	500	807	2020	10.2	89%	1	0.92	1,100
TOTAL[i]		**4,104**	**794**	**2021**	**9.5**	**47%**	**66%**	**0.90**	**704**

i. MW-weighted for LRHs; ii. Capacity only for owned portion;

3.1.2 *Tokyo Electric Power Company*

Like Kansai EPC, Tokyo Electric Power Company (TEPCO) is notable in that its planned coal generation capacity (5.4GW) is high relative to its current operating capacity (5.90 GW). However this planned coal capacity (5.4GW) only represents 36% of TEPCO's total planned generation (14.72 GW). Further, TEPCO has 54.0GW of existing generation in total, of which currently only 11% (5.90 GW) is coal.

On a MW-weighted basis, TEPCO's existing coal-plants in Tokyo and Tohuku regions may need to compete with 11,784MW of shutdown nuclear power. TEPCO also has planned or under construction coal-fired power in regions which may nuclear power be restored to generating a MW-weighted average of 10,130MW. The potential for CCS retrofitability is also poor for TEPCO's existing coal fleet at 0%, and only 26% for planned plants.

TEPCO's existing and planned coal capacity is highly exposed to asset stranding. Of TEPCO's 5.90 GW of existing coal capacity, 3.20GW was recently built in 2008-09 and therefore has incurred little depreciation. Further, Tokyo Electric has 5.36 GW of planned capacity between 2017 and 2035, where most is planned for pre-2020. Accordingly, TEPCO has the highest exposure to asset stranding of all five companies analysed in each of the three future scenarios.

Table 48: Environment-related risk exposure of TEPCO operating plants

PLANT	CAPACITY[ii] [MW]	GENERATION[ii] [GWH]	UR[iii]	LRH-1: CARBON INTENSITY [kg.CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLL'N [µgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: CCS RETROFITABILITY [1 = RETROFITABLE]	LRH-6: FUTRE HEAT STRESS [Δ°C]	LRH-7: REGIONAL NUC. RESTARTS [MW]
SHINCHI	1,000	7,104	81%	857	1995	7.7	15%	0	0.95	17,263
HIRONO	1,200	3,352	32%	773	2009	7.4	15%	0	0.88	17,263
NAKOSO	1,700	8,802	59%	926	1992	7.6	15%	0	0.88	17,263
HITACHINAKA	2,000	6,103	35%	846	2008	8.8	16%	0	0.88	1,100
TOTAL[i]	**5,900**	**25,361**	**49%**	**856**	**2001**	**8.0**	**15%**	**0%**	**0.89**	**11,784**

i. MW-weighted for LRHs and UR; ii. Capacity and generation only for owned portion; iii. UR: Utilisation Rate

Table 49: Environment-related risk exposure of TEPCO planned plants

PLANT	CON/ PLN	CAPACITY[ii] [MW]	LRH-1	LRH-2	LRH-3	LRH-4	LRH-5	LRH-6	LRH-7
HIRONO 'CGAS'	CON	540	652	2020	7.3	00%	0	0.88	17,263
SHINCHI	PLN	500	835	2035	7.7	15%	0	0.95	17,263
SOMA CORE	PLN	112	849	2017	7.7	15%	0	0.95	17,263
HIRONO	PLN	540	652	2020	7.4	15%	0	0.88	17,263
HIRONO	PLN	1,200	765	2020	7.4	15%	0	0.88	17,263
NAKOSO	PLN	180	652	2021	7.6	15%	0	0.88	17,263
HITACHINAKA	PLN	325	768	2021	8.8	16%	0	0.88	1,100
KITAKYUSHU	PLN	1,000	900	2019	11.4	18%	0	0.90	4,699
YOKOHAMA	PLN	500	900	2020	10.4	89%	1	0.92	1,100
SHIN YOKOSUKA	PLN	500	767	2020	10.2	89%	1	0.92	1,100
YOKOSUKA	PLN	500	807	2020	10.2	89%	1	0.92	1,100
TOTAL[i]		**5,897**	**787**	**2021**	**8.9**	**33%**	**25%**	**0.90**	**10,130**

i. MW-weighted for LRHs; ii. Capacity only for owned portion;

3.1.3 Chubu Electric Power Company

Although Chubu Electric Power Co (Chubu EPC) has 30.32GW of operating capacity and only 4.10GW (or 14%) is coal-fired, of its 2.33GW of total planned generation, 2.03GW or 88% is coal. Nevertheless the absolute quantity of additional coal-fired power planned from Chubu is low relative to the other regional utilities.

Although we are bearish on CCS generally, the generation units of Chubu EPC are favourably situated with regard to CCS retrofitability. By our definition, 100% of Chubu EPC's existing and 71% of its planned coal plants may have the potential to be CCS retrofitable.[183]

With regard to the risk of nuclear restart, Chubu EPC's planned coal plants can be considered to have medium exposure with an average of 7,619MW of potential nuclear capacity located in the same region as its planned coal plants, whereas its existing coal plants are only exposed on average to 3,617 MW.

Chubu Electric Power Co has relatively low exposure to coal asset overall stranding, with green lights in Table45 for both existing and planned coal generation. Specifically, Chubu has 4.1GW of existing coal capacity from a single plant which was built in 1996 but has since depreciated in value over time. Its planned coal capacity is also among the lowest, with only 2.33GW of planned capacity expected to begin operating between 2020 and 2035. This low capacity and long projected start times reduces the risk of coal asset stranding in future years as it provides an opportunity to cancel these later projects.

Table 50: Environment-related risk exposure of Chubu EPCO operating plants

PLANT	CAPACITY[ii] [MW]	GENERATION[ii] [GWH]	UR[iii]	LRH-1: CARBON INTENSITY [kg.CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLL'N [µgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: CCS RETROFITABILITY [1 = RETROFITABLE]	LRH-6: FUTRE HEAT STRESS [Δ°C]	LRH-7: REGIONAL NUC. RESTARTS [MW]
HEKINAN	4,100	30,610	85%	869	1997	9.0	53%	1	0.84	3,617
TOTAL[i]	**4,100**	**30,610**	**85%**	**869**	**1997**	**9.0**	**53%**	**1**	**0.84**	**3,617**

i. MW-weighted for LRHs and UR; ii. Capacity and generation only for owned portion; iii. UR: Utilisation Rate

Table 51: Environment-related risk exposure of Chubu EPCO planned plants

PLANT	CON/ PLN	CAPACITY[ii] [MW]	LRH-1	LRH-2	LRH-3	LRH-4	LRH-5	LRH-6	LRH-7
SHINCHI	PLN	500	835	2035	7.7	15%	0	0.95	17,263
HITACHINAKA	PLN	325	NA[iii]	2021	NA	NA	0	NA	NA
TAKETOYO	PLN	1,070	763	2022	9.0	53%	1	0.84	3,617
TOYOHASHI AKEMI	PLN	135	780	2020	8.6	23%	1	0.84	3,617
TOTAL[i]		**2,030**	**785**	**2025**	**8.6**	**39%**	**59%**	**0.87**	**7,619**

i. MW-weighted for LRHs; ii. Capacity only for owned portion; iii: ND: No Data, omitted in MW weighting

3.1.4 Kyushu Electric Power Company

Kyushu EPC is the sole regional utility based on the island of Kyushu. Although Kyushu EPC has 3.64GW of existing coal capacity (23% of total existing capacity: 15.5GW), it only has plans for another 0.67GW of coal

[183] According to Geogreen's data, plant locations are within 40km of a 'possible' CCS reservoir.

generation. However, almost 100% of total planned generation (0.70GW) is expected to be derived from coal. Kyushu EPC is sole owner of the Matsuura coal plant, which is the largest coal plant (1.0GW) currently under construction in Japan, and joint owner of the planned 2.0GW Sodegaura power plant.

Kyushu EPC's existing coal plants are all in the Kyushu region, where there are 4,699MW of restartable nuclear power capacity, a medium risk level relative to the other utilities. Its planned coal plant (Sodegaura) is in the Tokyo region where there is less restartable nuclear capacity, 1,100MW. Its existing power plants also have relatively low potential CCS retrofitability at only 46%.

Our analysis shows that Kyushu Electric Power Co has low exposure to asset stranding. Kyushu has 3.64GW of existing capacity which was built between 1964 and 2001. Most of the capacity has already been significantly depreciated. Only 0.67GW of new capacity is planned for 2020. This low amount of planned capacity reduces the level of asset stranding in later years.

Table 52: Environment-related risk exposure of Kyushu EPCO operating plants

PLANT	CAPACITY[ii] [MW]	GENERATION[ii] [GWH]	UR[iii]	LRH-1: CARBON INTENSITY [kg.CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLL'N [µgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: CCS RETROFITABILITY [1 = RETROFITABLE]	LRH-6: FUTRE HEAT STRESS [Δ°C]	LRH-7: REGIONAL NUC. RESTARTS [MW]
REIHOKU	1,400	7,369	60%	874	1999	11.8	0%	1	0.90	4,699
MATSUURA KYUDEN	700	4,982	81%	861	1989	11.9	19%	0	0.90	4,699
KANDA	740	2,132	33%	896	1986	11.4	18%	0	0.90	4,699
KARITA PBFC	360	850	27%	911	2001	11.4	18%	1	0.90	4,699
TOBATA	446	1,198	31%	744	1979	11.5	18%	0	0.90	4,699
TOTAL[i]	**3,646**	**16,531**	**52%**	**864**	**1992**	**11.7**	**11%**	**48%**	**0.90**	**4,699**

i. MW-weighted for LRHs and UR; ii. Capacity and generation only for owned portion; iii. UR: Utilisation Rate

Table 53: Environment-related risk exposure of Kyushu EPCO planned plants

PLANT	CON/ PLN	CAPACITY[ii] [MW]	LRH-1	LRH-2	LRH-3	LRH-4	LRH-5	LRH-6	LRH-7
MATSUURA KYUDEN	CON	1,000	767	2020	11.9	19%	1	0.90	4,699
SODEGAURA	PLN	667	900	2020	11.0	35%	1	0.88	1,100
TOTAL[i]		**1,667**	**820**	**2020**	**11.5**	**25%**	**100%**	**0.89**	**3,259**

i. MW-weighted for LRHs; ii. Capacity only for owned portion;

3.1.5 Kansai Electric Power Company

Kansai EPC is notable in that, should all its planned plants be built, the total coal capacity of Kansai will almost triple from 1.80GW to 5.26GW. This planned increase of 3.46GW in coal generation represents 82% of Kansai EPC's total planned capacity (4.22GW). Kansai EPC's coal fleet also has the youngest average age of all major Japanese utilities at just 9 years (2007 average).

Although Kansai EPC's single existing coal plant (Maizuru, 1.8GW) has no exposure to nuclear restart, we classify its planned coal plants as having a medium risk of nuclear restart with 4,276 MW on average in the same region. Japan generally has ample access to water resources, but certain areas (particularly cities) have high water stress. Kansai EPC's Maizuru coal plant is noteworthy in that it has a relatively high level of water stress, at 77% of renewable water resources recovered and used. Many Japanese power plants utilise seawater for cooling and Maizuru is no exception. At the same time, while Maizuru power is potentially CCS retrofitable, only 53% of Kansai EPC's planned coal plants have that possibility as well.

Kansai Electric Power Co has low exposure to asset stranding for existing capacity, but a medium risk for planned capacity. Kansai plans to build an additional 3.46GW of capacity between 2017 and 2035. The large additional capacity expected to come online in the 2020s increases Kansai's risk of asset stranding over time.

Table 54: Environment-related risk exposure of Kansai EPCO operating plants

PLANT	CAPACITY[ii] [MW]	GENERATION[ii] [GWH]	UR[iii]	LRH-1: CARBON INTENSITY [kg.CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLL'N [µgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: CCS RETROFITABILITY [1 = RETROFITABLE]	LRH-6: FUTRE HEAT STRESS [Δ°C]	LRH-7: REGIONAL NUC. RESTARTS [MW]
MAIZURU	1,800	5,507	35%	806	2007	8.1	77%	1	0.93	0
TOTAL[i]	**1,800**	**5,507**	**35%**	**806**	**2007**	**8.1**	**77%**	**1**	**0.93**	**0**

i. MW-weighted for LRHs and UR; ii. Capacity and generation only for owned portion; iii. UR: Utilisation Rate

Table 55: Environment-related risk exposure of Kansai EPCO planned plants

PLANT	CON/ PLN	CAPACITY[ii] [MW]	LRH-1	LRH-2	LRH-3	LRH-4	LRH-5	LRH-6	LRH-7
SENDAI PORT	PLN	112	900	2017	7.3	37%	0	0.95	17,263
AKITA	PLN	650	807	2025	8.6	13%	1	0.92	17,263
AKO	PLN	1,200	800	2020	8.5	40%	1	0.88	0
ICHIHARA	PLN	500	807	2025	11.0	35%	0	0.88	1,100
KANSAI ELECTRIC POWER CHIBA PREF.	PLN	500	743	2035	11.0	35%	0	0.88	1,100
KEPCO CHIBA	PLN	500	839	2020	10.9	35%	0	0.88	1,100
TOTAL[i]		**3,462**	**803**	**2024**	**9.5**	**33%**	**53%**	**0.89**	**4,276**

i. MW-weighted for LRHs; ii. Capacity only for owned portion;

4 Conclusion

- The future for Japan's power generators is highly uncertain, particularly for heavily polluting thermal generators such as coal. Factors including climate change policy and renewables subsidies, the prospect of nuclear restarts, energy efficiency, and macroeconomic factors like low levels of population and GDP growth, will all affect power demand and supply in ways that would likely harm the economics of coal-fired power stations in Japan.

- Despite the highly uncertain context for coal-fired generation – the government has encouraged a major expansion of coal-fired generating capacity. As a result, the number of coal plants under development has increased rapidly in the past few years. Although there are currently four coal plants under construction with a combined capacity of 1.9 GW, there are now 49 planned plants comprising a significant 28 GW at various stages of planning.

- The amount of planned and under construction coal-fired generating capacity greatly exceeds the capacity required to replace the retiring fleet - by 191%. This may result in overcapacity and combined with competition from other forms of generation capacity with lower marginal costs (e.g. nuclear and renewables), lead to significant asset stranding of coal generation assets.

- To examine the scale of potential stranded coal assets in Japan, we used three illustrative scenarios where existing and planned coal-fired power stations are stranded over 5-year, 10-year, and 15-year periods. We selected these three periods to reflect the different speeds and scales at which the risk factors identified in this report could realistically materialise. While highly illustrative, these scenarios highlight the potential impact of stranded coal assets on the utility sector in Japan, particularly from coal-fired power plants that are planned, but not currently under construction.

- We found that stranded coal assets could be ¥6,857bn - ¥8,924bn ($61.6bn - $80.2bn), equivalent to 22.6% - 29.4% of the current market capitalization, and 4.5%-5.9% of total assets, of Japan's power utilities. This highlights the risks of continuing to proceed with the planning and development of new coal-fired power plants in Japan.

- In the 5-year scenario, where coal-fired power stations become stranded assets by 2021, the total value of stranded coal assets are estimated to be ¥8,453 billion ($76bn). In the 10-year scenario, where coal-fired power stations become stranded assets by 2026, the total value of stranded coal assets are estimated to be ¥8,924 billion ($80.2bn), of which ¥6,223 billion ($55.9bn) are plants built after 2016. Finally, in the 15-year scenario where coal-fired power stations become stranded assets by 2031, the total value of stranded coal assets are estimated to be ¥6,857 billion ($61.6bn), of which ¥5,307 billion ($47.69bn) are plants built after 2016.

- We judge that the five-year, ten-year, and 15-year scenarios are a suitable time horizon to consider given the pace of change in the global energy system. Renewables deployment has increased from 10% of global capacity to 15%in the last five years,[184] the cost of onshore wind and solar PV has fallen by 39% and 41% respectively over the same period, and sales of electric vehicles have grown by 1,031%.[185] Disruption appears to be accelerating as tipping points are reached and the idea that the power sector will remain relatively static and 'safe' for new thermal coal assets is counter to the evidence we see internationally across the G20.

[184] BNEF (2015) 'global trends in renewable energy investment 2015'
[185] Office of Energy Efficiency & Renewable Energy (2016) 'Fact #918: march 28, 2016 global plug-in light vehicle sales increased by about 80% in 2015' [Online] Available at: http://energy.gov/eere/vehicles/fact-918-march-28-2016-global-plug-light-vehicle-sales-increased-about-80-2015

- At the company-level, we prepared five case studies of selected utilities. These were for: 1) J-Power; 2) Tokyo Electric Power Co; 3) Chubu Electric Power Co Inc; 4) Kyushu Electric Power Co; and 5) Kansai Electric Power Co. We find that Tokyo Electric Power Co has the highest exposure to asset stranding in absolute value for the five-year, ten-year, and 15-year scenarios of the five comparator companies. Tokyo Electric Power Co also has some of the highest exposure to environment-related risk, especially for planned or under construction power stations. J-Power has the most exposure to asset stranding relative to total assets (>20%).

- Given significant proposed coal expansion on the one hand and growing environment-related risks on the other, companies, investors, and policymakers should examine the exposure of Japan's existing and proposed coal-fired power plants to the risk of asset stranding. Stranded coal assets would affect utility returns for investors; impair the ability of utilities to service outstanding debt obligations; and create stranded assets that have to be absorbed by taxpayers and ratepayers. Moreover, new coal-fired power stations will generate significant negative externalities for the duration of their shorter than anticipated lives, particularly in terms of carbon emissions that cause climate change, as well as air pollution that harms human health.

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Appendix A: Dataset Preparation

This report uses a number of data sources to provide analysis of coal-fired power utilities, thermal coal mining companies, and coal processing technologies. Table 46 summarises the main sources of data. Where the data was not available for all plants and mines, the remainder was either estimated from available data or completed by the Oxford Smith School as noted. For example, 74% of all coal-fired generating assets had generation data (in MWh) from CARMA, and the remaining 26% was estimated by the Oxford Smith School.

Table 56:2 Data sources and completeness

Data	Data Source (in order of seniority)	Completion %	Notes
Number of Coal-Fired Generating Assets (N = 154 coal-fired power stations)			
Location	CoalSwarm's Global Coal Plant Tracker (CoalSwarm, Q4 2015) Enipedia Carbon Monitoring for Action Database (CARMA, v3.0 released Jul 2012) Platts' World Electric Power Plant Database (WEPP, Q1 2016)	100%	
Capacity [MW]	CoalSwarm, WEPP, Enipedia, CARMA	100%	
Generation [MWh]	Enipedia, CARMA, Oxford Smith School	100%	48% estimated
Plant Age	CoalSwarm, WEPP, Enipedia, CARMA, Oxford Smith School	100%	4% estimated
CO_2 Intensity	CoalSwarm, WEPP, CARMA, Oxford Smith School	100%	3% estimated
Market Analysis			
General Information	S&P CapitalIQ, Trucost	-	
Capital Spending Trends	S&P CapitalIQ	-	
Bond Issuances	S&P CapitalIQ	-	
Ownership Trends	S&P CapitalIQ	-	
Local Risk Hypotheses			
$PM_{2.5}$ Emissions 2012-2014 Average	Atmospheric Composition Analysis Group, Dalhousie University	Global	
NO_2 Emissions 2015	NASA GES DISC OMNO2	Global	
Mercury Emissions 2010	AMAP/UNEP 2010	Global	
Water Stress 2015	WRI Aqueduct	Global	
CCS Geologic Suitability	Geogreen	Global	
Heat Stress Change 2016-2035	IPCC AR5 WGII	Global	
Nuclear Restart Risk	WEPP	Global	
National Risk Hypotheses			
Renewables Outlook	EY Renewable Energy Country Attractiveness Index	See NRHs for details	
Renewables Policy	REN21 Global Status Report	See NRHs for details	
Water Regulatory Risk 2015	WRI Aqueduct	See NRHs for details	
CCS Legal Environment	Global CCS Institute Legal and Regulatory Indicator	See NRHs for details	

Individual power station information is taken from the most recent version (v3) of the Carbon Monitoring for Action (CARMA) database, Enipedia, and CoalSwarm's Global Coal Plant Tracker (CPT). These databases are merged, and when power station matches occur, we preferentially use fields from CoalSwarm, then Enipedia, and finally CARMA. The Platts World Electric Power Plants Database (WEPP) is used to exclude power stations that have been closed, but not reported as such in CARMA, Enipedia, or CPT. We also use WEPP to identify non-coal-fired power stations that are operational, but not included in CARMA.

CARMA contains data on existing and planned plants and was last systematically updated to the end of 2009, CPT has data on coal-fired power plants planned and added to the global stock since the start of 2010 onwards (we currently used the most recent December 2015 update), and Enipedia is continuously updated on an individual power plant basis. WEPP is updated quarterly (we currently use data from the Q4 2015 release). The merger between these datasets has produced a database that effectively defines the locations of all the world's power plants, their ownership, the annual megawatt hours of electricity produced, plant age, fuel type, capacity, and carbon intensity. It is particularly current and comprehensive for coal-fired power stations.

Information on the accuracy of the CoalSwarm, Enipedia, and WEPP databases are not available, but the CARMA data has a number of caveats that are thoroughly enumerated on its website (carma.org), two of which are particularly relevant to this database. The first is that CARMA estimates electricity generation and CO2 emissions using statistical models that have been fitted from detailed US plant data. CARMA reports that fitted CO2 emissions values are within 20% of the true value 60% of the time, and that electricity generation is within 20% of the true value 40% of the time. Second, CARMA geographical location data varies in its degree of precision. For almost all power plants the state/province location is known, for 80% of power plants at least the city location is known, for 40% county/district data is known, and for 16% of power stations a unique postal code is assigned. Comparisons of approximate and precise coordinates suggest that the average spatial error is about 7 km, which is well within the bounds of all our geographical analyses (scales of 40km and 100km used).

International Securities Identification Numbers (ISINs) which uniquely identify securities have been matched to the equities of top coal-fired utilities, thermal coal miners, and coal processing technology companies where possible. Equity ISINs are not available for private companies. Multiple bond ISINs could be matched to each company, however that has not been completed at this time. ISINs were acquired directly from the public database[186] and through internet research.

[186] Accessible at http://www.isin.org.

Appendix B: Financial Data

Figure 57: Ratio analysis for coal-fired power utilities

Year	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)
	Net Profit Margin	CAPEX to Revenue	Current Ratio	Quick Ratio	Total Debt to Equity	Total Debt to Capital	EBIT to interest expense	EBITDA to interest expense	(EBITDA-CAPEX) to interest	Total Debt to EBITDA	Total Debt to (EBITDA - CAPEX)	Net Debt to EBITDA	Net Debt to (EBITDA - CAPEX)
1995	0.90%	6.49%	0.93x	0.65x	231.37%	69.82%	1.60x	2.29x	1.85x	9.94x	11.80x	6.93x	9.51x
1996	1.89%	5.84%	0.84x	0.61x	250.51%	71.47%	1.96x	3.86x	3.56x	6.97x	7.91x	5.67x	6.57x
1997	1.62%	9.03%	0.90x	0.62x	232.98%	69.97%	1.99x	4.32x	3.01x	7.99x	14.30x	5.74x	12.93x
1998	1.64%	10.56%	0.86x	0.59x	303.01%	75.10%	1.71x	4.52x	1.86x	8.15x	18.36x	6.40x	15.88x
1999	1.42%	11.42%	0.90x	0.63x	308.62%	75.43%	1.71x	4.40x	2.38x	8.01x	16.45x	6.76x	15.59x
2000	1.63%	10.36%	0.94x	0.63x	291.46%	74.44%	2.00x	5.19x	2.22x	5.93x	15.80x	5.57x	14.25x
2001	2.09%	7.95%	0.85x	0.53x	249.76%	71.41%	2.38x	5.72x	3.22x	5.53x	10.85x	5.38x	9.28x
2002	1.39%	7.81%	0.81x	0.51x	282.78%	73.88%	2.39x	6.14x	2.74x	6.01x	13.37x	5.81x	13.15x
2003	1.35%	6.17%	0.83x	0.53x	254.31%	71.78%	3.05x	7.05x	3.54x	5.93x	11.12x	5.42x	10.28x
2004	2.54%	6.15%	0.87x	0.51x	235.46%	70.19%	3.90x	8.38x	5.07x	5.21x	9.02x	4.83x	8.04x
2005	3.60%	6.04%	0.93x	0.57x	184.26%	64.82%	5.29x	10.67x	6.52x	4.47x	7.95x	4.20x	6.88x
2006	4.24%	7.00%	0.93x	0.53x	158.34%	61.29%	6.05x	12.76x	6.78x	4.92x	8.14x	4.80x	7.86x
2007	4.03%	7.25%	0.99x	0.55x	132.47%	56.98%	5.94x	11.45x	5.63x	4.79x	8.91x	4.71x	7.75x
2008	3.09%	7.69%	1.00x	0.55x	148.01%	59.68%	4.10x	11.35x	5.07x	5.02x	10.10x	5.02x	9.62x
2009	0.47%	7.46%	1.07x	0.59x	181.65%	64.49%	4.40x	9.43x	4.93x	5.49x	11.42x	5.07x	10.10x
2010	2.70%	6.50%	1.12x	0.69x	141.65%	58.62%	3.35x	12.21x	5.13x	5.04x	11.65x	4.78x	13.11x
2011	3.08%	5.41%	1.17x	0.70x	122.98%	55.15%	6.28x	15.32x	8.60x	4.28x	6.49x	3.93x	6.80x
2012	1.40%	5.85%	1.13x	0.69x	128.41%	56.22%	6.50x	12.80x	8.76x	5.22x	8.91x	5.22x	9.25x
2013	1.28%	6.09%	1.12x	0.71x	120.54%	54.66%	5.23x	12.22x	7.08x	6.13x	10.15x	5.70x	9.60x
2014	2.54%	6.00%	1.20x	0.79x	112.08%	52.85%	6.83x	13.48x	6.77x	5.92x	8.56x	5.18x	8.98x
2015	2.60%	5.78%	1.20x	0.77x	107.64%	51.84%	6.82x	14.29x	6.15x	5.57x	10.71x	4.41x	9.22x

Table 58: Debt issuance of Japan's utility companies

	Total Debt Outstanding	Peak Debt outstanding	Unsecured Debt		Total DEBT/EBITDA
Air Water Inc.	¥154,861.00	2020	¥ 122,994	79.4%	2.48
Asahi Kasei Corporation	¥269,017.00	2019	¥ 266,280	99.0%	1.06
Chubu Electric Power Company, Incorporated	¥2,936,214.00	2017	¥ 2,245,293	76.5%	7.75
Chuetsu Pulp & Paper Co., Ltd.	¥50,940.00	NA	¥ 46,636	91.6%	4.97
The Chugoku Electric Power Co.,Inc.	¥1,960,594.00	2018	¥ 768,927	39.2%	10.90
Daicel Corporation	¥86,957.00	2018 / 2019 / 2023	¥ 86,957	100.0%	1.13
Hokkaido Electric Power Co. Inc.	¥1,298,394.00	2018	¥ 489,052	37.7%	13.15
Hokuren Federation of Agricultural Cooperatives	NA	NA	NA	NA	0.00
Hokuriku Electric Power Company	¥874,285.00	2018	¥ 360,708	41.3%	7.92
Idemitsu Kosan Co. Ltd.	¥1,006,180.00	2018	¥ 1,006,180	100.0%	NM
Itochu Enex Co. Ltd.	¥52,103.00	2022	¥ 40,954	78.6%	2.05
JFE Holdings, Inc.	¥1,501,760.00	2017	¥ 1,519,094	101.2%	3.77
Electric Power Development Co., Ltd.	¥1,723,656.00	2017	¥ 1,380,342	80.1%	10.37
The Kansai Electric Power Company, Incorporated	¥4,315,724.00	2017	¥ 2,065,719	47.9%	14.07
Kashima-Kita Electric Power Corporation	NA	NA	NA	NA	0.00
Kobe Steel Ltd.	¥709,855.00	2017	¥ 661,713	93.2%	3.39
Kuraray Co. Ltd.	¥59,444.00	2021	¥ 59,236	99.7%	0.54
Kyushu Electric Power Company, Incorporated	¥3,340,367.00	2017	¥ 1,763,100	52.8%	22.17
Marubeni Corporation	¥3,410,535.00	2017	¥ 3,369,024	98.8%	12.39
Mitsui Matsushima Co., Ltd.	¥12,736.00	NA	¥ 8,003	62.8%	5.35
Mazda Motor Corporation	¥701,019.00	2019	¥ 644,526	91.9%	2.58
NC Miike Co., Ltd	NA	NA	NA	NA	0.00
Mitsubishi Corporation	¥6,402,754.00	2016	¥ 6,092,106	95.1%	22.82
Mitsui & Co. Ltd.	¥4,793,957.00	2016	¥ 4,600,743	96.0%	9.55
JX Holdings, Inc.	¥2,660,282.00	2018	¥ 2,393,257	90.0%	6.87
Nippon Paper Industries Co., Ltd.	¥729,697.00	2017	¥ 729,806	100.0%	8.35
NIPPON STEEL & SUMITOMO METAL CORPORATION	¥1,975,159.00	2017	¥ 2,244,968	113.7%	2.91
Oji Holdings Corporation	¥862,579.00	2017	¥ 849,256	98.5%	7.16
The Okinawa Electric Power Company, Incorporated	¥231,204.00	2018	¥ 120,468	52.1%	6.26
ORIX Corporation	¥4,419,626.00	2017	¥ 4,126,095	93.4%	7.13
Osaka Gas Co., Ltd.	¥632,980.00	2018	¥ 588,659	93.0%	3.19
Shikoku Electric Power Co. Inc.	¥713,328.00	2017	¥ 343,550	48.2%	7.52
Showa Denko K.K.	¥368,835.00	2021	¥ 368,831	100.0%	5.78
Sumitomo Corporation	¥4,520,047.00	2022	¥ 3,913,707	86.6%	15.40
Taiheiyo Cement Corp.	¥421,754.00	2018	¥ 364,888	86.5%	3.81
Teijin Ltd.	¥306,761.00	2018 / 2021	¥ 306,758	100.0%	3.74
Tohoku Electric Power Co. Inc.	¥2,583,923.00	2017	¥ 1,327,745	51.4%	6.61
Tokai Kyodo Hatsuden K.K.	NA	NA	NA	NA	0.00
Tokuyama Corp.	¥283,195.00	2020	¥ 276,691	97.7%	7.38
Tokyo Electric Power Company Holdings, Incorporated	¥7,018,090.00	2017	¥ 2,348,553	33.5%	7.46
Tokyo Gas Co. Ltd.	¥728,597.00	2018	¥ 727,897	99.9%	2.35
Toshiba Corporation	¥1,341,384.00	2069	¥ 1,309,876	97.7%	3.72
Tosoh Corporation	¥271,526.00	NA	¥ 269,017	99.1%	3.12
Ube Industries, Ltd.	¥239,714.00	2016	¥ 238,399	99.5%	4.21
TonenGeneral Sekiyu k.k.	¥334,207.00	2019	¥ 334,207	100.0%	7.64
Abl Co.,Ltd.	NA	NA	NA	NA	0.00
HIROSHIMA GAS Co.,Ltd.	¥39,170.00	2018/ 2021 / 2023	¥ 39,157	100.0%	3.55
New Frontier Capital Management Co.,Ltd.	NA	NA	NA	NA	0.00
Maeda Corp.	¥81,342.00	2018 / 2019	¥ 74,022	91.0%	5.25
Meiko Trans Co., Ltd.	¥288.00	NA	NA	0.0%	0.05
Seika Corporation	¥8,397.00	NA	¥ 6,502	77.4%	2.22
Japan Energy Partners	NA	NA	NA	NA	NA
Hokuzai Transport Co.,Ltd.	NA	NA	NA	NA	0
Joban Joint Power Co., Ltd.	NA	NA	NA	NA	0
Chiba Prefecture	NA	2024 / 2025	NA	NA	0

Table 59: Ownership of Japan's utility companies

	Ticker	Ownership	Insiders	Institutions	Corporate	ESOP	Public/Other
Air Water Inc.	TSE:4088	**Public Company**	**1,316.04**	**115,701.64**	**16,797.61**	**8,796.15**	**183,676.66**
Asahi Kasei Corporation	TSE:3407	**Public Company**	254.44	538,458.40	NA	26,972.77	495,398.04
Chubu Electric Power Company, Incorporated	TSE:9502	**Public Company**	369.59	340,527.08	155.09	29,204.66	721,294.65
Chuetsu Pulp & Paper Co., Ltd.	TSE:3877	**Public Company**	37.16	6,030.02	9,317.38	NA	11,722.38
The Chugoku Electric Power Co.,Inc.	TSE:9504	**Public Company**	280.59	156,484.72	1,010.08	10,235.46	251,471.23
Daicel Corporation	TSE:4202	**Public Company**	308.84	167,807.81	44,693.58	7,334.71	263,449.61
Hokkaido Electric Power Co. Inc.	TSE:9509	**Public Company**	118.93	75,491.64	NA	4,233.25	125,932.43
Hokuren Federation of Agricultural Cooperatives		**Trade Association**	NA	NA	NA	NA	NA
Hokuriku Electric Power Company	TSE:9505	**Public Company**	352.01	69,575.98	26.26	10,358.84	183,987.40
Idemitsu Kosan Co. Ltd.	TSE:5019	**Public Company**	326.87	96,384.88	82,739.45	15,041.56	182,341.72
Itochu Enex Co. Ltd.	TSE:8133	**Public Company**	186.91	11,811.61	61,116.15	1,269.53	26,203.56
JFE Holdings, Inc.	TSE:5411	**Public Company**	142.52	256,048.71	12,519.53	NA	642,175.21
Electric Power Development Co., Ltd.	TSE:9513	**Public Company**	541.26	264,840.52	NA	12,145.71	329,258.84
The Kansai Electric Power Company, Incorporated	TSE:9503	**Public Company**	350.79	156,408.06	21,158.03	NA	463,907.21
Kashima-Kita Electric Power Corporation		**Private Company**	NA	NA	NA	NA	NA
Kobe Steel Ltd.	TSE:5406	**Public Company**	178.34	87,613.54	17,428.32	NA	282,229.35
Kuraray Co. Ltd.	TSE:3405	**Public Company**	372.59	227,511.25	NA	NA	265,897.00
Kyushu Electric Power Company, Incorporated	TSE:9508	**Public Company**	309.62	145,570.94	572.30	11,248.55	364,326.75
Marubeni Corporation	TSE:8002	**Public Company**	658.74	387,616.09	103.58	NA	628,677.64
Mitsui Matsushima Co., Ltd.	TSE:1518	**Public Company**	1,019.10	2,570.44	NA	NA	12,077.06
Mazda Motor Corporation	TSE:7261	**Public Company**	103.36	350,240.09	21,813.99	NA	670,702.88
NC Miike Co., Ltd		**Private Company**	NA	NA	NA	NA	NA
Mitsubishi Corporation	TSE:8058	**Public Company**	1,468.01	1,098,466.23	182.35	NA	1,851,470.11
Mitsui & Co. Ltd.	TSE:8031	**Public Company**	516.22	585,931.02	NA	NA	1,818,103.73
JX Holdings, Inc.	TSE:5020	**Public Company**	290.82	410,788.73	42,841.85	NA	716,015.04
Nippon Paper Industries Co., Ltd.	TSE:3863	**Public Company**	154.09	99,521.27	7,657.35	6,988.59	129,396.80
NIPPON STEEL & SUMITOMO METAL CORPORATION	TSE:5401	**Public Company**	472.28	639,676.31	45,104.22	1,022.10	1,427,118.28
Oji Holdings Corporation	TSE:3861	**Public Company**	6,924.73	104,136.24	8,140.97	10,904.66	317,556.48
The Okinawa Electric Power Company, Incorporated	TSE:9511	**Public Company**	206.04	24,309.22	NA	3,381.71	36,308.07
ORIX Corporation	TSE:8591	**Public Company**	772.11	1,140,408.92	723.71	NA	935,158.24
Osaka Gas Co., Ltd.	TSE:9532	**Public Company**	469.94	259,165.63	158.76	10,792.51	554,810.88
Shikoku Electric Power Co. Inc.	TSE:9507	**Public Company**	204.93	63,557.76	13,444.83	6,028.24	188,100.94
Showa Denko K.K.	TSE:4004	**Public Company**	248.88	68,348.29	2,557.53	2,830.22	90,257.51
Sumitomo Corporation	TSE:8053	**Public Company**	608.34	360,785.39	53,475.05	NA	1,045,301.80
Taiheiyo Cement Corp.	TSE:5233	**Public Company**	101.02	142,758.30	2,943.25	NA	212,920.38
Teijin Ltd.	TSE:3401	**Public Company**	259.67	117,724.03	3,876.90	9,980.57	258,352.80
Tohoku Electric Power Co. Inc.	TSE:9506	**Public Company**	288.15	162,961.54	NA	19,825.20	483,753.87
Tokai Kyodo Hatsuden K.K.		**Private Company**	NA	NA	NA	NA	NA
Tokuyama Corp.	TSE:4043	**Public Company**	24.14	24,612.16	1,136.36	NA	35,097.95
Tokyo Electric Power Company Holdings, Incorporated	TSE:9501	**Public Company**	108.03	144,015.81	2,333.91	28,150.19	745,128.03
Tokyo Gas Co. Ltd.	TSE:9531	**Public Company**	374.48	463,697.49	13,075.36	20,794.00	661,387.72
Toshiba Corporation	TSE:6502	**Public Company**	296.27	270,525.99	27,767.91	NA	696,370.74
Tosoh Corporation	TSE:4042	**Public Company**	330.43	130,158.56	5,027.84	NA	195,398.94
Ube Industries, Ltd.	TSE:4208	**Public Company**	144.08	83,832.98	572.18	NA	137,632.11
TonenGeneral Sekiyu k.k.	TSE:5012	**Public Company**	7.34	84,104.55	43,969.09	NA	253,266.00
Abl Co.,Ltd.		**Private Company**	NA	NA	NA	NA	NA
HIROSHIMA GAS Co.,Ltd.	TSE:9535	**Public Company**	735.95	4,256.95	5,375.40	NA	13,336.47
New Frontier Capital Management Co.,Ltd.		**Private Company**	NA	NA	NA	NA	NA
Maeda Corp.	TSE:1824	**Public Company**	169.55	41,566.43	30,147.32	3,854.99	78,793.68
Meiko Trans Co., Ltd.	NSE:9357	**Public Company**	670.31	6,881.68	4,118.55	NA	16,281.95
Seika Corporation	TSE:8061	**Public Company**	324.98	1,968.21	2,198.18	NA	10,516.05
Japan Energy Partners		NA	NA	NA	NA	NA	NA
Hokuzai Transport Co.,Ltd.		**Private Company**	NA	NA	NA	NA	NA
Joban Joint Power Co., Ltd.		**Private Company**	NA	NA	NA	NA	NA
Chiba Prefecture		**Government Institution**	NA	NA	NA	NA	NA

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Appendix C: Summary of Coal Plant Data

Table 60: Operating, under construction, and planned generating capacity by fuel type

	Coal-Fired Generation [GWh]	All Capacity [MW]			Fleet Emissions [kg.CO_2/MWh]	CAPEX [mJPY, 2015]
		OPR	CON	PLN		
Electric Power Development Co., Ltd.	60,352	17,472	1,483	4,339	868	-148,404
Tokyo Electric Power Company	25,360	54,852	1,960	15,047	863	-567,470
Tohoku Electric Power Co. Inc.	36,273	16,045	1,344	1,426	845	-257,649
The Chugoku Electric Power Co.,Inc.	23,106	12,829	84	1,445	898	-170,330
Chubu Electric Power Company,	30,610	30,322	2,599	2,701	869	-260,347
Kyushu Electric Power Company,	17,231	15,525	1,480	700	866	-293,944
Hokuriku Electric Power Company	18,492	6,547	8	873	894	-117,322
Hokkaido Electric Power Co. Inc.	15,868	5,962	400	1,726	871	-121,374
The Kansai Electric Power Company,	5,507	26,328	NA	4,220	806	-415,859
Kobe Steel Ltd.	8,753	2,058	NA	2,900	695	-95,353
NIPPON STEEL & SUMITOMO	6,739	2,623	NA	320	949	-324,074
Sumitomo Corporation	7,994	2,893	38	365	934	-247,965
Shikoku Electric Power Co. Inc.	7,040	4,702	280	500	886	-59,120
Tokuyama Corp.	1,730	883	NA	NA	906	-32,470
The Okinawa Electric Power Company,	4,912	2,369	35	634	867	-23,023
Nippon Paper Industries Co., Ltd.	2,473	1,466	100	513	1,046	-48,692
Tosoh Corporation	3,474	678	NA	NA	932	-34,133
Kashima-Kita Electric Power	789	647	NA	NA	578	NA
Mitsubishi Corporation	1,700	2,168	NA	377	985	-307,539
Oji Holdings Corporation	1,415	705	NA	NA	1,140	-69,890
Taiheiyo Cement Corp.	1,689	704	NA	NA	1,066	-38,402
NC Miike Co., Ltd	1,659	175	NA	NA	995	NA
Mitsui & Co. Ltd.	721	808	NA	623	1,118	-378,374
Osaka Gas Co., Ltd.	870	1,755	110	500	900	-105,082
Tokai Kyodo Hatsuden K.K.	822	149	NA	NA	826	NA
JFE Holdings, Inc.	652	1,247	NA	943	1,140	-220,809
Showa Denko K.K.	438	802	NA	124	1,130	-40,645
Idemitsu Kosan Co. Ltd.	416	303	NA	667	767	-111,698
Itochu Enex Co. Ltd.	344	158	37	NA	862	-14,054
Asahi Kasei Corporation	364	550	NA	120	1,070	-82,990
Chuetsu Pulp & Paper Co., Ltd.	267	50	NA	NA	1,140	-8,177
Toshiba Corporation	279	294	NA	101	1,130	-236,510
Mazda Motor Corporation	206	42	NA	NA	812	-123,370
Teijin Ltd.	25	74	NA	70	386	-26,527
Hokuren Federation of Agricultural	8	26	NA	NA	386	NA
JX Holdings, Inc.	143	76	NA	NA	637	-388,400
Kuraray Co. Ltd.	74	19	NA	NA	1,140	-43,099
Mitsui Matsushima Co., Ltd.	33	9	NA	NA	986	-1,753
Daicel Corporation	33	13	NA	NA	1,140	-29,629
Tokyo Gas Co. Ltd.	1	1,216	204	2,648	403	-180,097
Ube Industries, Ltd.	NA	543	NA	400	NA	-41,961
Marubeni Corporation	NA	309	28	838	NA	-322,419
ORIX Corporation	NA	44	153	519	NA	-716,755
Abl Co.,Ltd.	NA	NA	NA	110	NA	NA
Air Water Inc.	NA	NA	NA	56	NA	-30,055
Chiba Prefecture	NA	NA	NA	500	NA	NA
HIROSHIMA GAS Co.,Ltd.	NA	NA	NA	56	NA	-7,339
Hokuzai Transport Co.,Ltd.	NA	NA	NA	56	NA	NA
New Frontier Capital Management	NA	NA	NA	100	NA	NA
Seika Corporation	NA	NA	NA	NA	NA	-413
Joban Joint Power Co., Ltd.	NA	NA	NA	180	NA	NA
Maeda Corp.	NA	NA	NA	1,100	NA	-7,599
Meiko Trans Co., Ltd.	NA	NA	NA	15	NA	-2,533
Japan Energy Partners*	NA	NA	NA	15	NA	NA
TonenGeneral Sekiyu k.k.	NA	NA	NA	500	NA	-37155

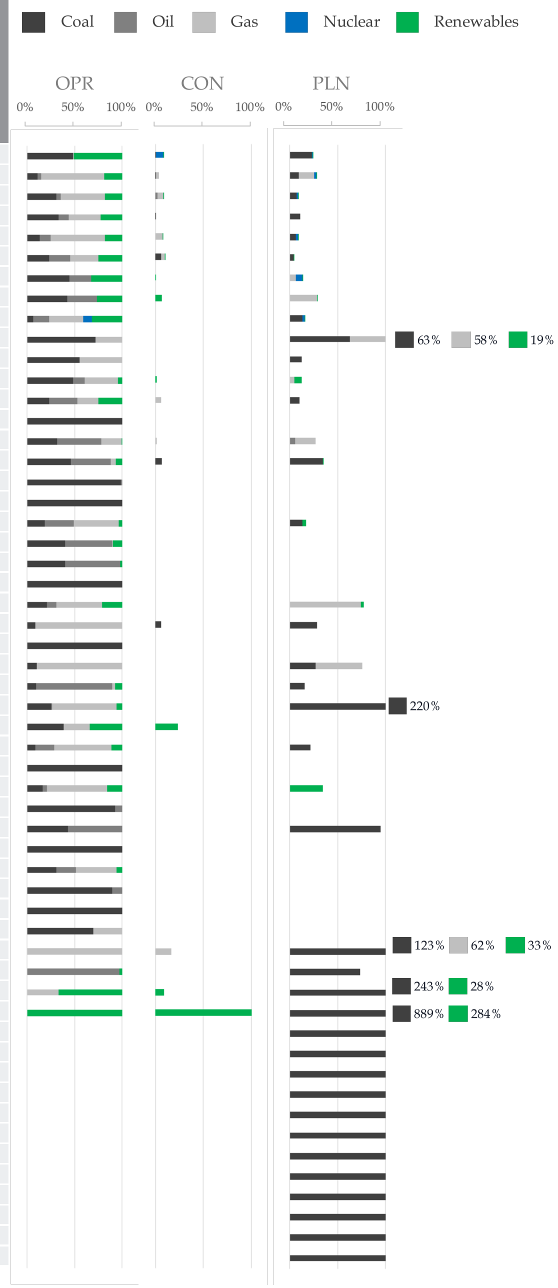

Table 51 aggregates data on the *operating* capacity of all generation and coal generation only across each of our 55 companies. This table is ordered according to total coal generation capacity.

It is interesting to note that even though Tohoku EPC has less coal capacity than TEPCO, it has greater MWh of generation; perhaps replacing greater lost nuclear capacity. Another point that stands out from the data is that a number of steelmakers and conglomerates have coal generation capacity in excess of some regional monopolies.

Table 61: Detailed exposure of 55 companies with operating coal-fired power stations

	All Operating Capacity				Coal Operating Capacity								
	MW	GWh	Avg. CO2 Intensity	Avg. Age	MW Coal	GWh Coal	Avg. Coal CO2 Intensity	Average Age Coal	PM 2.5	Baseline Water Stress	CCS Potential	Heat Stress	Average Potential Nuclear (MW)
J-POWER	17472	72690	423	1983	8414	59943	868	1991	10	0.26	39%	0.89	2483
TOHOKU ELECTRIC POWER CO	16895	67733	530	1987	5751	38147	845	1993	6	0.2	0%	0.8	17263
TOKYO ELECTRIC POWER CO	54002	152098	444	1987	5900	21993	865	2000	7	0.13	0%	0.77	12348
CHUBU ELECTRIC POWER CO INC	30070	110216	463	1988	4100	29129	869	1997	9	0.53	100%	0.84	3617
KYUSHU ELECTRIC POWER CO	15525	56450	453	1987	3646	16532	868	1991	10	0.1	46%	0.81	4699
CHUGOKU ELECTRIC POWER CO	11873	38402	565	1982	3252	19870	881	1989	10	0.2	24%	0.9	820
HOKURIKU ELECTRIC POWER CO	6547	25479	558	1980	2903	18492	894	1992	9	0.41	83%	0.93	0
HOKKAIDO ELECTRIC POWER CO INC	5712	19890	566	1981	2250	14709	873	1984	6	0.27	0%	1.09	2070
NIPPON STEEL & SUMITOMO METAL	3130	13208	864	1991	1950	9859	949	1992	8	0.18	23%	0.69	4491
KANSAI ELECTRIC POWER CO	26328	79345	360	1988	1800	5507	806	2007	8	0.77	100%	0.93	0
KOBE STEEL LTD	2058	9443	761	1999	1475	8753	695	2003	9	0.55	100%	0.84	0
SHIKOKU ELECTRIC POWER CO	4702	12770	540	1979	1106	7040	886	1991	9	0.17	63%	0.88	2022
SUMITOMO CORP	2451	8253	632	1990	888	4874	934	1999	9	0.26	12%	0.84	2898
TOKUYAMA CORP	913	1750	881	1977	883	1730	906	1977	10	1.7	0%	0.87	439
OKINAWA ELECTRIC POWER CO	2369	10424	714	1993	754	4912	867	1999	4	0.42	58%	0.68	0
NIPPON PAPER INDUSTRIES CO LTD	1592	3958	707	1986	680	2473	1046	1983	7	0.41	0%	1	9606
TOSOH CORP	681	3486	923	1989	667	3474	932	1990	10	0.18	72%	0.91	4536
KASHIMA-KITA ELEC POWER CORP	647	789	578	1983	647	789	578	1983	10	0.3	0%	0.88	1100
MITSUBISHI CORP	2251	5553	528	1990	406	1700	985	1994	8	0.21	0%	0.85	7627
OJI PAPER CO LTD	1155	2342	444	1975	283	1415	1140	1973	6	0.13	0%	1.09	2070
TAIHEIYO CEMENT CORP	704	2130	758	1987	281	1689	1066	2003	7	0.05	64%	0.71	7462
MIIKE THERMAL POWER CO	175	1659	995	1975	175	1659	995	1975	12	0.24	0%	0.9	4699
MITSUI & CO LTD	878	1844	493	1987	170	721	1118	1984	12	0.22	0%	0.9	4699
OSAKA GAS CO LTD	1755	9009	446	2006	149	870	900	2000	9	0.53	100%	0.84	3617
TOKAI KYODO ELEC POWER CO	149	822	826	1990	149	822	826	1990	9	0.53	0%	0.93	3617
JFE STEEL CORP	1247	3475	602	1979	124	652	1140	1984	9	0.68	0%	0.88	820
SHOWA DENKO KK	802	1449	652	1970	78	438	1130	1994	10	0.89	0%	0.92	1100
IDEMITSU KOSAN CO LTD	303	1484	415	1992	76	416	767	1989	9	0	0%	0.84	3617
ITOCHU ENEX CO LTD	166	541	416	1996	61	344	862	1995	11	0.15	0%	0.9	820
ASAHI KASEI GROUP	562	1395	603	1976	50	364	1070	2006	10	0.02	100%	0.9	4699
CHUETSU PULP INDUSTRY CO LTD	167	350	450	1990	50	267	1140	1990	9	0.2	0%	0.93	0
TOSHIBA CORP	303	1399	480	1998	48	279	1130	2005	12	0.24	0%	0.9	4699
MAZDA	42	209	801	2001	39	206	812	2002	5	0.54	0%	0.45	820
TEIJIN LTD	115	70	386	2000	32	25	386	2020	10	0.28	0%	0.88	2022
HOKUREN NOKYO RENGOKAI	26	8	386	1999	26	89	386	1999	4	0.03	100%	1.13	2070
NIPPON MINING HOLDINGS CO LTD	77	348	529	1989	24	143	637	1998	9	0.68	0%	0.88	820
KURARAY COMPANY LTD	147	166	278	1971	17	74	1140	1975	9	0.68	0%	0.88	820
MATSUSHIMA COAL MINING CO LTD	9	33	986	1969	9	33	986	1969	12	0	0%	0.9	4699
DAICEL CHEMICAL INDUSTRIES CO	116	134	246	1980	9	33	1140	1986	10	0.23	0%	0.95	17263
TOKYO GAS	1216	5900	409	2011	0	1	403	1983	10	0.39	0%	0.92	1100
Ube Industries	543	559	538	1990	0	0	NA	NA	NA	NA	NA	NA	NA
MARUBENI CORP	309	706	158	2006	0	0	NA	NA	NA	NA	NA	NA	NA
ORIX CORP	44	120	149	2011	0	0	NA	NA	NA	NA	NA	NA	NA
ABL Co Ltd.	0	0	NA	NA	0	0	NA	NA	NA	NA	NA	NA	NA
Air Water Inc.	0	0	NA	NA	0	0	NA	NA	NA	NA	NA	NA	NA
Chiba Prefecture	0	0	NA	NA	0	0	NA	NA	NA	NA	NA	NA	NA
Hiroshima Gas	0	0	NA	NA	0	0	NA	NA	NA	NA	NA	NA	NA
Hokuzai Transport	0	0	NA	NA	0	0	NA	NA	NA	NA	NA	NA	NA
IDI infrastructures F-Power	0	0	NA	NA	0	0	NA	NA	NA	NA	NA	NA	NA
Japan Energy Partners	0	0	NA	NA	0	0	NA	NA	NA	NA	NA	NA	NA
Joban Joint Power Co	0	0	NA	NA	0	0	NA	NA	NA	NA	NA	NA	NA
Maeda Corporation	0	0	NA	NA	0	0	NA	NA	NA	NA	NA	NA	NA
Meiko Trans	0	0	NA	NA	0	0	NA	NA	NA	NA	NA	NA	NA
Seika Corporation	0	0	NA	NA	0	0	NA	NA	NA	NA	NA	NA	NA
Tonen General Sekiyu	0	0	NA	NA	0	0	NA	NA	NA	NA	NA	NA	NA

Values for Average CO2 Intensity, Average Age, PM 2.5, Baseline Water Stress, CCS Potential, Heat Stress, and Average Potential Nuclear are weighted according to the MW capacity of each constituent plant.
Joint ownership of plants is taken into account by fractional attribution of MW capacity according to ownership percentages.

Table 52 below examines the *planned* capacity of all generation and coal generation only across each of our 55 companies. This table is also ordered according to total coal generation capacity. As in the previous table detailing operating plants, a number of industrial companies in Table also have greater *planned* coal-fired capacity than some regional monopolies. Also of note is that fact that the utility with the second biggest planned coal capacities (J-Power at 4,020 MW) also has the second smallest Average Potential Nuclear capacity risks at only 702 MW. Perhaps unsurprisingly, the regional monopolists in the areas of Tokyo and Kansai which are expecting to see some of the most robust electricity demand growth also have the highest and third highest planned coal capacities (5,682 MW and 3,462 MW).

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Table 62: Detailed exposure of 55 companies with planned coal-fired power generation

	All Planned Capacity				Coal Planned Capacity								
	MW	GWh	Average CO2 Intensity	Average Age	MW Coal	GWh Coal	Average Coal CO2 Intensity	Average Age Coal	PM 2.5	Baseline Water Stress	CCS Potential (Fraction)	Heat Stress	Average Potential Nuclear (MW)
TOKYO ELECTRIC POWER CO	14722	54169	505	2015	5357	25840	798	2021	6	0.25	26%	0.64	8936
J-POWER	4339	12061	738	2020	4020	11004	796	2021	6	0.29	67%	0.54	702
KANSAI ELECTRIC POWER CO	4220	11757	659	2019	3462	9443	803	2024	6	0.2	53%	0.55	4276
CHUBU ELECTRIC POWER CO INC	2701	7905	563	2018	2355	5959	785	2026	7	0.3	71%	0.67	7619
TOKYO GAS	2648	7241	616	2019	1500	4116	859	2020	4	0.13	44%	0.33	1100
CHUGOKU ELECTRIC POWER CO	1445	3953	781	2022	1445	3953	781	2022	6	0.13	73%	0.58	885
KOBE STEEL LTD	2900	6639	579	2020	1300	3559	872	2022	9	0.55	100%	0.84	0
Maeda Corporation	1100	3005	839	2023	1100	3005	839	2023	8	0.24	0%	0.94	17263
MARUBENI CORP	838	2209	719	2024	750	2044	804	2024	5	0.08	87%	0.49	15108
KYUSHU ELECTRIC POWER CO	700	1912	865	2020	667	1829	900	2020	4	0.12	100%	0.29	1100
IDEMITSU KOSAN CO LTD	667	1829	900	2020	667	1829	900	2020	4	0.12	100%	0.29	1100
TOHOKU ELECTRIC POWER CO	826	3091	649	2018	600	2395	781	2022	9	0.26	50%	0.96	17263
NIPPON PAPER INDUSTRIES CO LTD	513	1409	857	2017	508	1400	865	2017	7	0.91	22%	0.94	14577
SHIKOKU ELECTRIC POWER CO	500	2894	936	2022	500	2894	936	2022	9	0	0%	0.88	2022
OSAKA GAS CO LTD	500	1366	877	2023	500	1366	877	2023	4	0.08	0%	0.35	876
Tonen General Sekiyu	500	1361	807	2025	500	1361	807	2025	6	0.17	0%	0.44	1100
Chiba Prefecture	500	1339	743	2035	500	1339	743	2035	6	0.17	0%	0.44	1100
Ube Industries	400	1091	872	2024	400	1091	872	2024	4	0.05	0%	0.3	820
ORIX CORP	519	1384	495	2017	390	1074	659	2018	8	0.08	0%	0.81	11851
JFE STEEL CORP	943	2223	548	2025	333	915	807	2020	4	0.12	0%	0.29	1100
NIPPON STEEL & SUMITOMO METAL	320	878	767	2020	320	878	767	2020	5	0.15	0%	0.44	1100
MITSUBISHI CORP	377	963	564	2021	292	801	727	2020	4	0.07	0%	0.39	12029
Joban Joint Power Co	180	493	652	2021	180	493	652	2021	3	0.05	0%	0.29	17263
SHOWA DENKO KK	124	342	786	2017	124	342	786	2017	10	0.89	100%	0.92	1100
ASAHI KASEI GROUP	120	530	930	2018	120	530	930	2018	10	0.1	100%	0.9	4699
ABL Co Ltd.	110	303	800	2018	110	303	800	2018	7	0.15	0%	0.88	17263
IDI infrastructures F-Power	100	275	849	2019	100	275	849	2019	4	0.07	100%	1.13	2070
TEIJIN LTD	70	193	790	2017	70	193	790	2017	10	0.28	0%	0.88	2022
Hokuzai Transport	56	154	610	2017	56	154	610	2017	6	0	0%	0.45	4699
Air Water Inc.	56	154	900	2018	56	154	900	2018	5	0.08	100%	0.45	820
Hiroshima Gas	56	154	849	2019	56	154	849	2019	5	0.19	0%	0.44	820
Meiko Trans	15	42	794	2018	15	42	794	2018	4	0	100%	0.42	3617
Seika Corporation	15	42	794	2018	15	42	794	2018	4	0	100%	0.42	3617
Japan Energy Partners	0	0	794	2018	0	0	794	2018	0	0	100%	0	3617
HOKKAIDO ELECTRIC POWER CO INC	1,726	2,246	447	2023	NA	NA	NA	NA	N	NA	NA	NA	NA
HOKURIKU ELECTRIC POWER CO	873	2,255	224	2007	NA	NA	NA	NA	N	NA	NA	NA	NA
OKINAWA ELECTRIC POWER CO	634	1,150	504	2018	NA	NA	NA	NA	N	NA	NA	NA	NA
MITSUI & CO LTD	623	1,241	438	2020	NA	NA	NA	NA	N	NA	NA	NA	NA
SUMITOMO CORP	365	707	191	2019	NA	NA	NA	NA	N	NA	NA	NA	NA
TOSHIBA CORP	101	243	0	2015	NA	NA	NA	NA	N	NA	NA	NA	NA
CHUETSU PULP INDUSTRY CO LTD	NA	NA	NA	NA	NA	NA	NA	NA	N	NA	NA	NA	NA
DAICEL CHEMICAL INDUSTRIES CO	NA	NA	NA	NA	NA	NA	NA	NA	N	NA	NA	NA	NA
HOKUREN NOKYO RENGOKAI	NA	NA	NA	NA	NA	NA	NA	NA	N	NA	NA	NA	NA
ITOCHU ENEX CO LTD	NA	NA	NA	NA	NA	NA	NA	NA	N	NA	NA	NA	NA
KASHIMA-KITA ELEC POWER CORP	NA	NA	NA	NA	NA	NA	NA	NA	N	NA	NA	NA	NA
KURARAY COMPANY LTD	NA	NA	NA	NA	NA	NA	NA	NA	N	NA	NA	NA	NA
MATSUSHIMA COAL MINING CO LTD	NA	NA	NA	NA	NA	NA	NA	NA	N	NA	NA	NA	NA
MAZDA	NA	NA	NA	NA	NA	NA	NA	NA	N	NA	NA	NA	NA
MIIKE THERMAL POWER CO	NA	NA	NA	NA	NA	NA	NA	NA	N	NA	NA	NA	NA
NIPPON MINING HOLDINGS CO LTD	NA	NA	NA	NA	NA	NA	NA	NA	N	NA	NA	NA	NA
OJI PAPER CO LTD	NA	NA	NA	NA	NA	NA	NA	NA	N	NA	NA	NA	NA
TAIHEIYO CEMENT CORP	NA	NA	NA	NA	NA	NA	NA	NA	N	NA	NA	NA	NA
TOKAI KYODO ELEC POWER CO	NA	NA	NA	NA	NA	NA	NA	NA	N	NA	NA	NA	NA
TOKUYAMA CORP	NA	NA	NA	NA	NA	NA	NA	NA	N	NA	NA	NA	NA
TOSOH CORP	NA	NA	NA	NA	NA	NA	NA	NA	N	NA	NA	NA	NA

Values for Average CO2 Intensity, Average Age, PM 2.5, Baseline Water Stress, CCS Potential, Heat Stress, and Average Potential Nuclear are weighted according to the MW capacity of each constituent plant.
Joint ownership of plants is taken into account by fractional attribution of MW capacity according to ownership percentages

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