November 2021
Energy Insight: 104

Energy transition in Japan and implications for gas

1. Introduction

2020 is likely to be remembered as the year when the COVID-19 pandemic swept the world. It is also likely to be seen as the year when global interest in the "Climate Emergency" started to accelerate. Prior to 2020, interest in decarbonising the energy system had largely been focussed in European countries and more specifically in affluent Western European ones. 2020, however, saw pledges to achieve Net Zero from several countries, including China (by 2060), Japan and South Korea (both by 2050). In the United States, the election of President Biden in late 2020 set the scene for their Net Zero pledge and a much more active role of the US in driving global climate ambitions, which has already started to be seen in 2021.

In the case of Japan, on 26 October 2020, Prime Minister Suga announced the Net Zero target in his first speech to both houses of the Diet (Parliament) since becoming leader.[1] This initial declaration of intent was then followed up with a more detailed "Green Growth Strategy" document published by the Ministry of Economy Trade and Industry (METI) on 25 December 2020.[2] In April 2021, Prime Minister Suga made the shorter term ambition more specific by setting a target to reduce greenhouse gas (GHG) emissions by 46 per cent by 2030, compared with 2013 levels. The previous 2030 commitment had been a reduction of 26 per cent.[3] METI published an initial draft of its 6th Basic Energy Plan in July 2021, aiming to be consistent with the target 46 per cent reduction by 2030.[4] This plan was approved by Cabinet with only minor changes in October 2021.[5]

The Net Zero by 2050 pledge brings Japan into line with similar pledges made by the European Union, several of its member states and the United Kingdom, among others, but it should be recognised that the scale of the ambition is significantly greater for Japan than many other countries. In 2018 (the latest year for which fully consistent data is available) Japan's GHG emissions were assessed at 1,238 million tonnes CO_{2e}, only slightly lower than 1,270 million tonnes CO_{2e} in 1990. By contrast EU emissions in 2018 were 4,226 mt CO_{2e}, a 25 per cent drop from the 5652 mt CO_{2e} in 1990, while UK emissions had fallen by 46 per cent over the same period.[6] A related challenge for Japan is around public acceptance, and the extent to which society supports the need to move towards Net Zero with the associated lifestyle changes and additional costs which are required. Since the policy is relatively new, it may take some

[1] https://asia.nikkei.com/Politics/Suga-vows-to-meet-Japan-s-zero-emissions-goal-by-2050
[2] https://www.meti.go.jp/english/press/2020/pdf/1225_001b.pdf
[3] https://english.kyodonews.net/news/2021/04/21d433ecc75c-japan-set-to-decide-more-ambitious-2030-emissions-reduction-target.html
[4] https://www.reuters.com/business/energy/japan-boosts-renewable-energy-target-2030-energy-mix-2021-07-21/
[5] https://www.meti.go.jp/english/press/2021/1022_002.html
[6] https://climateactiontracker.org/

Martin Lambert, Senior Research Fellow, OIES

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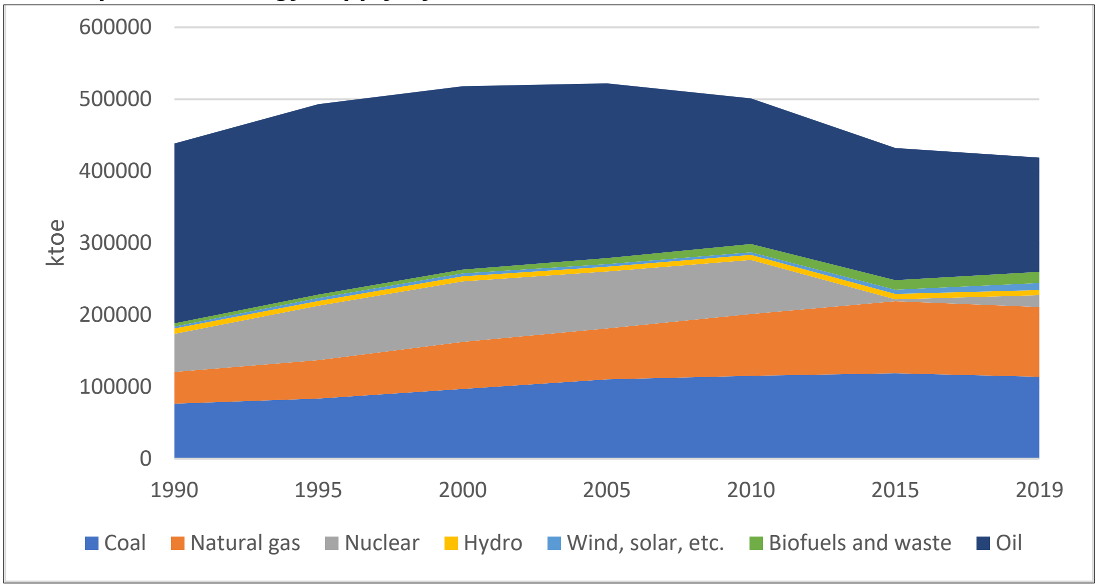
time for wider society to come to terms, with and buy into, its wider implications. The recent announcement (September 2021) of Prime Minister Suga's resignation[7] and the forthcoming election may give some indication of the level of public support for the decarbonisation drive.

This Insight will examine, in more detail, the challenges for Japan to achieve Net Zero, and considers some potential pathways which could be taken. The actual choice of pathway (which is likely to differ from the scenarios presented here) will be strongly influenced by government policy, public opinion and consumer acceptance. The Insight focusses particularly on the power generation sector as this is the largest source of emissions, the sector best able to take rapid action to reduce carbon emissions and the most important sector for LNG imports into Japan.

2. Current energy situation in Japan

As shown in Figure 1, Japan's energy mix was significantly affected by the closure of nearly all of its nuclear power plants since the Fukushima accident in the wake of the 2011 earthquake and tsunami. With a lack of indigenous energy resources, Japan has therefore been reliant on a large share of imported fossil fuels, balanced between coal, gas and oil. In 2019, Japan produced just 15 per cent of its total primary energy supply (TPES) domestically, and fossil fuels accounted for 88 per cent of TPES, the sixth highest globally in an IEA comparison.[8]

Figure 1: Japan total energy supply by source 1990–2019



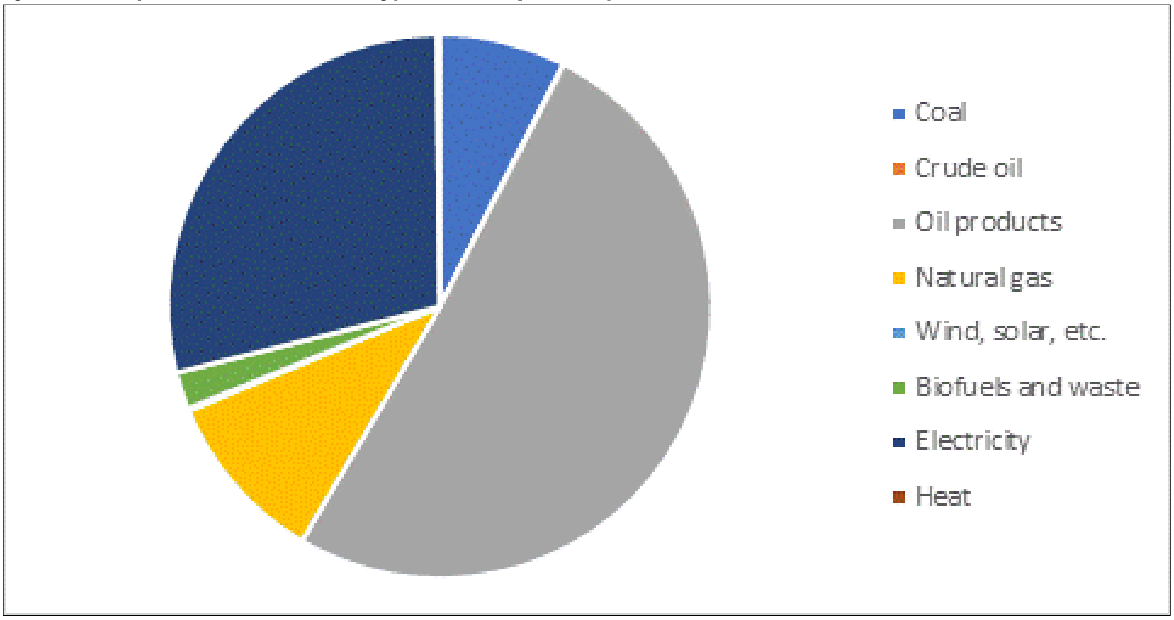
Source: OIES analysis of IEA data

In terms of final energy consumption, as shown in Figure 2, oil products at 51 per cent has a relatively high share (compared to around 41 per cent share global average).[9] On the other hand, electricity also has a relatively high share at 29 per cent of final consumption in Japan, compared with the global average around 20 per cent. While the high share of oil products increases the challenge of decarbonisation, the high share of electricity provides a relative advantage for Japan, since it is

[7] https://theconversation.com/japan-why-pm-suga-unexpectedly-stepped-down-and-what-happens-next-167300
[8] IEA Japan Energy Policy Review (2021): https://iea.blob.core.windows.net/assets/3470b395-cfdd-44a9-9184-0537cf069c3d/Japan2021_EnergyPolicyReview.pdf
[9] https://www.iea.org/data-and-statistics/charts/global-share-of-total-final-consumption-by-source-2018

generally accepted that decarbonisation will increase the share of electrification, perhaps to around 50 per cent of total final consumption.[10]

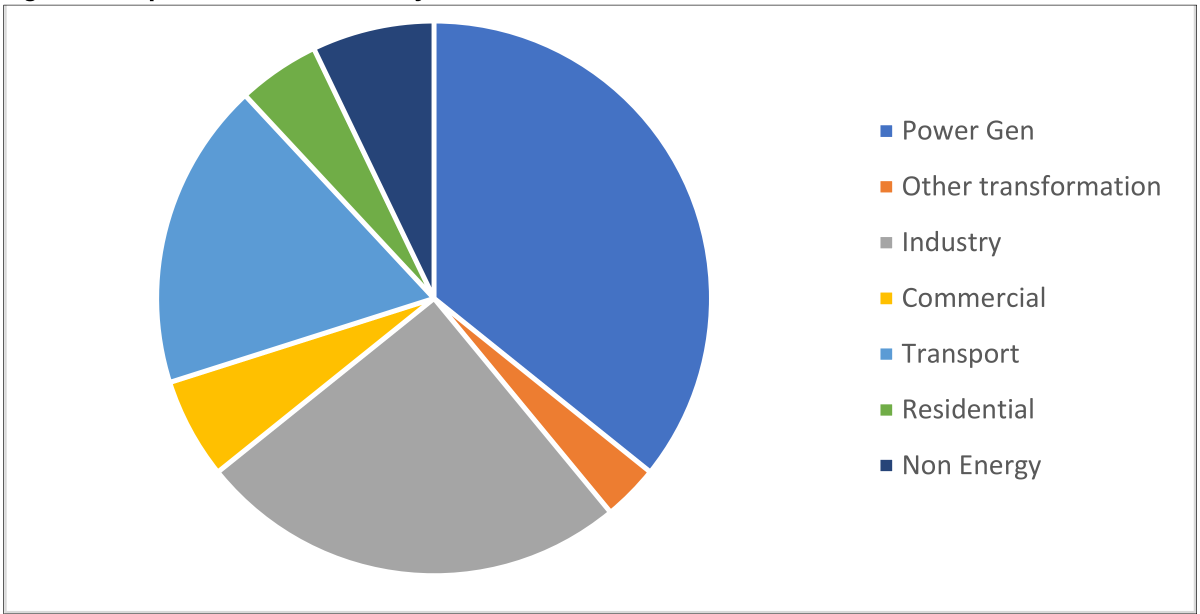
Figure 2: Japan 2018 final energy consumption by source



Source: OIES analysis of IEA data

Power generation produced 35 per cent of total Japan GHG emissions (including non-energy) in 2019 (396 million tonnes CO_{2eq} out of a total of 1107 million tonnes CO_{2eq}),[11] as shown in Figure 3.

Figure 3: Japan CO_2 emissions by sector 2019



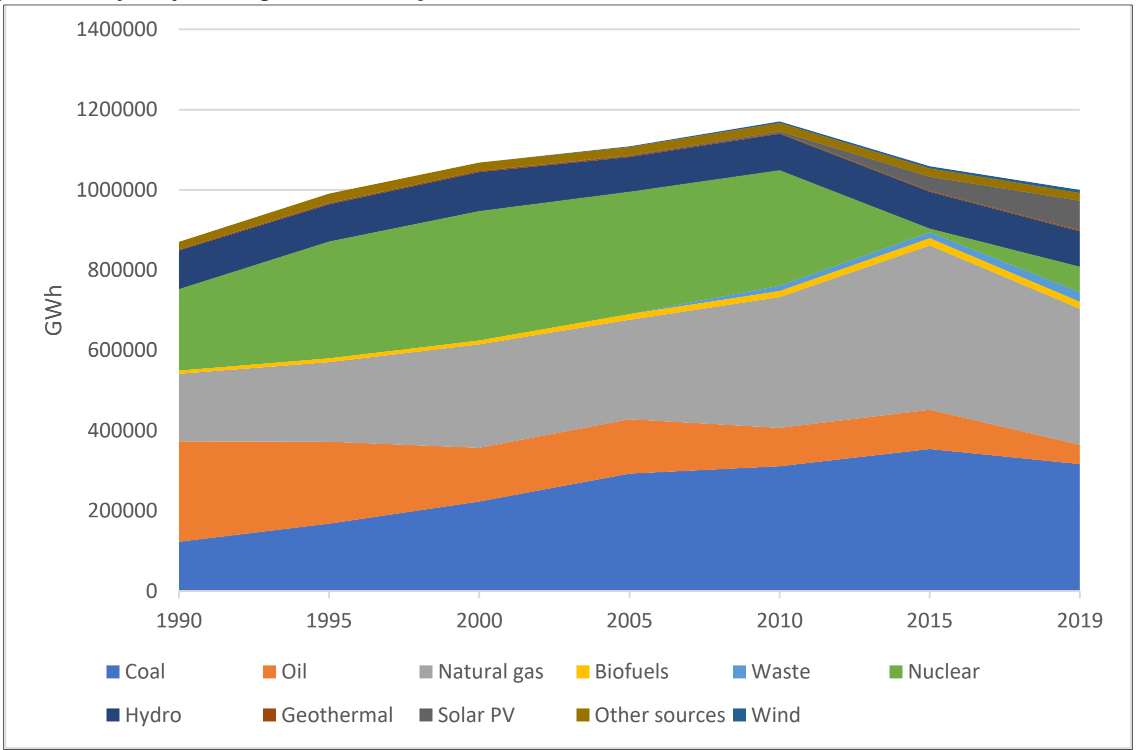
Source: OIES analysis of Japan Center for Climate Change Action data

[10] See, for example, IEA (2021): A Global pathway to net-zero CO2 emissions in 2050, p61 https://www.iea.org/reports/net-zero-by-2050
[11] OIES analysis of Japan Center for Climate Change Action data

In a global ranking, Japan's CO_2 intensity of power and heat generation in 2019 ranks third highest (after Australia and Poland) among IEA countries at around 500 g CO_2/kWh.[12] This high ranking is at least partly related to the lack of nuclear power generation post-Fukushima, as well as the continued significant use of coal-fired (31 per cent of total) generation, and to a lesser extent gas-fired (34 per cent) power generation and a relatively small share of intermittent renewables (7 per cent solar and less than 1 per cent wind). The power generation mix by source is illustrated in Figure 4.

It may be thought surprising that Japan has significantly expanded the share of coal in the power generation mix, and indeed there are still several coal-fired plants with a total capacity in excess of 1,800MW under construction.[13] However, Japan's energy policy has been driven by the principle of "3Es plus S" (Energy Security, Economic Efficiency, Environmental Sustainability, plus Safety), and in particular the desire for energy security has led to a preference to avoid undue reliance on any one source of power generation. Nuclear power had been an important component of meeting the Energy Security criterion, and when that was no longer available a diversified energy mix including coal went at least some way to providing some energy security. However, following Prime Minister Suga's "Net Zero" announcement, it does now appear that all coal-fired power plant projects which were still under development prior to Final Investment Decision have now been abandoned.[14]

Figure 4: Japan power generation by source 1990–2019



Source OIES analysis of IEA data

Table 1 gives an analysis, based on 2019 data, of the split of total power generation (GWh) and installed capacity (GW) by fuel type.[15] While nuclear capacity is shown as 33.2 GW, this includes all plants which are potentially available to operate, but only around 9GW of nuclear capacity had been fully approved by national and local authorities and was able to operate. While the percentage utilisation for nuclear is shown as only 23.7 per cent this is based on the total capacity of 33.2GW. The utilisation of

[12] IEA Japan Energy Policy Review (2021), p.46
[13] https://nocoaljapan.org/the-problem/coal-expansion-in-japan/
[14] https://www.bloomberg.com/news/articles/2021-04-27/japan-s-coal-pipeline-is-bare-after-last-planned-project-axed
[15] Data derived from METI: https://www.meti.go.jp/shingikai/enecho/denryoku_gas/denryoku_gas/pdf/030_06_00.pdf

those plants actually in operation was around 90 per cent. The large (27GW) capacity of pumped hydro is also notable, but this capacity was designed to complement nuclear power, able to pump water uphill on those occasions when nuclear generation exceeded immediate demand. With limited nuclear generation, this pumped storage capacity has not been fully utilised. Subject to appropriate transmission infrastructure, this storage capacity may be a useful asset to complement increasing generation from intermittent renewables. It is also notable that coal and LNG together provided nearly 70 per cent of total generation. While LNG operated at 56 per cent utilisation, coal operated at 76 per cent utilisation, presumably on account of lower fuel costs for coal, but suggesting some scope for reducing emissions in the short term by increasing LNG and reducing coal. For example, if the LNG plants were to operate at 75 per cent utilisation, coal would only have needed to generate 164 TWh rather than the 305 TWh actually generated. At assumed CO_2 emissions of 1,000 g/kWh for coal and 500 g/kWh for gas[16] this switch could have reduced emissions by around 70 million tonnes per year or 7 per cent of Japan's total emissions, although with coal prices lower than those of LNG the total cost would have been higher.

Table 1: Japan power generation and capacity mix 2019

2019 data	Generation (GWh)	% total generation	Capacity (GW)	% of total capacity	% utilisation (capacity factor)
Hydro (run of river)	86327	8.4	21.8	7.1	45.3
Hydro (pump storage)	7194	0.7	27.6	9.0	3.0
Coal	305227	29.7	46.0	15.0	75.7
LNG	409025	39.8	83.7	27.3	55.8
Oil	31858	3.1	29.7	9.7	12.2
Nuclear	68856	6.7	33.2	10.8	23.7
Renewables	106880	10.4	64.7	21.1	18.9
Total	**1027700**		**306.7**		

Source OIES analysis of METI data

Japan's peak electricity demand is around 156 GW[17] which, with total capacity of 306GW as shown in Table 1 could be assumed to indicate considerable spare capacity. In reality, however, this is not the case, partly on account of the limited availability of nuclear capacity, but also on account of constraints on transmission infrastructure such that the available capacity is not adequately linked to the high demand areas.

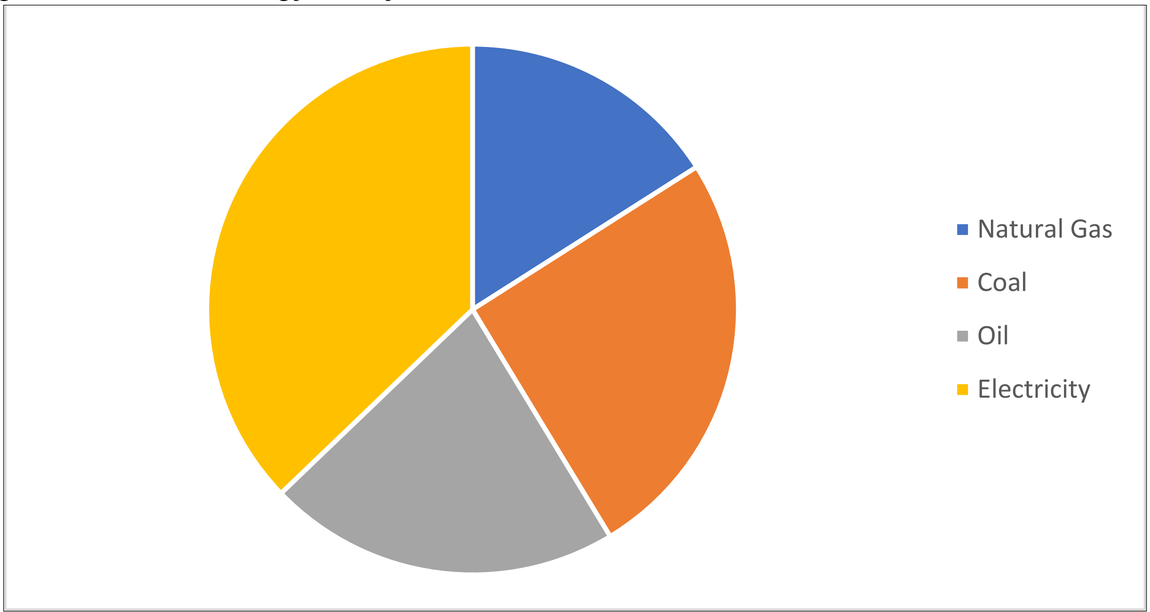
As shown in Figure 5, electricity already has a significant 37 per cent share of energy use in the industrial sector, with coal in second place with a 25 per cent share. Natural gas has the smallest share with just 16 per cent.

Japan's total natural gas consumption, nearly all from imported LNG, totalled 108 billion cubic metres,[18] of which 66 per cent was consumed in power generation, with the remainder being fairly evenly distributed between industrial (12 per cent), commercial (9 per cent) and residential (9 per cent) use as city gas. Since the power generation sector is, by a considerable margin, the most important sector for natural gas (and hence LNG) consumption, most of this paper will concentrate on the possible decarbonisation scenarios for the power sector. In the commercial and residential sectors it is likely that use of gas will decline, perhaps quite significantly, and be replaced by further electrification. In a Net Zero world, there is no role for unabated fossil gas, and since it is unrealistic to assume deployment

[16] Based on https://www.volker-quaschning.de/datserv/CO2-spez/index_e.php . Note that depending on methane emissions from both coal and gas supply chains the comparison could be less favourable for gas.
[17] JEPIC: The electric power industry in Japan (2020 edition) https://www.jepic.or.jp/pub/pdf/epijJepic2020.pdf
[18] 2018 data, IEA Japan 2021 Energy Policy Review

of carbon capture and storage in the residential sector, any remaining use of gas would need to be low carbon gases such as biomethane or perhaps hydrogen. Use of hydrogen in the residential sector would require considerable investment in conversion of the distribution network and end user equipment so is unlikely to be economically feasible. Since much of the residential sector in Japan has both heating and cooling demand the use of heat pumps to provide both heating and cooling is already well developed [19] and likely to grow further. The industrial sector is more complex with multiple decarbonisation options depending on the particular industrial process. While some further electrification is likely (for example for low temperature heat), alternative routes, perhaps including low-carbon hydrogen (for example for high temperature heat and steel-making) and carbon capture and storage are also likely to play a role, although the timing of such changes remains uncertain. In all sectors, government policy will be an important determining factor for the course of the energy transition.

Figure 5: Industrial energy use by source 2018



Source: Author's analysis of IEA data

3. Potential pathways to Net Zero for Japan

This section considers the various levers potentially available for Japan to use on a pathway to Net Zero, and then develops some scenarios, focussing mainly on the power generation sector (as the largest source of CO_2 emissions and the most relevant for consideration of the impact on LNG) for contributing to the target 46 per cent reduction in CO_2 emissions by 2030.

3.1 Nuclear power

In the short term, any effort to reduce CO_2 emissions from Japan's power generation would benefit from making maximum use of the existing nuclear power fleet. Ideally, purely from a CO_2 emission perspective, all of the 33 GW of nuclear capacity (as shown in Table 1) would be restarted as quickly as possible. However, out of a total of 36 reactors available to operate, only 10 have restarted, 5 are "preparing for restart" (subject to local safety approvals), 12 are under review and 9 have not filed applications. [20] Thus, progress has been very slow in reactors completing all of the complex process

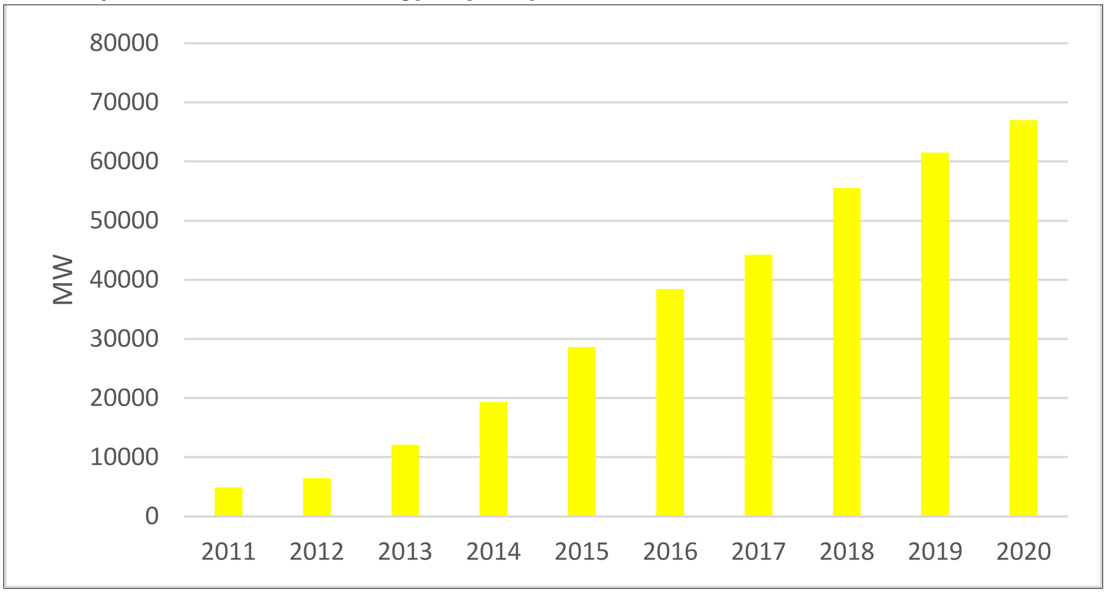
[19] https://heatpumpingtechnologies.org/publications/market-report-japan/
[20] JEPIC: The electric power industry in Japan (2020 edition p.13.

to restart. The extent to which further increases in operational nuclear capacity will be achieved therefore remains highly uncertain.

3.2 Solar power

As shown in Figure 6, Japan has increased solar capacity significantly in the last 10 years, with 2020 capacity of around 67GW, having been increasing at approximately 5GW per year.[21]

Figure 6: Japan installed solar energy capacity 2011–2020



Source: IRENA.Renewable Capacity Statistics 2021

The rapid rise in solar PV generation has been supported by a generous feed-in tariff (FIT) which started in 2012 at JPY 40/kWh (approx. 0.4 USD/kWh) and was gradually reduced to JPY 12-13/ kWh by 2020.[22]

Total generation from solar in 2020 was around 100 TWh, implying a capacity factor around 18 per cent, or around 1,500 full load hours per year. According to a study from the Japan Ministry of Environment, the total solar energy potential is assessed at around 500 TWh.[23] Despite the historic trend of adding around 5GW capacity per year (which would lead to around 120 GW by 2030) and the bullish assessment of total solar potential, the current plans of the regional electricity companies in Japan only indicate growth to around 80GW capacity by 2030.[24] It is likely that further government policy incentives could drive more rapid uptake of solar generation.

3.3 Wind power

By contrast to the rapid growth in solar generation, there has been relatively little investment in wind power, which has grown from 2.4 GW capacity in 2011 to just 4.2 GW by 2020.[25] Since 2012 there has been a feed-in tariff around 20 JPY/kWh for onshore wind, and since 2015 at a level around 35 JPY/kWh for offshore wind, but this does not appear to have been sufficient to stimulate significant investment. The higher cost of wind power compared to solar appears to have discouraged investment,

[21] IRENA.Renewable Capacity Statistics 2021: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Apr/IRENA_RE_Capacity_Statistics_2021.pdf
[22] IEA Japan Energy Policy Review (2021), p.98
[23] http://www.renewable-energy-potential.env.go.jp/RenewableEnergy/doc/gaiyou3.pdf p. 3
[24] https://www.occto.or.jp/kyoukei/torimatome/files/210331_kyokei_torimatome.pdf p.31
[25] IRENA.Renewable Capacity Statistics 2021: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Apr/IRENA_RE_Capacity_Statistics_2021.pdf

but this view perhaps overlooked the beneficial system impact of wind power being available for more annual full load hours than solar, as well as providing generation when solar power is not available.

In addition, prolonged environmental impact assessments and local opposition have limited the progress of wind projects (particularly for offshore wind). There have, however, been recent positive developments to stimulate investment in offshore wind. For example, the Offshore Wind Promotion Law (Law No 89 of 2018) came into force in April 2019. Later in 2019, government published guidelines for an offshore wind auction process and selected eleven sea areas as potential zones for offshore wind projects.[26] Construction started in 2020 on the 139MW Akita Noshiro offshore wind project under a 20 year power purchase agreement with Tohoku Electric.[27] In June 2021, METI announced that a consortium led by Toda Corporation had won the first offshore wind auction to build a 16.8 MW (so still relatively small) floating wind project offshore Goto City in Nagasaki Prefecture.[28]

According to a study from the Japan Ministry of Environment, there is offshore wind potential of 1,500 TWh (equivalent to a capacity of 375 GW capacity at 4,000 operating hours per year), plus a further 450 TWh potential for onshore wind.[29] Despite this very large potential there remain significant challenges to developing offshore wind projects in Japan, notably from challenging water depths and fishing rights, as local fishery cooperatives have the formal right to manage the coastal areas under the system of common fishery rights.[30]

3.4 Geothermal energy

Japan is estimated to rank third in geothermal resources globally, with 23 GW (after USA with 30GW and Indonesia with 28GW), but only has around 500MW of geothermal power plants in operation.[31] Assuming 6,000 operating hours per year, this would generate around 3,000 GWh of electricity. In addition, 30,000 TJ/year (a rather small 110 MWh) of geothermal heat is used directly (the vast majority for bathing and swimming in many Japanese “onsen” or spas).[32]

Thus Japan has considerable potential to increase use of geothermal energy for power generation and potentially for space heating. If installed power generation capacity were around 15 per cent of theoretically available resources (as in, for example US or Iceland), capacity could be 6 times higher than currently, around 3GW, potentially generating 18 TWh per year. This would be only around 2 per cent of total current electricity demand, but with the advantage (unlike wind and solar) of being a dispatchable form of power generation. It may also be possible to raise the ambition further. In the Philippines, with a total estimated geothermal capacity of 6GW, installed capacity is nearly 2GW, or 1/3 of the theoretical maximum.

3.5 Carbon capture and storage

Many studies of potential pathways to Net Zero globally put a strong reliance on significantly increased use of carbon capture and storage (CCS). For example, the IEA’s landmark report on Net Zero by 2050 envisages total global CO_2 capture of 1,670 million tonnes per year by 2030 and 7,600 million tonnes per year by 2050.[33] This already sounds very ambitious compared to the 40 million tonnes captured globally in 2020, but the report points out that their 2050 target is considerably lower than the median of 15,000 million tonnes per year CO_2 capture envisaged by reports reviewed by the IPCC.[34]

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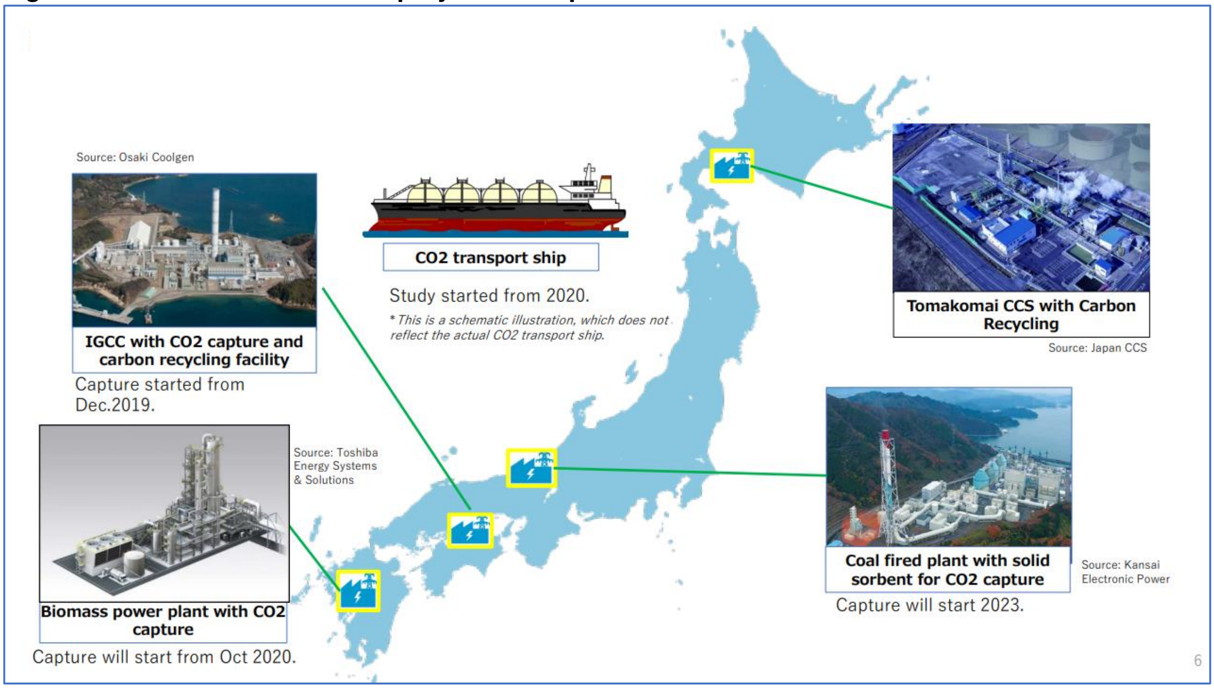
[26] https://cms.law/en/int/expert-guides/cms-expert-guide-to-renewable-energy/japan
[27] https://aow.co.jp/en/
[28] https://www.offshorewind.biz/2021/06/14/japan-selects-winner-of-first-offshore-wind-auction/
[29] http://www.renewable-energy-potential.env.go.jp/RenewableEnergy/doc/gaiyou3.pdf p. 3
[30] https://www.un.org/Depts/los/consultative_process/icp13_presentations-abstracts/2012_icp_abstract_matsuura.pdf . See also https://www.oecd.org/japan/2507622.pdf
[31] http://www.jogmec.go.jp/english/geothermal/geothermal_10_000005.html
[32] https://grsj.gr.jp/english/gej/?l=en_US
[33] https://www.iea.org/reports/net-zero-by-2050 Table 2.9, p. 80
[34] https://www.iea.org/reports/net-zero-by-2050 Figure 2.11, p. 63.

For Japan, at first glance, it may be thought difficult to implement secure storage of CO_2 on account of the high incidence of significant earthquakes. However, there does not appear to be scientific evidence to support this assumption. Indeed, considerable research has been carried out regarding CCS in Japan, including a 3-year demonstration project at Tomakomai in the northern island of Hokkaido. This project injected 100,000 tonnes CO_2 per year into underground reservoirs between 2016 and 2019, and is now being monitored to check that the CO_2 remains safely stored.[35]

For Japan as a whole, it has been estimated that there is a CO_2 storage potential of 146 billion tonnes (equivalent to over 100 years of the country's current annual CO_2 emissions) in water depths of less than 200m around the coast.[36] Building on that theoretical potential, several sites have been covered by various levels of seismic survey, including 3 significant locations each with 1-5 billion tonnes storage potential already appraised with 3D seismic.[37] However, it will also be necessary to build the necessary infrastructure to capture the CO_2 and transport it (potentially by long distance pipelines) to the storage locations.

In addition to the Tomakomai project, several other carbon capture projects are being investigated around Japan, as shown in Figure 7 (including CO2 utilisation, hence CCUS). As shown in the figure, in addition to CO_2 storage around the coast of Japan, consideration is also being given to potential export of CO_2 by ship for storage overseas, potentially in locations such as Australia or the Middle East.

Figure 7: CCUS demonstration projects in Japan



Source: METI (Sept 2020)

It is important to recognise, however, that there are likely to be long lead-times for development of CCS projects. This is true anywhere in the world, but particularly in Japan with the need to convince local stakeholders about the safety of proposed projects, particularly in view of the prevalence of earthquakes. It is notable that the company developing the Tomakomai demonstration project was formed in 2008, with surveys conducted between 2008 and 2011, design and construction of facilities

[35] https://www.meti.go.jp/english/press/2020/pdf/0515_004a.pdf
[36] http://www.env.go.jp/earth/ccs/ccus-kaigi/2-1_CCUS_storage.pdf p.4
[37] METI (Sept 2020) https://www.japanccs.com/wp/wp-content/uploads/2020/09/CCUS-in-Japan-Present-and-future_Yukihiro-Kawaguchi.pdf

between 2012 and 2015 before injection started in 2016.[38] However, it remains to be tested whether local opposition to CCS will be greater or less than the opposition to nuclear restarts.

3.6 Possible future scenarios

To explore possible future energy mixes, we developed two scenarios, “Rapid Renewables” (RR) and “Nuclear Rebirth” (NR), focussing on the power generation mixes for 2030 and 2040. In July 2021, METI released a draft of its 6th Basic Energy Plan, with its main focus on seeking to achieve the government’s target of 46 per cent reduction in CO_2 emissions by 2030.[39] This plan was then approved by Cabinet with only minor changes on 21st October 2021.[40] The two OIES scenarios were felt to cover the key features of two contrasting approaches by which Japan may be able to achieve deep decarbonisation approximately consistent with a 46 per cent reduction by 2030, as a stepping stone towards Net Zero by 2050. The main alternative could have involved much greater reliance on carbon capture and storage but, until there is more evidence of large scale CCS projects progressing in Japan, this was not felt plausible to be explored in detail. The following sections describe the key features of the OIES scenarios and the METI plan before comparing them and discussing the implications. Table 2 compares the assumed GW capacities in the two OIES scenarios and compares this with the METI plan, while Figure 8 shows the corresponding total GWh generation per year.

Table 2: Power Generation Capacity (GW) by OIES scenario and in METI plan

Capacity (GW)	2019	Rapid Renewables		Nuclear Rebirth		METI 6th BEP
		2030	2040	2030	2040	2030
Hydro	50	50	50	50	50	50
Solar	60	120	170	100	135	115
Wind	4	50	100	30	60	23
Biomass	2.2	5	10	5	10	10
Geothermal	0.5	5	10	5	10	2
Nuclear	9	10	10	30	50	27
Oil	30	20	10	20	10	20
Coal	46	23	10	23	5	27
LNG	84	84	60	84	50	60

Source: Author's analysis

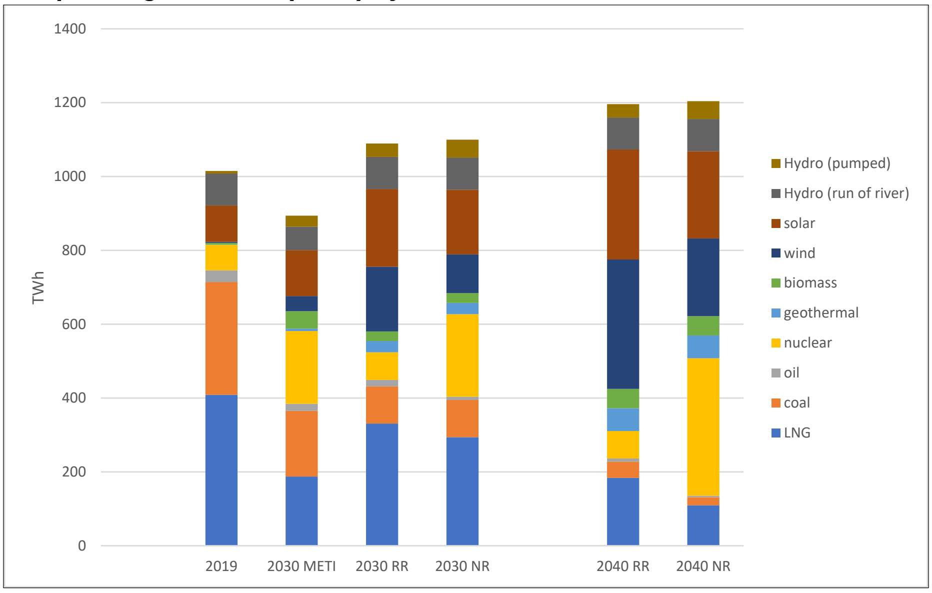
3.6.1 Rapid Renewables

In both OIES scenarios, we assumed an increase in total electricity generation from 1,027 TWh in 2019 to 1,100 TWh by 2030 and 1,200 TWh by 2040. This assumption was thought to be reasonable, as the share of electrification in total final consumption is expected to grow to around 50 per cent by 2040 and there is an expectation that with declining population and increasing energy efficiency total energy demand could reduce from around 4,000 TWh in 2019 to around 2,500 TWh by 2040.

In both scenarios, we also assumed a halving of coal capacity from 46 GW to 23 GW by 2030, consistent with the stated policy to phase out “inefficient coal” by 2030, and the assumption that all coal plants other than the latest ultra-super-critical technology fall into the “inefficient” category.[41] While coal currently operates at around 75 per cent utilisation rate, it is assumed that this reduces to around 50 per cent in future consistent with a drive to reduce emissions.

[38] https://businessdocbox.com/Green_Solutions/72998273-Tomakomai-ccs-demonstration-project-in-japan.html
[39] Summary of 6th Basic Energy Plan (in Japanese): https://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/2021/046/046_004.pdf
[40] https://www.meti.go.jp/english/press/2021/1022_002.html
[41] There has not yet been any clarity from policy makers regarding which coal plants would be considered to be “inefficient”.

Figure 8: Total power generation (GWh) by source and scenario



Source: Author's analysis

In the Rapid Renewables scenario, we assumed that solar capacity continues to grow at a similar rate to recent years at around 5GW per year, together with a very rapid increase in wind generation to reach 50GW by 2030 and 100 GW by 2040. While such a rapid buildout of wind-power would not be unprecedented by experience elsewhere (for example in Europe), it would require a step change in Japanese government policy regarding wind power. It could be argued, given previous experience in Japan, that it may be easier to accelerate the roll out of solar power further, but given the already high level of solar generation and the lower full-load hours for solar compared to wind, a greater focus on wind is considered preferable. The restricted available land area and challenging subsea conditions will make wind more difficult and expensive than in some other countries, but it is notable that several major wind project developers have already established development teams in Japan in the expectation that there will be an increased focus on wind generation.[42] There is also assumed to be some increase in biomass and geothermal generation, but these remain relatively small in the overall power mix.

In RR, it is assumed that there is little change in the status of nuclear power, resulting in available capacity remaining around the current level of 10 GW.

It is assumed that LNG plays the role of balancing fuel, with capacity being unchanged from current levels, but with the utilisation rate varying to provide back up to the intermittency of solar and wind, and to meet the total generation requirement not provided by other sources. This balancing assumption is considered reasonable given the higher operational flexibility of gas-fired plants. In order to meet a specific emission reduction target, it may prove beneficial to reduce the utilisation of coal plants further and increase the utilisation of LNG, although using less coal and more LNG would likely be a higher cost option and therefore require government policy to insist on lower coal utilisation.

3.6.2 Nuclear Rebirth

The key differentiator of the Nuclear Rebirth scenario is the assumption that all the existing nuclear power plants which are still potentially available will be operating by 2030, giving a capacity of 30GW, operating at a utilisation rate of 85 per cent and so making a significant contribution to the total generation requirement. To balance this assumption, we have assumed that while solar and wind generation continue to grow they do so at a slower rate than in RR.

[42] For example, Ørsted https://orsted.jp/en and RWE https://jp.rwe.com/en

Beyond 2030, it is further assumed that additional nuclear capacity, perhaps new modular nuclear, comes onstream. Higher nuclear capacity is a key enabler which would make it considerably easier for Japan to reach its Net Zero target. However, given the continued public reluctance to accept nuclear power ten years after the Fukushima accident, it is not clear what might enable such a significant change in public attitudes.

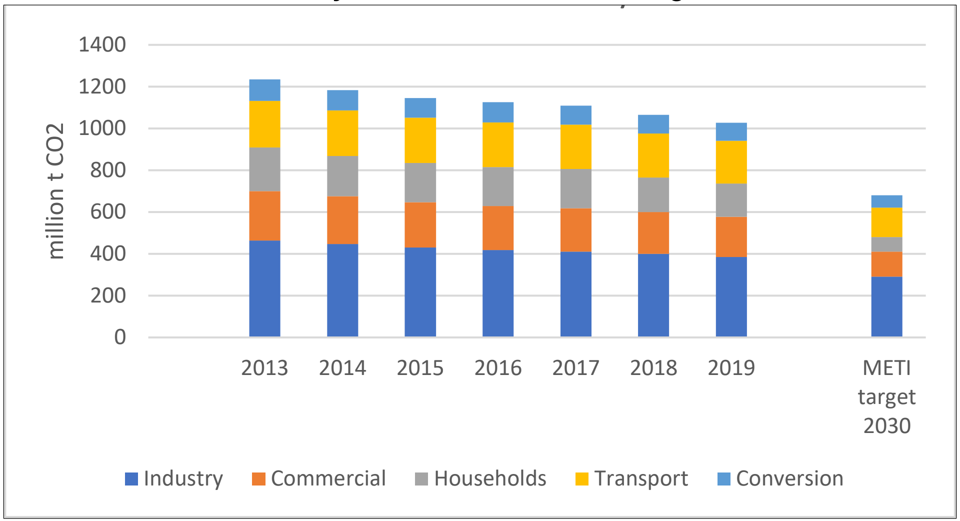
3.6.3 METI 6th Basic Energy Plan

The METI Energy Plan starts from a reduction in total power generation to 934 TWh in 2030 (compared to 1,024 TWh in 2019). This assumption is somewhat surprising since an earlier government forecast was that 2030 power generation would be 2 per cent higher than 2018.[43] With increasing decarbonisation ambition, it is likely that the demand for electricity would increase rather than decrease. Apart from that significant difference, the power generation capacity mix is broadly similar to the OIES Nuclear Rebirth scenario.[44]

Although not yet significant numerically, the plan contemplates that by 2030 around 1 per cent of power generation will come from hydrogen or ammonia. It is envisaged that hydrogen will be co-fired with LNG and ammonia co-fired with coal, with the intention that the share of the low-carbon hydrogen and ammonia will gradually be increased over time. A number of pilot projects are already underway to explore these possibilities,[45] although it is not yet clear the extent to which these new low-carbon fuels will become a significant part of the longer-term power generation mix.

The METI plan also provides an estimate of the total CO_2 emissions allocated by sector, as illustrated in Figure 8 9. While emissions have been declining steadily from 1,235 million tonnes in 2013 to 1.027 million tonnes in 2019, it will require a step change in the rate of decline if the target of 677 million tonnes by 2030 is to be achieved. Particularly noteworthy is the proposed reduction of emissions in the household sector. Between 2013 and 2019 this declined from 208 to 159 million tonnes, but is shown more than halving to reach 70 million tonnes by 2030. It is not yet clear how that dramatic reduction is to be achieved.

Figure 8: CO_2 emissions allocated by sector and METI 2030 target



Source: METI 6th Energy Plan

[43] IEA 2021 Japan Energy Policy Review p. 136.
[44] The METI plan does not give GW capacities for all power generation sources (it is only provided for renewables), so the numbers in Table 2 are calculated based on typical annual utilisation levels
[45] See, for example, the HyStra project (http://www.hystra.or.jp/en/) to demonstrate the import of liquid hydrogen from Australia, the project to import hydrogen from Brunei using a Liquid Organic Hydrogen Carrier (https://www.nyk.com/english/news/2020/20200625_01.html) and plans by JERA to co-fire ammonia at a thermal power plant (https://www.jera.co.jp/english/information/20210524_677).

3.6.4 Comparison between scenarios and commentary

A comparison of the scenarios highlights the challenges which Japan will face if it is to reach its ambition of 46 per cent emissions reduction (from 2013) by 2030 and continuing onwards to reach Net Zero by 2050. While the 2030 target requires a reduction in CO_2 emissions of around 350 million tonnes per year from 2019, for the power sector, we estimate that our RR scenario reduces emissions by around 230 million tonnes and our NR scenario reduces emissions by around 250 million tonnes over the same period. Combining this with the increasing share of electrification (for example in the transport and household sectors) suggests that both scenarios are broadly consistent with the 2030 target.

A key uncertainty is the future level of electricity demand and hence power generation. The OIES scenarios assumed around 10 per cent increase in total power generation by 2030, whereas the METI scenario assumed a 7 per cent decrease. As noted previously, with an increasing drive to reduce carbon emissions, most likely through greater electrification, it is more likely that power demand would increase.

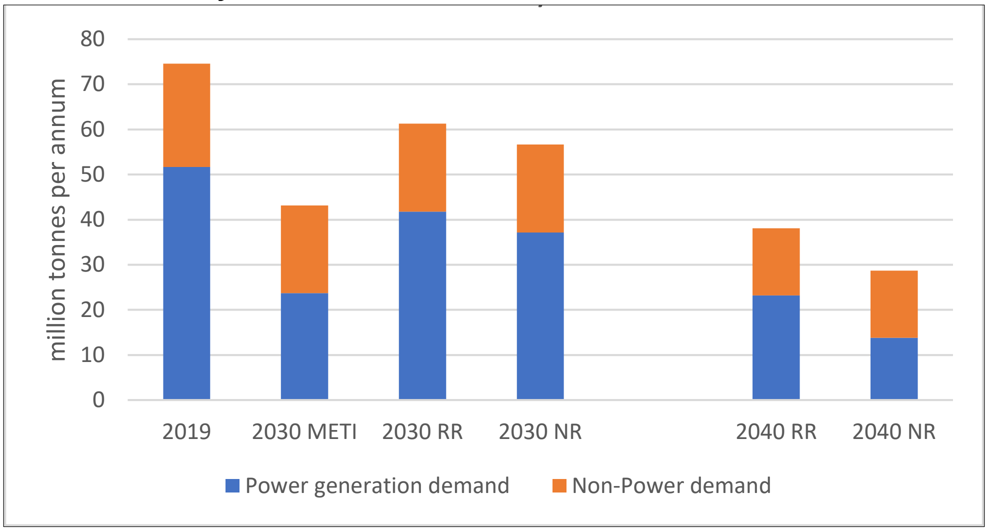
An increase in renewable capacity is a common theme across all scenarios, with the differences being only in how much renewable capacity is added how quickly. Given the current high dependence on fossil fuels, and the relatively low share of renewables, particularly wind power, it is safe to conclude that Japan should implement a rapid roll out of renewables. As well as renewable generation facilities it will also be important to make significant upgrading investments in the power transmission grid as well as in electricity storage.

The future of nuclear power is also very important for the approach to be taken by Japan in reducing emissions. As shown by the METI plan and the OIES NR scenario, a restart of existing nuclear power plants could generate around 200TWh per year, providing around 20 per cent of total generation requirements. Given the limited success in being able to obtain all necessary central and local approvals to restart nuclear plants so far, there must be considerable doubt whether it will prove possible to reach this ambitious goal. Against that background, it is perhaps surprising that the METI plan does not (at least in the current draft) provide an alternative scenario for the situation where a widespread nuclear restart does not prove possible, although this may follow in a subsequent draft of the basic energy plan.

3.6.5 Implications for LNG

A comparison of the level of power generation scenarios in Figure 8 indicates a considerable range of uncertainty for LNG demand. While LNG accounted for 409 TWh of generation in 2019 (requiring around 50 million tonnes per annum (mtpa) of LNG, the level of generation in 2030 ranges from a low of 187 TWh (using around 24 mtpa LNG) in the METI plan to 330 TWh (42 mtpa LNG) in the OIES RR scenario. These figures illustrate the considerable uncertainty in annual volumes of LNG, which will make it more difficult for Japanese LNG buyers to commit to long-term contracts in the same way as was common practice in the past. The uncertainty of LNG demand within each year will also be a significant change from past practice. Historically LNG buyers committed to a delivery schedule some months ahead of actual deliveries, although in recent years the availability of spot cargoes, both for selling surplus volumes or buying additional cargoes at times of high demand has provided valuable flexibility. Where LNG is increasingly being used to balance intermittent solar (and perhaps wind) power, the level of within year uncertainty is likely to increase. Thus, as the share of intermittent renewable power generation increases, it appears likely that Japan will either seek much more flexible long term contracts or become increasingly reliant on short-term and spot LNG purchases. This in turn is likely to make it more difficult for Japanese LNG customers to commit to the type of long-term offtake contracts with limited flexibility traditionally used to underpin a new, or expanded LNG production project.

Figure 10: LNG demand by scenario



Source: Author's analysis

Less information is currently available about the future role of LNG in the non-power sector, but directionally, it is likely that on the path to Net Zero there will be greater electrification in all of the industrial, commercial and residential sectors. Thus, directionally, LNG demand in these sectors will decline, but at this stage it is difficult to be clear on the rate of decline. Greater clarity should emerge as Japanese city gas utilities develop plans to address the Net Zero challenge. Figure shows an estimate of total Japan LNG demand under each scenario, combining an assumed gradual decline in non-power demand with increased uncertainty in power generation demand.

4. Conclusions and further research

As head of a world-leading economy, the Japanese Prime Minister probably had little choice but to join the "Net Zero" club when he made his historic announcement in October 2020. Reaching Net Zero will not be easy for many countries, but in some cases, particularly in major European countries, decarbonisation has been an important policy driver for several years and plans of how to achieve Net Zero are, arguably, well developed (although by no means easy to achieve!). In Japan, its unique circumstances make plotting a pathway to Net Zero even more challenging than in many other countries. In the shorter term, it seems equally, if not more, challenging to achieve the intermediate target of 46 per cent emissions reduction by 2030, compared to the 2013 baseline, particularly given the extremely short time scale.

Nuclear power could have been a significant advantage for Japan, but the Fukushima accident in 2011 and the subsequent closure of nearly all nuclear power plants has made that option much more difficult. While we have included significant restart of nuclear power and then further expansion in one of the OIES scenarios, based on the slow progress of obtaining the required approvals over the last 10 years, it is difficult to see what will change to enable this to happen. Against that background, it is perhaps surprising that the METI Basic Energy Plan currently relies on significant nuclear restart, without considering any alternative should that optimistic scenario not prove to be realistic.

Solar power has made good progress in Japan, with installed capacity increasing by around 5GW per year for the last several years. It is likely that this growth will continue, although finding suitable sites in the relatively small available land area may add additional constraints. Wind power (both onshore and offshore) has made little progress, partly because it has been seen as higher cost than solar power, and partly because of the challenging water depth offshore and the difficulty of obtaining required approvals from the impacted communities. The higher cost concern appears to have been based on the levelized cost of electricity criterion, whereas from an overall system perspective, to provide power when solar power is not available, there is likely to be a justification for wind power. Indeed, given the large potential for wind power and the limited alternative options to produce low carbon electricity, it is hard to see how Japan can progress towards Net Zero without much more investment in (mainly offshore) wind. To achieve significant growth in wind generation is likely to require stronger government policy drive and the ability to streamline the current complex local approval processes.

Imports of low carbon fuels, such as ammonia or hydrogen, are likely to make a contribution to decarbonisation, and indeed several organisations are already involved in pilot projects to investigate the potential further. With the METI plan envisaging 1 per cent of power generation from hydrogen or ammonia by 2030 this will not yet have a significant impact on LNG demand, although it may have the potential to grow to significant levels beyond 2030.

Carbon capture and storage is another possible lever, with sufficient storage capacity theoretically available for many years of current total CO_2 emissions. The completed demonstration project has shown that CCS can be deployed in practice, despite the high prevalence of earthquakes in Japan. However, much more work needs to be done in order to develop significant scale CCS projects. CCS could also be beneficial for the future of LNG in Japan: LNG with CCS would provide a low carbon way to balance the power grid at times when intermittent renewables were not available. While not quantified in our scenarios, widespread deployment of CCS could represent a significant upside for LNG (and potentially coal) demand.

Turning to implications for LNG more generally, analysis of our power generation scenarios suggests that future demand for LNG will be much more uncertain than has been the case in the past. This applies both to total annual demand and to timing of demand within each year as use of gas becomes much more dependent on backing up intermittent renewables. Combining power generation with the non-power sectors, the long-term prospect is for an overall reduction of LNG demand, but it is difficult to be definitive at this stage about the speed of that decline. What is more certain is that there will need to be a growing trend for LNG contract terms to become more flexible than in the past, to address the uncertainties identified while also meeting the requirement for security of energy supply.

Japan remains a key market for the global LNG industry, so OIES will continue to research the evolving thinking on how to achieve the ambitious emissions reduction targets, and its impact on LNG demand. In particular, as thinking develops on the steps to be taken to electrify end-use sectors, the impact on total power generation demand and the power generation mix, there should be further data to inform more accurate forecasts to 2030 and beyond.

This short introductory paper has necessarily only touched on the complex issues related to energy transition pathways in Japan, and has focussed primarily on the power generation sector and the implications for LNG. It provides a basis for further, more detailed, research on the energy transition in Japan which OIES intends to develop in future. The following topics may be particularly relevant:

- Consideration of the policy and regulatory levers which could be appropriate to drive the energy transition;
- Further in depth consideration of the potential deployment of large scale CCS in Japan, including the required policy support mechanisms, building on the results of the Tomakomai demonstration project;
- Further consideration of the prospects for imports of low carbon hydrogen and ammonia building on experience from the initial demonstration projects;
- More detailed consideration of the overall Japan energy system, to understand further the extent to which end use sectors could be electrified (with associated implications for demand for LNG in the non-power sector as well as for electricity demand and infrastructure). It would also assess further the role of other decarbonisation options like hydrogen, synthetic low carbon fuels, or CCS.
- Consideration of the regulatory framework, including the impact of the process of energy market liberalisation in Japan

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