GE VERNOVA

DECARBONIZATION PATHWAYS FOR JAPAN – CHALLENGES IN THE POWER SECTOR FROM 2023-2050

The role of gas and renewables to achieve energy security, economic efficiency, environmental sustainability and safety

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JAPAN OUTLOOK

Executive Summary

Energy systems around the world are undergoing complex transformations, with decarbonization[1] at the forefront of their transition. Major economies are exploring multiple avenues to help reduce emissions and adapt technologies that will enable them on a path to more reliable, and affordable energy security. One of the largest consumers of primary energy, Japan is heavily dependent on fossil fuels. The country is the third largest electricity producer in Asia and the fifth largest in the world. Historically (post 2011), the system is dominated by thermal capacity, mainly comprising liquid natural gas (LNG)-based plants followed by coal.

Figure 1: Japan's electricity supply mix[2]

[1] Decarbonization in this paper is intended to mean the reduction of carbon emissions on a kilogram per megawatt hour basis
[2] OCCTO Electricity Supply Plan Reports

Japan has an important economy, contributing significantly to the world's industrial output, and Japan's power generation system produces a large amount of greenhouse gases emissions (GHGs). However, as illustrated in Figure 1, the country's renewable capacity (solar and wind excluding hydro) has gradually increased each year. By 2022, it comprised approximately 24% of the installed base while contributing 10% to the generation mix. With the incorporation of more renewables in the system, Japan has observed decreasing emission trends over the years.

The transformation of the electricity sector in Japan will be complex. It will require advancement in technologies such as carbon capture, utilization, and storage (CCUS); exploration and development of cleaner fuels (such as hydrogen and ammonia) in the energy supply chain; as well as a strong push in policy and regulations to bolster emission reduction targets.

To develop insights into this complex transition, a scenario-based analysis using a production cost simulation model focusing on prevalent available options was considered. The analysis aimed to identify the challenges and possible solutions necessary to enable a decarbonization pathway. The outcome of this study revealed the following key areas for consideration:

- Along with long-term (until year 2050) and short-term (year 2030) targets, it also would be beneficial to consider mid-term goals (from 2030 to 2045). These intermediate targets lay the foundation and planning necessary to help meet long-term objectives. This may bring to light some of the challenges in high near-term targets. Certain technologies are currently still in development for wider-scale application or are currently more expensive. Similar to the growth of renewable capacity in the grid in the initial stages, (through competitive Feed In Tariffs (FIT) followed by Power Purchase Agreements (PPA), auctions, and market participation), adoption and development of decarbonization technologies can be further augmented through a similar support mechanism (carbon tax, fuel subsidy etc.).
- Higher penetration of renewable technologies will be possible with the help of flexible and dependable capacity. Across all the scenarios, gas-based capacity plays a critical role, and consideration needs to be made in supporting flexible generation capacity and applying premium for fast start power capacity. Storage options such as batteries and pumped storage are also expected to play a key role in this transition period.
- Augmentation of the transmission network is expected to help decarbonization efforts. Current plans for a subsea transmission cable connecting Hokkaido (a wind-rich region) to Tokyo (a high-demand zone) will help meet new electricity demand (with electrification of other sectors of the economy).
- The role of nuclear technology in the system must be explored. Restarting these large, low-emission fleets could be beneficial in meeting demand requirements. Public sentiment toward nuclear capacity is shifting, and with advancements being made in both storage of spent fuel and the development of Small Modular Reactors (SMRs), exploration and development in the long term is expected to help the system achieve lower emissions. Decommissioned sites could be used to develop safer and more advanced nuclear capacity (such as with SMRs).
- Policy and regulations are needed to help incentivize marketplace participants to adopt technologies that produce less emissions. The current 6th Strategic Energy Plan (focus on S+3E)[3] and the Green Transformation (GX) Basic Policy address and set targets to help reduce emissions in the energy sector[4]. However, there is need to bolster targets and penalties to push the adoption rate and accelerate decarbonization efforts. In addition, in order to decarbonize existing thermal capacity, a support mechanism for low-carbon fuels and CCUS (e.g. contract-for-difference type mechanism) should be considered.

[3] JAPAN: The 6th Strategic Energy Plan, Outline of Strategic Energy Plan
[4] OVERVIEW OF JAPAN'S GREEN TRANSFORMATION (GX)

Introduction

Japan has set ambitious targets to achieve net zero by 2050[5] as per the latest Nationally Determined Contribution (NDC) plans. The system is in transition, with policies and targets to help achieve these decarbonization goals, such as setting up investments in lower carbon generation sources and promoting alternatives. The revised 6th Strategic Energy Plan follows the "S+3E" (Safety plus Energy Security, Economic Efficiency, and Environmental Sustainability) approach, as the future grid will be complex and must ensure a reliable, secure, and environmentally more sustainable electric grid that also will cater to the demand of sectors such as transportation, heating, and industry[6]. Rigorous endeavours are planned under the revised 6th Strategic Energy Plan, which underscores the commitment to reduce GHG emissions by 46% to 50% by fiscal year (FY) 2030 compared to FY 2013 levels[7]. The GX Basic Policy is another government-led initiative that aims to facilitate a transition from a fossil fuel-dependent system to a structure driven by energy sources that produce less emissions. Key targets[8] under this initiative include reaching higher renewable penetration, increasing nuclear power in the energy mix, supporting the development of supply chain for ammonia/hydrogen fuels, and building CCUS value chains aimed to capture 120 to 240 million tonnes of CO_2 annually by 2050.

To analyze this transition, the electricity system of Japan was modeled in GE Vernova's Multi Area Production Simulation (MAPS) software. It factors in the constraints of operating various generation technologies as well as the transmission limitations between the modeled utility areas. The production cost model was simulated with an hourly resolution to capture system performances.

Four scenarios were conceptualized, denoting pathways that could help decarbonize the electricity grid as shown in Table 1 below.

Baseline scenario – This considers a business-as-usual case, assuming the target additions of capacity to help meet demand requirements reliably.

Nuclear Restart scenario – Here, a more aggressive nuclear restart is considered, with the rest of the assumptions remaining largely in line with the base case.

High RE/Low RE scenarios – These two scenarios are variations, based on a higher or lower wind and solar capacity addition compared to the base case.

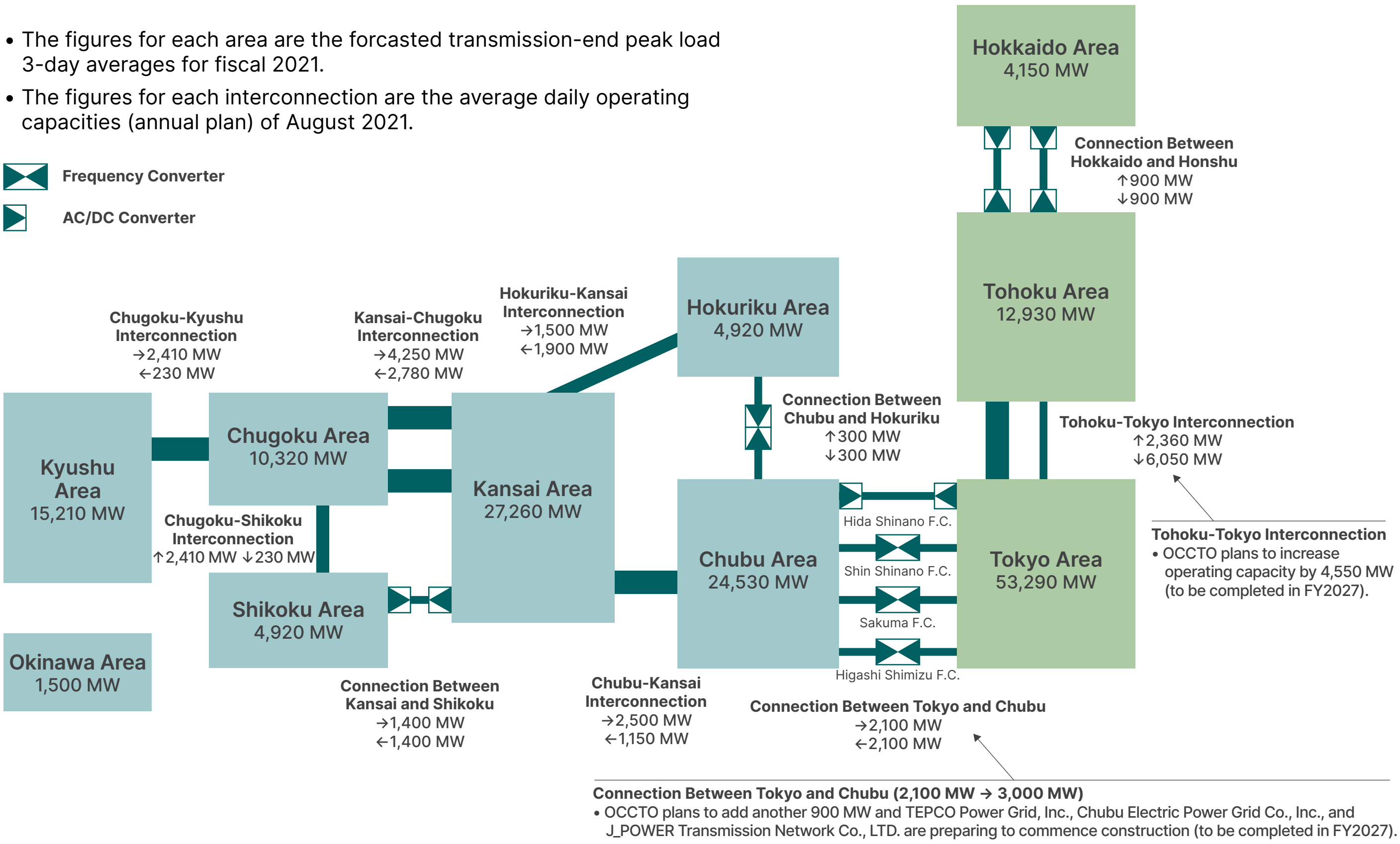
Scenario →		Baseline			Nuclear Restart			High RE			Low RE		
Particulars ↓	Year →	2030	2040	2050	2030	2040	2050	2030	2040	2050	2030	2040	2050
Wind targets/capacity	GW	18	50	72	18	50	72	26	68	97	16	40	57
Solar targets/capacity	GW	110	147	185	110	147	185	125	173	217	83	110	138
Restart of nuclear capacity based on NRA applications	-	Currently certified by NRA			Including capacity yet to be certified by NRA			Currently certified by NRA			Currently certified by NRA		
	GW	20	13	4	37	28	20	20	13	4	20	13	4
Capacity additions to support system demand	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 1: Scenarios simulated

Along with these differentiators, common assumptions across the scenarios include grid modeling and transmission capacity and demand growth projections.

[5] Japan's Nationally Determined Contribution (NDC)
[6] JAPAN: The 6th Strategic Energy Plan, Outline of Strategic Energy Plan
[7] JAPAN: The 6th Strategic Energy Plan, Outline of Strategic Energy Plan
[8] Overview of Japan's Green Transformation (GX)

National Grid Connections



Line Ratings (MW)	2022	2030	2040	2050
Hokkaido to Tohoku	900	1,800	2,400	3,000
Tohoku to Tokyo	6,500	13, 200	15,400	17,600
Tokyo to Chubu	2,100	4,500	6,000	7,500
Chubu to Hokuriku	300	500	600	700
Chubu to Kansai	1,150	1,800	2,200	2,600
Hokuriku to Kansai	1,900	3,000	3,625	4,250
Kansai to Chugoku	2,780	6,120	8,160	10,200
Kansai to Shikoku	1,200	3,750	5,000	6,250
Shikoku to Chugoku	1,00	3,750	5,00	6,250
Chugoku to Kyushu	230	2,970	3,960	4,950
Kyushu to Okinawa	—	500	1,000	1,500
Kyushu to Shikoku	—	3,000	4,000	5,000

Figure 2: Japan's transmission infrastructure[9] and line ratings – 2022 to 2050 horizon

[9] Electricity Review Japan 2023

The existing system includes Japan's nine Eastern and Western pools connected through a power transmission network. The structure and capacity of these interconnections are depicted in Figure 2 along with the projected transmission ratings across the simulation horizon. Okinawa is assumed to gain interconnection to the mainland by 2030. Transmission capacity between the electric power companies (EPCOs) was considered, with expansion plans incorporated until 2030. Beyond 2030, it was assumed that transmission capacity would be augmented by 25% on average across all interconnections (from 2030 to 2040 and 2040 to 2050).

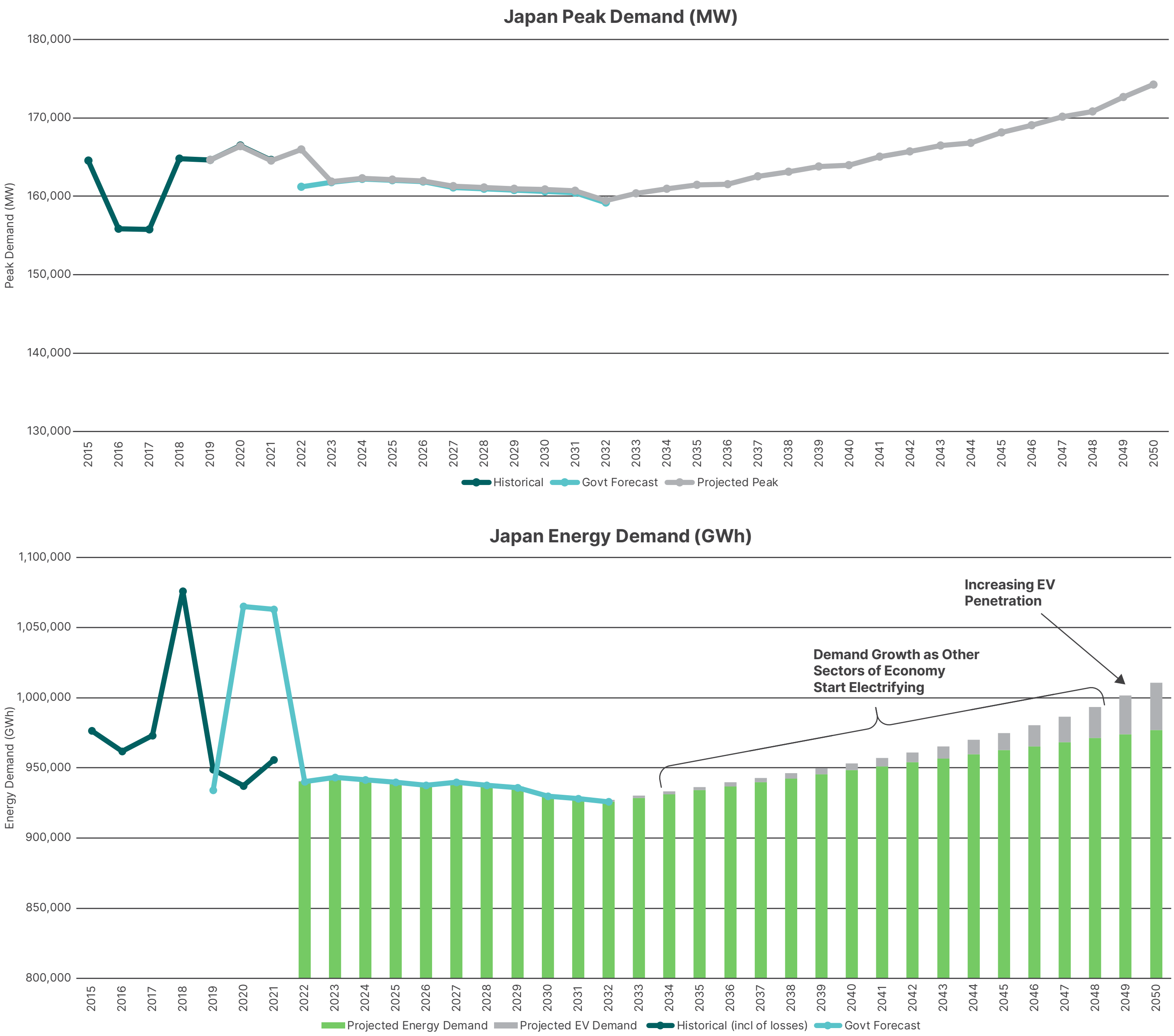


Figure 3: Demand projections

Annual energy demand and peak demand forecasts considered the government projections until 2032[10]. Beyond 2032, the impact of electrifying the transportation sector (assumed to reach 40% of vehicles by 2050) and other sectors of the economy also was considered until 2050. In the short to medium term (until 2032), government and utility forecasts would account for success from recently enacted energy efficiency programs associated with their respective climate goals.

[10] OCCTO Annual Report Fiscal Year 2023, OCCTO Reports

Analysis Results

Outcomes of these simulations are listed below, beginning with the outlook on the system installed base and the generation mix.

Installed base and generation

Across the scenarios, the installed base (Figure 4) and the generation mix (Figure 5) depict an increasing contribution of renewable energy (RE), mainly wind and solar, as per targets. The Baseline and Nuclear Restart scenarios observe a contribution of ~54% by 2050. The High RE scenario considers the highest amount of RE in the system by 2050 accounting for 59% of the installed base, while the Low RE scenario accounts for 48% of the installed base. These RE targets are derived based on the 6th Strategic Energy Plan. In terms of generation across the scenarios, RE contribution to the generation mix ranges between 31% (Low RE) to 40% (High RE) by 2050, indicating a significant contribution to the energy mix from renewable sources.

Coal capacity

Coal-based capacity across scenarios remains the same. New firm capacity additions of ~4 GW are expected to come online by 2024. Coal capacity made up 15% of the installed capacity in 2022, reducing to 10% by 2030, 7% by 2040, and 3% by 2050 with consideration of retirements. Generation across the scenarios is at similar levels and follows a decreasing trend with 2030 at 20%, 2040 at 16%, and 2050 at 7%.

Nuclear

Nuclear capacity remains similar between Baseline, High RE, and Low RE based on existing plans and schedules of retirements. The Nuclear Restart scenario includes capacity of plants that have yet to apply as well as those that have applied but not passed Nuclear Regulation Authority (NRA) inspection. Under this scenario, these plants are considered to have a 20-year extension in operations on the basis of government projection (60-year operation) targets. The highest capacity expected to be online is in the Nuclear Restart scenario at 36 GW (11%) in 2030 and 4% by 2050. Nuclear contribution in the generation mix is the highest in the Nuclear Restart scenario with levels of 30% in 2030, 23% in 2040, and 15% in 2050.

Gas-based capacity

Firm/planned additions are common across all scenarios. The difference in capacity is mainly due to the addition of expansion units (to meet reserve margin (RM) and demand requirements). The additions of expansion units are mainly delayed in the Nuclear Restart and High RE scenarios to beyond 2031 as compared to the Baseline and Low RE scenarios, where additions are required beginning in 2028. Gas technology will be the largest thermal base across all scenarios, making up at least 20% of the installed base. Considering retirements across all technology categories, gas-based capacity is expected to represent the new capacity additions in the system. Gas is expected to increasingly contribute to the generation mix as coal decreases. In addition, gas power will continue to play an important role as it can provide essential and reliable services, can help meet demand requirements, and can also help drive emission reductions with the possibility of using fuels that result in reduced CO_2 emissions (hydrogen/ ammonia) and the implementation of CCUS technology.

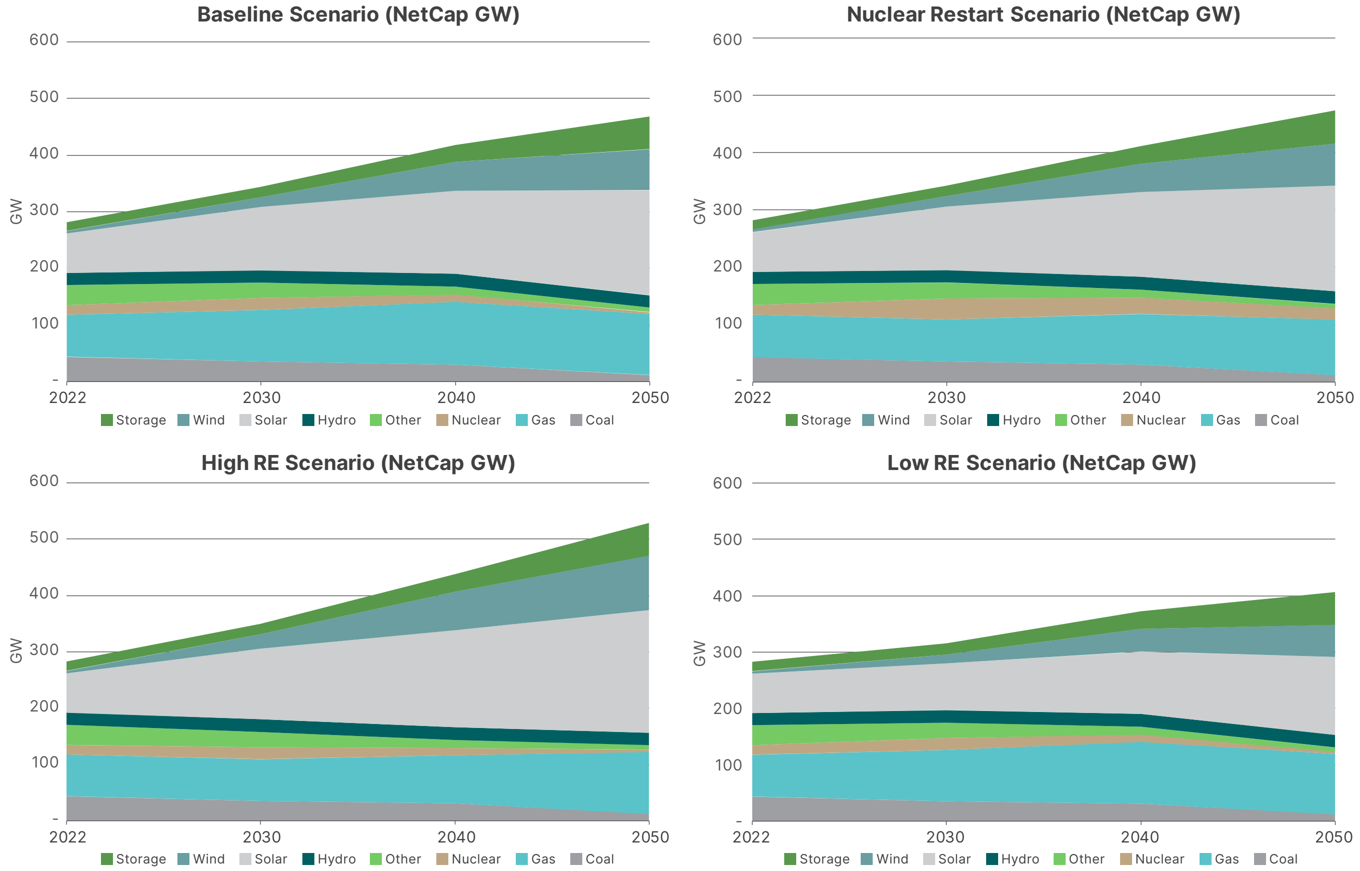


Figure 4: Installed Capacity (GW) across scenarios

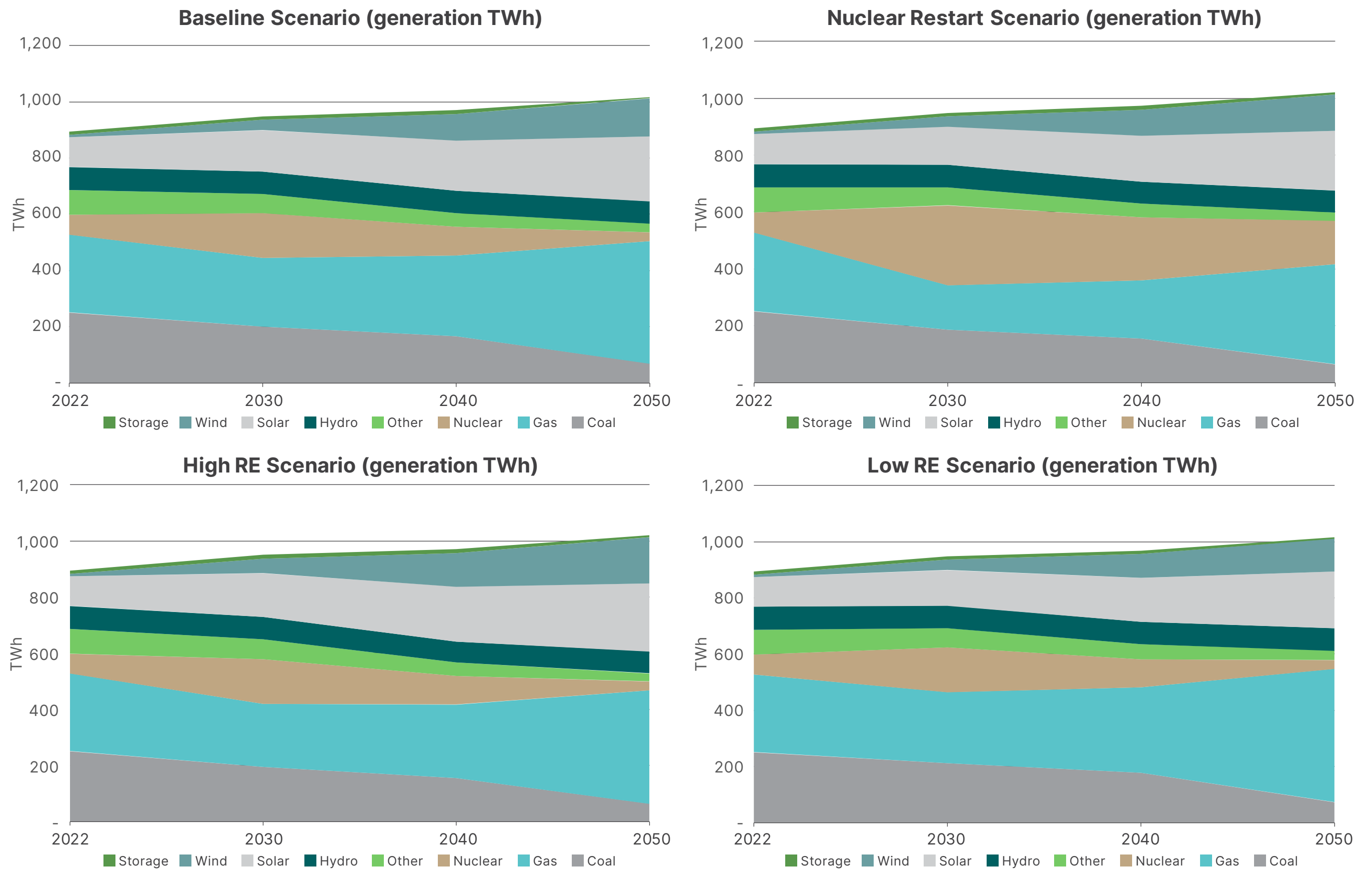


Figure 5: Energy mix (TWh) across scenarios

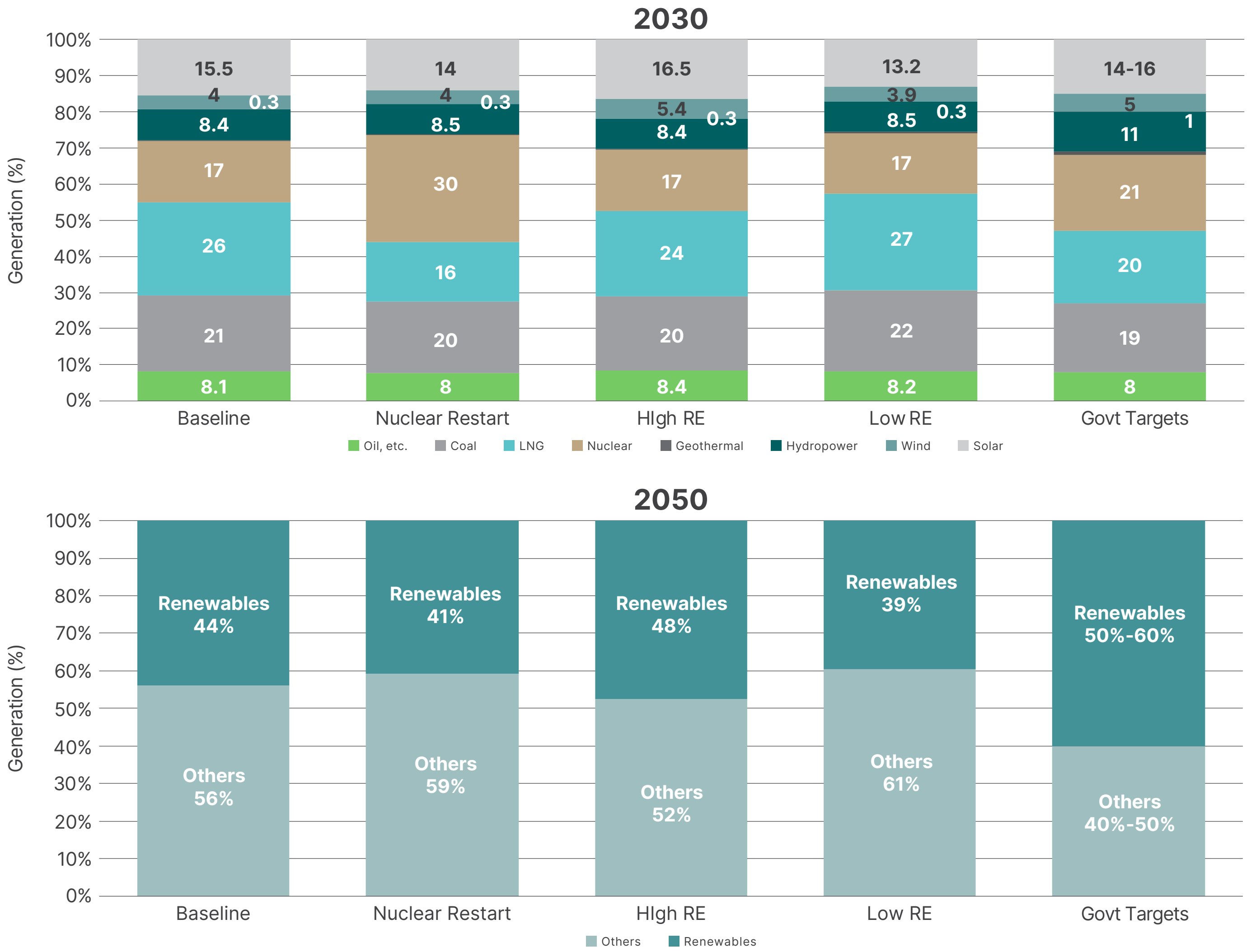


Figure 6: Scenario comparison of energy generation mix by 2030 and 2050

Government targets for the short term of 2030 consider ~33% of generation coming from hydro, RE, and other lower emission sources as shown in Figure 6. Compared to government targets, most of the scenarios have similar levels of generation for technologies such as oil, geothermal, and hydro. Variations in coal, gas, and nuclear generation are based on the installed capacity in each scenario.

By 2050, the Nuclear Restart scenario pushes the contribution of thermal base technology to ~60% of the generation mix. Renewables (solar, wind, offshore wind, geothermal, and hydro) contribute close to 50% in the High RE scenario. The Baseline scenario could be considered as a moderate view in terms of RE absorption by the system. Including hydro and nuclear, the system can achieve close to 50% of its generation from less emitting sources by 2050.

RE generation and curtailment

With an increasing installation capacity of RE in the system, the RE curtailment details also were analyzed from the simulation results. Figure 7 indicates the curtailment of RE in the system across scenarios while Figure 8 shows the levels of RE curtailment across the utilities/EPCOs for the Baseline scenario. From Figure 7, the absolute value of curtailment (GWh) varies as the amount of RE differs between scenarios. The Baseline and Nuclear Restart scenarios have the same RE additions, while the High RE and Low RE scenarios have higher and lower RE additions, respectively. From Figure 8 it is observed that with increasing RE in the system across the EPCOs, the percentage of curtailment is at similar levels. Reducing curtailment by increasing storage capabilities, better forecasting, and synchronizing the electrification of other sectors within the economy will help increase RE penetration in the system while further reducing emissions.

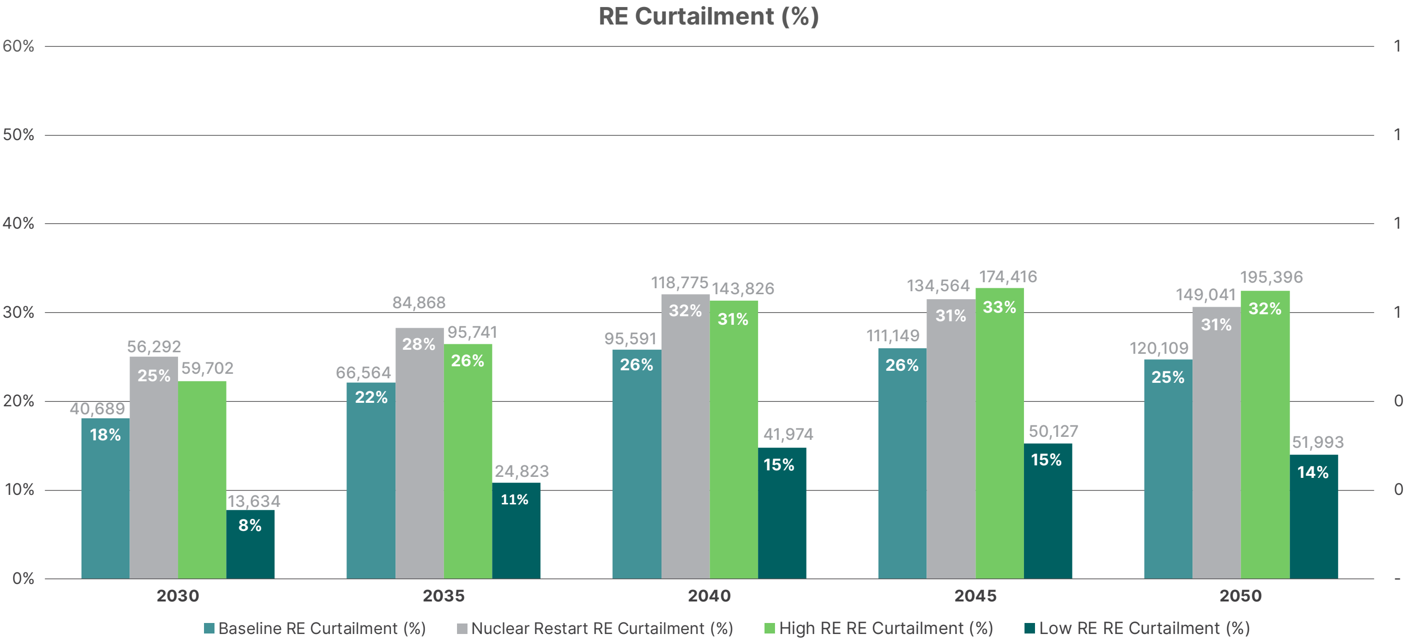


Figure 7: RE curtailment across scenarios (%)

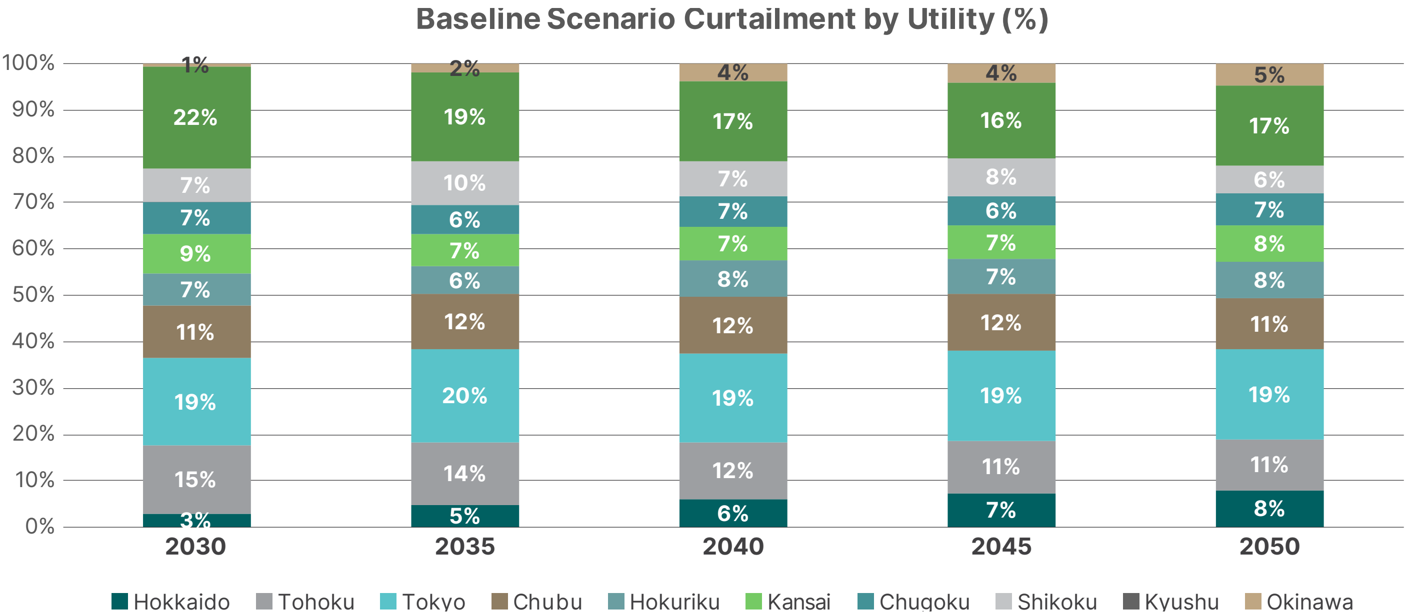


Figure 8: Baseline RE curtailment distribution by utility (%)

Transmission capacity

Transmission capacity between the EPCOs was considered with the expansion plans incorporated until 2030 as indicated in Figure 9. Beyond 2030, it was assumed that transmission capacity will increase by 25% on average across all interconnections (from 2030 to 2040 and 2040 to 2050).

The transmission capacity considered is the same across all scenarios. The simulations suggested that the interconnections between Chubu and neighbouring EPCOs had the highest flows in the system. Figure 10 depicts the hours binding from the simulation, which indicates the number of hours in the year when the flows on the lines were at the modeled limits. These interconnections could be potential candidates for increasing capacity.

Hokkaido to Tohoku and Tokyo to neighboring EPCOs were the other interconnections observing high utilization as seen in Table 2. The table depicts the line utilization for both forward and reverse flows. The install mix across the various EPCOs dictates the flows that are used to help meet the demand across various EPCOs in the system. Tokyo, Chubu, and Kansai are some of the largest demand zones in the country. With the proportion of RE and nuclear capacity spread across various EPCOs, the augmentation of transmission capability will be a pivotal development that enables the system to absorb more RE generation and cater to its energy requirements.

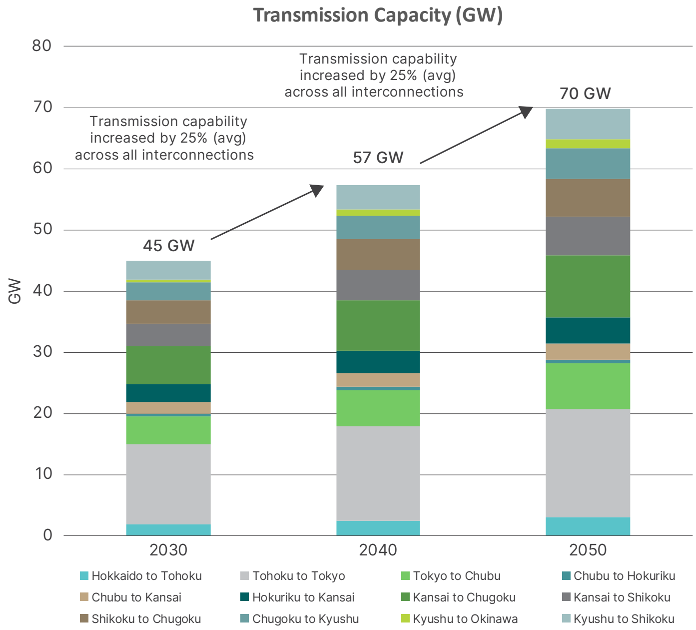


Figure 9: Interconnection capacity (GW)

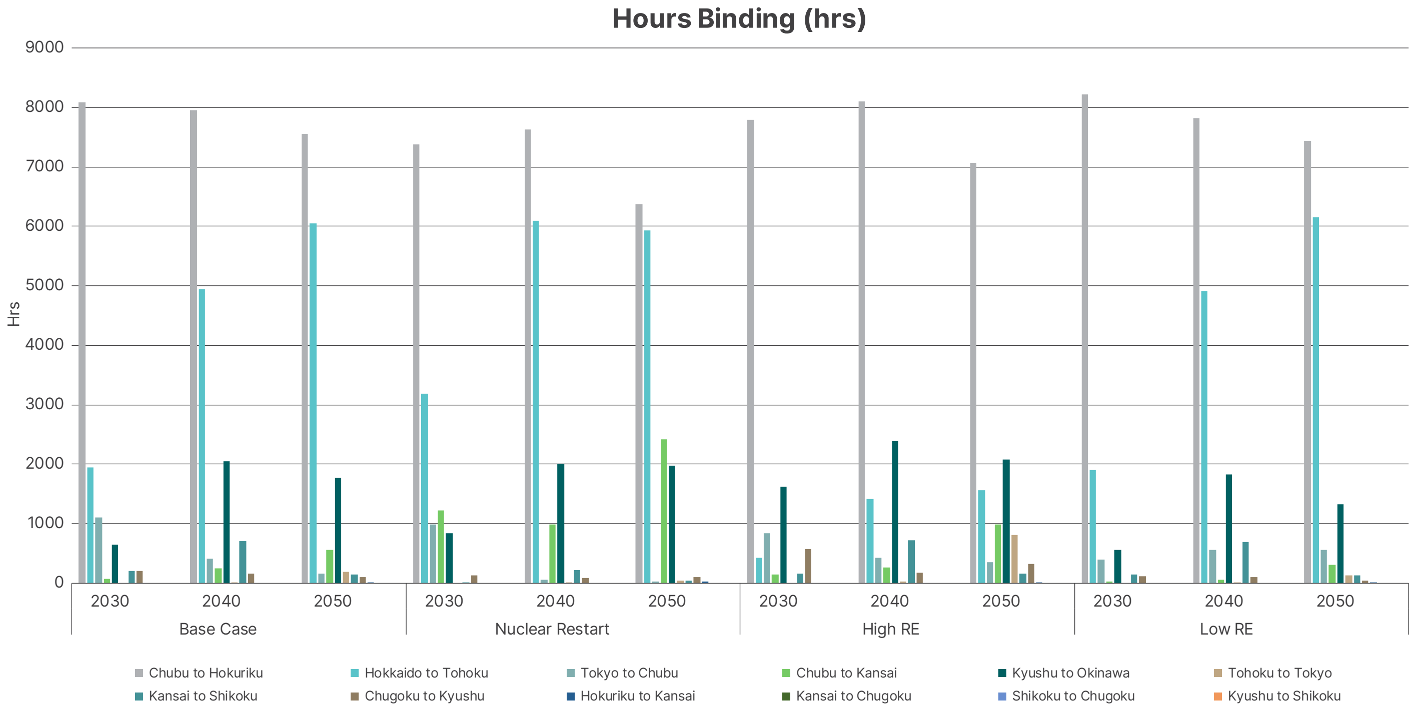


Figure 10: Transmission utilization (hours binding)

Scenario →	Base line	Nuclear Restart	High RE	Low RE	Base line	Nuclear Restart	High RE	Low RE	Base line	Nuclear Restart	High RE	Low RE
Line Utilization	2030 Forward Flow (%)				2040 Forward Flow (%)				2050 Forward Flow (%)			
Hokkaido to Tohoku	56%	72%	24%	56%	82%	90%	42%	83%	89%	91%	37%	90%
Tohoku to Tokyo	48%	46%	42%	50%	56%	51%	48%	56%	63%	59%	63%	64%
Tokyo to Chubu	28%	40%	31%	29%	19%	28%	17%	20%	29%	38%	38%	31%
Chubu to Hokuriku	2%	4%	3%	1%	4%	6%	4%	3%	4%	5%	6%	2%
Chubu to Kansai	6%	38%	9%	5%	7%	36%	8%	6%	25%	56%	33%	22%
Hokuriku to Kansai	7%	32%	9%	7%	8%	31%	9%	7%	23%	43%	27%	23%
Kansai to Chugoku	1%	7%	3%	1%	0%	1%	0%	0%	0%	1%	1%	0%
Kansai to Shikoku	0%	3%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Shikoku to Chugoku	10%	14%	9%	10%	14%	14%	14%	15%	11%	11%	11%	11%
Chugoku to Kyushu	9%	21%	10%	9%	8%	12%	9%	7%	22%	28%	26%	22%
Kyushu to Okinawa	31%	34%	20%	32%	12%	14%	11%	13%	17%	18%	16%	18%
Kyushu to Shikoku	1%	0%	1%	1%	1%	0%	1%	1%	0%	0%	0%	0%
Line Utilization	2030 Forward Flow (%)				2040 Forward Flow (%)				2050 Forward Flow (%)			
Hokkaido to Tohoku	5%	1%	11%	4%	1%	0%	8%	1%	0%	0%	11%	0%
Tohoku to Tokyo	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Tokyo to Chubu	19%	13%	20%	14%	16%	10%	17%	13%	14%	9%	13%	9%
Chubu to Hokuriku	95%	90%	93%	97%	93%	90%	94%	94%	97%	85%	87%	99%
Chubu to Kansai	70%	24%	72%	65%	66%	22%	74%	60%	32%	14%	36%	26%
Hokuriku to Kansai	30%	9%	32%	27%	29%	8%	34%	25%	13%	4%	15%	9%
Kansai to Chugoku	32%	15%	28%	30%	39%	25%	38%	37%	29%	22%	29%	28%
Kansai to Shikoku	50%	23%	40%	49%	69%	49%	67%	69%	50%	39%	50%	50%
Shikoku to Chugoku	11%	6%	11%	9%	7%	4%	8%	6%	7%	6%	8%	6%
Chugoku to Kyushu	51%	30%	49%	47%	48%	33%	47%	48%	28%	22%	29%	26%
Kyushu to Okinawa	13%	13%	33%	11%	36%	34%	41%	34%	31%	30%	35%	28%
Kyushu to Shikoku	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 2: Line utilization (%) across scenarios

Emissions

RE and nuclear generation are some of the lowest emission sources in the Japanese grid, which is reflected in the reductions in emissions under the High RE and Nuclear Restart scenarios. The Baseline scenario is observed as a midpoint in projected emission reductions as seen in Figures 11 and 12 below. The emissions predominantly are due to the presence of thermal capacity over the horizon. Because newer capacities are predominantly gas based, considerations of capacities with CCUS as well as capacities that could use alternate fuels such as hydrogen and ammonia could be explored to further reduce emissions.

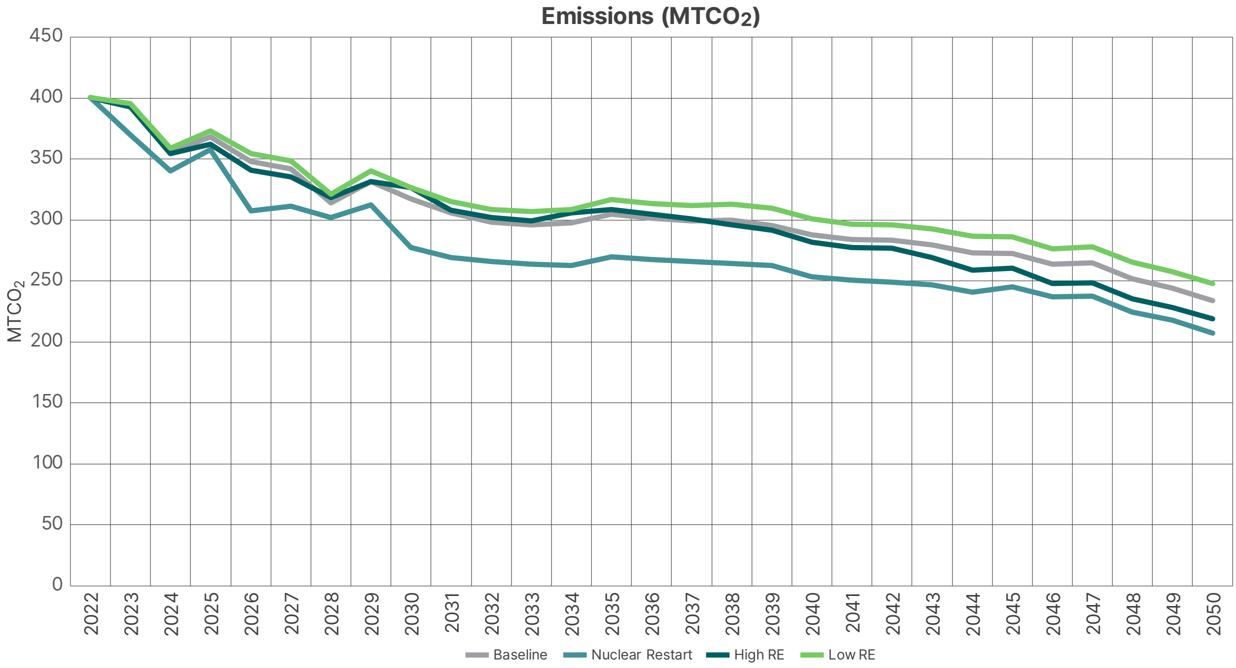


Figure 11: Emission ($MTCO_2$)

By 2030, compared to historical emissions of 2013, the system observes a reduction of emissions of 52% in the Baseline and High RE scenarios, 50% in the Low RE scenario, and 58% in the Nuclear Restart case. By 2040, the system observes a reduction of emissions of 57% (Baseline, High RE), 55% (Low RE), and 62% (Nuclear Restart). By 2050, the reduction of emissions is observed to be 65% (Baseline), 67% (High RE), 63% (Low RE), and 69% (Nuclear Restart).

Current policies have set carbon capture roadmaps for 2030 with a target of 6 to 12 million tonnes/year[11]. By 2050, under the GX Basic Policy, 120 to 240 million tonnes of CO_2 are targeted for capture and storage every year[12]. From the simulations across scenarios, emissions are averaging in the range of 260 to 300 million tonnes by 2050, indicating that the roadmap planning targets need to be increased.

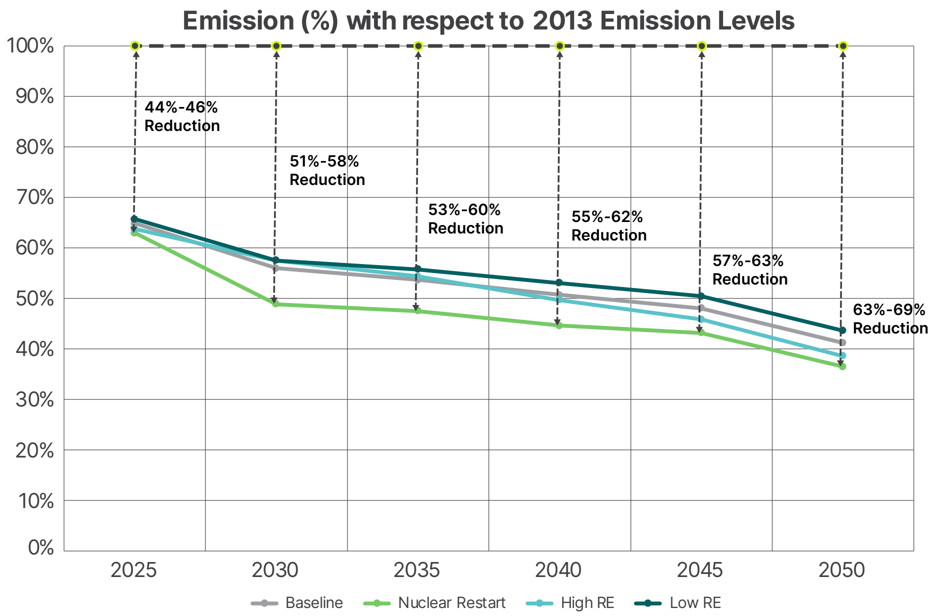


Figure 12: Emission reduction

The Japanese government is performing consultations and reviews to revise the current carbon price of ~$2 USD/tonne CO_2[13]. A carbon levy is planned for introduction in 2028. The current carbon price is relatively low compared to other developed economies such as the EU-ETS, U.S., and Singapore. Higher carbon prices will help push companies and utilities to accelerate their decarbonization efforts.

Across the globe, multiple mechanisms and instruments are in place to track and cover emissions. As of 2023, 23%[14] (11.6 $GtCO_2e$) of global GHG emissions were covered (18% under Emission Trading Systems (ETS) and 5% under a carbon tax) with prices ranging from $0.07 USD/$tCO_2e$ to $155.86 USD/$tCO_2e$. These mechanisms/instruments are put in place to:

- Levy a cost on carbon emissions;
- Impose these costs on emitters and push them to reduce their emission contributions;
- Stimulate and aid in the development of technologies that produce less carbon emissions

Countries could implement an ETS, which is a cap-and-trade system where a cap is imposed on the total GHG emissions, and allows low emitters to sell extra allowances to larger emitters. This system creates a supply and demand for emission credits and establishes a marketplace price for GHG emissions, with the cap to help ensure that emissions are within allocated targets. A direct approach is to levy a carbon tax on GHG emissions. Implementation of either mechanism is dependent on the economic and national interest of individual countries.

Marketplace developments in Japan are pushing a revision of the current carbon tax to create funds and propel investments in technologies that produce less CO_2 emissions. The current national carbon tax, implemented in 2012, is imposed on 75%[15] of jurisdiction emissions covering combustion of fossil fuels across all sectors (with some exemptions across industry, power, agriculture, and transport) with compliance to the tax being upstream (producers of the fossil fuel can be liable). Total revenue through this tax in 2023 was 220 billion JPY (~$1.8 billion USD). At the global level through both mechanisms, revenues for governments as of 2022 totalled $97 billion USD (ETS $67 billion USD, carbon tax $30 billion USD)[16].

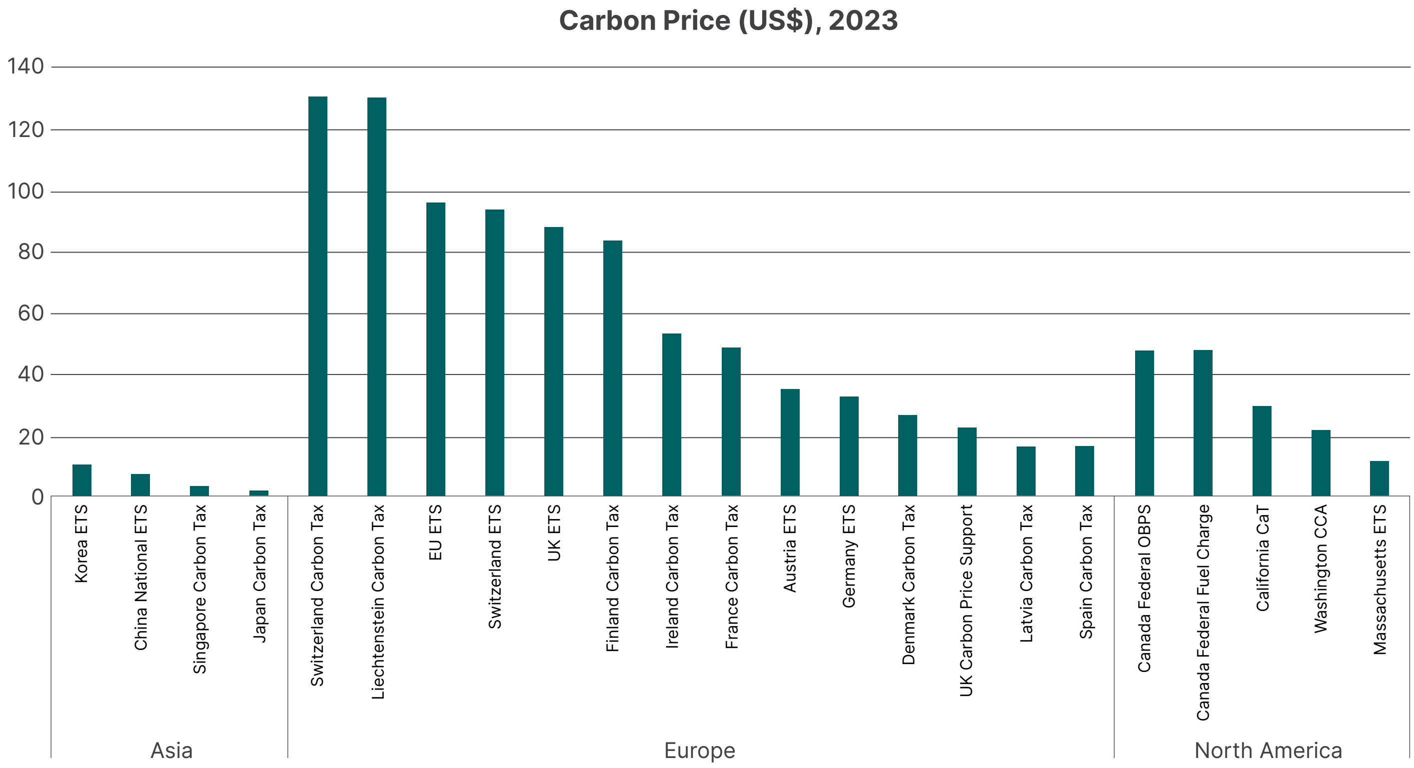


Figure 13: 2023 Carbon prices in US$ across major economies

The Asia region, accounting for large economic and emission outputs, lags the European and North American regions in terms of carbon pricing. As decarbonization comes to the forefront in ensuring a more sustainable economic pathway, current mechanisms must revise prices to push for technology innovations to help reduce emissions.

[11] Japan Policy for Full-Scale CCS Operation by 2030, Reuters News Article
[12] OVERVIEW OF JAPAN'S GREEN TRANSFORMATION (GX)
[13] Ministry of the Environment, Government of Japan, Carbon Tax
[14] The World Bank. State and Trends of Carbon Pricing Dashboard
[15] The World Bank. State and Trends of Carbon Pricing Dashboard
[16] The World Bank. State and Trends of Carbon Pricing Dashboard

Key Observations & Conclusions

As the system undergoes a complex transition, this study aims to develop insights through simulation of the electric system under different scenarios. Some of the main observations that can be synthesized from this study fall under the following categories:

Support increasing RE penetration: Japan's power system will gain complexity with the electrification of other sectors of the economy during the transition to decarbonization. Decreasing costs of wind, solar, and storage technologies will help Japan push for more renewables in the system. With the High RE scenario looking to incorporate close to 60% of the installed base with RE (wind and solar), more storage and dependable and flexible generation capacity must be added to the system with an objective to reduce the RE curtailment levels and maximize RE penetration. Also, to support flexible generation capacity, a premium for fast-start power capacity should be considered. Government support and policy also play a crucial role in increasing the levels of RE installation in the future.

Set and track targets: With a 2030 short-term target and a long-term 2050 net-zero target set by the government, intermediate targets between 2030 and 2050 also should be considered. The study results indicate widely differing outcomes based on scenarios with generation from non-emitting resources varying from 43% in the Low RE case to 56% in the Nuclear Restart scenario. This intermediate planning will provide the necessary targets to help shape policy and regulations to bolster the 2050 target achievement pathway.

Review emission taxes and emission reduction policies: Under the GX Basic Policy, the current $2US/tonne$CO_2$ for carbon pricing is under review. It is to be revised because compared to other developed economies, the current pricing mechanism is relatively low. A higher carbon price will help push companies and utilities to look for alternatives to emitting sources (particularly coal). Use of fuels such as ammonia and hydrogen also are being explored. However, the current 2050 targets do not clearly indicate the quantum of capacity for establishing a concrete plan to begin implementing the usage of fuels that produce less CO_2 emissions. These fuel sources are in the early stages of commercialization, with supply and production stages still being planned.

Allow nuclear power to play a key role: As seen from the Nuclear Restart scenario, using the existing plants that are yet to apply for NRA certifications and those that have applied and are pending approval could bring significant emission reductions in the system. Using the sites of existing plants that are to be decommissioned for next-generation advanced reactors can further accelerate the system toward net zero.

Increase flexible and dependable capacity to support RE absorption: With increasing RE in the system, it is necessary to ensure flexibility and dependable capacity in the system. Gas-fired and hydro solutions, storage systems, and demand-side management (demand response and EVs) can increase stability and provide flexibility to the system. Across the four scenarios analyzed, the system will have significant gas-based capacity. The requirement of the new gas-based capacity is observed to be needed by 2028 in the Low RE scenario (due to a shortfall of planned RE additions) and beyond 2031 for the other scenarios. The substantial growth in the power system infrastructure and lead times of deployment of technologies (e.g., more than 10 years for nuclear, 6 to 10 years for CCGTs, and 5 to 15 years for transmission links) demand that concrete actions be taken as early as possible. A combination of various electricity generation, transmission, and system control/management technologies with underlying supportive policy and regulatory measures will be essential. To reduce the carbon emissions of this gas power solution, a support mechanism for lower carbon fuels and carbon capture, utilization, and storage (CCUS) (e.g., a contract for difference (CFD) type mechanism) should be considered.

Meet infrastructure challenges: Augmentation of the transmission network can help boost efforts to decarbonize. The current plans for a subsea transmission cable connecting Hokkaido (a wind-rich region) to Tokyo (a high-demand zone) will help meet new electricity demand (with electrification of other sectors of the economy). As more RE and new capacity come online, a transmission grid capable of evacuating power from generation to the load centers coupled with innovation in grid management, better RE forecasting and Demand Side Management (DSM) measures will be key factors in improving system reliability and security. EPCOs can help balance the system more efficiently as bottlenecks in the transmission system are reduced.

Overall, as Japan navigates a complex energy transition, the country must make tangible progress regarding the above key recommendations. GE Vernova, with its unique portfolio of generation and grid technologies, global project experience, and a comprehensive footprint and corresponding expertise, is well positioned to support Japan in reaching its net-zero mission.

GE Vernova is privileged to work with its customers and stakeholders across Japan to deliver more reliable, affordable, secure, and resilient energy to help realize a net-zero target.

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