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JAPANESE ENERGY SECURITY

by

Lakir Patel

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This thesis explores whether Japan's energy marketplace reforms after the 2011 Fukushima nuclear disaster, as outlined and executed by the Ministry of Economy, Industry, and Trade (METI), will aid Japan in achieving greater energy security. This thesis qualitatively evaluates the state of reforms administered in various energy sectors (fossil fuels, nuclear power, and renewable technologies) and comments on their feasibility against Japan's energy transition goals within the energy trilemma. The conclusion reached is that of the two milestones set by METI (2030 and 2050), Japan will likely miss the energy target for 2030, but 2050 outcomes are promising with continued reform, liberalization of energy markets, and penetration of innovation within the energy sector. Japan's carbon dioxide emission reduction goals in combating climate change are misaligned with their desired energy portfolio. Use of liquid natural gas is quickly replacing oil and coal, which is likely to shift Japan's supply chain toward Southeast Asia and the United States but does little to reduce import dependence. A restart of nuclear power plants has been delayed, exacerbating traditional fuel demand signal. The renewable energy sector faces bureaucratic headwinds and market saturation. Liberalization of power generation and transmission markets, along with the elimination of curtailment policies, are likely to alleviate saturation and provide greater market penetration for Japan to become energy secure.

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LIST OF ACRONYMS AND ABBREVIATIONS

AEC	Atomic Energy Commission
ANRE	Agency for Natural Resources and Energy
APERC	Asia Pacific Energy Research Center
CCCU	Carbon Capture Storage and Utilization
COP21	United Nations Conference of Parties 21
ECS	East China Sea
EEZ	Exclusive Economic Zone
FDI	Foreign Direct Investment
FERC	Federal Energy Regulatory Commission
FIT	Feed-in Tariff
GHG	Green House Gas
GOJ	Government of Japan
GW	Gigawatt
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
ITA	International Trade Administration
JNOC	Japan National Oil Company
JOGMEC	Japan Oil Gas and Metals National Corporation
JPDC	Japan Petroleum Development Corporation
JPEA	Japanese Photovoltaic Energy Association
JUSEP	Japan-U.S. Strategic Energy Partnership
JWPA	Japan Wind Power Association
LCOE	Levelized Cost of Electricity
LDP	Liberal Democratic Party
LNG	Liquid Natural Gas
METI	Ministry of Economy, Trade and Industry
MEXT	Ministry of Education, Sports, Science, and Technology
MOFA	Ministry of Foreign Affairs
NEESTI	National Energy and Environmental Strategy for Technological Innovation towards 2050
NICE	Nuclear Innovation: Clean Energy Future
NISA	Nuclear and Industrial Safety Agency
NRA	Nuclear Regulatory Agency

NSC	Nuclear Safety Commission
OECD	Organisation for Economic Cooperation and Development
REN21	Renewables Now 21
RPS	Renewable Portfolio Standard
SDR	Self-Development Ratio
SSR	Self-Sufficiency Ratio
SWOT	Strength, Weakness, Opportunity, Threat
TEPCO	Tokyo Electric Power Company
UNFCCC	United Nations Framework Convention on Climate Change
WETI	World Energy Trilemma Index

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For Meghu, Stanzi, and the wonderful life ahead.

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I. INTRODUCTION

A. MAJOR RESEARCH QUESTION

This research investigates whether the policy initiatives pursued by the Japanese government in the wake of the March 11, 2011, Fukushima nuclear disaster will be sufficient for Japan to meet their energy security portfolio for sustainable energy security? Japan's *Fifth Strategic Energy Plan* document discusses the requirements and trade-offs for access, affordability, implementation, and sustainment within its energy trilemma.[1] The energy trilemma requires Japan to develop an analytical framework with robust measurement variables such as overall supply, overall demand, cradle-to-grave cost structure, logistical volatility, safety considerations, reserve production margin at peak demand, environmental opportunity cost, industry adaptation rate, per-capita energy expenditure, and consumer incentives just to name a few. Each viable energy source has unique strengths and weaknesses for long-term sustainability. This research qualitatively evaluates each alternative to fossil fuel in terms of its strengths, weaknesses, opportunities, and threats to determine whether Japan's energy security strategy is reforming the energy marketplace to achieve Japan's future consumer and industrial energy requirements.

B. CONCEPTUAL ORIENTATION

Energy security is broadly defined as the "availability of energy at all times, in various forms, in sufficient quantities, and at affordable prices, without unacceptable or irreversible impact on the economy or the environment."[2] The energy security dialogue in Japan only intensified after the Fukushima catastrophe.

The Japanese government has acknowledged its vulnerability in its current energy analysis models. Japan recognizes the absolute requirement and the significance of meeting

[1] Ministry of Economy, Trade and Industry, *Cabinet Decision on the New Strategic Energy Plan* (Tokyo, Japan: Agency for Natural Resources and Energy, 2018), https://www.meti.go.jp/english/press/2018/pdf/0703_002c.pdf.

[2] Vlado Vivoda, *Energy Security in Japan: Challenges after Fukushima* (London, UK: Routledge, 2016), 5, https://doi.org/10.4324/9781315579566.

their energy security with a diverse energy portfolio. With minimal domestic fossil fuel production, Japan must have a resilient energy portfolio composed of advanced nuclear power and renewable sources, such as wind, geothermal, solar, bio-energy, and hydroelectric power, to maintain Japan's economic competitiveness while balancing capital resource constraints, resource politics, economic necessity, demographic changes, and environmental constraints in developing policy responses.

C. SIGNIFICANCE OF THE RESEARCH QUESTION

Japan is an important industrialized ally of the United States in the Far East. Japan still has the world's third-largest economy despite experiencing two decades of slow growth. The Japanese economy heavily relies on net energy imports, even with an efficient pattern of use. The negative economic cost of Fukushima on the Japanese economy has spurred lawmakers to reprioritize energy consumption toward renewable resources. The causal anthropogenic effects of climate change, especially for an island nation, are more readily apparent and can significantly disrupt Japan's economy and its national security. In turn, the Japanese government has steadily worked to reduce import dependence on fossil fuel for domestic energy security. Based on the current trend, by year 2100, there is an 80 percent likelihood that climate change would depress Japan's economy by more than 10 percent.[3]

As a signatory to the United Nations Framework Convention on Climate Change (UNFCCC or Kyoto Protocol) in 1977, the Japanese government has since taken a holistic approach to diversifying their energy mix. Since the Fukushima nuclear reactor disaster, the political and economic forces have intensified the debate toward a safe, efficient, and effective domestic energy security for Japan. The Fukushima Daiichi incident imposed significant economic costs on Japan. As Samuels writes, "The official estimate of the physical cost of this disaster was put at 16.9 trillion yen—more than 10 trillion yen in buildings and nearly 4 trillion yen in power, communications, and transport infrastructure.

[3] Marshall Burke, Solomon M. Hsiang and Edward Miguel, "Global Non-Linear Effect of Temperature on Economic Production," *Nature* 527, no. 7577 (November 2015): 236, https://doi.org/10.1038/nature15725.

Standard & Poor's, however, estimated that 20–50 trillion yen was more accurate."[4] Japan's economy cannot risk another Fukushima-type disaster.

After World War II, the economic development in Japan focused on rapid industrialization and reconstruction. It was aided by an extensive use of fossil fuels powering growth and expansion due to its cost-effectiveness in energy security. In the decades following it, the oil crises and energy supply shocks of 1973 and 1979 forced the Japanese government to adopt policies and strategies to shore up energy access. Japan created stockpiling reserves, increased usage efficiency across all industrial sectors, and began investing in nuclear power generation to tame exogenous disruptions to its economy; hence, these efforts resulted in Japan becoming the most energy-efficient nation in the world.[5] However, the Fukushima incident revived the political and economic debate around reducing import dependence in industry and consumer economy, while maximizing safety. With anthropogenic climate change at the forefront of the global discussion, reverting to relying only on fossil fuels is a politically contentious issue and not a viable option for the Japan in achieving a greater energy security.

Nuclear energy safety concerns elevated the discussion of the role of nuclear reactors in energy production in the overall demand equation. After Fukushima, the majority of Japan's nuclear power fleet was taken offline for safety evaluations, exacerbating the energy security problem. If Japan wishes to reduce foreign dependence on energy, it must find innovative solutions to produce energy domestically—for which nuclear power is an unavoidable part of the medium-term solution. Former Japanese Prime Minister Junichiro Koizumi, once a proponent of a Japan "built on nuclear power," has recently altered his position and said, "There is nothing more costly than nuclear power… [and] Japan should achieve zero nuclear plants and aim for a more sustainable society."[6]

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[4] Richard J. Samuels, *3.11 Disaster and Change in Japan* (New York: Cornell University Press, 2013), 6.

[5] Vlado Vivoda, "Japan's Energy Security Predicament Post-Fukushima," *Energy Policy* 46 (July 2012): 135, https://doi.org/10.1016/j.enpol.2012.03.044.

[6] Martin Fackler, "Former Japanese Leader Declares Opposition to Nuclear Power," *New York Times*, October 02, 2013, https://www.nytimes.com/2013/10/03/world/asia/former-prime-minister-declares-opposition-to-nuclear-power-in-japan.html?_r=0&module=inline.

Today, Japanese politics led by the Liberal Democratic Party (LDP) and Prime Minister Shinzo Abe recognize the political cost of keeping nuclear fleets online, but nuclear fleets are absolutely essential in meeting Japan's energy needs in a volatile energy market.

Japan is also a net exporter of sophisticated technology; thus, a Japanese energy revolution will aid in solving energy security challenges abroad as well. Japan will have a more substantial impact in assisting developing nations to meet their own energy challenges, especially if the catastrophic events of global climate change continue to worsen. In keeping with pledges of Kyoto Protocol and Paris conferences on climate change, Japan is structurally shifting away from fossil fuels to reduce greenhouse gas (GHG) emissions and supplement the energy deficiency with a *National Energy and Environment Strategy for Technological Innovation towards 2050* (NEESTI). Advanced nuclear power generation, intelligent transport systems, improved structural materials, superconducting power transmission, and high-performance electricity storage are a few of the technologies outlined in NEESTI report that could be exported while supporting Japan's policy goals.

Energy market volatility has a direct and a causal reaction within the rest of the Japanese economy, ranging from automotive manufacturing to consumer electronics. Japan is a leading contributor of innovative and groundbreaking technologies within the world's leading economies and a significant energy consumer even with an efficient pattern of use. Japanese technology is traded extensively around the world. A disruption in the energy security of Japan would have significant negative ripples within the global community. A forward-looking, renewable and sustainable energy strategy will be critical for Japan to maintain its economic prowess.

Japan does not have an abundance of natural resources within its borders. Along with rising domestic consumption of energy, Japan must contend with the rising energy demand within the Asia-Pacific region, particularly in China and India, putting additional strain on the hydrocarbon-based energy supplies imported to Japan. Political leaders recognize this reality but their decisions are at the mercy of political forces, not grounded in loss-gain economic matrix. Japan should carefully navigate and negotiate resource diplomacy with other countries while developing an organic, domestic energy portfolio that will enhance self-reliance in the interest of national security. The 2017 *World Energy Trilemma* Index ranks Japan at No. 30 in a grouping of energy security, energy equity, and environmental sustainability.[7] While the Japanese leaders are continuously and rationally evaluating energy generation portfolio to meet Japan's future energy needs, they must include a combination of reduced fossil fuels dependency, increased used of advanced nuclear power, and the largest-scale integration of renewable energy technology in the reformed economic structure and policy agenda.

D. LITERATURE REVIEW

In July 2018, the Japanese government, the Ministry of Economy, Trade, and Industry (METI) and Agency for Natural Resources and Energy (ANRE) jointly published a revised *Fifth Strategic Energy Plan* policy document for the Japanese economy. In it, Japan identified goals that would "contribute to further growth of the Japanese economy, improvement of the standard of living, and global development through an energy supply that is stable, sustainable long term, and independent."[8] Embedded within the document are objectives of safety through technological and governance reform, specific energy generation security by expanding the diversity of choice, environmental considerations by working toward decarbonisation, and economic efficiency to enhance domestic industrial competitiveness.[9]

A declining population and lackluster economic growth have depressed the overall energy demand, specifically in end form electricity for Japan's producers. In fact, today, the total demand in watt-hours has declined more than 10% compared to 2010. Following this current trend, demand will continue to slow through the 2030 and 2050 milestones, an important consideration in planning for energy security. By 2030, when combined with the projected energy efficiency of Japan, the total Japanese electrical demand is set to drop

[7] World Energy Council, *World Energy Trilemma Index 2018: Monitoring the Sustainability of National Energy Systems* (London, UK: World Energy Council, 2018), https://www.worldenergy.org/publications/2018/trilemma-report-2018.

[8] Ministry of Economy, Trade and Industry, *Fifth Strategic Energy Plan* (Tokyo, Japan: Agency for Natural Resources and Energy, 2018), https://www.meti.go.jp/english/press/2018/pdf/0703_002a.pdf.

[9] Ministry of Economy, Trade and Industry, 1.

from 1140-terawatt hour (TWh) to 868 TWh.[10] As the overall demand weakens, the existing infrastructure will be able to support the industrial and consumer energy transition. Restructuring is likely to raise reliability and security within the trilemma and the Japanese economy as a whole.

Essentially, the Japanese energy security policy responses are trying to address three distinct dimensions of the energy trilemma. The three broad dimensions of energy independence are energy security, energy equity, and environmental sustainability.[11] Japan has failed to rank in the top 10 countries of the *World Energy Trilemma* Index (WETI) with greatest diversified energy security where Denmark, Switzerland, and Sweden are leading the charge, respectively. Japan has the technological know-how to certainly contend for top marks, but political forces often delay or restrict implementation of a broadly progressive agenda. WETI interprets energy security as the

> effective management of primary energy supply from domestic and external sources, the reliability of energy infrastructure, and the ability of energy providers to meet current and future demand. Energy equity is defined as—accessibility and affordability of energy supply across the population, and environmental sustainability is defined as encompassing the achievement of supply-side and demand-side energy efficiencies and development of energy supply from renewable and other low-carbon sources.[12]

Japan's energy anxiety is a product of its rapid post-war industrial development and its economic development occurring through two significant oil supply shocks in the 1970s. Amid the crisis, the government responded quickly by creating energy stockpile requirements for the energy sector to shield against a future crisis. Although stockpiling requirements are an adequate near-term solution, it is not viable in the long-term because of the dynamic demands of the industrial sector, negotiated or pending open market futures contracts, and an overall energy market supply-demand volatility. The 1975 Petroleum

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[10] Tim Buckley and Simon Nicholas., *Japan: Greater Energy Security through Renewables Electricity Transformation in a Post-Nuclear Economy* (Cleveland, OH: Institute for Energy Economics and Financial Analysis, 2017), http://ieefa.org/wp-content/uploads/2017/03/Japan_-Greater-Energy-Security-Through-Renewables-_March-2017.pdf.

[11] World Energy Council, 9.

[12] World Energy Council, 9.

Stockpile Act required 70 days of reserves as measured by the previous year's domestic consumption, which was further supplemented by the creation of the Japan National Oil Company (JNOC) in 1978, which raised an additional 36 days of oil reserves. Maintaining a significant reserve to guard against a shortage has remained a cornerstone of the Japanese government's energy policy to this day. In addition to establishing stockpiles, Japan has taken additional steps to modernize and pursue higher efficiency from existing energy usage. With the 1979 Energy Conservation Act, the government established efficiency standards in all industries to reduce overall consumption and encourage an efficient pattern of use—leading to Japan's place as a worldwide leader in energy efficiency across consumer and industrial sectors.[13]

METI has outlined two comprehensive energy independence targets by the years 2030 and 2050. By setting realistic near-term and medium-term goals, Japan is able to rationalize milestones and isolate policy responses needed to achieve each of them. Forecasting future energy demands inherently faces uncertainties of technological change, inter-technology cost competition as a byproduct of innovation, and an intensified competition between domestic firms and international firms to secure profitability. By 2030, METI aims to achieve a considerable reduction in GHG emissions by using a comprehensive and diverse energy portfolio. For the 2030 milestones, a renewable energy portfolio requires laying the foundations of operating renewables as an adequate and reliable power source by investing in cost reduction and solving system constraints.[14] For a safe and reliable nuclear power industry, a recurring comprehensive safety inspection and report is required to restore public faith in fission thermal power generation, simultaneously encouraging investment into developing safer technologies, as nuclear power should become a significant cornerstone of complete decarbonisation for long-term energy independence for Japan.

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[13] John S. Duffield, *Fuels Paradise: Seeking Energy Security in Europe, Japan, and the United States* (Baltimore: Johns Hopkins University Press, 2015), 202–203.

[14] Ministry of Economy, Trade and Industry, 13–14.

For 2050, METI's goal to reduce GHG emissions is significantly more ambitious than 2030, striving for a complete decarbonisation of major sectors of the economy. To achieve this goal, METI understands that a fundamental pivot away from fossil fuels will be required. Specifically, renewable energy must be an independent, reliable, and economically efficient primary power source. A safe and effective nuclear fleet strategically located throughout the island to serve the needs of the Japanese people will also be required. Nuclear energy is an important medium-term alternative to aid a full-scale economy-wide decarbonisation. One of the most common challenges associated with regional energy security is power distribution and storage systems, and are likely to intensify with increased independence from fossil fuels that currently supports Japan's infrastructure. Japan's 2050 energy goals will require large investment into research and development, upgrading infrastructure to support an energy economy in transition, embracing uncertainty and emerging technology, and unyielding financial support to achieve them.[15]

There are two wide-ranging categories of energy technologies under debate to help Japan meet its energy security: renewables energy including wind, solar, geothermal, hydro, and to a lesser extent biological fuels as well as an advanced nuclear reactor fleet. Before 2011, Japan was only marginally self-sufficient in its overall energy requirements. It was labeled with one of the highest risk indices of an *Organisation of Economic Cooperation and Development* (OECD) nations in the world.[16] Learning from the oil supply shocks of the 1970s, METI had started to invest in renewable power, mainly solar, via their Sunshine Program. Japan's geography is prone to earthquakes, and thus legitimate concerns of safety are unavoidable with nuclear power. The LDP, led by Shinzo Abe recognizes nuclear power as a viable solution, although the commercialization of solar and

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[15] Ministry of Economy, Trade and Industry, 115–122.

[16] Frank Umbach, "The Energy Security of Japan after Fukushima 3/11," in *the Political Economy of Renewable Energy and Energy Security. Common Challenges and National Responses in Japan, China, and Northern Europe*, ed. Espen Moe and Paul Midford (New York: Palgrave Macmillan, 2014), 47.

wind power is relatively easier to sell to the public after Fukushima Daiichi.[17] A combination of both policies will help advance Japan's energy future.

Prior to the Fukushima nuclear accident, nuclear thermal power generation provided a significant percentage of the overall energy production. Japan had intended to continue scaling nuclear power to offset rising demand and reduce import dependency. Immediately after the accident, utilities were forced to rely on traditional fuel sources with higher import costs, leading to Japan's first ever trade deficit since 1980 with an overall import cost rising to 25.2%.[18] As Hayashi and Hughes explain, a rapid and sudden shift away from nuclear power for Japan is unlikely, even with the significant opposition from the public. Such opposition is likely to fade in the future, as the exporting of nuclear power technology remains an important basis of economic growth for Japan; however, it presents a unique opportunity to incorporate renewable energy into the Japanese energy portfolio.[19]

The thermal generation capacity lost after the Fukushima accident has been progressively replaced by Liquid Natural Gas (LNG). The easy substitution and availability of LNG make it an attractive alternative, even though it works against the climate policy goals set by METI. In the six months following the Fukushima accident, the consumption of LNG rose by nearly 25.9%, and Japan's LNG imports were 7.8 million tons, nearly a 13.5% increase compared to previous year's consumption.[20] Natural gas storage and transport require an intricate infrastructure and technological capacity to re-gasify the liquefied gas before use. LNG is a reliable fuel source and has seen increased use across Japan in both industrial and commercial applications. There are no pipelines connecting the importing of natural gas into Japan, and it is all done by specialized cargo ships requiring advanced docking terminals. LNG also has the lowest carbon emissions of all

[17] Stephen Stapczynski and Chisaki Watanabe, "Japan Court Allows Nuclear Reactor to Reopen in Boost to Abe's Energy Push," *Bloomberg Business,* last modified September 24, 2018, https://www.bloomberg.com/news/articles/2018-09-25/japan-court-rules-shikoku-electric-can-restart-nuclear-reactor.

[18] Vivoda, 136.

[19] Masatsugu Hayashi and Larry Hughes, "The Policy Responses to the Fukushima Nuclear Accident and Their Effect on Japanese Energy Security," *Energy Policy* 59, (August 2013): 97, https://doi.org/10.1016/j.enpol.2012.08.059.

[20] Hayashi and Hughes, 92.

fossil fuels, and hence, is an attractive option to supplement traditional and renewable energy sources to meet rising demand. Since the Fukushima accident, METI has classified "natural gas as an intermediate power source, which can be produced by low cost next to baseload power source, whose power output can respond quickly and flexibly to the situation of electricity demand."[21]

Japan is technologically sophisticated enough and capable of integrating renewable energy sources within their utilities; however, the required structural changes for mass-scale adaptation have not reached a vested interest and the required cost-efficiencies within the energy markets, argues Moe.[22] The infrastructure required to incorporate reliable solar power is drastically different from one required to integrate wind power into existing systems. Solar panels have the added benefit of integrating direct consumer markets into the categorical system, whereas large-scale wind power generation requires regulated industries in specific geographies with its associated environmental concerns.

Wind power is a credible alternative for Japan. Although highly dependent on location and weather conditions, offshore windfarms integrated into the Japanese energy market have the potential to serve densely populated areas of Japan. While land availability in Japan is limited, offshore wind farms carry an enormous potential to contribute to Japan's energy future. Again, as an intermediate energy source to base load demands, combined with the technical and manufacturing expertise of the Japanese industry, a utilization rate of 50% is achievable, generating nearly 10 gigawatt (GW).[23] Consistent with the United Nations Conference of Parties (COP21) pledge, METI has outlined a strategy to achieve Japan's overall energy needs from renewable sources as much as practically possible. A combination of capital market and regulatory reforms should allow Japan to generate 159 GW by 2030 from offshore wind farms alone to service highly

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[21] Ministry of Economy, Trade and Industry, 20.

[22] Espen Moe, "The Energy Security of Japan after Fukushima 3/11," in *the Political Economy of Renewable Energy and Energy Security. Common Challenges and National Responses in Japan, China, and Northern Europe,* ed. Espen Moe and Paul Midford (New York: Palgrave Macmillan, 2014), 280.

[23] Buckley and Nicholas, 3.

specific coastal areas on the eastern edge, where the threat of another tsunami remains credible.[24]

Achieving energy security is a complicated policy and technical matter for Japan. It requires a complete and comprehensive buy-in from all the stakeholders. For a free-market economy like Japan, reforms must be market oriented. Energy producers will need incentives to develop new cost-effective technologies and merge them with the economies of scale to reduce the overall cost of adaptation for consumers. The Government of Japan (GOJ) will need to act as an intermediary and to provide adequate regulatory compliance guidance to meet its 2030 and 2050 energy security goals. This research will largely deal with the economics of energy security with very limited political science influence unless necessary.

E. POTENTIAL EXPLANATIONS AND HYPOTHESES

Most promising solutions to Japan's energy security would ideally come from a robust and dynamic combination of an advanced nuclear reactor fleet for thermal power generation coupled with sustainable generation sources when they are geographically and environmentally significant in the region in which they are utilized. Japan's unique geography will require unique policy recommendations for each region. Some parts of Japan have a more efficient solar radiation map than others, wind patterns are more easily mapped in some parts and easily mechanized in others. With Fukushima's history looming clear on policy makers, nuclear power would be better suited in areas less prone to earthquakes and tsunamis. Lastly, for renewable resources, proximity to transmission lines and infrastructure available for power integration and storage is key. Given the anxiety and the suppression of nuclear-power use after the Fukushima Daichii accident in 2011, rebuilding the public trust with extensive safety inspections and transparent government oversight is critical to incorporate nuclear technology as a core element of Japan's long-term energy stability.

[24] Ministry of Economy, Trade and Industry, 48.

Many political and industry leaders believe removing nuclear power plants from operation will substantially raise energy costs and further slide Japan into an economic slowdown. However, during many public hearings, Japanese citizens often displayed significant support to suspend nuclear power generation in Japan. For the people of Japan, "The unmistakable theme of the hearings was mistrust of the government's ability to oversee nuclear safety."[25] However, Japan is unwilling to part with nuclear power. The Nuclear Regulation Authority (NRA) of Japan, created after Fukushima, is charged with tighter regulation of the industry in an effort to restore public confidence.

Second, an extensive infrastructure upgrade investment will need to supplement the recommendations of the energy policy. Improvements to the power grid, transmission systems, and control systems to manage dynamic power fluctuations rising from renewable sources will need to be integrated across all sectors. In the short-term, Japan must reduce the dependence on foreign oil and fossil fuel sources, while gradually increasing the integration of LNG into the Japanese industrial and consumer economy at market prices since large-scale use infrastructure currently does not exist in Japan. Even though Japan currently boasts the highest energy efficiency of any nation, a significant gain in the transportation industry with the introduction of electric vehicles should considerably reduce the demand for fossil fuels. In the medium to long-term, Japan must recognize the importance, safety, and reliability of nuclear power and use it as leverage to reach full energy security in combination with renewable sources. Market led incentives provided to both consumers and industry to increase mass-adaptation would accelerate the independence from fossil fuels while achieving energy security and meeting the climate change GHG reduction goals simultaneously.

F. RESEARCH DESIGN

In this thesis, various energy sources will be explored and evaluated for their strengths, weaknesses, opportunities, and threats. An analysis of the current state of use for

[25] Hiroko Tabuchi, "Japan, Under Pressure, Backs Off Goal to Phase Out Nuclear Power by 2040," *New York Times*, September 12, 2012, https://www.nytimes.com/2012/09/20/world/asia/japan-backs-off-of-goal-to-phase-out-nuclear-power-by-2040.html.

energy sources will be determined within the Japanese economy. This study will include an analysis of various fossil fuels, nuclear power, and renewables programs and recommendations currently implemented. A qualitative and analytical evaluation method for each sector will be considered separately as outlined below. The overall goal for the Japanese government is to provide a robust, reliable, affordable consumption, cost-effective generation, and an environmentally sustainable energy supply to all sectors of the economy while raising energy efficiency standards throughout the economy. This two-prong approach should suppress demand while shoring up the supply chain within the Japanese energy market structure.

To answer the research question of overall energy reassurance and self-sufficiency, this thesis research has the five overarching goals first. First, to identify, describe, and comparatively analyze the stated energy market reform goals of the Ministry of Economy, Trade and Industry (METI). Second, to determine if the prescribed policy reforms are appropriate to shift the energy focus away from heavy hydrocarbons dependence to economy-wide respite from import dependence. Third, this thesis will also consider whether Japan's climate goals are consistent with the international agreements, designed to combat anthropogenic climate change. Fourth, given the diverse landscape of Japan and modern technological capacity for innovation, evaluate economic policy recommendations for alleviating market saturation, time lag for adoption, and sophisticated challenges such as an overhaul of current power generation-delivery nexus. Finally, this analysis will also consider an overarching reality of changing demographics of Japan, specifically an aging population, which must be considered to provide affordable energy security in order to reduce the intertemporal per capita burden to access energy.

The identification of Japan's energy policy and strategy is derived from the documents produced by METI and ANRE. This is the most obvious, consistent, and approved means of analyzing Japan's energy strategy. It contains an extensive synthesis, legislative priorities, trade-off considerations, and an overall policy agenda Japanese politics allows. METI and ANRE most recently updated the *Fifth Strategic Energy Plan* in July 2018 for public consumption, which lays out the guidelines for the markets to operate in. Its unstated and nuanced goals to be achieved will be analyzed in conjunction with academic sources, global think tanks, as well as scholarly journals that evaluate the efficacy and viability of Japan's policies as a regionally significant economy in East Asia.

The effectiveness of the Japan's policy recommendations must be evaluated in terms of their strengths, weaknesses, opportunities, and threats (SWOT analysis) to understand the time-horizon in which Japan is trying to realize its goals. The SWOT analysis will undertake energy security as a single case study; however, each sector is given its own due consideration. For example, nuclear fuel safety is a critical component of nuclear power, whereas ecological consideration is critical for sustainability. In a broad scope, major themes for current and future energy posture and their relative viability of integration are considered for hydrocarbons, nuclear power, and renewables. In measuring the feasibility of the stated policy objective of each fuel source, economic trade-offs, opportunity costs, and political constraints will be presented to the reader if applicable. This will allow a rational determination of which strategies are the most effective and which are the most probable. In a democratic country like Japan, the diversity of ideas often results in conflicts and a moderate solution is often produced to advance a political agenda. Since METI has two distinct goals by 2030 and 2050, an assessment will be offered on the likelihood of meeting those binding goals.

Japan is one of the United States' more staunch allies in East Asia. It is necessary to comment on how Japanese energy security is beneficial to the state security of Japan, and ultimately beneficial to the United States. Rapid expansion of the Chinese domestic economy and its quest to achieve energy supply security as a matter of state objective further underscores Japan's energy insecurity. In this pursuit, scholarly sources such as energy transition journal articles, newspapers like the *New York Times*, professional organizations like the International Energy Association (IEA), or *Bloomberg Business* Analytics that comment on the combination of energy policy, international relations, and security studies will be consulted. While Japan has a broad energy policy portfolio, this thesis research will not comment or evaluate Japanese policy against other states. Japan is a unique country with unique energy needs, and a comparison to China or South Korea will almost certainly not be commensurate. This research will show that given the geographic isolation of Japan, it must undertake a radically different and innovative policy reforms.

Since Japan cannot physically connect its supply chain to another country in Asia right now, its energy transition is rooted in altering economic preferences and mounting technical progress to substitute traditional energy portfolios. As an advanced economy in the region, and a country that exports technology throughout the world, Japanese energy policy can be used as a state tool to influence economic security outcomes. Energy security for Japan is a time-sensitive matter, and Japan must take steps now to reduce foreign dependence and develop domestic energy production infrastructure in order to achieve stable, reliable, and cost-efficient energy supplies in order to maintain its economic preeminence on the global stage.

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II. HYDROCARBONS

A. OVERVIEW

The fossil fuel-based energy supply comprises the largest share of energy availability in Japan. A common measurement to readily display the scarcity has been adopted in this research. It is called Japan's energy Self-Sufficiency Ratio (SSR). It explains the total primary energy necessary for all lifestyles and economic activities. In a comparison of total primary source availability (including coal, crude oil, natural gas, nuclear power, hydro-electric power, and renewable resources combined), Japan's 2018 SSR was a mere 9.6% compared to, for example, Norway at 792.6% and Australia at 306.0% because of their abundance of domestic energy resources.[26] With one of the lowest ratios among OECD countries, Japan's energy security is vulnerable due to extreme dependence on exporting countries.[27] In East Asia, the demand for a diversified fossil fuel portfolio is strong. The Japanese and the Chinese economies are voracious consumers of energy. China is able to extract resources from its vast landmass whereas Japan lacks such advantage. Prior to March 2011, Japan heavily relied on imports and the Fukushima accident simply exacerbated the energy imbalance. As Figure 1 shows, Japan's net energy imports rose sharply immediately after the Fukushima incident in 2011.

[26] "Japan's Energy 2018. 10 questions for understanding the current energy situation," Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy, June 2019, https://www.enecho.meti.go.jp/en/category/brochures/pdf/japan_energy_2018.pdf."

[27] Ministry of Economy, Trade and Industry, 10 questions for understanding the current energy situation, 2.

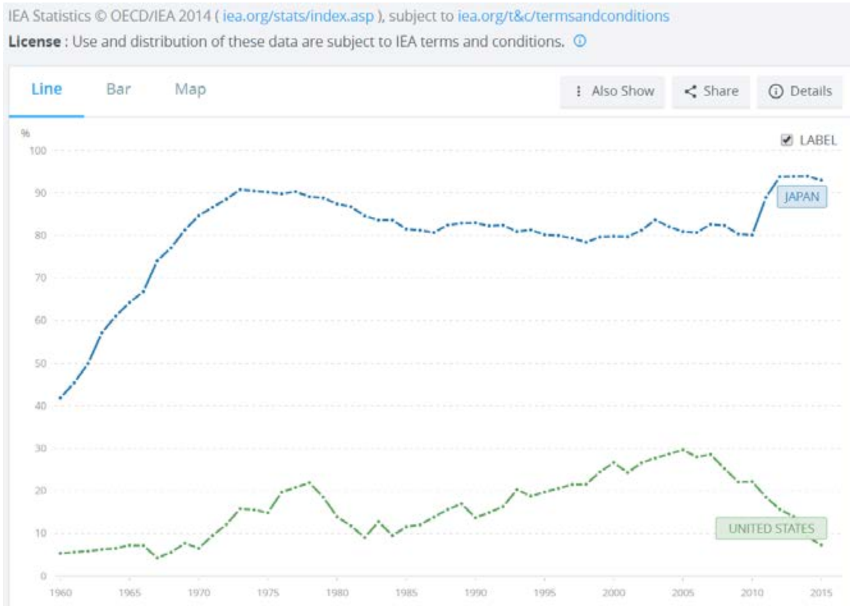

Figure 1. Net energy imports, percentage of energy use in Japan from available data, 1965–2015.[28]

The U.S. Energy Information Administration's (EIA) country brief labels Japan as the largest liquefied natural gas importer (LNG), and fourth in the world for coal and petroleum imports.[29] EIA goes on to mention that

> in the wake of the Fukushima nuclear incident, Japan's energy fuel mix shifted as natural gas, oil, and renewable energy now provide larger shares and supplant some of the nuclear fuel. Oil remains the largest source of primary energy in Japan, although its share of total energy consumption has declined from about 80% in the 1970s to 42% in 2015.[30]

Within the hydrocarbon category, the relative dependence on energy imports remain high, but the combination imports have shifted depending on the global market forces and Japan's commitment to reduce GHG emissions to meet the carbon dioxide cap

28 Adapted from "Energy Imports, net (% of energy use) —Japan, United States," The World Bank, accessed October 18, 2019, https://data.worldbank.org/indicator/EG.IMP.CONS.ZS?end=2015&locations=JP-US&start=1960&view=chart.

29 "Country Analysis Brief: Japan," U.S. Energy Information Administration, February 2, 2017, https://www.eia.gov/beta/international/analysis_includes/countries_long/Japan/japan.pdf.

30 U.S. Energy Information Administration, 2.

set at both the Kyoto Protocol and most recently at Paris climate accords. Figure 2 illustrates how the energy supply landscape in Japan has shifted over the years. The sharp decline in nuclear power is noteworthy after 2010, as it was readily substituted by LNG and coal.

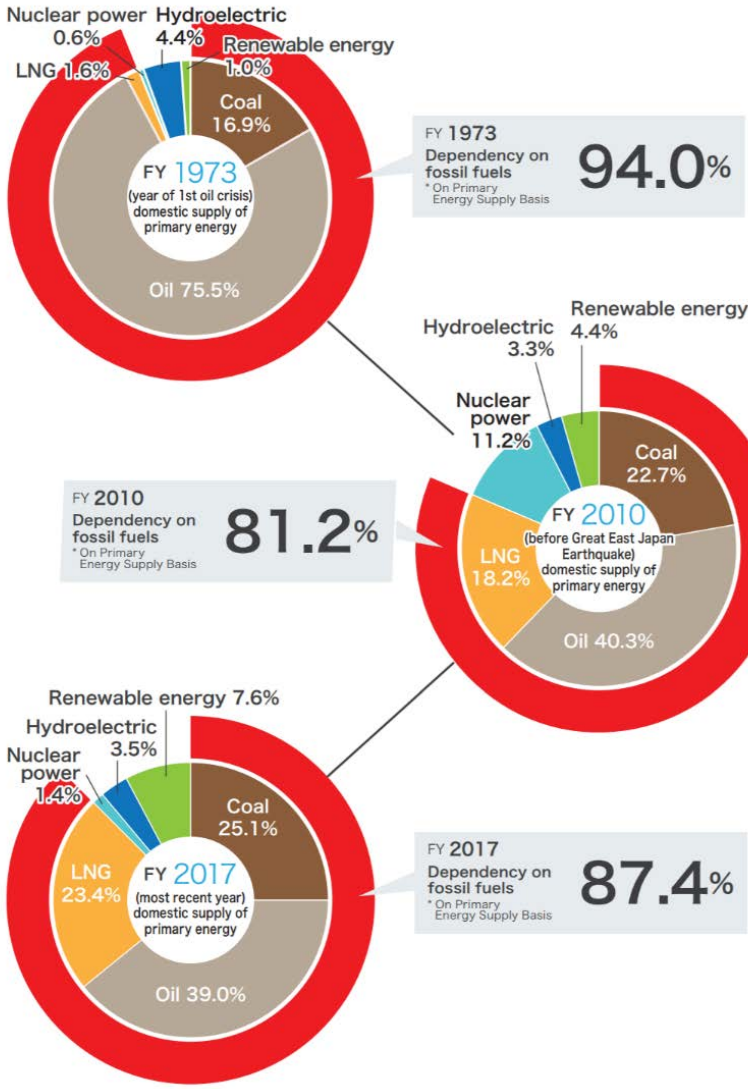

Figure 2. Trends in composition of primary energy supply of Japan.[31]

[31] Source: Ministry of Economy, Trade and Industry and Agency for Natural Resources and Energy, 2.

Japan has navigated a careful resource diplomacy strategy to ensure its energy demands are met efficiently and at a reasonable cost given its 4.037 million barrels of oil consumption per day, the fourth highest in the world.[32] Despite foreign policy pressures, Japan has managed to maintain a diversified network of imports from various countries. In 2018, top crude oil suppliers to Japan were as follows: Saudi Arabia at 38.6% and United Arab Emirates at 25.4%, followed by Qatar at 7.9% and Kuwait at 7.7% of the total 1.1 billion barrels imported; in importing LNG, Japan relied on Australia at 34.6%, Malaysia at 13.6%, Qatar at 12.0%, and Russia at 8.1% followed by various others; and lastly for coal imports to Japan, the vast majority of them come from Australia at 71.5% followed by Indonesia at 11.8%.[33] Japan's Resource diplomacy's top objective is "securing the flow of oil and facilitating concession agreement extensions and signing of new production sharing contracts (PSC)."[34]

Japan's excessive dependence on hydrocarbons has concerned the Ministry of Economy, Trade, and Industry (METI) since the 1960s. METI has since teamed up with Agency for Natural Resources and Energy (ANRE) and Ministry of Foreign Affairs (MOFA) to develop policy proposals that will enhance and strengthen hydrocarbon supply resiliency. Both agencies are engaged in a concerted effort to raise Japan's self-development and production ratio (SDR)[35] by providing financial incentives for national oil projects (mainly by Japan Gas, Oil, and Metals National Corporation (JOGMEC), Japan National Oil Corporation (JNOC), and Japan Petroleum Development Corporation (JPDC) government agencies) for off-shore and overseas exploration of hydrocarbon resources.[36] Additionally, both vertical and horizontal consolidation have been encouraged to leverage bargaining power of companies and increase market-driven competitiveness because of the

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[32] "BP Statistical Review of World Energy," BP, June 2017, https://www.bp.com/content/dam/bp-country/de_ch/PDF/bp-statistical-review-of-world-energy-2017-full-report.pdf."

[33] Ministry of Economy, Trade and Industry and Agency for Natural Resources and Energy, 2.

[34] Loftur Thorarinsson, *A Review of the Evolution of the Japanese Oil Industry, Oil Policy and its Relationship with the Middle East*, Report No. OIES PAPER: WPM 76 (Oxford, UK: Oxford Institute for Energy Studies, 2018), https://doi.org/10.26889/9781784671020.

[35] Self-development and production ratio (SDR) is generally defined as a percentage of total annual domestic production for life and economic activity against total annual imports into Japan.

[36] Thorarinsson, 5–13.

fragmentation of the domestic industry comprised of independent actors with competing interests. Given the volatility of the commodity and numerous international factors, Vivoda explains:

> Japan has been a key participant in the zero-sum competition among Asian oil importers, particularly since the emergence of China as a major oil importer in the early 1990s. These interrelated challenges stem from the Japanese government's treatment of oil as a strategic commodity, which is not surprising given that Japan remains almost exclusively reliant on oil imports and given the country's experience during the 1970s oil crises.[37]

METI has developed an ambitious future policy proposal that is designed to elevate Japan's energy security, increase resiliency by diversifying its portfolio, and reduce dependence on imported oil while meeting carbon dioxide reduction goals outlined in global climate change action agreements.

B. AMBITIONS

Japan's *Fifth Strategic Energy Plan* document seeks to make structural changes to the energy requirements within Japan's economy with staggered achievement goals for 2030 and 2050. To meet these goals, improving energy efficiency is key across all industrial and commercial sectors that rely on fossil fuels. The overall population growth trend in Japan is negative, and thus developing concentrated hubs of energy consumption in urban areas will provide dual benefits: enable affordable access by reducing supply costs over a longer geographic distance and reduce environmental risk externalities. METI's plan seeks to reduce hydrocarbon energy demand associated with lifestyle and economic activity and replace it with technological innovation without compromising power density. By 2030, Japan has pledged to reduce its GHG emissions by 26% (which is approximately 1.042 billion tons) compared to 2013 levels in an effort to reduce fossil dependence in their energy mix.[38]

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[37] Vivoda, 70.

[38] "Submission of Japan's Intended Nationally Determined Contribution (INDC)," Ministry of the Environment, Government of Japan, accessed October 18, 2019, https://www.env.go.jp/en/earth/cc/2030indc.html.

Japan has agreed to major international and intergovernmental pacts in reducing GHG emissions in an effort to combat climate change. Divesting from fossil fuels will require a concerted effort among all industrial and commercial partners. The *Fifth Strategic Energy Plan* document aims for an effective government energy policy designed to balance the energy trilemma to ensure access and reliability while meeting environmental protection goals Japan has signed on to as outlined in Figure 3. Additionally, Figure 4 displays the trajectory of Japan's emissions since the 1990s. Under these collective agreements (Paris Agreement, Copenhagen Accords, and Kyoto Protocol),

> Japan will lead the international community under the Paris Agreement so that major greenhouse gas (GHG)-emitting countries will undertake the reduction of their emissions under a fair and effective international framework in which all major countries participate and will aim at the long-term goal of reducing greenhouse gas emissions by 80% by 2050 while reconciling global warming countermeasures and economic growth.[39]

JAPAN	Summary of pledges and targets	Climate Action Tracker
PARIS AGREEMENT	Ratified	Yes
	2030 unconditional target(s)	26% below 2013 by 2030 [15% below 1990 by 2030 excl. LULUCF] [17% below 2010 by 2030 excl. LULUCF]
	Coverage	Economy-wide, incl. LULUCF and overseas credits for 2030
	LULUCF	LULUCF credits considered
COPENHAGEN ACCORD	2020 target(s)	3.8% below 2005 by 2020 [7% above 1990 by 2020 excl. LULUCF] [5% above 2010 by 2020 excl. LULUCF]
	Condition(s)	LULUCF credits considered
KYOTO PROTOCOL (KP)	Member of KP CP1 (2008–2012)	Yes
	Member of KP CP2 (2013–2020)	No
	KP CP1 target (below base year)	6% below 1990
	KP CP2 target (below base year)	N/A
LONG-TERM GOAL(S)	Long-term goal(s)	80% by 2050 (base year not specified) [78% to 80% below 1990 by 2050 excl. LULUCF] [79% to 81% below 2010 by 2050 excl. LULUCF]

Figure 3. Japan's agreements to reduce greenhouse emissions.[40]

[39] Ministry of Economy, Trade and Industry, 108.

[40] Source: "Pledges and Targets Summary Table," Climate Action Tracker, September 19, 2019, https://climateactiontracker.org/countries/japan/pledges-and-targets/.

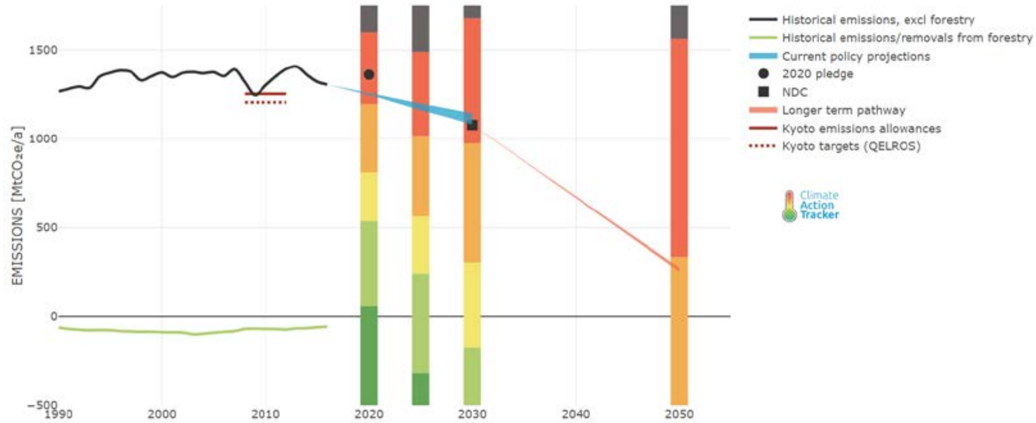

Figure 4. Historical view of Japan's emissions projections.[41]

Japan's ambitious energy policy is classified under the 3E + S framework. It includes energy security, economic efficiency, environmental suitability, and safety.[42] The desired energy mix in 2030 is comprised of 27% LNG, 26% coal, and less than 5% oil, while the rest supplemented by renewable sources.[43] METI has planned to work with the Japanese business sector to liberalize production and delivery energy markets. METI is careful to balance industrial and commercial use to ensure a desirable energy mix going forward. Japan has pledged to go even further to build energy resiliency. Japan's cabinet under the government of Prime Minister Shinzo Abe has adopted a plan to go carbon-neutral soon after 2050, with largescale introduction of advanced Carbon Capture, Storage, and Utilization (CCU) technologies to support such goal.[44] A high degree of energy trilemma attainment is the highest common denominator for Japan. A trilemma score of AAA in all three categories is ideal. Figure 5 clearly shows that Japan is an effective in ensuring energy equity with 100% electrification across the population, but has some structural issues to resolve stemming from high import dependence and its associated GHG emissions.

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[41] Source: "Country Summary," Climate Action Tracker, September 19, 2019, https://climateactiontracker.org/countries/japan/.

[42] Ministry of Economy, Trade and Industry, 118.

[43] "Discussions on the Energy Mix." IEEJ e-Newsletter No. 61, May 15, 2015, https://eneken.ieej.or.jp/en/jeb/150515.pdf.

[44] Yuka Obayashi and Jan Harvey, "Japan adopts long-term emissions strategy under Paris Agreement," *Reuters,* June 11, 2019, https://www.reuters.com/article/us-japan-environment/japan-adopts-long-term-emissions-strategy-under-paris-agreement-idUSKCN1TC1AJ.

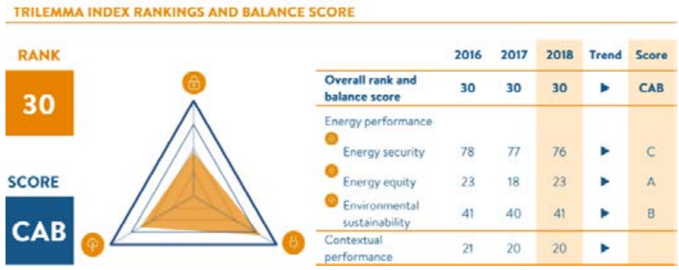

Figure 5. The 2018 Japan trilemma index rankings and balance score.[45]

C. PETROLEUM

Japan's petroleum refining infrastructure is quite robust, as shown in Figure 6; however, it is rarely used at peak capacity.

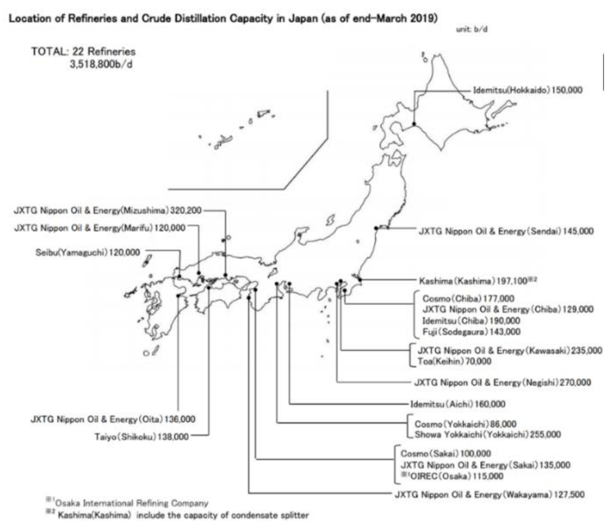

Figure 6. Japan's oil refineries and their production capacities.[46]

Energy security is rooted in the diversity of the supply chain. A multilayer, diversified network that is capable of appropriate elasticity during times of high uncertainty, crisis, and routine fluctuations in the demand matrix is ideal. Japan has taken

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[45] Source: "Country Profile: Japan," World Energy Council, accessed October 19, 2019, https://trilemma.worldenergy.org/#!/country-profile?country=Japan&year=2018.

[46] Source: "Oil Capacity, Location of Refineries and Crude Distillation Capacity in Japan," March 2019, https:// https://www.paj.gr.jp/english/statis/.

steps toward accomplishing this goal by seeking production contracts, joint ventures on resource exploration, and by partly shifting the geographic focus from which it obtains natural resources. While the Middle East remains a hub for Japanese crude oil imports, Southeast Asia has become an increasingly strategic supplier of energy resources for Japan. Vivoda underscores the importance of supplier diversity by highlighting that, "Should one supplier fall victim to natural disasters, terrorism, war, regime change, or other export-damaging events, importers will only experience minor disruptions to their total supply."[47] Japan understood that a comprehensive energy security must include an efficient demand management strategy, a technique in which "Japan seeks to leverage its comparative advantage in energy efficiency to further reduce its energy intensity."[48] The competition of resources from the emerging economies in the region make energy supply a zero-sum proposition for Japan. Even so, oil remains a flexible means with large stockpiles. It is scalable to various sectors and will remain an important source of energy throughout Japan's economy during its energy transition. METI's policy direction has classified oil as a resource of last resort to promote energy development and to achieve a multilayer portfolio but has refused to exclude it outright.

Japan unsurprisingly has consistently earned an "A" in energy equity, a multidimensional issue. The social stability and economic benefits generated from reliable physical availability and affordable energy access are high. Access is instrumental to the overall welfare of citizens. Reducing barriers to entry and promoting open market competition has been a key part of Japan's energy policy to expand access and reduce cost for the end-user. In the *Electricity Review of Japan*, a report published by the Federation of Electric Power Companies of Japan, 100 percent of Japanese residents have access to reliable electric power generated from thermal sources.[49] Within the trilemma, only realistic advancements in energy equity can occur by reducing the probability of blackouts

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[47] Vlado Vivoda and James Manicom, "Oil Import Diversification in Northeast Asia: A Comparison between China and Japan," *Journal of East Asian Studies* 11, no. 2 (May 2011): 232, https://doi.org/10.1017/S1598240800007177.

[48] Vivoda and Manicom, 231.

[49] The Federation of Electric Power Companies of Japan, "*Electricity Review Japan*, (Tokyo, Japan, 2018), https://www.fepc.or.jp/library/pamphlet/pdf/04_electricity.pdf.

and brownouts and improving the power transmission infrastructure to reduce the cost of transporting electricity. In Zhang's analysis, he writes that a high level of penetration of substitute technologies in place of oil and coal are compulsory to maintain existing levels of energy access and equity while reducing carbon dioxide levels as required.[50]

The United States and Japan are strong allies bounded by a security guarantee against threats in the region. Their economic and security interdependence often makes it difficult for Japan to be completely independent of the American influence in its resource resiliency. The weakness in the Japanese energy security actually stems from Japan's inability to make completely independent geopolitical decisions. Japan cannot commercially interact with regimes that either are at odds with Washington or are economically sanctioned. Broadly speaking, within the *Fifth Strategic Energy Plan*, Japan strives to reduce its dependence on the Middle East in terms of total energy consumption due to the substitution of LNG; however, for crude oil, Japan is still vulnerable to energy shocks originating from that region, a significant threat to energy security.

Act on the Rational Use of Energy enacted in 1978, also known as the Energy Conservation Act, mandates that all sectors ratify efficiency measures to assist in the national policy of energy security while improving affordability and access across the population. It is amended often to keep in line with strategic energy security goals. The latest revision proposal in 2016 includes thermal power generation facility efficiency standards upgrades for effective utilization of heat.[51] A continuous opportunity to improve energy security exists within Japan's immense efficiency capability. An interesting intersectional threat exists nested within this opportunity for more efficient use of energy. China's access to the global reserves of oil are larger than that of Japan simply due to the Chinese aversion of rules and norms of the international community. China routinely conducts business with states that are sanctioned by the western industrialized economies. In direct competition with China, Japan will most certainly lose a race for resources;

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[50] Qi Zhang et al. "Scenario Analysis on Future Electricity Supply and Demand in Japan." *Energy* 38, no. 1 (November 2011): 376–85. https://doi.org/10.1016/j.energy.2011.11.046.

[51] "Act on the rational use of energy (Energy Conservation Act)," International Energy Agency, September 28, 2016, https://www.iea.org/policiesandmeasures/pams/japan/name-24362-en.php.

however, strategic political cooperation could raise energy security of Japan. Vivoda underscores the importance of supply diversification and explains that

> Japan effectively needs Chinese acquiescence to gain direct access to Central Asian oil, while China continues to need assistance in improving energy efficiency…. cooperating with China for access to global resources, in exchange for assistance with energy efficiency technologies, should have resonance in Tokyo. This could lead to a way out of the zero-sum perspective in a region where there is little tangible cooperation on energy security [in 2019].[52]

The added factor of a population decline reduces the pressure on the Japanese government to act or collaborate with China and successful technological efficiency gains domestically make it even less likely they Tokyo will do so. METI's current energy policy directive is lukewarm at the idea of a Sino-Japanese collaboration due to the political distrust between the two. Tokyo would rather direct national resources towards independent oil exploration to raise the domestic SDR and energy-related technological development. The overlapping territorial claims in the East China Sea (ECS) over Exclusive Economic Zones (EEZ) make direct cooperation unlikely since the energy security linkages directly extend to national security. Herberg writes, "This struggle for Asian mastery fuses energy security with regional geopolitics and is reflected in intensifying disputes over territorial sovereignty in the South and East China Seas between China and neighboring states [especially Japan, the most militarily capable]."[53]

Japan currently maintains 36 thermal generation power plants, connecting the national trunk line power grid at either 500kV or 154–275 kV.[54] In 2013, Japan consumed 966.6 billion kWh of actual electrical energy, accounting for approximately 1.7% annual economic growth, and Japan is aiming to consume 1,278 billion kWh of energy by 2030.[55]

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[52] Vivoda and Manicom, 248.

[53] Mikkal Herberg, "Japan, Southeast Asia, and Australia," in *Energy & Security: Strategies for a world in transition*, ed. Jan H. Kalicki and David L. Goldwyn (Washington, DC: Woodrow Wilson Center Press, 2013), 128.

[54] "Principal Thermal Power Plants (1500MW or greater)," The Federation of Electric Power Companies of Japan, March 1, 2015, https://www.fepc.or.jp/english/energy_electricity/location/thermal/index.html.

[55] The Federation of Electric Power Companies of Japan, 3.

Through innovative conservation methods and energy-efficient improvements, Japanese energy policy calls to lower the importance of petroleum based thermal power generation and lower consumption by either direct reduction or via a substitution of more sustainable resources to achieve trilemma maximization. ANRE's energy transition methods are

> aiming to increase the energy self-sufficiency ratio and create a composition of power sources that is resistant to changes in international oil prices, the government of Japan is working to stabilize electricity rates by promoting competition between business operators through the full liberalization of the electricity retail market that was started in FY 2016.[56]

The vast majority of imported crude oil is refined within Japan as a cost-effective measure to reduce the costs that are passed on to the consumer. According to the Central Intelligence Agency (CIA)'s 2017 World Fact Book, Japan produces approximately 384 thousand barrels of crude oil per day, compared to the consumption rate of nearly 4 million barrels per day.[57] Immediately after the negative public sentiment of the Fukushima crisis, Japan shut down its nuclear power generation fleet and began to rely solely on fossil fuel energy, throwing the trilemma in to a state of chaos. Lain Wilson of *Bloomberg* notes, "To fill the hole, Japan turned to gas and oil. In 2013, a mere two years after Fukushima, Japan was generating 42 percent of its electricity from gas, while oil accounted for 15 percent and coal 31 percent."[58] The Fukushima accident inflicted a high cost of short-term energy import on Japan because of the tightly linked global oil supply that was slow to respond to a change in demand. As a direct result, the cost of electricity and transport across Japan increased rapidly. Electrical rates have risen nearly 30% for industrial users and 20% for consumer users, adding 1.8 trillion yen in surcharge to the downstream end-user consumption cost.[59]

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[56] Ministry of Economy, Trade and Industry and Agency for Natural Resources and Energy, 3.

[57] Central Intelligence Agency, *The World Factbook* (Washington, DC: Central Intelligence Agency, 2019), https://www.cia.gov/library/publications/the-world-factbook/geos/ja.html.

[58] Lain Wilson, "Japan's Energy Transition – This Time It May Be For Real," *BloombergNEF*, last modified March 18, 2019, https://about.bnef.com/blog/wilson-japans-energy-transition-time-may-real/.

[59] The Federation of Electric Power Companies of Japan, 4.

With the sweeping changes in the energy sector implemented, the overall oil demand in Japan has been declining and is projected to drop below 2.5 million barrels per day interchanged by substitute products in energy production, according to the *Oxford Institute of Energy Studies.*[60] As innovation displaces dated energy production and use practices, Japan is poised to expand energy access and affordability by engaging in extensive research and development of disruptive technologies. *Organisation for Economic Cooperation and Development* (OECD)'s book titled *Energy: The Next Fifty Years*, outlines the overall approach as, "Japan's survival strategy in a constrained economic environment: substitute a constraint-free production factor such as technology for a constrained one such as energy."[61]

As Japan's demographics shift, it is possible that per capita energy use will decline. Figure 7 shows the projected demand for traditional sources if the status quo is maintained while absorbing the negative opportunity cost of the foregone innovation. Development of highly technical and sophisticated technologies may very well be energy intensive in the production phase before they are able to return a net-positive energy independence.

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[60] Thorarinsson, 10.

[61] Chichiro Watanabe, *Organisation for Economic Co-Operation and Development, Energy: The Next Fifty years* (Paris: OECD Publication Service, 1999), 135, https://doi.org/10.1787/9789264173163-en.

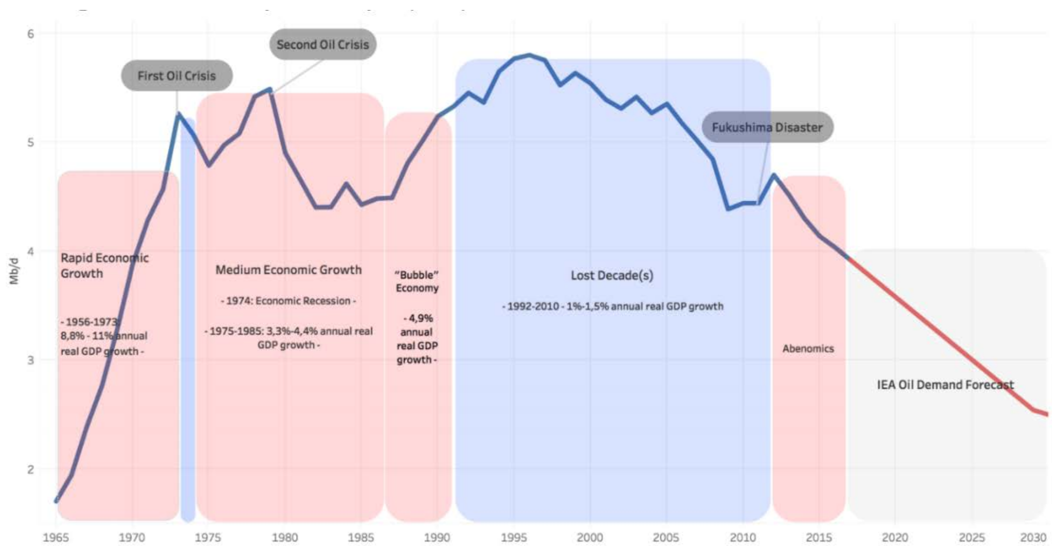

Figure 7. Japan's oil demand forecast through 2030.[62]

In Japan, stockpiling of oil resources began in the 1970s to reduce supply shocks to the economy. This practice is still widely in use today. In addition to the strategic resources for national security, Japan has maintained an oil stockpiling target as determined by METI and ANRE and as required by the Oil Stockpiling Act of 1975. The Japanese government and private companies are explicitly required to hold stockpiles, approximately 208 days of domestic consumption, which amounts to approximately 80 million kiloliters of oil.[63] As part of the negotiated contracts and soft diplomacy, Japan also maintains some reserves with petroleum-producing nations to further safeguard its supply and bolster energy security, consistent with their strategy.

Aiding the quest for energy security in Japan is its modern, well-developed, adaptive, and scalable network of infrastructure. The mesh network of delivery and transport system is engineered to survive many decades even with the frequency of seismic activity in the region. METI's multi-layer approach includes comprehensive upgrades to utilities infrastructure to deliver a resilient network in support of the end-user.

62 Source: Loftur Thorarinsson, 10.

63 "Stockpiling system," Japan Oil, Gas and Metals National Corporation, March 2017, http://www.jogmec.go.jp/english/stockpiling/stockpiling_10_000002.html.

Interconnected infrastructure with another state is unfortunately not an option for Japan at this time, unlike Germany or France. Market transactions in buying and selling power based on peak or adjusted demand significantly limits Japan in achieving energy security in the electrical power generation sector. Thus, it has become essential for Japan to establish and maintain a robust energy support infrastructure for access and affordability to elevate the trilemma score as defined by the World Energy Council and WETI. Jansen and Van der Welle write that

> to ensure "energy security," most policymakers tend to content themselves by and large with two major activities. These are: (1) standard energy infrastructure planning and plan realization, and (2) diversification of fuel sourcing and fuel transport routing to hedge against resource concentration as their main supply security concerns.[64]

Energy transport infrastructure can be considered a public good even though the case for hard action in favor of public infrastructure investment in energy markets is complex. Given the nature of Japan's geography, public policy options to accommodate energy access, affordability, and transport require regional solutions, which are being dealt with by Japan in a limited extent. One such aspect, the reliability dimension the energy transition, advocates for a resilient infrastructure to which Japan's construction industries are responding. Insuring against acts of terrorism and preventing energy delivery bottlenecks should further stabilize market volatility.

Reliable electrical access is key to ensuring a high quality of life for citizens and maintaining a favorable economic landscape in the economy as in whole. As an OECD country, Japan's Human Development Index is quite high, 0.909 to be exact, ranked 19th worldwide.[65] The Fukushima accident suddenly removed the nuclear power source for electricity generation, approximately 30 gigawatts, or about 17.3%, of Japan's total

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64 Jaap C. Jansen and Adriaan J. Van der Welle, "The Energy Services Dimension of Energy Security," in *The Routledge Handbook of Energy Security*, ed. Roman V. Sidortsov (London: Routledge, 2010), 247.

65 "United Nations Development Programme, Human Development Indicators," United National Development Programme, Human Development Reports, accessed October 19, 2019, http://hdr.undp.org/en/countries/profiles/JPN.

capacity,[66] which required petroleum-based power generation sources to adjust to dynamic demand, raising electricity prices in face of a reduced supply. METI's 3E+S energy policy specifically calls for the separation of transmission and distribution markets from electrical generation markets to provide consumers greater access while fostering innovation and competition to lower overall cost of electricity.[67] Chapman and Itaoka identify four key mechanisms of Japan's potential pathway to transition—transformation, reconfiguration, technological substitution, and de-alignment/realignment—to achieve higher energy security and a balanced trilemma.[68] A fully liberalized market supports price-signaling mechanisms to promote investment based on consumer preferences. In Japan, these are reduced price volatility, transparency of costs, and price/service competition among companies with a focus on environmentally sustainable power generation.

The multi-layered energy transition of Japan is benefiting from the guidance of the energy policies outlined by the government. The abolition of regional monopolies on the consumer side and creation of wholesale power market exchanges with increased oversight on power grid neutrality in the high-rate supply areas are key for systemic reforms. Competing open market demands are unlikely to be met by the market alone, especially because the industry is risk-averse in responding to changes in the population location and concentration throughout Japan. Government policy is reducing the influence of exogenous variables in the prospective energy transition decision making, encouraging a rapid transition away from conventional fuel sources, but the transition will likely still require significant behavioral change leading to a large-scale adaption of alternate energy sources to meet energy security goals of 2030 and 2050.

Energy source mix dictates the requirements of the infrastructure. After the Fukushima accident, much of the nuclear infrastructure became underutilized and the

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66 John S. Duffield, "Japanese Energy Policy after Fukushima Daiichi: Nuclear Ambivalence," *Political Science Quarterly* 131, no. 1 (March 2016): 136, https://doi.org/10.1002/polq.12431.

67 Ministry of Economy, Trade and Industry, 82–84.

68 Andrew J. Chapman and Kenshi Itaoka, "Energy Transition to a Future Low-Carbon Energy Society in Japan's Liberalizing Electricity Market: Precedents, Policies and Factors of Successful Transition," *Renewable and Sustainable Energy Reviews* 81, no. Part 2 (January 2018): 2021, https://doi.org/10.1016/j.rser.2017.06.011.

demand pressure was transferred to the petroleum-supported sector. Japan's industrial strength in the infrastructure construction and development sector is supporting energy transition. METI's policy guidance suggests a need to not only replace aging infrastructure but also enact large-scale capital spending projects

> for constructing power transmission and distribution networks that can adapt to the different power generation time zones and power output characteristics of various energy sources as well as for taking measures to enhance the stability of power grids, including the installation of load following power sources and storage batteries.[69]

The energy landscape is clearly changing in Japan. The qualitative review of the energy trilemma is moving in the positive direction to further reinforce Japan's energy strategy and policy. The overall focus of the oil-dependent transport, residential, commercial, and industrial sectors is to reduce their dependency. It can be accomplished via diversification, innovation, and energy efficiency upgrades to meet the consumer demand while attaining goals designed to combat climate change. A shift in the consumption behavior of petroleum resources is critical to Japan's survival in the changing geopolitical landscape. Japan's shrinking population should soften the overall demand for petroleum goods and aiding energy security; however, vast majority of the improvements in the energy security will be realized from a systematic shift away from fossil fuels and utilization of alternate-source domestic energy production. Petroleum is deeply rooted in the Japanese economy as a relatively cost-effective baseline fuel used to power economic growth and socioeconomic progress. Even though Japan strives to become a net-zero emissions society after 2050, Japan will likely remain an importer of fossil fuels through 2030 and 2050.

D. NATURAL GAS

While oil and coal-based power generation may provide relatively cheap electrical and thermal power generation, the appeal of natural gas as part of the energy security mix in Japan after Fukushima has been rising. As some coal-fired energy production plants are

[69] Ministry of Economy, Trade and Industry, 27.

being scrapped, *BloombergNEF*, an energy research firm, points out that many of Japan's utility companies are replacing coal with natural gas, following the direction of Ministry of the Environment and METI. Earlier this year, Tokyo Gas, Idemitsu Kosan, and Kyushu Electric discarded their new coal power plant plans to study the feasibility and cost effectiveness of building LNG plants instead with a similar phenomenon occurring throughout the Japanese energy market to provide a stable and secure energy source.[70] The firm further elaborates,

> While the Ministry of Environment has voiced concerns about carbon emissions from Japan's coal-fired fleet, the decisions to scrap the plants [and replace it with LNG or other less volatile sources] are also being driven by economics. Gross electricity demand in Japan is expected to drop from 1,075 terawatt-hours today to 1,010 terawatt-hours in 2030, BNEF estimated in July.[71]

LNG is considered a bridge fuel because of its ability to assist base-load power generation. LNG's integration in to the Japanese energy market has been swift following the Fukushima accident. The cost of integration has been relatively high for Japan since it lacked the appropriate receipt, storage, re-gasification, and delivery infrastructure prior to Fukushima. Additionally, Japan lacked production contracts with suppliers overseas and the sudden influx of demand with the removal of the nuclear fleet disrupted energy market equilibrium. In an intense competition of energy resources with China and India, Japan opted to pay a premium market price to receive LNG quickly to provide reliable energy across all sectors of the economy.

Outlined in the *2016 Strategy for LNG Market Development*, Japan is aiming to achieve the following: "(1) improvement of the liquidity of the LNG trade, (2) establishment of an LNG price discovery mechanism reflecting supply and demand, and (3) open and sufficient infrastructure development."[72] The shale revolution in the industrial-scale extraction of LNG has shifted the global supply in a positive direction from which Japan can benefit. Innovation in drilling technology in the U.S., which has an

[70] Wilson, 5.

[71] Wilson, 6.

[72] Ministry of Economy, Trade and Industry, 34.

abundant shale natural gas, is reducing the cost of drilling and raising production rapidly. METI and ANRE recognize that “the export of the first LNG from the U.S. mainland in February 2016 was a key indicator that the shale revolution will affect the gas market worldwide. It is better for Japan to benefit from the decoupling of oil prices and gas prices by optimizing LNG transactions.”[73] Figure 8 shows the infrastructure capacity in place to receive LNG and transmit it to the highly dense areas of Japan.

Figure 8. Japan’s existing and planned LNG receiving infrastructure.[74]

[73] Ministry of Economy, Trade and Industry, *Strategy for LNG Market Development: Creating flexible LNG Market and Developing an LNG Trading Hub in Japan* (Tokyo: Government of Japan, 2016), https://www.meti.go.jp/english/press/2016/pdf/0502_01b.pdf.

[74] Source: Mike Fulwood, *Asian LNG Trading Hubs: Myth or Reality*, (New York: Center on Global Energy Policy, 2018), https://energypolicy.columbia.edu/sites/default/files/pictures/Asian%20LNG%20Trading%20Hubs_CGEP_Report_050318.pdf.

Unfortunately, Japan's domestic production of LNG will remain in a structural downturn due to the lack of strategic reserves within its own borders with limited, if any, realistic opportunity for commercialization and harvest of significant new discoveries underground. Fitch Solutions, a firm in the United Kingdom, predicts that "Japan will produce about 3.6 bcm [billion cubic meteres] of natural gas in 2019 then decline at an average rate of 5% per annum to reach 2.3 bcm by 2028. The chance of a major discovery with the potential to change the country's gas production outlook over the coming years remains slim."[75] Even though METI has aimed at increasing Japan's LNG SDR, it is unlikely to provide a domestic boost to reduce import dependency. LNG will remain an intermediate power source with a relatively cheap cost-basis to quickly respond to electricity demand as a substitute for oil. Fitch's Oil and Gas report shows that

> Japan will rely on natural gas for about 40% of total power generation over the coming decade. This is despite newly reiterated government targets to lower this share to 27% by 2027 as the country aims to reduce its reliance on natural gas imports in order to reduce high retail electricity prices for consumers.[76]

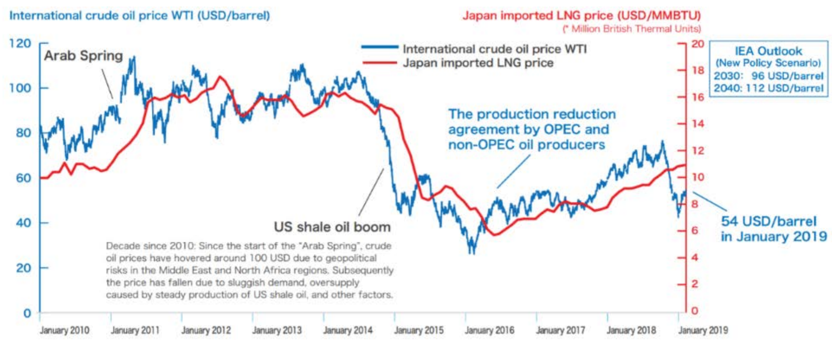

Figure 9. Japan's LNG price trend, compared to global crude oil prices as a substitute good.[77]

[75] Japan Oil & Gas Report - Q3 2019. London: Fitch Solutions Group Limited, 2019. http://libproxy.nps.edu/login?url=https://search.proquest.com/docview/2218542597?accountid=12702, 11.

[76] Fitch Solutions Group Limited, 20.

[77] Adopted from, Ministry of Economy, Trade and Industry, Agency for Natural Resources, 4.

Since 2012, Japan has hosted the LNG producers-consumers dialogue conference to ensure that the Japanese energy industry is able to meet the future energy security challenges. In an effort to the diversify energy mix and strengthen ties through resource diplomacy, Japan aims to bring together government leaders, industry professionals, heads of organizations, and various stakeholders to discuss mutual opportunities and challenges to reduce energy supply volatility. Organized by METI, the 8th Annual LNG producers-consumers conference will be jointly hosted in Tokyo with Asia Pacific Energy Research Centre (APERC) to discuss the issues outlined in the *Fifth Strategic Energy Plan*. Overall targets of energy security with respect to LNG remain similar to that of oil for Japan. Japan wants to ensure an overall supply availability, a strong carbon emission reduction agenda to meet climate accord agreements, energy security as a part of an overall economic growth, safe and reliable energy supply throughout the country, efficient operation of energy markets, improvement in the SDR if possible, and lastly realignment of the LNG supply-demand forces to support improvement in energy trilemma as outlined by METI in the strategic document.[78] Figure 10 shows the forecasted supply trends in the LNG market.

[78] John S. Duffield and Brian Woodall, “Japan’s New Basic Energy Plan,” *Energy Policy* 39, no. 6 (April 2011): 3743, https://doi.org/10.1016/j.enpol.2011.04.002.

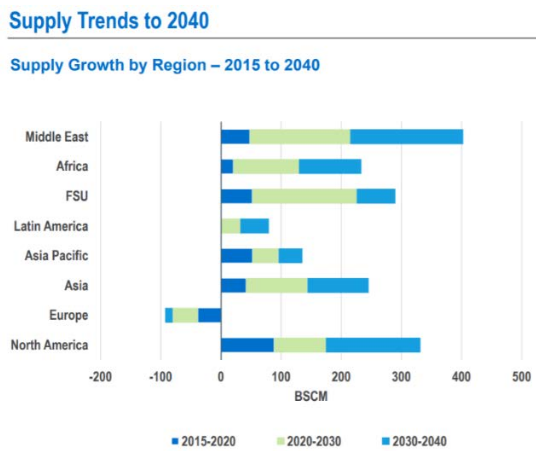

Figure 10. Supply growth forecast, LNG by region through 2040.[79]

LNG utilization provides direct substitution with oil. Combined with the market incentives to potentially lower operational costs and increase supply diversity in energy portfolio for Japanese companies, LNG remains a highly lucrative bridge fuel. While still a fossil fuel, its carbon dioxide footprint is lower than that of coal or heavy crude oil. LNG burning power generation plants are required to have a thermal efficiency of 44.3% or higher by 2030 as directed by the Act on Rational Use of Energy.[80] LNG is considered a cleaner-burning fuel, hence the bridge fuel criteria is appropriate for LNG. The 3E+S energy policy underscores the importance of LNG as stated in METI's strategic document. METI states that "[even] though Japan does not import natural gas through pipelines, the gas involves relatively low geopolitical risk compared to oil and emits the least amount of greenhouse gases among fossil fuels. Therefore, natural gas plays the central role as an intermediate power source."[81] Competitive pricing negotiations with producers in Southeast Asia and North America will allow Japan to lower procurement costs substantially. Lifting destination restraints and providing financial incentives for Japanese companies to explore LNG offshore and in the Sea of Japan are boosting interest in the extensive development of a flexible and responsive LNG market.

[79] Source: Global LNG Outlook: Medium and Long Term," Nexant, April 2017, https://eneken.ieej.or.jp/data/7283.pdf.

[80] Ministry of Economy, Trade and Industry, 70.

[81] Ministry of Economy, Trade and Industry, 24.

Diversification of suppliers is a core driver of the LNG market stability for Japan to reduce the "Asian Premium."[82] A flourishing shale and natural gas market in North America is a boon for Japan's prospect for leveraging LNG as its strategic source of energy while reducing geopolitical uncertainty with its suppliers. Japan has embarked on a unique cooperation with the United States to expand LNG market access, increase investment for scaled future demand, and essentially guarantee stability in this partnership. The attempted pivot away from the imported Middle Eastern suppliers in the oil markets nicely complements LNG market opportunities in Japan. According to U.S. Department of Commerce's export data, "Japanese companies are considering further investments in U.S. power plants and gas liquefaction export facilities. Such infrastructure investors would again, include, electric and gas utilities, as well as major trading companies, who said recently they will increase their LNG production capacity by 60% by 2020."[83]

The U.S.-Japan joint statement on energy development, signed in November 2018, reaffirmed a strong economic interdependence of the two countries and deepening economic ties. In the energy sector development, consistent with Japanese energy policy, the Japan-U.S. Strategic Energy Partnership (JUSEP) was signed. Both countries committed to spend $10 billion in LNG capacity building through highly advanced networked infrastructure with public-private partnerships in both countries.[84] Both Japan and the U.S. will benefit from a well-functioning, competitive energy clearinghouse by fully integrating American shale-derived LNG into the Japanese energy markets. The subsequent competition should leverage the entire LNG value chain in helping to drive the economic and energy policies of the United States and Japan. This diversification and strategic energy partnership with a key ally has been immensely popular in Japan to help

[82] Asian Premium is generally noted as the discrepancy between European and Asian market prices in energy markets, mainly due to incomplete liberalization of market forces and protectionist policies.

[83] "Japan – Liquefied Natural Gas (LNG)," U.S. Department of Commerce and International Trade Administration, September 6, 2019, https://www.export.gov/article?id=Japan-Liquefied-Natural-Gas-LNG.

[84] "U.S.-Japan Joint Statement on Advancing a Free and Open Indo-Pacific through Energy, Infrastructure and Digital Connectivity Cooperation," The White House, November 13, 2018, https://www.whitehouse.gov/briefings-statements/u-s-japan-joint-statement-advancing-free-open-indo-pacific-energy-infrastructure-digital-connectivity-cooperation/.

meet Japan's energy goals while providing a hedge against increasing Chinese LNG market share.[85]

Trade with the well-developed North American LNG market should allow Japan to raise access and affordability criterion in the energy trilemma. In May 2018, the first shipment of the shale-extracted LNG was delivered to Japan by American suppliers.[86] As the world's largest LNG importer, Japan has led the development and liberalization of LNG markets to establish a highly flexible, efficient, and transparent trading for LNG. A market rebalancing toward Asia due to the rising regional demand is providing capital investment influx from electric and utilities companies of Japan. Figure 11 shows the LNG demand signal and the contracting opportunities for export, which are fantastic after 2020.

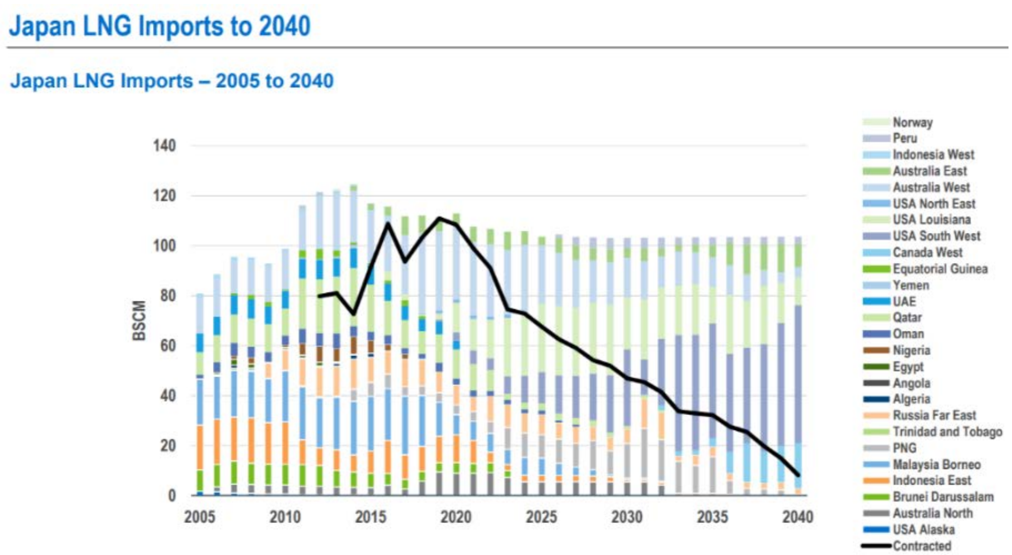

Figure 11. Japan's LNG import forecast by suppliers.[87]

One of the strengths of Japan's LNG policy is rooted in its location. Japan has a relatively easy access to receive imports from the United States. For purchasers, a Japanese

[85] The White House, 2.

[86] U.S. Department of Commerce and International Trade Administration, 3.

[87] Source: Nexant, 29.

hub can provide flexibility in spot transactions, routing options to receive the optimal market price for non-contract buyers. For sellers, volume risk is diminished as Japan continues to transition to an LNG-centric energy consumer, which will lead to a sustainable and predictable sales targets. Additionally, open market access to the rest of Asia from Japan will lead to transparency and reasonable price stability, likely creating new demand.[88]

The strategy for LNG market development also recognizes the benefits to the consumers of Japan. In the context of energy trilemma, it is a win-win scenario. The policy states that

> a flexible LNG market will also benefit the general public, the final consumers of natural gas. Expanding arbitrage trades of LNG is expected to reduce the Asian Premium, which becomes conspicuous when the crude oil price is noticeably higher than the gas price, and this will contribute to a reduction of energy prices and trade balance improvements. It will also be effective in enhancing the capacity to cope with emergencies in the event of a disruption of supply from specific regions or difficulty in securing a different power source. A stable supply of LNG not only supports sustainability and stable livelihoods and economic activities but may also help solve the issue of climate change. Furthermore, futures trading and other financial businesses may develop in addition to LNG trade. A flexible LNG market will also enable the global expansion of Japan's LNG-related technologies and know-how and will thus contribute to expanding market frontiers for Japanese and international companies.[89]

In the overall LNG market, a flexible energy policy is striving to achieve reduction of barriers such as elimination of destination clauses, a key issue discussed during the G7 meetings and at the annual producers-consumers conference. Japan's willingness to finance and provide technical expertise in both upstream and downstream projects to develop a strong global market with Japan as an LNG trading hub in Asia will not only increase the robustness of the energy markets in Asia but will provide a solid foundation for Japan's energy transition. Once LNG has been established as a replacement for

[88] Ministry of Economy, Trade and Industry, *Strategy for LNG Market Development: Creating flexible LNG Market and Developing an LNG Trading Hub in Japan*, 6–13.

[89] Ministry of Economy, Trade and Industry, *Strategy for LNG Market Development: Creating flexible LNG Market and Developing an LNG Trading Hub in Japan*, 6.

traditional sources, the excess capital resources can be focused toward renewable energy transition. In the dawn of the LNG age, the term "Enevolution (or Energy Evolution)" effectively captures the bold policy steps Japan is taking to develop infrastructure and support the underlying human resource development.

LNG trade requires a unique infrastructure to support import and export. Lack of land-based transport requires Japan to receive LNG shipments strictly via the sea. LNG terminals where enormous tankers can bunker is an extremely costly investment. Not only a phase conversion is required from gas to liquid at the export facility but a re-gasification terminal must be available at the import facility. The surge in the supply from American producers available to the Japanese demand forces is expected to intensify. Marcus King underscores the historic geographic disadvantage and writes that "North American liquefied natural gas (LNG) exports are bottlenecked [to Japan] due to the fact that there is now only one operable natural gas export terminal located in Alaska. This terminal is used primarily for exports to Japan. However, exports will increase with the construction of new terminals. The U.S. Federal Energy Regulatory Commission (FERC) has approved the construction of seven additional terminals and six are under construction."[90] In Japan, the LNG market triangle—tradability, infrastructure, and price discovery—are signaling mechanisms to reveal a fundamental shift in the energy trilemma. Additionally, METI has approved a market expansion pathway via the development of LNG bunkering base where "Ship to Truck" and "Ship to Ship" infrastructure expansion can increase volume shipment and decrease time to delivery for consumers.

Finally, as an emergency measure, LNG is also covered under the national stockpiling regulations. Compliance requirements also extend to the private sector with comprehensive required stockpiles of approximately 100 days of supply or 2.8 million tons of LNG by volume.[91]

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90 Marcus D. King, "Evolving factors affecting energy security," in *Handbook of Transitions to Energy and Climate Security*, ed. Robert E. Looney (New York: Routledge, 2017), 20.

91 Japan Oil, Gas and Metals National Corporation, 1.

E. FINDINGS

The Great East Earthquake has fundamentally altered the energy policy trajectory of Japan. It has accelerated the innovative developments in the private sector, such as development of hydrogen-based technologies, in an effort to remove hydrocarbon-based use chains. Market targets and transactions have generally received positive support from the government in the attempt to decouple dependency on fossil fuels with economic growth. Japan continues to be a key international actor in changing the discourse around energy policy. Energy access, supply reliability, affordability and the overall integration of energy security in all aspects of consumer and industrial activities are at the center of Japan's energy security vision and Japan is making progress in achieving goals set out in its *Fifth Strategic Energy Plan* document.

Nesheiwat writes, "A more energy-secure Japan is not only a stronger U.S. ally, but an important regional leader. And a more energy-secure Japan is a stronger leader within the international community on critical global issues."[92] Japan's unique vulnerability in energy security leads to a self-insuring behavior as a state from all of its economic partners. Lesbirel writes,

> It relies heavily on a portfolio approach which uses diversification and other measures such as stockpiling, alternative energy development and conservation, to reduce both specific and systemic risks to supply disruptions and to manage perceived or actual threats to oil supplies. But the insuring state also uses inducements which combine both deterrence and incentives to reduce risks and threats of interruptions to oil supplies. While Japan does not rely on direct military retaliation as a form of deterrence, it does rely indirectly on military retaliation by the U.S. and her allies in the context of the U.S. alliance system in the event of oil supply disruptions. However, in addition, it also employs incentives, mainly in the form of Overseas Development Assistance, to both oil supplier and non-supplier nations in the Middle East to reinforce that portfolio approach to minimising both specific and systemic risks and threats.[93]

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[92] Julia Nesheiwat, "Japan's energy security: Challenges, prospects, and global implications," in *Handbook of Transitions to Energy and Climate Security*, ed. Robert E. Looney (New York: Routledge, 2017), 293.

[93] S. Hayden Lesbirel, "The Insuring State: Japanese Oil Import Security and the Middle East," *Asian Journal of Political Science* 21, no.1 (May 2013): 42, https://doi.org/10.1080/02185377.2013.793560.

Japan can leverage its unique advantage in engineering, infrastructure development, scientific research, and energy efficiency to accelerate energy transition. A strong technical expertise is allowing Japan to sponsor oil and LNG exploration domestically; however, unfortunately Japan's geology is unlikely to reveal any significant opportunities. Japanese companies continue to provide significant assistance abroad in exchange for favorable supply lines and is likely to continue doing so in the future.

Japan's well-developed and modern infrastructure can be easily converted into delivering LNG instead of oil in a cost-effective manner without significantly disrupting domestic supply chains to consumers. A well-functioning private market enterprise in the energy transition policy can reduce frictions in transactions; however, for Japan, the exact energy mix for sustainable future is a matter of some political contention after Fukushima. Diversification, integration of LNG (both originating from Southeast Asia and American shale), and firm a diplomatic commitment should limit supply shocks and price vulnerability for end-users given the current energy strategy.

Japan's economic growth has peaked early compared to the rest of the powerhouse economies of Asia. Even though the overall demand is likely continuing to rise, Japan's declining population should soften the demand signal in Northeast Asia. A soft demand projection provides little incentive for a liberalized, private enterprise to make large-scale capital investments, thus the existing METI and ANRE policy of incentivizing structural changes is aiding the transition, albeit slower than desired, to meet complete transition goals in a climate-change context. Extraction of methane hydrates from seabed can also help Japan achieve a positive movement in the energy trilemma; however, the technology still requires extensive research for commercialization. A high amount of public debt precludes the Federal Government of Japan from making significant investments on their own, thus a private enterprise buy-in is be required for a structural shift.

The recent political sanctions on Iran by the United States should not affect Japan since American shale-derived natural gas can easily offset any demand shocks Japan experiences. The more significant political contention is likely to rise from maritime boundary disputes and competing economic zone claims in the Sea of Japan and East China Sea (ECS). American shale deliveries to Japan are in motion and are unlikely to stop soon, thus Japan can easily opt to continue or even escalate maritime dispute over resources and ownership of the seabed in the name of national strategic interest if required.

Overall, Japan's energy strategy in the wake of the 2011 Fukushima disaster is driven by the rational market-oriented decision making with the assistance from METI and ANRE to reduce externalities. With a sluggish economic growth, Japan's ambitious 2030 target is likely to be missed; however, Japan's 2050 energy transition and carbon emissions goals are more likely to be achieved based on its current policies of energy transition away from hydrocarbons.

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III. NUCLEAR ENERGY

A. OVERVIEW

The Fukushima Daiichi nuclear reactor catastrophe unfolded on March 11, 2011. A powerful earthquake-generated tsunami destroyed the infrastructure and nuclear power generation facilities at Fukushima. Prior to the Fukushima event, Japan maintained a 55-reactor fleet to aid its electrical power demand throughout Japan, as shown in Figure 12. At the time of the incident, nuclear power was absolutely essential to the Japanese economy. It provided energy portfolio diversification, allowed flexibility in import independence from the Middle Eastern energy supply, and most importantly, it was an emissions-free energy source.[94] According to the World Nuclear Association (WNA), before 2011 Japan harvested 30% of its electrical demand from nuclear fission and was expected to rise to 40% by 2017.[95] Currently, there are 17 reactor plants are awaiting governmental approval to restart operations pending safety inspections with another 37 reactors in operationally capable status.[96] Figure 13 shows the reactor status as of November 2018.

To adequately understand the development of energy policy surrounding nuclear power generation, it is useful to illustrate the overview of interconnected governmental offices that dictate policy positions. The collective political capital of politicians will become an important point in determining the future of Japan's nuclear power after the Fukushima Daichii nuclear power stations disaster. Prior to March 11, 2011, there were two separate offices at the cabinet level. The first was the Nuclear Safety Commission (NSC), responsible for developing the nuclear infrastructure, safety of nuclear facilities, and promoting an effective dialogue with the general public on the responsible use of nuclear technologies. On the other hand, the Atomic Energy Commission (AEC) outlined

[94] S. Hayden Lesbirel, "Diversification and Energy Security Risks: The Japanese Case," *Japanese Journal of Political Science* 5, no. 1 (October 2004): 1–22, https://doi.org/10.1017/S146810990400129X.

[95] "Nuclear Power in Japan," World Nuclear Association, August 2019, https://www.world-nuclear.org/information-library/country-profiles/countries-g-n/japan-nuclear-power.aspx.

[96] World Nuclear Association, 1.

the basis of nuclear policy for incorporating nuclear energy in the national energy mix. It was also responsible for oversight among Ministry of Foreign Affairs (MOFA), Ministry of Education, Sports, Science, and Technology (MEXT), Ministry of Economy and Trade (METI), Agency for Natural Resources and Energy (ANRE), and Nuclear and Industrial Safety Agency (NISA). Much of the decision structure was reformed to create a separate Nuclear Regulatory Agency (NRA), an independent organization.

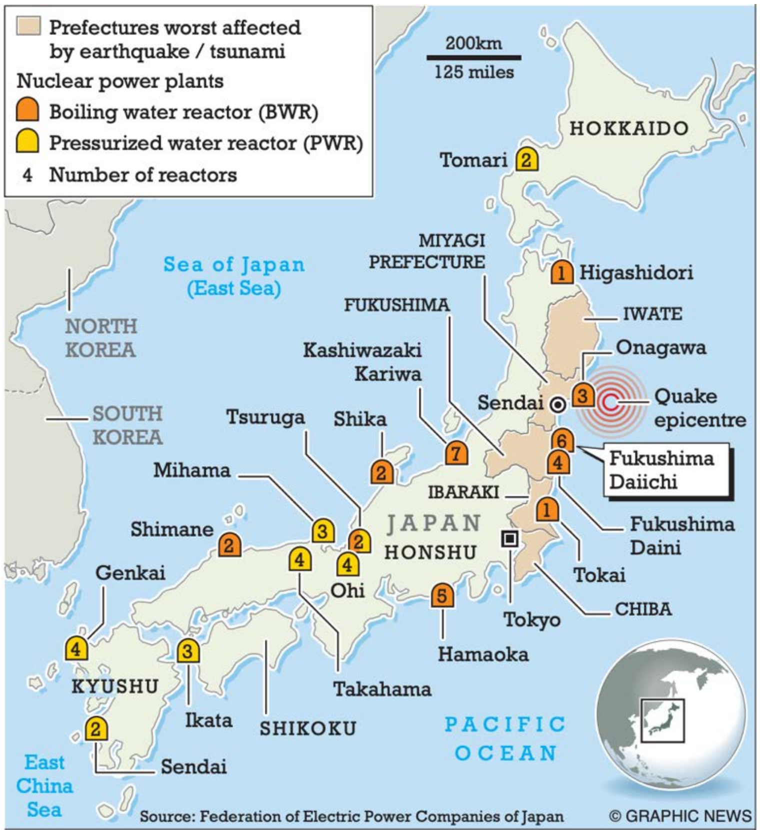

Figure 12. Location of Japan's nuclear reactor fleet.[97]

[97] Source: Rebecca Pool, "Fukushima: The Facts," *Engineering & Technology* 6, no. 4 (May 2011): 36 https://doi.org/10.1049/et.2011.0400.

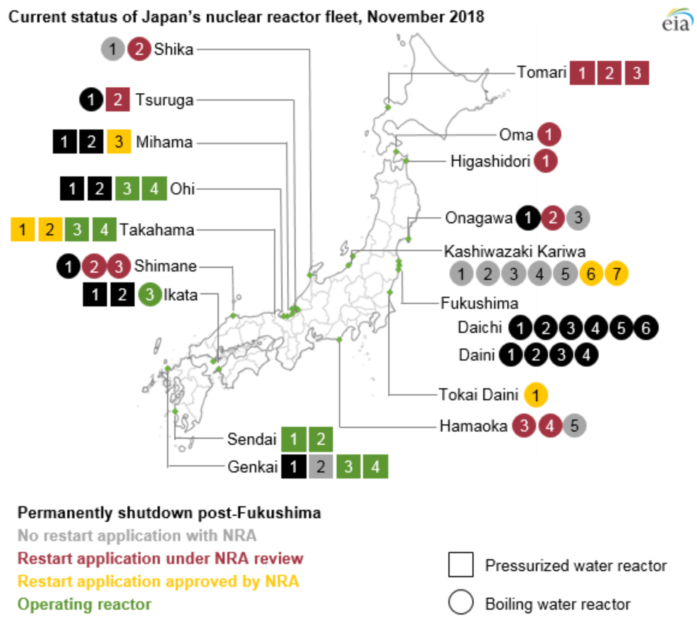

Figure 13. Current status of Japan's nuclear reactor fleet, as of November 2018.[98]

The Fukushima catastrophe clearly had a major impact on the economic vitality of Japan. Figure 14 shows the relative economic cost, compared to other catastrophes in the world. The economic cost of energy production, storage, transmission, and delivery in the supply-demand framework is critical to understand why Japan has placed nuclear power in the national security dialogue. Just before Fukushima, Japan met nearly 30% of its energy demand from nuclear power as mentioned before, which was planned to increase substantially by 2030 as part of an increased self-sufficiency agenda in the domestic energy production. The price stability of nuclear power was an attractive trait for both the government and the investors. Average cost of energy production via nuclear reactor is cheaper and is relatively stable, as it is not explicitly tied to foreign exchange rates. Broadly speaking, per kWh generation price increased after Fukushima as Japan experienced a negative supply shock and had to substitute imported sources to supplement the loss of nuclear power.

98 Source: Slade Johnson, "Japan has restarted five nuclear power reactors in 2018," U.S. Energy Information Administration, last modified November 28, 2018, https://www.eia.gov/todayinenergy/detail.php?id=37633.

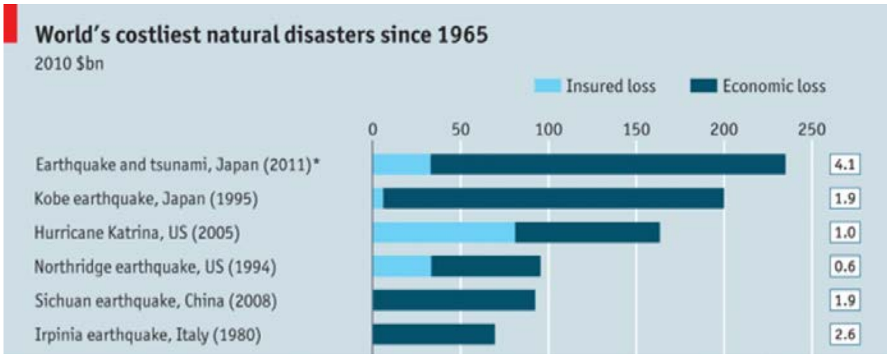

Figure 14. Financial cost of Fukushima disaster in Japan.[99]

METI amended its target goals as significant structural changes were enacted in the overall energy policy in response to Fukushima. Within the 3E+S (Energy Security, Energy Equity, Environmental Considerations, and Safety) framework, the Japanese energy policy seeks to attain a high level of success within the energy trilemma by emphasizing safety in nuclear power plant restarts while simultaneously capitalizing on thermal efficiency and zero carbon dioxide emissions in power generation.[100] The political forces against reimplementation of nuclear power remain a concern; however, the collective vested interest of the industry and their political sway, the economic cost of infrastructure replacement to abolish nuclear power, and a national desire to reduce import dependency on fossil fuels will keep nuclear thermal power generation a significant part of the discussion in the medium term.

B. AMBITIONS

In 2018, the Japanese Cabinet approved the strategic energy plan, which outlined new guidance and policies in reference to restart and operational use of nuclear power in the Japanese commercial, consumer, and industrial sector. Reinstating nuclear power with higher margins of safety has been the goal of industrial and government leaders. On one hand, scrapping the entire infrastructure supporting nuclear power generation, delivery,

99 Adopted from, “Counting the cost,” The Economist, March 21, 2011, https://www.economist.com/graphic-detail/2011/03/21/counting-the-cost.

100 Ministry of Economy, Trade and Industry, 56–76.

and radioactive waste management is not feasible. On the other hand, the public outcry over safety lapses in the past are politically sensitive and must be tended to. Nonetheless, Japan's nuclear power objectives for 2030 and 2050 remain essentially the same: raising Self-Sufficiency Rate (SSR), reduce the cost of electricity from current levels, and drastically cut GHG emissions in to the environment, stabilize the overall energy supply while elevating safety levels across the nuclear power enterprise.[101]

It is worth mentioning the current work being done to restore public trust and transparency surrounding the Fukushima reactor decommissioning. TEPCO, Tokyo Electric Power Company Holdings, Inc. – is committed to decommissioning the Fukushima Daiichi Nuclear power station safely. Any Japanese reactors not meeting the current standards set by NRA have been placed on a permanent shutdown until they can be upgraded and inspected prior to returning to normal operation, if at all. By December 2011, cold shutdown conditions were achieved at Fukushima to significantly reduce the threat of radioactive emission into the atmosphere. By November 2013, fuel removal from spent fuel rods had started, and by December 2021, fuel debris removal is to be complete whereas the complete decommissioning of the reactor site is expected to take nearly 40 years at a high financial cost, according to the NRA.[102] The following key principles are driving the energy policy surrounding reintroduction of nuclear power in Japan: separation of regulatory policy from utilization policy, comprehensive integration and merger of various regulatory offices under NRA's jurisdiction, effective and transparent dissemination of information, enhanced nuclear power specific regulations to include development of countermeasures, back-fit of dated systems, establishing a 40-year operational limit, and a comprehensive nuclear emergency preparedness system.[103] Under the updated NRA policy, "Twenty nuclear reactors in Japan have permanently retired in the wake of the Fukushima accident. Out of the remaining fleet of 34 operable reactors, nine are currently

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[101] Ministry of Economy, Trade and Industry, 14–19.

[102] "Japan's Energy Plan: Decommissioning TEPCO's Fukushima Daiichi Nuclear Power Station," Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy, 2019, https://www.enecho.meti.go.jp/en/category/brochures/pdf/energy_plan_2015.pdf."

[103] Nuclear Regulation Authority – Japan, *Nuclear Regulation for People and the Environment*, (Tokyo, Japan: Nuclear Regulation Authority – Japan, 2018), https://www.nsr.go.jp/data/000067218.pdf.

operating, six others have received initial approval from the NRA, and another 12 units are under review and some reactor facilities have yet to file a restart application."[104] Figure 15 shows the limited role played by nuclear power in 2017 due to regulatory constraints. Based on this trend, the 20–22% desired attainment for nuclear power seems wishful. In Figure 16, the total power utilization profile is presented.

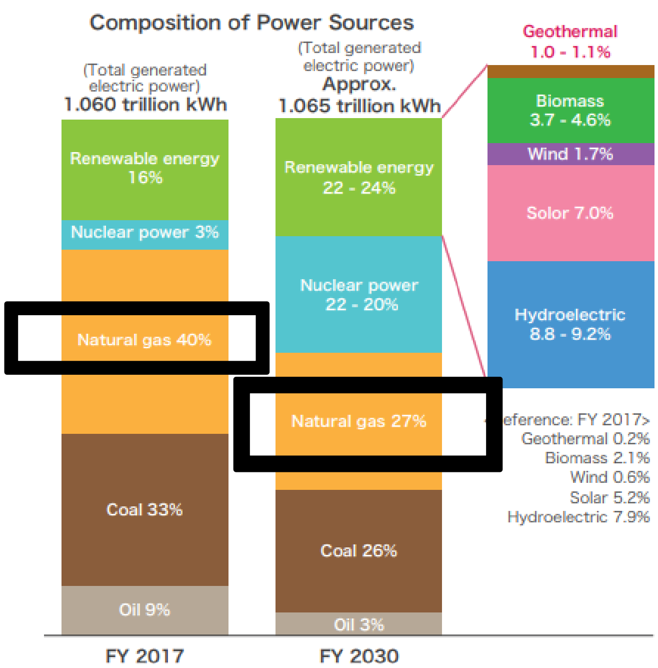

Figure 15. Total energy supply in Japan's policy projection, energy policy mix from 2017 to 2030.[105]

METI's long-term projections show that nuclear energy remains a dependable and an important input into Japan's economy and its overall energy demands. The power delivery infrastructure is complex and is tied significantly to the economic output of Japan. According to METI,

> Since the earthquake, the amount of emissions in the electric power field increased by 54 million tons due to reasons including generation of more electric power by thermal power plants as a substitution for nuclear power.

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104 Johnson, 2.

105 Adapted from: Ministry of Economy, Trade and Industry, Agency for Natural Resources, 9.

This is an increase of about 4% of the amount of greenhouse gas emissions in Japan as a whole.[106]

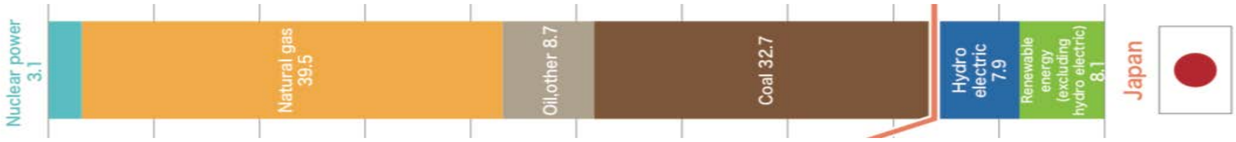

Figure 16. Japan's total power utilization profile, 2017.[107]

Japan's incredible technical expertise is well respected within the international community, but the events surrounding Fukushima provide a valuable learning opportunity for nations seeking to integrate nuclear power in to their economic energy security plan. Not just within METI, but the GOJ is actively involved as a respected member of the international community in promulgating issues discovered at Fukushima so they can be corrected at similar plant locations. 3E+S framework seeks to harness industry-leading safety practices as well as the latest technology to reinstate nuclear power in Japan. International cooperation in the energy supply-demand fluctuations is a central focus of Japan. Fission generation fits well within the overall strategy of reducing emissions while developing high levels of SSR in Japan. As METI outlines,

> Japan and the U.S., as partners, play a significant role in enhancing a global system for nuclear use while internationally ensuring peaceful use of nuclear power, nuclear non- proliferation, nuclear security, and so on through R&D cooperation and industrial cooperation utilizing the Japan-U.S. Bilateral Commission on Civil Nuclear Cooperation and other mechanisms.[108]

International engagement is built within the agreements of the Kyoto Protocol, COP21, and COP23 and thus Japan is taking the lead in conversing with other members to fully integrate nuclear energy back into its economy. Japanese technological giants such as

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[106] Agency for Natural Resources and Energy, *Japan's Energy: 20 Questions to understand the current energy situation* (Tokyo: Ministry of Economy, Trade and Industry, 2018), https://www.enecho.meti.go.jp/en/category/brochures/pdf/japan_energy_2017.pdf.

[107] Source: Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy, 13.

[108] Ministry of Economy, Trade and Industry, 103.

Hitachi, Mitsubishi, and Toshiba have already started to work with AREVA, a French company, to work toward improved technological design, engineering, and then export of energy technology.[109] Countries like France effectively rely on nuclear power as a single major production source for their economic engine, and such model, at least partially, sought upon by Japan for its 2030 and 2050 goals to reach nuclear energy goals of 20–22% by 2030 and as required to achieve a carbon-neutral strategy beyond 2050. Specifically,

> in Europe, cooperation with France in the field of nuclear energy has been proceeding, such as the response to the TEPCO's Fukushima nuclear accident and the international deployment of a jointly developed reactor, in addition to cooperation regarding the nuclear fuel cycle and the development of a fast reactor. GOJ continues to further enhance this cooperation through dialogues at the "Japan-France Nuclear Cooperation Committee," etc. As to the cooperation with the United Kingdom, GOJ shares its knowledge concerning research and development of decommissioning and other technologies and exchanges views on an appropriate business environment of nuclear power generation in a liberalized market through dialogues of the "Japan-U.K. Nuclear Dialogue," etc. Furthermore, with Europe as a whole GOJ promotes cooperation, including an exchange of information concerning common energy policy challenges, etc.[110]

Promise of a reformed nuclear power in Japan is encouraging but will require compromise. As the memory of Fukushima failure fades and the efforts of the GOJ remain proactive in addressing the challenge, the public sentiment seems to favor energy independence. Citizens of Japan are more likely to support a policy objective that maintains accountability and sovereignty within the borders of Japan. Structurally, the issue of nuclear power in energy policy is fundamentally different from that of fossil fuels. To start: there are almost no import restrictions on raw materials and technology, existing infrastructure favors restart of nuclear power at its maximum safe capacity, and the politics have shifted from anti-nuclear leadership to the trusted pro-nuclear lobby in the government of Prime Minister Abe Shinzo.

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[109] Sung Chull Kim and Yousun Chung, "Dynamics of Nuclear Power Policy in the Post-Fukushima Era: Interest Structure and Politicisation in Japan, Taiwan and Korea," *Asian Studies Review* 42, no. 1 (December 2017): 113, https://doi.org/10.1080/10357823.2017.1408569.

[110] Ministry of Economy, Trade and Industry, 105.

C. FEASIBILITY OF NUCLEAR POWER IN JAPAN, SHORT AND LONG TERM

Japan faces a tough reality in energy security. Innovation is likely to replace many of the legacy technologies currently in use. From a SWOT analysis perspective, the applicability and feasibility of nuclear power is excellent. Core of nuclear power strength is that technology is widely available. A weakness and threat in nuclear power is the possibility of another nuclear accident on the island, but proactive safety considerations can reduce the likelihood of another one. Opportunities for use and implementation are abundant within Japan, even after Fukushima. As long as proper safety protocols are met, the direct public opposition has largely abated and managing expectations of the population will be paramount. Unfortunately, the risk of a disaster remains given Japan's geography, but engineering and design changes can minimize the overall impact should there be another Fukushima-type event. Fortunately, the greatest threat to nuclear power is innovation in renewable technologies. As long as the collective renewable energy sources are able to sustain the power demand throughout the day, the economic forces of supply and demand may help to diminish nuclear power from Japan's energy mix with the current trend. Today, Japan's nuclear energy sector is slow to recover but the return to previous levels of nuclear energy production is completely possible as long as safety protocols and improved regulations imposed by NRA are met. *Business Monitor International (BMI)* emphasizes that "despite the delays in restarts, we expect that the Japanese government will focus on increasing nuclear generation in the country's power mix."[111] The nuclear power paradox is a trade-off choice between either meeting emissions reduction goals and securing domestic energy supply or risk missing emission targets and risk greater foreign dependency, a true opportunity cost.

Japan faces a precarious energy demand forecast at the national level with zero-sum demand trends. While some government intervention would distort the market efficiency mechanisms due to deadweight losses, the GOJ intentionally refuses to solely

[111] Japan power report - Q1 2017. (2017). London: Fitch Solutions Group Limited. Retrieved from Earth, Atmospheric & Aquatic Science Collection; ProQuest Central Retrieved from http://libproxy.nps.edu/login?url=https://search.proquest.com/docview/1844744412?accountid=12702, Page 7.

rely on market-clearing mechanisms to balance the supply-demand equilibrium for nuclear issues. Built-in reserve capacity allows maximum flexibility when peak power demands are relayed on the infrastructure. During which nuclear power can serve as a base-loading energy source during an unassisted (no LNG or renewable sources feeding the grid) peak demand windows. Nuclear power is the fastest way to meet rising demand in a short period of time and when required LNG or renewables can be used as supplemental power sources during severe needs or adverse weather conditions. The de-regulation of the transmission markets and separate, independent enforcing mechanisms should again allow nuclear power to achieve greater credibility in the energy markets for investors and consumers. The significant capital investment requirements for nuclear power and long lead times for planning to delivery of an operational plant can cause significant mismatches in the supply-demand portfolio often leading to cost overruns and underutilization of infrastructure. This is equally politically risky given the significant debt burden of the government as it is. The endogenous variable of declining electricity use in a declining population base makes planning for large-scale capital investments difficult to synchronize with the energy policy published by METI and ANRE.

Conventional commercial labor safety and NRA standards have been revised to include more stringent criteria to permit operation, delaying the restart of capable power plants due to significant economic costs. If the specifics of the regulatory requirement are balanced against the future revenue forecasts from a given plant are net negative, utility companies are inclined to decommission the plant to shift resources elsewhere, mainly to renewables. Many of the newly imposed requirements after Fukushima require intense infrastructure construction. For example, power plants must meet the following criteria as part of a broader safety targets to produce energy again: guarding against intentional airplane crashes, measures to suppress radioactive diffusion of material, measures against preventing damage of containment vessels, procedures to prevent core damage, unexpected fire considerations, reliability of ancillary facilities, uninterrupted power supplies in the event of main power disruption, breakwater walls to prevent tsunami damage if one occurs, core cooling capacity with portable pumps from portable power sources for significant period of time.[112] To achieve a zero-accident facility, Behling, Williams, and Managi mentions,

> Japan could also invest in upgrades to its existing reactors. According to a 2014 estimate by the Ministry of Economy, Trade and Industry (METI), a total of about $17 billion would be needed to harden all reactors, except for those to be decommissioned. There were 40 dormant reactors at the time, so this would amount to $425 million per reactor. Costs would likely be more today. While hardening seems like a desirable goal, the program would apply to reactors that are based on technology and designs dating back to the 1960s, and many of these reactors are located near seismically active geologic faults.[113]

The marginal gain in revenue may or may not be sufficient to justify capital investment in the nuclear energy market, especially when coupled with a declining population. The uncertainty in demand forecasting and the added NRA requirements pose a significant threat to the economic decision making in fortifying Japanese energy security with regard to nuclear power.

The incremental added capacity as latent reactors are operational poses a net loss to the industry due to opportunity cost of investing elsewhere. Additionally, energy use is relatively strongly correlated with national economic performance. This historic relationship guides decision making to determine the accurate energy needs of the country. Currently, Japan operates to the left of the average total variable cost curve, meaning the cost of electricity from nuclear power is higher than it needs to be due to shortages in supply. A cost-minimizing power-generation capacity balanced against the overall energy goals is a complex equilibrium, largely led by private-sector market forces. As Medlock and Hartley write from their research, "In the power market model, new capacity will be constructed if and only if the discounted present value of the margin between the

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112 Agency for Natural Resources and Energy, 13.

113 Noriko Behling, Mark C. Williams and Shunsuke Managi, "Regulating Japan's Nuclear Power Industry to Achieve Zero-Accidents," *Energy Policy* 127 (April 2019): 314, https://doi.org/10.1016/j.enpol.2018.11.052.

(anticipated) wholesale electricity price and the marginal operating costs of production of the new capacity is greater than or equal to the capital cost of construction."[114]

In the global market for energy, Japan faces an acute challenge: currency fluctuations and weakening of the Japanese Yen. Affordable electricity access, considered an essential utility and a public good for the purposes of this analysis as part of the energy trilemma, is vital for the Japanese economy. The consumer faces variable import costs at the mercy of global market forces. Just in the past few years, energy import costs have risen nearly 30% for an average Japanese consumer. Fortunately, price rise was limited with the concurrent fall in oil prices, but based on Medlock and Hartley's analysis, "nuclear power helps provide stable fuel costs on a day-to-day basis and protect overall national economic performance during times of disruption or crisis."[115]

Prime Minister Abe's return to power has helped to revive the nuclear power prospects in Japan. The economic stagnation in Japan allows political flexibility in dismissing nuclear-free energy policies of the previous administration. The legal opposition is filtering through the judicial systems as outlines in Fitch's Japan report that "the Fukui District Court, for example, ruled against the restarting of the No. 3 and 4 reactors at Kansai Electric's Ohi plant in May 2014, accepting arguments that an accident at the plant could endanger surrounding residents."[116]

Overall, nuclear energy is poised to return to the energy mix in a greater capacity to supplement the trilemma and provide opportunities for growth, but it faces long-term structural challenges of being displaced by innovation and renewable technologies.

Japan is a core member of the Nuclear Innovation: Clean Energy Future (NICE) development group. As all countries move toward decarbonisation of their economies, Japan has taken an advisory lead in reforming their market structures, valuation methods

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[114] Kenneth B. Medlock III and Peter Hartley, *The Role of Nuclear Power in Enhancing Japan's Energy Security*, (Houston, TX: Baker Institute, 2004), http://large.stanford.edu/publications/coal/references/baker/studies/tepco/docs/TEPCOweb_FinalPaper.pdf.

[115] Medlock III and Hartley, 48.

[116] Fitch Solutions Group Limited, *Japan power report - Q1 2017*, 16.

of assets, providing financial assistance and in construction of new reactors while providing technical and managerial assistance. Domestically, a key threat to the Japanese nuclear energy policy, at least in the 2030 timeline is the remaining financial value of the reactors already built. In the 2050 timeline, most, if not all, will have depreciated enough to not warrant significant capital investment to extend their lifetimes by refueling. Behling, Williams, and Managi further outlines that

> Japan's government and electric power industry invested a total of about $130 billion over the past 50 years to build a total of 57 power-generating reactors, or an average of $2.3 billion per reactor. A large majority of these reactors were based on so-called Generation II designs that were introduced in the 1960s. Today, a Generation III advanced boiling water reactor (ABWR) would cost $4 billion to build. Assuming an advanced reactor that was consistent with a goal of zero accidents would cost at least $4 billion, and Japan were to aim for a fleet of 25 ABWRs, capital costs would amount to at least $100 billion, spread over the next decade or so. Additional costs would be incurred to locate these new reactors in geologically "quiet" areas.[117]

Aside from safety and dismantling costs, operating costs will be minimal and will free up capital resources to be invested in renewable technologies that enjoy significant political support and economic feasibility. Pure economic models advise against incremental investments in the existing power industry due to variability in capital resource requirements. In striving for a zero-accident culture while maintaining nuclear energy as a core driver of energy policy through 2030 and toward decarbonisation in 2050, it would cost Japan approximately $193 to $215 billion to build new reactors and $132 to $582 billion for modernizing its existing fleet, including the estimated cost of accidents underwritten by the probability of having accidents.[118] This is a significant total cost of nuclear power generation, a large share of the overall economic activity. According to the Federation of Electric Power Companies of Japan, the cost of an additional Fukushima-

[117] Behling, Williams and Managi, 314.

[118] Behling, Williams and Managi, 316.

type disaster would be nearly $850 billion, the value of all the power generated in Japan over the last 40 years, an unacceptable proposition.[119]

D. FINDINGS

Nuclear power in Japan is poised to return to the energy mix in a greater capacity through 2025 as a greater percentage of sidelined power plants are recertified for operation. The Japanese government and METI's goals of 2030 are likely to be missed for incorporating nuclear power, but prospects for 2050 are realistic toward both integration of nuclear power in a greater capacity as well as toward complete decarbonisation. In 2019, the political support remains firm from the power-generation industry and lobbyists in favor of returning to nuclear power in a greater capacity. Systemic financial challenges obstruct an efficient implementation of energy policy as envisioned by METI and the GOJ. On a per kWh cost-basis, nuclear energy remains the cheapest option with the closest direct substitution of coal when viewed with a long time horizon and with economies of scale. It is relatively difficult to scale up nuclear power production from the existing fleet during times of peak demand, thus LNG and traditional fuel sources will have to bridge the chasm when needed. The financial incentives provided by the government are likely not enough to stem the transition away from nuclear power and toward alternate energy sources. While it may be even cheaper to produce kWh with newer technologies, the economies of scale do not yet exist for large-scale implementation to displace nuclear power.

The strength of the nuclear enterprise in Japan is the reserve capacity and relatively short notice scalability to provide adequate and affordable power throughout Japan, independent of weather patterns and seasonal considerations. Fission power is also free of GHG emission, helping Japan meet its international climate accord goals. Unfortunately, new capital investment will be limited to the cost-benefit analysis of marginal revenue against marginal cost, and it is unlikely that the market will justify large-scale investment in construction of new reactors. Limited immediate opportunities exist to return the existing fleet to full normal operation given the imposed safety requirements by NRA and the

[119] Behling, Williams and Managi, 316.

financial cost of implementing them, especially for those reactors near the end of their service life. Opportunities in the liberalization of generation and transmission markets should allow flexibility to reduce cost for the consumers, enhancing the trilemma score. The single greatest threat to the nuclear power industry is the innovation in solar, wind, hydrogen, tidal, and biomass power-generation techniques since they offer benefits of a clean energy infrastructure without the extremely high downside risk of a nuclear disaster.

Japan continues to recover from the Fukushima nuclear disaster and the progress has been modest. The popular sentiment toward reinstatement of nuclear power is a battle between domestic independence versus foreign dependency and high variable costs of LNG and oil versus the relatively stable cost of nuclear thermal generation. The radioactivity concerns will limit the complete decommissioning of the remaining reactor infrastructure, and the exact same risks and limitations apply to the rest of the fleet when they are decommissioned. Storage and disposal of spent fuel and contaminated reactor vessel water further complicate the decision making for leaders in embracing nuclear power generation after Fukushima. In the short to medium term, nuclear power provides a transition bridge to a completely green economy as nuclear energy remains a vital part of the energy mix. However, in the long-term, with the development of efficient green markets, research and development, and global innovation, should lead the Japanese energy sector out of the reliance on nuclear power as a source of base-loading in the commercial and industrial sectors.

The free-market forces are leaning toward energy independence harvested from renewable energy sources. The opportunity cost of delaying capital investment into renewable energy enterprise is extremely high. Japan’s international reputation as an innovative state and a leader in bold reforms toward decarbonisation is at stake. Japan’s current energy portfolio filled with modest renewable energy, excluding nuclear power, is respectable given the topography of the land. Japan has recognized the market opportunities in embracing green technologies, and given the right set of policies, full decarbonisation beyond 2050 is an attainable goal.

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IV. RENEWABLE ENERGY

A. OVERVIEW

In Japan, the energy security gap can easily be bridged with renewable energy sources. Electricity generated from solar radiation and kinetic wind energy, geothermal, hydropower (harvested from water movements), tidal energy (harvested from coastal tide fluctuations), biomass, and various other non-traditional energy sources have developed a footprint in Japan. For the purposes of this research, most of the focus will be devoted to solar and wind power and to a lesser extent the potential of geothermal, hydropower, ocean energy (also called marine energy or tidal power), and hydrogen technology will be discussed. At the expense of uncertainty, the developmental state of hydrogen power and its viability in Japanese economy are mentioned at the end as part of broader energy security discussion in the future.

In 2016, Japan was one of the premier market investment destinations for alternate fuel sources, according to International Trade Administration's (ITA) *2016 Top Markets Report on Renewable Energy*.[120] The report goes on to note that Japan's sector rankings were favorable for energy security and further investment in the renewables market. It ranked solar sector 1st overall, geothermal at 11th, hydropower at 20th, and wind at 40th.[121] In just two years' time since ITA's report, Japan has made significant development in adopting renewable technologies as part of its energy security model. According to REN21, a global think-tank researching sustainable energy issues noted significant gains the Japanese renewable market has made. In REN's *Renewable 2019: Global Status Report*, it ranked Japan 3rd in annual investment and net capacity addition via production

[120] International Trade Administration, *2016 Top Markets Reports: Renewable Energy – Country Case Study* (Washington, DC: U.S. Department of Commerce, 2016), https://www.trade.gov/topmarkets/pdf/Renewable_Energy_Japan.pdf.

[121] U.S. Department of Commerce and International Trade Administration, *2016 Top Markets Reports: Renewable Energy – Country Case Study*, 1.

in the renewable power and fuels, behind China and the United States.[122] Excluding hydropower, the report goes on to rank Japan as fifth overall in total capacity generation as of end of the 2018.[123] Additionally, Japan's nationwide solar photovoltaic installation capacity and per capita photovoltaic installation capacity are ranked behind China, the United States, and Germany.[124] In the post-Fukushima era, Chen, Kim, and Yamaguchi identify the need for countries of East Asia to fully and completely integrate the sustainability model within their national energy systems.[125] Through policy prescriptions such as the Sunshine Project, the New Sunshine Project, the 1997 New Energy Act, the 2009 Non-Fossil Energy Act, and the general pivot toward a Renewable Portfolio Standard (RPS) since 2003, the market has been shifting the Japanese energy industry in a more sustainable direction to achieve an optimized energy trilemma. This trend is simultaneously reducing the dependence on imported fossil fuels and racing to meet the emissions requirements set forth by treaties Japan is signatory to.

In Chen, Kim, and Yamaguchi's analysis,

> Japan has set a goal to expand its renewable energy capacity from the current 39.2 GW to 85.83 GW by 2020, in which 21 GW will come from hydropower. The country aims to increase its PV capacity to 28 GW – almost six fold – and double its wind capacity to 5 GW in the next decade. Solar PV will share one-third of the total renewable energy capacity by 2020 if the goal is achieved.[126]

Chen, Kim and Yamaguchi's article was published in 2014 and while it accurately identifies the trends in the sustainable energy marketplace, the energy security policy and marketplace has shifted dramatically since then in the positive direction. The abundant

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[122] Renewables Now 21 (REN21), *Renewables 2019: Global Status Report,* Report No. 978–3-9818911-7-7 (Paris: REN21, 2019), https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf.

[123] Renewables Now 21 (REN21), 25.

[124] Renewables Now 21 (REN21), 25.

[125] Wei-Ming Chen, Hana Kim and Hideka Yamaguchi, "Renewable energy in eastern Asia: Renewable energy policy review and comparative SWOT analysis for promoting renewable energy in Japan, South Korea, and Taiwan," *Energy Policy* 74 (April 2014), 320–323, https://doi.org/10.1016/j.enpol.2014.08.019.

[126] Chen, Kim and Yamaguchi, 321.

potential of renewable energy remains promising and technological innovation is surpassing new efficiency limits in harvesting energy from various sources. Japan's *Fifth Strategic Energy Plan*, most recently updated in 2018 highlights the need to shift to a large-scale adoption of renewable technologies in the consumer and industrial sectors. It attempts to set realistic and attainable goals for the Japanese energy transition and overall energy security consistent with Japan's 2030 and 2050 objectives.

B. AMBITIONS

Energy transition in any country requires structural change and in that, Japan is not unique. Japan's two distinctive milestones of energy security in 2030 and in 2050 require a unique and an innovative economic landscape to succeed. Renewable energy is particularly important because it is the least controversial. Viewed from the environmental sustainability lens, it is the least risk burdened, enjoys wide public acceptance, and achieves the goals of energy security while offsetting GHG emissions. Selena Kaneko underlines the importance of the public perception of renewable power policymaking and how it shifts based on adaptation. Kaneko writes that local participation, choice and availability, and strategy of business professionals in the industry provide the grassroots microeconomic forces needed to force energy transition.[127] Since the 2011 Fukushima catastrophe, public perception has been one of the driving forces of energy transition in Japan. As discussed previously, traditional fuel sources remain formidable, but the democratic forces have successfully parlayed the requirements of safety and environmental sustainability as the supreme concern for voters. To that end, minimum achievement of 24% renewable energy by 2030, the reduction of GHG by 80% in 2050 and aggressive and near-complete de-carbonization are the stated goals of the GOJ and METI.[128] Continued pressure from the electorate is critical for continued reform.

Traditional fuel sources enjoy the built-in economic advantage such that they require no changes in the consumer or industrial consumption preferences. The economic

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[127] Selena Kaneko, "Renewable Energy Policy and Public Opinion," U.S.-Japan Research Institute, last modified October 2, 2016, http://www.us-jpri.org/en/cspc/2015-2016.

[128] Ministry of Economy, Trade and Industry, 108.

aspect of energy transition is as much about supporting national goals of prosperity as they are about a more sustainable future. METI's strategic energy plan does provide a point of consideration. It states that "initiatives aimed at energy transitions are not about unfettered optimism. All energy sources have strengths and weaknesses. The energy structure is characterized by the complex interaction between technology, infrastructure, industrial structure, and policy system."[129]

In Japan's energy transition, it will become essential, as much as possible to substitute renewable power in place of traditional sources. Power variability is often pointed out as unsuitability of renewable power as the primary source, but it is a problem of engineering and not of feasibility. Stewart Needham, in his analysis of renewable energy as a primary power, states that "the more decentralized distribution of renewable resources compared to fossil fuels will require reconfiguration of the national electricity grid to better integrate power inputs from more variable input sources and reduce transmission losses from the more remote renewable sites."[130] The grid integration problem is one of the biggest challenges facing Japan. In fact, the *2016 Top Markets Report* stated that "in December 2014, a report from the Ministry of Economy, Trade and Industry, said that seven out of the ten utilities would not be able to integrate the planned solar capacity under the FIT mechanism with their existing network."[131] The incentives of lower operating costs and higher margins are forcing regulators and industry professionals to work together to find a solution.

Needham's research notes that when compared to traditional sources, even when per kWh cost may be higher "this differential disappears when the costs of carbon capture and sequestration are included in the price of coal and gas-based generation."[132]

[129] Ministry of Economy, Trade and Industry, 115.

[130] Stewart Needham, *The potential for renewable energy to provide baseload power in Australia*, Research Paper No. 9 (Canberra: Parliamentary Library of Australia: Science, Technology, Environment and Resources Section, 2008), https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/rp0809/09rp09.

[131] U.S. Department of Commerce and International Trade Administration, *2016 Top Markets Reports: Renewable Energy – Country Case Study*, 2.

[132] Needham, 17.

Needham's analysis focuses on Australia, but the analytical results are equally applicable to Japan in their energy security ambitions. Japan's energy policy and energy trilemma goals are focused on achieving renewable energy as a competitive, cost-effective, and widely adopted substitute power source during times of peak demand.

One of the greatest weaknesses to the current renewable energy policy is involuntary output curtailment program practiced by METI. Currently in Japan,

> A power producer is subject to the output curtailment rule under which a power producer must temporarily cease or curtail the supply of power to the grid at a general transmission and distribution operator's request on the grounds listed in the related ministerial ordinance such as certain technical or safety reasons, and balance of the supply and demand of electricity in the entire grid, in principle, without compensation.[133]

Even though output curtailment compensation is provided over 360 hours for solar, or 720 hours for wind, it must be constantly amended to reflect true realities of the marketplace, as more renewable technologies join the grid to compete against traditional power sources. Bird et al. write in their analysis of curtailment policies around the world that various variables including generation mix, market structure, operating rules of the power companies, and power management at the transmission level affect the curtailment and renewable energy penetration.[134] Market reforms and liberalization are essential in high output renewable sectors to sustain the growth pace as penetration levels increase in different geographic areas. Ultimately, flexibility in generation and transmission systems, availability and flexibility in storage technologies, and dynamic demand management will allow Japan to reach their ambitious goal of high utilization of renewable sector within their energy trilemma while reducing GHG emissions from traditional sources.

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[133] Geoffrey Picton-Turbervill and Julia Derrick, "Energy 2017: Fifth Edition," Global Legal Group, last modified 2017, http://www.mhmjapan.com/content/files/00023849/GLI_EN5_Japan.pdf.

[134] Lori Bird et al., "Wind and solar energy curtailment: A review of international experience," *Renewable and Sustainable Energy Reviews* 65 (June 2016): 585, https://doi.org/10.1016/j.rser.2016.06.082.

C. SOLAR ENERGY

In the decades before Fukushima, Japan had made steady progress toward achieving a high degree of renewable energy market development. Japan also is the highest exporter of solar photovoltaic technology due to free market forces in operation without local content or import tariff policies, which allow it to directly compete with both the United States and European markets.[135] Kinoshita, Wagatsuma, and Okada's research alludes to solar radiation availability and daily average temperature reached per day in Japan.[136] Kinoshita, Wagatsuma, and Okada's data range covers years 1971 to 2000 and it is a useful map to understand solar photovoltaic potential of Japan contemporarily which is extracted from SolarGIS for Japan. Rodrigues et al. point out that "Japan has a good solar insolation value (4.3–4.8 kW h/m2 day) and is a leading manufacturer of solar panels, in which most of the PV systems are grid-connected."[137]

[135] U.S. Department of Commerce and International Trade Administration, *2016 Top Markets Reports: Renewable Energy – Country Case Study*, 2.

[136] Setsuko Kinoshita, Yukiko Wagatsuma and Masafumi Okada, "Geographical Distribution for Malignant Neoplasm of the Pancreas in Relation to Selected Climatic Factors in Japan," *International Journal of Health Geographics* 6, no. 1 (July 2007): 3. https://doi.org/10.1186/1476-072X-6-34.

[137] Sandy Rodrigues et al., "Economic feasibility analysis of small scale PV systems in different countries," *Solar Energy* 131, (June 2016): 84, https://doi.org/10.1016/j.solener.2016.02.019.

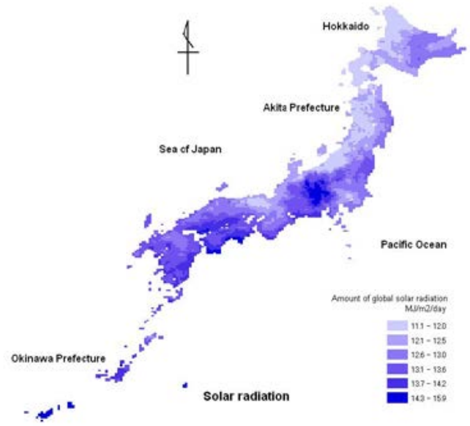

Figure 17. Distribution map of amount of global solar radiation in Japan.[138]

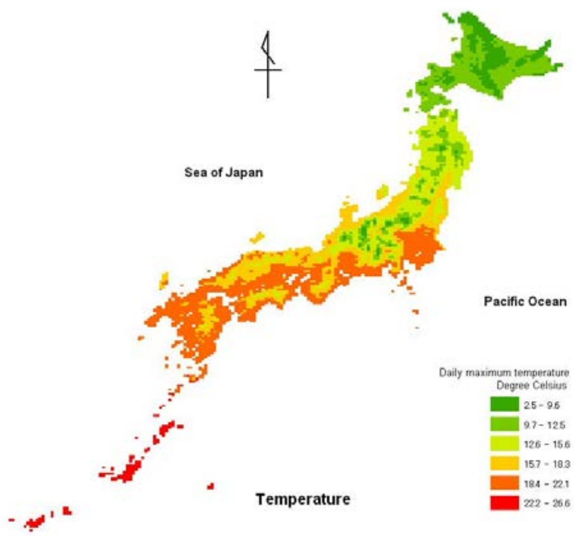

Figure 18. Distribution map of mean daily maximum temperature in Japan.[139]

138 Source: Kinoshita, Wagatsuma and Okada, 3.

139 Source: Kinoshita, Wagatsuma and Okada, 4.

Figure 19. Distribution map of solar photovoltaic potential in Japan.[140]

In Chowdhury et al.'s analysis of data shows an exponential increase in the development of solar photovoltaic installed capacity in Mega Watts (MW).[141]

140 Source: "Solar resource maps of Japan," SOLARGIS, accessed October 20, 2019, https://solargis.com/maps-and-gis-data/download/japan.

141 Sanjeeda Chowdhury et al., "Importance of Policy for Energy System Transformation: Diffusion of PV Technology in Japan and Germany," *Energy Policy* 68, (May 2014): 288, https://doi.org/10.1016/j.enpol.2014.01.023.

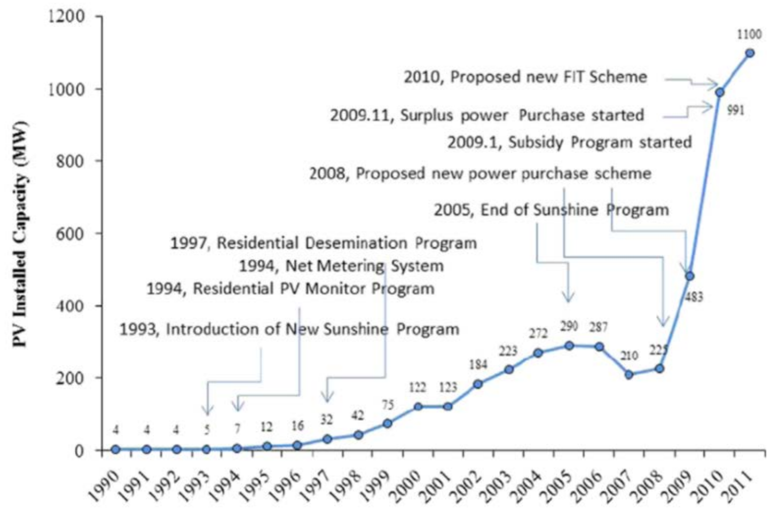

Figure 20. Trend of solar photovoltaic capacity in Japan since 1990.[142]

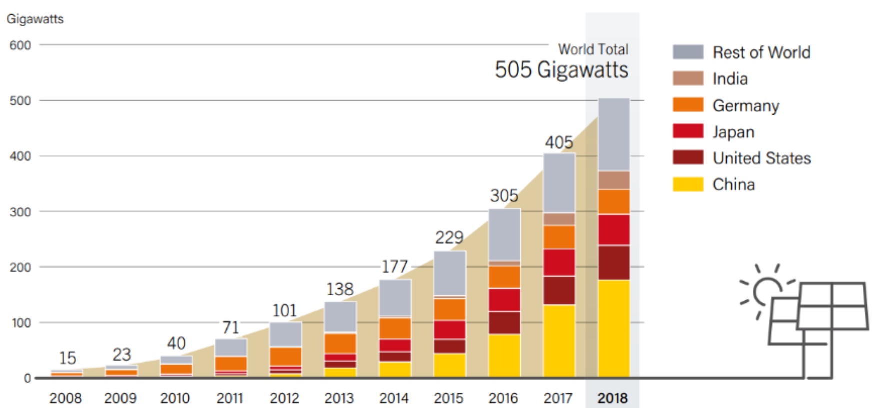

Figure 21. Exponential rise of photovoltaic, comparison of largest markets compared to Japan.[143]

Chowdhury's analysis goes on to discuss the initial phasing of the solar photovoltaic market development in Japan under the Sunshine Project between 1974 and 1981 with an investment from METI of approximately 2.5 billion JPY. With the oil crises of the 1970s, the need for alternate fuel sources to power the Japanese economy became apparent. Chowdhury identified three distinct phases of integration of solar photovoltaic

142 Chowdhury, 288.

143 Renewables Now 21 (REN21), 95.

into the Japanese economy with 1) initial technology development, 2) market development to incentivize adoption, and 3) market development with and without subsidy to understand the economic forces that directly impact the energy security of Japan.[144]

This research is intended to focus on events in the renewable marketplace to understand energy security challenges in the post-Fukushima era; however, the policy enacted prior to it is an important scene setter in understanding how Japan intends to fully integrate solar power in the economy. METI had ambitious solar photovoltaic goals as early as 1980s. Chowdhury et al.'s analysis shows that in the 1990s METI simplified installation procedures of photovoltaic systems to lower bureaucratic burden, an energy buy-back system was developed to sell back excess energy at reasonable market prices.[145] Their research goes on to note that with the New Sunshine Project, penetration of photovoltaic technologies accelerated in the consumer marketplace with subsidy of up to 50% of installation costs by the GOJ. The analysis points out that METI provided upfront seed money for the advanced development and industrialization of photovoltaic technologies, essentially reducing the negative monetary externality to zero as failure costs would be absorbed by the GOJ.[146] Since 2011, GOJ has continued to subsidize photovoltaic market development by reforming purchasing mechanisms of excess grid power, adjusted residential photovoltaic system subsidy for installation and net-metering, and implemented a feed-in-tariff (FIT) mechanisms.

The introduction of FIT in 2012 greatly expanded market access to investors across the world, overriding the existing RPS and purchasing mechanisms for photovoltaic electricity in Japan. The Ichigo Green Infrastructure Investment Cooperation (IGIIC) accurately describes FIT policy as an incentive to "create a virtuous cycle of investment, innovation, and cost reductions."[147] FIT end-goals are consistent with METI's 2030

[144] Chowdhury et al., 287.

[145] Chowdhury et al., 288.

[146] Chowdhury et al., 288.

[147] "The Introduction of Japan's FIT System for Renewable Energy," Ichigo Green Infrastructure Investment Corporation, accessed October 20, 2019, https://www.ichigo-green.co.jp/en/operation/purchase.php.

innovation and implementation strategy noted in the *Fifth Strategic Energy Plan*. IGIIC goes on to note "Under Japan's FIT system, electric utilities and merchants purchase renewable-generated electricity at prices and contract durations set by the Ministry of Economy, Trade and Industry. End-users then pay a surcharge to help cover the renewable portion of the total power supply."[148] Having long-term FIT contracts in place allows capital intensive projects, such as large-scale photovoltaic installation, to recover the sunk cost at a guaranteed reasonable rate on investment because, "electric power companies are obliged to purchase electricity generated from renewable energy sources on a fixed-period contract at a fixed price,"[149] according to IEA's analysis.

Without parity to traditional sources, it is nearly impossible for renewables to compete with legacy energy markets. Keiji Kimura of Renewable Energy Institute in Japan writes

> by implementing the renewable energy support policies in the initial stage of deployment, the gradual cost reduction will eventually enable renewable energy to compete over time in the electricity market against conventional energy sources, inclusive of social costs, without any particular policy support.[150]

Kimura stresses the importance of METI and ANRE revising poor administration rules and pricing mechanisms need to be aligned with cost reduction goals for the entire market segment.[151]

FIT mechanism, essentially is a cost sharing agreement between power generation facilities and consumers since early stage implementation costs are high for new technologies before economies of scale are achieved. The policy element facilitates, and even obligates procurement transaction between buyers and sellers of electricity reducing

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[148] Ichigo Green Infrastructure Investment Corporation, 1–3.

[149] "Feed-in Tariff for renewable electricity and solar PV auction," International Energy Agency, April 09, 2018, https://www.iea.org/policiesandmeasures/pams/japan/name-30660-en.php.

[150] Keiji Kimura, *Feed-in Tariffs in Japan: Five Years of Achievements and Future Challenges*, (Tokyo, Renewable Energy Institute, 2017), https://www.renewable-ei.org/en/activities/reports/img/pdf/20170810/REI_Report_20170908_FIT5years_Web_EN.pdf.

[151] Kimura, 14–16.

the likelihood of market failure.[152] The end user pays the cost, in the form of a surcharge, for purchasing energy from renewable sources and utilities pay their share to the amount equal to the generation cost they would avoid had they purchased from producers.[153] A FIT mechanism is shown below in Figure 22 that shows the exchange of incentives for each party to reduce the externalities in the marketplace to reduce the transaction costs borne by the market and pass on the savings in terms of a consumer and a producer surplus.

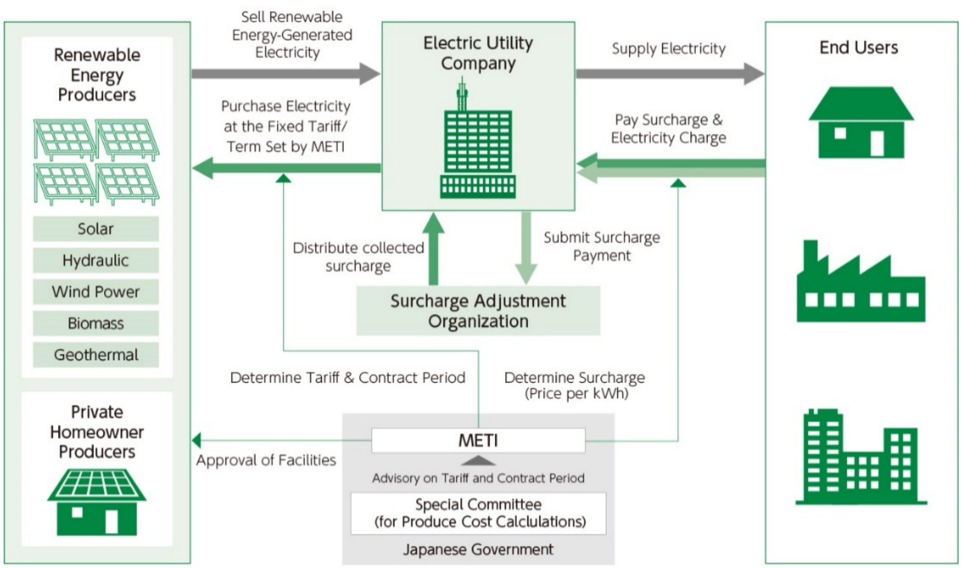

Figure 22. Japan's feed-in-tariff (FIT) mechanism in renewable energy marketplace.[154]

Takuya Yamazaki, Director of renewable energy division within ANRE and METI understand the importance of an efficient market operation in Japan to allow deeper penetration of sustainable energy sources. He points out that Japan's electrical markets were regionally segmented before Fukushima, with the 60 Hz frequency power in the west and 50 Hz frequency power distribution in the east, creating a requirement for a frequency conversion site. Yamazaki writes that markets become inefficient when Japan is divided

[152] Kimura, 2.

[153] International Energy Agency, 1–2.

[154] Source: Ichigo Green Infrastructure Investment Corporation, 1–2.

into 10 regional utilities that is operated and controlled by a single utility provider, making it extremely difficult to manage cross-regional supply and demand fluctuations.[155] Much of the transmission infrastructure for solar photovoltaic is shared with traditional utilities. Since the gradual deregulation of generation, transmission, distribution, and retail energy markets, renewable adoption rate has increased significantly. Renewable technologies in general enjoy a 26% annual average growth rate since 2012, with the largest share accounted by solar photovoltaic under the FIT scheme.[156] Additionally, FIT policy has raised renewable generation to 58.6 TWh, equivalent to approximately 18.89 million households.[157]

Japan's solar photovoltaic market faces systemic weaknesses and threats but also have many opportunities for gain due to inherent strength of the fuel source. F. Muhammad-Sukki et al.'s analysis suggest that any non-residential installation, greater than 100kW could see a gain of nearly 8% per annum, higher than European markets in a similar segment.[158] High cost of design-to-operation implementation, also called construction costs, and large number of total generation cells are required for meaningful commercial production. To reduce price volatility and provide adequate investor returns, often times the industry will resort to traditional fuel sources, which have a lower, established and predictable kWh unit cost.

As the solar photovoltaic market matures in Japan, the energy policies will have to change to account for the increased opportunity for adoption, use, and investment in the industry to achieve a high-energy trilemma score. As a direct competitor to the Japanese market, an analysis by Solar Power Europe points out that "the solar market is in the middle of a transition from its lucrative FIT scheme to auctions and self-consumption. But with a huge FIT pipeline waiting for installation…the Japanese photovoltaic Energy Association

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[155] Takuya Yamazaki, "Japan's Renewable Energy Policy," Agency for Natural Resources and Energy: Renewable Energy Division, last modified September 2018, https://www.ieabioenergy.com/wp-content/uploads/2018/09/0.2-Takuya-Yamazaki.pdf.

[156] Yamazaki, 6.

[157] Keiji Kimura, 3.

[158] Firdaus Muhammad-Sukki et al., "Feed-in tariff for solar photovoltaic: The rise of Japan," *Renewable energy* 68, (March 2014): 636, https://doi.org/10.1016/j.renene.2014.03.012.

(JPEA) expect the country's solar downturn to continue until 2024, before market design and infrastructure will be ready for further growth."[159]

Even though the promise of solar photovoltaic is immense in Japan, it is worth noting the demographic shifts, long-term deflationary forces, a declining population, and high levels of public debt as a cause for economic concern. A declining population often correlates to a shrinking economic output due to systematic unavailability of the labor force. The Japanese market runs the risk of overinvestment in solar photovoltaic sector due to its immense potential based on Japan's solar radiation availability. Komiyama and Fujii notes that "The expectation for future rapid deployment of PV system has highlighted the significance of efficiently balancing the temporal change of power supply and demand in the Japanese electricity system."[160] Their analysis goes on to say that Japanese markets may experience a slowdown when installed photovoltaic capacity is greater than efficient use patterns because their solar potential is equivalent to nearly 40 times of peak demand.[161] A policy review at a predetermined interval could help balance the supply and demand forces to efficiently transition to a fully renewable generation market.

Another constraint faced by the Japanese solar market is the variability in landscape and topography where generation projects could be installed. Geography specific climate and output variability will impact the management of energy agenda for METI. Variability in landscape and climate leads to an unbalanced mix of renewable power generation, says Yamazaki.[162] Unbalanced generation portfolio weakens the overall energy policy because the invisible hand of the market steers investment toward preferential products due to more immediate returns, which in this case is solar. While FIT scheme overall is effective at promoting solar photovoltaic, it also drowns out nascent technologies. Japan is aware of

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[159] Solar Power Europe, *Global Market Outlook: For Solar Power / 2018 -2022*, Report No. 9789082714319 (Brussels, Belgium: Solar Power Europe, 2018), http://www.solarpowereurope.org/wp-content/uploads/2018/09/Global-Market-Outlook-2018-2022.pdf.

[160] Ryoichi Komiyama and Yusumasa Fujii, "Assessment of massive integration of photovoltaic system considering rechargeable battery in Japan with high time-resolution optimal power generation mix model," *Energy Policy* 66, (March 2014): 88, https://doi.org/10.1016/j.enpol.2013.11.022.

[161] Komiyama and Fujii, 74.

[162] Yamazaki, 9–11.

such challenges and is addressing them slowly, for example, the right to use sea area to the lowest-bidding energy generators for offshore wind farms. Wind is quickly becoming an essential complimentary generation source to solar as will be discussed in the next section.

D. WIND ENERGY

A particular factor toward renewable wind energy in Japan is that there is a collective community buy-in mindset. The Japanese societal awareness of environmental issues is remarkable, resisting a modern lifestyle at the expense of nature.[163] Japan's ample coastline offers sufficient opportunities for offshore wind project development. Over the past couple of decades, the renewable energy investment trend has largely favored the solar sector; however, the wind energy development is rapidly expanding. Regulatory policy has lagged behind market capacity to capitalize a budding industry in the last few years. A combination of favorable legislative agenda and a short-term net-positive cost-benefit policy could strengthen the industry against other renewable energy options. Wind development growth is often inhibited by geographic constraints but is gaining prominence in Japanese communities to expand Japan's overall renewable reach and solidify energy trilemma.

Japan's Wind Power Association (JWPA), an industry group, is working towards developing better policies with the government to seamlessly incorporate wind power within Japanese energy security by aiming to supply nearly 20% of Japan's domestic electric power demand from wind generation, both onshore and offshore, by 2050.[164] JWPA's mid-term and long-term installation goals are distinct and aligned with the overall METI energy policy goals. A mid-term goal of approximately 84,000 GWh/year, about 9% of total demand and long-term goal of 188,000 GWh/year, totaling about 20% of domestic demand are feasible given the right set of market conditions and investments, as shown in

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[163] Yasushi Maruyama, Makoto Nishikido and Tetsunari Lida, "The rise of community wind power in Japan: Enhanced acceptance through social innovation," *Energy Policy* 35, no. 5 (May 2007): 2766, https://doi.org/10.1016/j.enpol.2006.12.010.

[164] "Vision (Mid/Long-Term Installation Goals)," Japan Wind Power Association, accessed October 20, 2019, http://jwpa.jp/englishsite/jwpa/vision.html.

the graph below.[165] Wind proponents in general face a problem of land availability in Japan. Current GOJ regulations state that land without ownership must be available for public use and not for power generation.[166] A justification could be made for power generation and its utility as a public good. METI and the cabinet must pass new legislation for markets to take advantage of this opportunity to provide an essential utility to the people of Japan at the lowest possible cost, enhancing the affordability aspect of the trilemma.

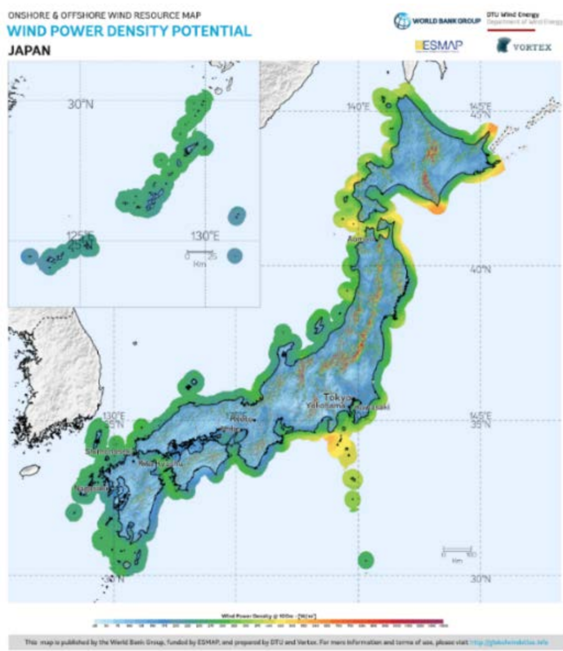

Figure 23. Japan’s wind resource availability, density potential map.[167]

[165] Japan Wind Power Association, 2.

[166] Lain Wilson, “Japan’s Secondary Solar Market Showing Strength: Q&A,” *BloombergNEF*, last modified September 17, 2018, https://about.bnef.com/blog/japans-secondary-solar-market-showing-strength-qa/.

[167] Source: “Power Density Potential,” Global Wind Atlas, accessed October 20, 2019, https://globalwindatlas.info/en/downloads/Japan.

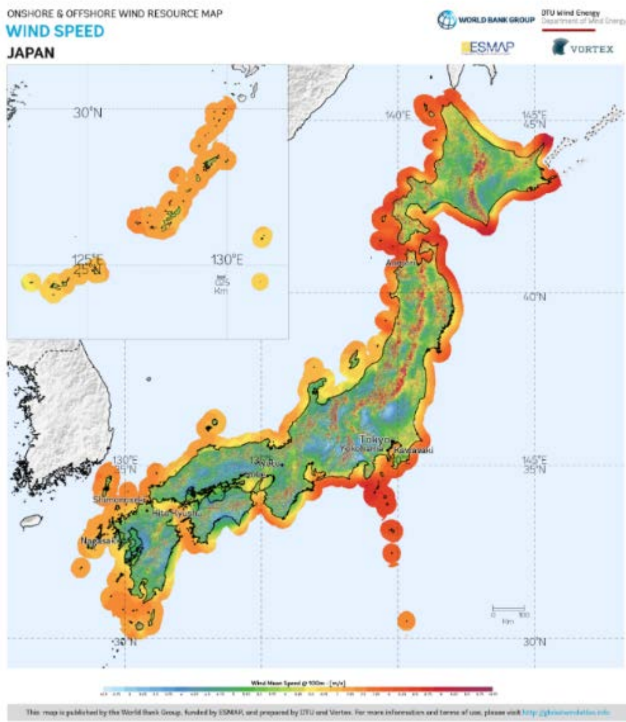

Figure 24. Japan’s wind resource availability, wind speed map.[168]

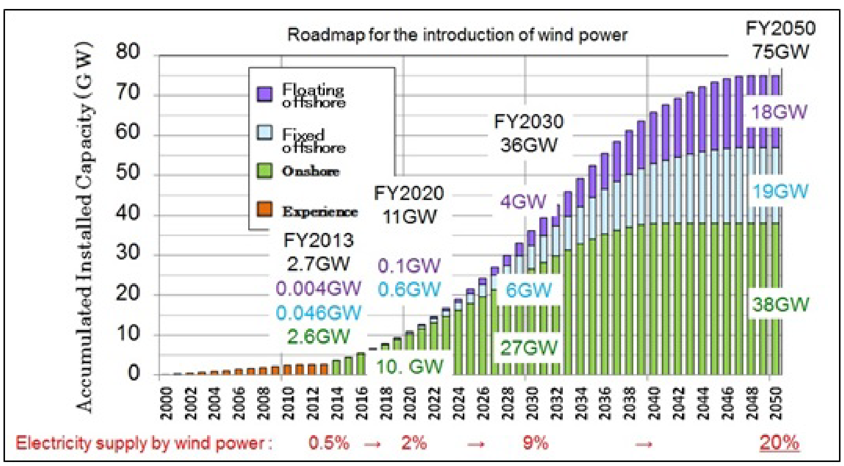

Figure 25. Japan’s wind power installation capacity roadmap.[169]

168 Source: “Wind Speed,” Global Wind Atlas, accessed October 20, 2019, https://globalwindatlas.info/en/downloads/Japan.

169 Source: Japan Wind Power Association, 1–2.

Japan remains one of the last untapped wind energy markets in the world. Carbon Trust, a leading organization for sustainable future, in their report titled *Appraisal of the Offshore Wind Industry in Japan* report that Japan must overcome regulatory, technical, and policy issues for effective wind power generation.[170] Reliability and compatibility of the transmission grid remain a central issue, a threat similar to solar power generation. Frequency converters are required at the nexus of east and west grids, making it more challenging to supply power reliably across all the prefectures. Especially with Hokkaido and Tohuku transmission lines, the bottleneck and limited band capacity require technical and policy solutions to solve because it is where wind power is both abundant and most cost-effective.[171] Markets are further hampered by the lengthy consenting process in the contracts that stretch deployment times, ultimately raising costs for investors and is a significant weakness of the market. Availability of wind is disproportionately high in the north, and thus Japan will have to build installation and maintenance facilities ports close to wind farms given the relatively deep waters near its shore across the board.

Japan dominates the wind turbine manufacturing industry. Fuji and Hitachi are giants in the industry with nearly 86% of the turbines manufactured by Japan in the world.[172] In March 2018, Japan's cabinet approved a set of rules that promote offshore wind development, a favorable decision because, "Onshore wind farms face resistance because of noise pollution concerns. Yet large offshore wind farms can be built since they are often located far from residential areas. In addition, offshore farms benefit from a feed-in-tariff price of 36 yen per kilowatt-hour, which is double the price for solar energy, and more than the 20 yen fetched by onshore wind generators."[173] JWPA's goals would

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[170] Al-Karim Govindji, Rhodri James and Adriana Carvallo, *Appraisal of the Offshore Wind Industry in Japan*, Report Number CTC 834 (London, UK: Carbon Trust, 2014), https://www.carbontrust.com/media/566323/ctc834-detailed-appraisal-of-the-offshore-wind-industry-in-japan.pdf.

[171] Yoshiaki Shibata, Evaluation of Wind Power Integration Potential in Japan by Strengthening of Interregional Transmission Lines and by Power Curtailment, (Tokyo, Japan: Institute of Energy Economics – Japan, 2014), https://eneken.ieej.or.jp/data/5497.pdf.

[172] Govindji, James and Carvallo, 5.

[173] Yukinori Hanada and Nana Shibata, "Offshore wind farms in Japan viable with new law," *Nikkei Asian Review*, February 14, 2019, https://asia.nikkei.com/Business/Business-trends/Offshore-wind-farms-in-Japan-turn-viable-with-new-law.

provide a CO2 reduction of approximately 32 M CO2 t/year by 2030 and would rise to nearly 99 M CO2 t/year.[174]

As part of the G7 member state consensus, Japan participates in site-specific auctions for off-shore wind development. It helps reduce investor risks by negating information asymmetry and increasing market efficiency. International Renewable Energy Agency states that "pre-selecting a site typically implies that the installed capacity and grid interconnections are determined beforehand, allowing policy makers and project developers to concentrate their efforts on the challenges and features of the chosen site, and to tailor the auction design and awarded contract to these conditions."[175] To strengthen the regulatory environment, Japan has revised the port and harbor statute, which eased restrictions on wind power development near port infrastructure. These statutes provide further guidance for domestic and Foreign Direct Investment (FDI), a strong policy signal for market development opportunity.

Wind power will become viable when its substitutability to traditional power reach parity in terms of costs. On average, wind generated power is far less costly than solar power per kWh and has slightly greater utilization rate.[176] The added reduced cost signals the market for more investment because one wind turbine offers an exponential power generation compared to a one photovoltaic panel. Cost reduction remains a significant goal for the manufacturers and policy makers for the market to encourage greater rates of adoption. Keiji Kimura, author is *Analysis of Wind Power Costs in Japan* at the Renewable Energy Institute provides an overview of the associated costs that must reach parity: Investment costs, operation and maintenance costs, and a cost-benefit analysis of

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[174] Japan Wind Power Association, 1–2.

[175] International Renewable Energy Agency, *Offshore wind investment, policies and job creation: Review of key findings for G7 ministerial meetings*, (Halifax, Canada: International Renewable Energy Agency, 2018), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Sep/IRENA_offshore_wind_note_G7_2018.pdf?la=en&hash=B186614D923AB1F0A07D7285612C4B037057A0C0.

[176] Vivoda, 166.

investment afforded to the actual amount of electricity generated.[177] Kimura notes that while global turbine costs have been decreasing due to economies of scale and competition between firms in the European Union and the United States, labor costs in Japan have varied and largely increased over the past decade.[178]

Ultimately, the global and domestic Levelized Cost of Electricity (LCOE)[179] must be comparable for a decisive wide-scale penetration into the consumer and industrial consumption. Today, that is not the case. As Tarak Shah posits, "government policy barriers are driving up costs for wind energy unfairly. Specifically, a long and complex land use planning and environmental assessment processes for onshore and offshore wind power development, which is said to take three-four years on average, raises project development costs unnecessarily. In addition, all wind power projects over 10MW are required to go through this process."[180]

Essentially, any largescale project laments the bureaucratic impetus mastered by the traditional energy corporations. The wind energy market, in turn, suffers from the loss of efficiency gains. Ultimately, the excess consumer surplus is wiped away, dead weight losses at the market equilibrium inevitably get larger, and delaying the greater adoption of renewable technologies in Japan. The status quo favors the existing business practices and threatens to delay transition. For example,

> priority dispatch is not given for renewable energy generators in Japan, and it is not described in either the FIT Act or the Ministerial Ordinance. According to the latest grid rule issued by the Electric Power Council of Japan, curtailment of wind and solar generation should be implemented before other measures such as interchanges between utilities, curtailment of

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177 Keiji Kimura, *Analysis of Wind Power Costs in Japan*, (Tokyo, Renewable Energy Institute, 2018), https://www.renewable-ei.org/en/activities/reports/img/pdf/20180125/JapanWindPowerCostReport_EN_20180124.pdf.

178 Kimura, *Analysis of Wind Power Costs in Japan*, 21–22.

179 The LCOE for wind power is defined as normalized costs for 1 kWh of electricity produced by power plants throughout their life cycle.

180 Tarak Shah, "Japan's Changing Electricity Market: Recommendations for Policy Makers," Sasakawa Peace Foundation USA, last modified July 05, 2018, https://spfusa.org/research/japans-changing-electricity-market-recommendations-for-policy-makers/.

> other power producers and suppliers (independent generators with mainly conventional combustion plants), or curtailment of baseload generators.[181]

The relatively lower cost of fossil fuels in this decade and the relatively high cost of technical deployment of wind power in Japan prohibit the market from accelerating wind to a base-load power source state, jeopardizing Japan's 2030 and 2050 energy mix targets.

E. PROMISE OF OTHER RENEWABLE TECHNOLOGIES

With 1.2% of the population, approximately 127 million, Japan consumes 5.3% of the world's total energy production.[182] Photovoltaic and wind are the most prominent renewable energy sources in the Japanese economy; however, geothermal, biomass, tidal power, and hydrogen technologies are capable suitors to capture niche market segments where appropriate. Hydrogen fuel cell technology is perhaps the most prepared for a wide-scale deployment because of its portability, especially in the transportation sector. The versatility of the renewable energy options will allow Japan to remain flexible in deploying different regional energy-mix to achieve a high degree of trilemma across the board. The utility of certain fuels is inherently higher in specific geographic areas, thus market development of such technologies is critical if Japan were to decarbonize beyond 2050, consistent with METI's energy transition plan.

Two structural factors are key to rapid development of nascent renewable technologies in addition to Research and Development (R&D). The GOJ must show the same level of support enjoyed by the fossil fuel industry and nuclear energy research industry in Japan in the previous decades, facilitating the transition away from current energy model and elevating the infrastructure for storage capacities for peak capacity use while in a non-peak generation status due to weather patterns, for example. As Komiyama and Fujii accurately point out in "addressing seasonal imbalance between solar insolation

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[181] Bird et al., 581.

[182] Scott Victor Valentine, "A STEP toward Understanding Wind Power Development Policy Barriers in Advanced Economies," *Renewable and Sustainable Energy Reviews* 14, no. 9 (December 2010): 2799, https://doi.org/10.1016/j.rser.2010.07.043.

and electricity demand, hydrogen storage system is regarded as one of the [best] technical options."[183]

Japan's volcanic activity is well documented in history. It should not come as a surprise that geothermal power availability in Japan in significant, only behind Indonesia and the United States.[184] Even though, given the potential, Japan's production is nominal. Shortall and Kharrazi report,

> it [geothermal power] is even more attractive when its low levelized cost, high capacity factor, reliability, and flexibility are taken into account. Research suggests that by 2050, geothermal electricity generation could supply around 3.5% of global electricity production, thus avoiding almost 800 megatonnes (Mt) of CO2 emissions per year.[185]

Geothermal power is not novel to Japan; it operated its first commercial plant in 1952. According to International Renewable Energy Agency (IREAN), similar to solar and wind, Japan's regulatory and initial cost burden on renewable technologies is high. IRENA's analysis show, "despite Japan's technical and construction preeminence and its significant energy potential, there are only around twenty geothermal plants in Japan, with a total output capacity of around 535 MW, only 0.3% of the country's total electricity generation."[186]

Efficiency losses due to temperature variability and drill depth capacity based on topology will likely prohibit localized geothermal power to be transported over long distance, but provides a suitable option for power generation in areas where geothermal power density is high compared to the demand signal. From a social adaption lens, "Japan faces significant environmental and social barriers to expanded use of geothermal energy,

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[183] Komiyama and Fujii, 88.

[184] International Trade Administration, *2016 Top Markets Report Renewable Energy: A Market Assessment Tool for U.S. Exporters* (Washington, DC: U.S. Department of Commerce, 2016), https://www.trade.gov/topmarkets/pdf/Renewable_Energy_Top_Markets_Report.pdf

[185] Ruth Shortall and Ali Kharrazi, "Cultural factors of sustainable energy development: A case study of geothermal energy in Iceland and Japan," *Renewable and sustainable energy reviews* 79, (November 2017): 102, https://doi.org/10.1016/j.rser.2017.05.029.

[186] "Unlocking Geothermal Potential in Japan through Small-scale Generation," International Renewable Energy Agency, July 23, 2018, https://www.irena.org/newsroom/articles/2009/Apr/Unlocking-geothermal-potential-in-Japan-through-small-scale-generation.

including concerns about potentially adverse impacts on traditional geothermal baths."[187] Additionally, nearly 80% of energy potential for geothermal in Japan is in natural areas protected by the Natural Parks Act, making it exceptionally difficult to lay industrial infrastructure surrounding it.[188] The markets will not tolerate the uncertainty surrounding easing of restrictions by the GOJ to develop geothermal power; hence, the development will largely be limited to small-scale development.

Hydropower, an emissions free resource can also complement the overall renewable energy portfolio in Japan with its some 2700 rivers and 600 or so lakes. According to International Hydropower Association, Japan has approximately 50 GW of installed capacity, including pumped storage to serve its energy needs, which is second in Asia behind China's 341 GW.[189] Given the land availability, Japan's achievement is not easily dismissed and hydropower enjoys a very low LCOE, about 0.05 per kWh USD in nearly all the markets because it requires minimal infrastructure to support power generation.[190]

Growth in hydropower is expected to be limited due to the same systemic issues faced by other land-derived renewable technologies: regulatory headwinds, environmental opposition to development of natural resource due to fear of pollution, limited storage capacity during peak-use and non-peak generation gap, transmission issues for feeding renewable power to the grid, and curtailment policies. GOJ is aware of these issues, and is working to reform the development processes with Japan's Water Agency. For example, amendment of the 2013 River Act has streamlines the permit process to use water for energy generation rather than solely dedicated to agricultural use.[191] By exposing low risks

[187] Renewables Now 21 (REN21), 84.

[188] Hossein Yousefi and Seyed Mostafa Mortazavi, "A Review on Robustness of Geothermal Energy in Japan" (Workshop, Stanford University, Stanford, CA, February 12–14, 2018), https://pangea.stanford.edu/ERE/pdf/IGAstandard/SGW/2018/Yousefi.pdf.

[189] International Hydropower Association, Hydropower Status Report: sector trends and insights, (London: UK, International Hydropower Association, 2018), https://www.hydropower.org/sites/default/files/publications-docs/2018_hydropower_status_report_0.pdf.

[190] International Hydropower Association, 89.

[191] Ministry of Economy, Trade and Industry, 51.

of the technology to the public, promoting understanding of the overall goal it may be possible for METI and GOJ to raise the outlook of hydropower in a post-Fukushima context in Japan.

Biomass energy policy was first introduced in Japan around 2002, nearly a decade before Fukushima. It was further codified with 2009 Basic Act for the Promotion of Biomass Utilization. Even though current biomass energy sector is under developed, the utilization potential remains localized near industrial plants that process the biomass. Additional energy required to transport and carbon footprint generated because of it make biomass an unlikely candidate for wide adoption potential because "crop potential for biomass usage in Japan is limited, despite its square mileage, owing to the disparity of climate between northern and southern Japan."[192] Biomass can aid in decentralizing energy infrastructure in areas with relatively low population density, aiding energy security goals of access, affordability while foregoing carbon emissions associated with energy transport.

Ocean energy is expected to compete for prominence in the energy security of Japan as the technology improves and economies of scale develop worldwide. Japan, as an island nation has the benefit of unidirectional stable flow generated from ocean currents, periodic horizontal flow generated near the coastline by tidal fluctuations, and wave power generation derived from universal vertical motion to support its energy needs. A technically demanding power generation environment, advances in marine engineering must occur before policy prescriptions can be made available for investors. The marine energy market overall is quite nascent and immature for commercial investment seeking an ROI. The GOJ must continue to subsidize research and early stage investment for prototype development for future deployment of ocean energy. The government must continue to facilitate and balance industry cooperation between businesses dependent on organic marine resource availability against power generation demands. Seafood diet is a staple in Japanese society,

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[192] Nugroho Agung Pambudi et al., "Biomass energy in Japan: Current status and future potential," *International Journal of Smart Grid and Clean Energy* 6, no. 2 (April 2017): 125, https://doi.org/10.12720/sgce.6.2.119-126.

thus any restrictions on fishing is likely to meet heavy resistance in legislature and in public opinion.

In addition to the general energy security strategy released by METI and GOJ, a separate *Basic Hydrogen Strategy* was released in December 2017 by Japanese leaders, recognizing the huge potential in aiding Japan's energy security challenges. Japan's technical knowledge has elevated its stature as the leading developer of hydrogen fuel cell technologies in the world. Hydrogen is poised to raise Japan's self-sufficiency development ratio (SSR), while reducing import dependence on Middle East fossil fuels with the added advantage of reducing Japan's carbon emissions. The versatility of hydrogen is key to its penetration in Japan's energy security due to its high power density. An integrated hydrogen power economy "could foster deep decarbonisation of the transport, power, industry and residential sectors while strengthening energy security."[193] The Hydrogen Council, a co-op between industry and government leaders report that "hydrogen use for CO2 emission reduction could create a $2.5 trillion market and 30 million jobs on the assumption that energy-related CO2 emissions would have to be cut by 60% by 2050 to achieve the so-called 2℃ scenario."[194] Japan's hydrogen venture has enormous implications for the world's energy markets as it leads technical innovation of hydrogen energy. Not only Japan will benefit from raising its energy security to unprecedented levels, but also the economic gains realized from exporting the technology will help it compete with China on the international economic stage in East Asia.

F. FINDINGS

Japan's quest toward complete decarbonisation of the economy is aligned to reduce not just the political and economic cost, but also the hidden social cost of price volatility and intergenerational health of their society. Energy security is not just about access and

[193] Monica Nagashima, *Japan's Hydrogen Strategy and its economic and geopolitical implications*, Report No. 978–2-36567-918-3 (Paris, France: IFRI, 2018), https://www.ifri.org/sites/default/files/atoms/files/nagashima_japan_hydrogen_2018_.pdf.

[194] Ministry of Economy, Trade and Industry, *Basic Hydrogen Strategy* (Tokyo, Japan: Agency for Natural Resources and Energy: Ministerial Council on Renewable Energy, Hydrogen and Related Issues, 2017), https://www.meti.go.jp/english/press/2017/pdf/1226_003b.pdf.

affordability; it requires reducing the vulnerability of its citizens in a modern society from negative externalities suffered from legacy technology and policy. Tarak Shah, writing for Sasakawa Peace Foundation says, "Policy makers must view fair competition and reliability as co-equal goals. Current policies favor incumbent forms of energy (coal, gas, and nuclear) while overstating the reliability challenges associated with variable renewable energy."[195]

In Japan, the wholesale electrical power market is merit-ordered for inputs with the lowest marginal or variable costs. "The wholesale electricity price is determined by the variable cost of the power plant that fills the final portion of demand. Solar photovoltaic and wind power have close to zero variable costs and should therefore always dispatch first from a cost optimization perspective."[196] However, as mentioned before such is not the case because the legacy infrastructure is designed to prioritize traditional fuel sources, and with the FIT and curtailment policies, penetration of renewable energy in Japan's energy market has been incremental. As the renewable market capacity increases, thermal power plants with higher variable cost-basis will likely be pushed out of the market.

Information asymmetry remains a barrier for scaled geographic resource development. Market failures are inevitable when information is shielded in an effort to gain advantage or to capture market share. The government must step in to ensure fair market practices to benefit local residents, especially in disaster affected areas such as Fukushima who may oppose any technological development as a principal effect of negative externalities already suffered. For example with solar technologies, "when prefectures share information about renewable resources with local residents, they can compete more evenly with extra prefectural companies. However, disaster areas face extra governance challenges when introducing solar. Good subnational governance is vital to creating a more equitable, locally engaged renewable energy transition."[197]

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[195] Shah, 4.

[196] Kimura, *Feed-in Tariffs in Japan: Five Years of Achievements and Future Challenges*, 8.

[197] Timothy Fraser, "How Governance and Disasters Shape Renewable Energy Transitions: The Case of Japanese Mega-Solar," *Social Science Quarterly* 100, no. 3 (February 2019): 975, https://doi.org/10.1111/ssqu.12603.

Ultimately, the Japanese community demands access to a reliable, affordable, and sustainable energy sources powering the economy. In its purest abstracts forms, becomes a quest for supply and demand derived from consumer preferences for regional, sub-national, and national energy security.

Figure 26. Supply and Demand trends in Japan's renewable energy transition.[198]

Renewable energy transition is inevitable as costs reach parity with traditional sources. The strength of Japan's transition is embedded in its ability to lead technical innovation in engineering as it already dominates manufacturing sector that underlies renewable energy equipment. Under the current FIT system, "it is becoming a requirement to set a long-term price target and to calculate values such as procurement prices for several years into the future. It has become extremely difficult to predict future costs from the sum

[198] Source: Marlene Motyka, Andrew Slaughter, and Carolyn Amon, "Global renewable energy trends: Solar and wind move from mainstream to preferred," Deloitte, last modified September 14, 2018, https://www2.deloitte.com/us/en/insights/industry/power-and-utilities/global-renewable-energy-trends.html.

of the capital cost and cost of operation and maintenance alone….”[199] An opportunity exists for METI to align incentives to timelines to provide better forecasting of market conditions to reduce investor risk. Additionally, this policy reform is likely to allow Japan to better compete in exporting its renewable energy expertise with Germany and China. Increasing technological diversity on a global scale will force competitive forces of the market to draw price equilibrium closer to its true center instead of paying inflated price margins designed to recoup initial research and development costs.

On the demand side, renewable energy growth is driven by changing consumer preferences and greater awareness of environmental and social impact of energy generation from fossil fuels. The Fukushima incident has significantly raised the opportunity for interested investors that were previously sidelined. Younger generations are more likely to push leaders to embrace change because they will have to live with the consequences of the status quo, which is a threat to the existing system and simultaneously an opportunity for innovation. Additionally, consolidating efforts toward a true smart national grid, combined with higher storage capacity, is likely to incentivize a higher adoption rate across the board on renewables choice availability. Cost-basis for adoption varies geographically and that choice based reform becomes critical to snowball transition, especially in urban areas where usage density is highest. As Tarak Shah mentions, strengthening market reforms such as “electricity futures market, a baseload power market, transmission interconnection rules that will require an implicit auction, a capacity market, a zero emission credit trading market, and real-time market,”,[200]are critical to reducing transaction costs and streamlining market transition toward greater energy security.

Restart of nuclear power in Japan, driven by powerful industrial interests with the support of the government of Prime Minister Shinzo Abe are likely to undermine the accelerated timeline desired to adopt renewable energy sources in Japan’s economy. While liberalization of generation and transmission markets have begun, it will take some time to

[199] Kimura, 16.

[200] Shah, 5.

fully remove barriers for renewable technologies to seamlessly integrate in the energy markets.

The future of renewable energy, particularly photovoltaic and wind is optimistic in Japan. There are significant economic forces driving the political will to reduce preference towards the status quo and allow an only market directed transition away from fossil fuels. Global innovation is likely to nudge Japan in accelerated renewable transition. With existing headwinds, Japan will likely miss renewable energy adoption goals of 2030 but may exceed it for the 2050s energy mix to secure an affordable, accessible, and environmentally sustainable energy future.

Lastly, across Japan, South Korea, and China, the potential for renewable energy is strong and abundant. If the political capital exists, then a sufficient opportunity also exists in East Asia to create a massive super grid to transfer energy resources in real time as needed, much like in Europe. Creating economic and energy interdependence may ease political and geographic tensions in the long run as an ancillary benefit of industrialized economies transitioning to renewable power together.

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V. CONCLUSION AND RECOMMENDATIONS

In this analysis, the various aspects of Japan's energy security are discussed in METI's 3E + S framework. The disparity between Japan's economic output and availability of domestic resources is high, making Japan one of the most resource deficient industrialized nations in the world. After World War II, Japan's industrial capacity rose rapidly and the energy requirements in the consumer and industrial sector with it. Much of the infrastructure developed in the decades following World War II was set up with fossil fuels as a baseline and abundant source. Japan has expertly navigated resource diplomacy throughout the past seven decades to ensure a ready and affordable supply of energy. Policy proposals were enacted by the GOJ to reduce supply shocks after the oil crises of the 1970s to tame the supply disruption supporting economic activity. The 2011 Fukushima nuclear disaster highlighted Japan's vulnerability in energy security. Even though much of the traditional, fossil fuel based supply chains were undisturbed, it emphasized the country's overwhelming reliance on a single energy source to sustain most of its economic activity.

Fossil fuels and the abundance of cheap energy has played a key role in elevating the welfare of citizens across countless states, including Japan. Cheap and readily available, fossil fuels have been used to thrust the economic well-being of a society ahead of social and environmental well-being of humans as a species. The *Intergovernmental Panel on Climate Change*'s (IPCC) report on energy systems specifically outline the importance of decarbonisation in all economies. The report advises in favor of implementing economic policies in support of shifting away from fossil fuels, developing infrastructure that can support multiple base-load energy sources, supporting nascent advanced renewable technologies, and most importantly adopt a large-scale Carbon Capture and Storage (CCS) technologies to simultaneously remove excess carbon dioxide from the atmosphere while promoting utilization of alternate renewable energy sources. In Japan, "although the nuclear accident represented a serious blow to the country's energy transition to a reduced carbon environment, the country has not been deterred from this goal."[201] As the preeminent leader in technological development combined with an environmentally conscience electorate, Japan has been diligently working to achieve its commitments made at the Kyoto Protocol and reaffirmed and expanded at COP21 and COP23.

The Fukushima nuclear disaster simply accelerated the inevitable debate in Japanese politics of energy transition and greater domestic self-reliance within the energy trilemma of access and equity, affordability and environmental security. The enormous economic and political cost of radioactive material clean up eroded public trust in the government. As Looney writes in *Handbook of Transitions to Energy and Climate Security*, "The energy trilemma is not a universal constant that will be with us for the indefinite future."[202] World Energy Council's *2019 Energy Trilemma Index* highlights the Nordic countries' policies and achievement toward high degree of attainment within the trilemma while reforming the economic landscape. Energy economics and its associated market forces of supply and demand are key to swinging the impetus of energy use toward a carbon-neutral and clean technologies for consumer and industrial energy requirements. A generational change and an existential crisis is likely to push leaders and governments toward a clean energy future. Yergin writes that "the interaction of environmental concerns with energy will continue to shape the energy marketplace."[203]

Discussed in the fossil fuels Chapter of this analysis, the challenge to Japan's transition away from fossil fuels remain formidable. Woven in every aspect of industrial and citizen consumption, the infrastructure supports the status quo. Fossil fuel reliance enjoy the built in economic advantage such that they require no change in consumption preferences resulting in no added cost. The debate to adopt alternate sources for reducing atmospheric carbon is a moral one in a sustainable future. While Japan has diversified its traditional fuels portfolio to include Southeast Asian suppliers for oil and coal, the LNG

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[201] Robert E. Looney, *Handbook of Transitions to Energy and Climate Security* (London, UK: Routledge, 2016), page 11, https://doi.org/10.4324/9781315723617.

[202] Looney, 4.

[203] Daniel Yergin, *The quest: Energy, Security, and the Remaking of the Modern World* (New York: Penguin, 2012), 720.

import policy promises to reduce foreign import dependence. The newly formed energy partnership with the United States is likely to reduce supply shocks and lower political risks associated with foreign energy dependence. Additionally, reform of the power generation and transmission markets expected to be complete by 2020 is likely to create more efficiency in energy exchange markets. Tremendous pressure from powerful energy companies in Japan have made it more difficult for alternate energy source penetration in Japan's markets.

The two distinct goals towards 2030 and 2050 set by METI face two specific structural challenges. Equity and access to energy are not as important for Japan compared to stable cost and reduced environmental impact. For 2030 objectives, the decision making revolve around economic policies and liberalization of markets in which fair competition and advancement of co-equal status of various energy sources is critical in consideration with the social cost of carbon. Whereas for 2050 objectives, the larger question of how to shift consumer preferences away from fossil fuels by setting up the infrastructure that allows the market clearing for energy transition choices while stemming anthropogenic change becomes more important. Japan's sluggish economic growth is likely to rearrange the political agenda toward economic expansion and economic stability and away from energy security. Hence, Japan's 2030 energy security targets are likely to be missed; however, Japan's 2050 energy mix targets are very achievable in a quest to decarbonize major sectors of the economy.

In nuclear power, Japan's future is more complicated. Politically, the nuclear energy sector enjoys the support of the GOJ led by Prime Minister Shinzo Abe. The government has made significant efforts toward increased transparency in the aftermath of Fukushima. Economically, the transition away from nuclear power is more difficult and costly. The incredible cost paid to get the reactor technology servicing the Japanese economy has not been realized thus far in returns. Much of the nuclear fleet still await safety inspections and NRA approval to start producing power again, which can lower domestic power generation costs. A strong public sentiment against nuclear power has generally abated, with vast majority of Japanese citizens choosing domestic energy stability instead of total foreign reliance.

Economically, it is viable to operate every nuclear reactor plant until the end of its designed service life because the sunk cost cannot be reclaimed and variable cost of operation is substantially lower per kWh, compared to traditional sources. Nuclear power helps Japan raise its SSR while stemming supply shocks. Additionally, nuclear power is scalable in its use as the usage patterns shift with a demographic change, a strong advantage. Even though post-decommissioning safety costs exist for nuclear power, it remains a cornerstone of Japan's energy security for the foreseeable future. If a similar level of governmental support applied to nascent nuclear technologies in the past can be transferred to nascent renewable technologies of the future, the efficiency gains likely to realize from economies of scale are large. Given Japan's topography, reasonable safety risks exist for Japan's existing nuclear fleet; however, stringent requirements from the NRA prior to re-start approval is likely to help the public gain confidence in reintroducing nuclear power within Japan on a similar scale prior to March 2011.

In a transition away from nuclear power, Japan is well advised to recapture gains from thermal fission foregone over the past eight years due to a nationwide shutdown of reactors. In the medium term, nuclear power is an efficient solution to support Japan's energy prerequisites of net zero carbon emissions from operation as it undergoes transition. It is a significant strength of thermal fission. Letting innovation forces compete freely to erode the nuclear power advantage is economically suitable because the opportunity cost of delaying capital investment into renewable energy enterprise is extremely high. Current idling of reactor plants without safety approval from The NRA make it more challenging for Japan to meet its 2030 energy-mix goals; however, full decarbonisation toward 2050 is an attainable goal if nuclear power is used as a transitional energy bridge.

Lastly, advances in renewable technologies are making it challenging for countries, including Japan, to adhere to the status quo. Continually lowered cost, geographically specific integration options, net-zero and net-positive carbon technologies, and innovation driven economies of scale are likely to offset fossil fuel dominance going forward. A central challenge to renewable technology adoption in energy security is market saturation. It tends to stagnate costs and casts an unstable pathway for investors, institutions, and governments. Both supply side and demand side of the renewable marketplace must strive toward cost parity and LCOE to accelerate market penetration. Prohibitive policies such as power curtailment are likely to risk market failure in energy transition away from fossil fuels. FIT must be continuously adjusted to accommodate a change in total energy capacity provided by renewables in Japan.

Japan remains a technical leader in renewable energy, but faces stiff competition in the cost of photovoltaic manufacturing from the Chinese and German firms. It is eroding market share from the Japanese firms and thus reducing incentive to widen the supply available to consumers. The outlook for wind turbine is a little better but could escalate to similar levels. Japan's renewable energy adoption energy strategy should be driven by regional suitability. Photovoltaic is generally universally applicable and feasible. Onshore and offshore wind have specific issues that need to be resolved with better engineering and political solutions to be viable economically on a large scale. Power density of sources vary dramatically based on where they are adopted and on what scale. The abundance of geothermal power remains weakly exploited due to social opposition rising from the high favorability of traditional *onsen* baths. Above all, the generated capacity is limited by transmission infrastructure set up to support fossil fuels and nuclear energy. Japanese energy markets must allow un-curtailed feed of renewable power at a cost-basis acceptable to both the consumer and electric utilities to wipe out negative externalities and reach a new supply-demand equilibrium. The regulatory environment undergoing reform is easing some of the land-use restrictions, helping investors gain confidence in the Japanese market.

Overall, METI and ANRE have done a commendable job in reforming the energy marketplace to allow greater penetration of photovoltaic and wind (both onshore and offshore), though more reform is needed in favor of the consumer and not the utilities conglomerate. Renewable technologies offer the greatest versatility for adoption given Japan's topography. Forecasting long-term price targeting is critical for investors to shift capital from energy sources with known ROI to ones with more uncertainty but a higher promise. As communities and socially responsible corporations demand reliable, affordable, and responsible energy generation and use, Japan's intertemporal energy mix must change with it. Continued liberalization of generation and transmission markets, expected is likely to pave a pathway toward reducing market saturation in photovoltaic and wind enabled generation. Japan is likely to need a resilient and competitive renewable energy portfolio to sustain economic growth in order to remain in the top tier of industrialized nations. Exporting emerging technologies is an excellent way to support Japanese industry leading the technical innovation. Many opportunities exist for Japanese firms to capture a significant market share in hydrogen and marine energy technologies. Current reform policies are insufficient to gain a large-scale energy transition momentum by 2030. Japan's 2050 goals of decarbonisation of major sectors of the economy enjoy a higher level of certainty.

Japan's energy trilemma remained essentially unchanged from 2018 to 2019. Japan realized minor gains in import reduction, achieving a balanced energy intensity, per capita reduction in carbon emissions, and raising the effectiveness of the central government to make headway toward its stated goal. Technical innovation and development continues to be Japan's strongest characteristic and will affect the timeline of Japan's energy transition. Long timeline for reform and the perceived lack of urgency from an industry vested in capital returns weakens Japan's transition and overall energy security. Status quo undercuts consumer preference and the global tide toward decarbonisation. In the medium term, opportunity exists to quickly restart idle nuclear power plants to simultaneously reduce import dependence and carbon emissions, and in the long-term, exporting of innovative and affordable renewable technologies offer the greatest opportunity for the Japanese firms to achieve energy security and economic vibrancy simultaneously. One of the greatest threats to Japan's transition is the zero-sum energy market in Asia. The markets are sending a strong demand signal, amid political tension and instability from current suppliers, mainly in the Middle East. The fragile state of transition requires time to fully embrace the evolution, or else it will default to the cheapest and most easily available energy source. And that is coal and oil, and it will set Japan back a couple of decades in its quest to become energy secure or more yet, energy independent.

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