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Assessing US Microgrid Systems and Their Potential Application in Japan

Nobuhiro Mitsuoka

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LIST OF ABBREVIATIONS

AMS	Advanced Microgrid Solutions
AOW	Alpha Omega Winery
CAISO	California Independent System Operator
CCA	Community Choice Aggregation
CCCE	Central Coast Community Energy
CEC	California Energy Commission
CERTS	Consortium for Electric Reliability Technology Solutions
CGC	Center for Global Commons
COP	UN Climate Change Conference
CPUC	California Public Utilities Commission
C2ES	Center for Climate and Energy Solutions
DOE	Department of Energy
EaaS	Energy-as-a-Service
EPA	United States Environmental Protection Agency
FIP	Feed-in premium
IEUA	Inland Empire Utilities Agency
IPCC	Intergovernmental Panel on Climate Change
JMA	Japan Meteorological Agency
LCA	Life Cycle Assessment
METI	Ministry of Economy, Trade and Industry
MEXT	Ministry of Education, Culture, Sports, Science, and Technology

MG	Microgrid
NACo	National Association of Counties
NREL	The National Renewable Energy Laboratory
NTT	Nippon Telegraph and Telephone Corporation
SB	Senate Bill
SCE	Southern California Edison
SDGs	Sustainable Development Goals
UET	UniEnergy Technologies
UNEP	United Nations Environment Programme
WBCSD	World Business Council for Sustainable Development
WMO	World Meteorological Organization

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Introduction

Currently, countries worldwide are working to shift to a decarbonized society to avoid further global warming and exacerbating the climate crisis. One of the ways to achieve a decarbonized society is to build a decentralized energy system, and Japan's Sixth Basic Energy Plan, approved by the Cabinet in October of 2021, includes the construction of a decentralized energy system and policy proposals by 2030. Distributed energy systems are expected to more effectively utilize local renewable energy sources to strengthen resilience in times of disaster. One form of a distributed energy system is a "microgrid" (MG), which efficiently uses renewable energy during regular times and is independent of power transmission and distribution networks during emergencies, making the region in which it operates energy self-sufficient. The Japanese government is promoting the building of MGs, having started a group to study their efficacy in 2019. Nippon Telegraph and Telephone Corporation (NTT) has also taken on the challenge by establishing a distributed energy business company in 2019. However, there are still many issues that must be solved for MGs to proliferate in Japan. In the study group on distributed energy systems organized by the Japanese government in 2019, businesses and organizations raised numerous issues regarding the construction and promotion of MGs, which were then compiled by the group in April of 2021.

On the other hand, in the United States, the birthplace of MG, the practical application of MG is said to be on the rise. According to a report by Wood Mackenzie, 546 new MG were installed in the US in 2019. [1] Also, the US accounted for 38.5% of the total global MG capacity

[1] Wood Mackenzie, "US microgrid forecast H1 2020," 14 July 2020.

market in 2019, and the market size is expected to grow steadily.[2] Why has the practical application of MG in the US advanced to the point where they account for more than one-third of the world's MG capacity? This paper wants to explore the reasons for this growth in the US as well as measures to further expand the use of MGs in the future by analyzing the leading cases in the US, focusing on the efforts of stakeholders such as the government, power companies, MG operators, local governments, and civil communities. This research may lead to future solutions to issues related to the spread of MGs in Japan.

Global Warming and Japan's Current Decarbonization Efforts

Global Warming

In August of 2021, the United Nations Intergovernmental Panel on Climate Change (IPCC) released its first report on the current state of global warming in eight years.[3] For the first time, this report determined that human activities have caused a warming of the atmosphere, and it warned us to reduce greenhouse gas emissions. As global warming has progressed, it has been pointed out that the frequency and intensity of "extreme events" caused by climate change will increase in various parts of the world. Already, the devastating effects of heatwaves and heavy rains are increasing in many countries, causing droughts, forest fires, and floods. On June 29, 2021, the temperature in parts of Canada reached 49.6 degrees Celsius, the highest temperature ever recorded there, and on the following day, a massive wildfire broke out. According to a 2020

[2] Emergen Research, "Microgrid Market, By Power, By Product, By Application Forecasts to 2027," October 2020, https://www.emergenresearch.com/industry-report/microgrid-market.

[3] IPCC, "Climate Change 2021 The Physical Science Basis Summary for Policymakers," 7 August 2021, https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

climate change forecast report released by Japan's Ministry of Education, Culture, Sports, Science, and Technology (MEXT) and the Japan Meteorological Agency (JMA), if greenhouse gas emissions continue to increase at the current rate, by the end of the century, the number of extremely hot days in Japan will increase by 19.1 days on average nationwide, the frequency of "torrential downpours" of 50 millimeters or more per hour will increase by about 2.3 times, and coastal sea levels will rise by about 0.71 meters, potentially increasing the risk of flooding from storm surges and tidal waves.[4] Under the Paris Agreement, adopted in 2015, the goal is pursuing efforts to limit the increase in the global average temperature to 1.5 degrees Celsius compared to pre-industrial levels.[5] However, according to a report released by the United Nations Environment Programme (UNEP) in October of 2021, the temperature will reach 2.7 degrees Celsius by the end of this century if current actions continue.[6] In September of 2021, the World Meteorological Organization (WMO) reported a study showing that greenhouse gas emissions in 2020 were the highest ever, despite the COVID-19 pandemic.[7]

Japan's Decarbonization Policies

In October of 2020, the Japanese government set a goal of achieving "carbon neutrality," which means virtually zero domestic greenhouse gas emissions, by 2050. In April of 2021, it announced a goal of reducing greenhouse gas emissions in 2030 by 46% compared to fiscal year

[4] 文部科学省, 気象庁, "日本の気候変動 2020, 大気と陸・海洋に関する観測・予測評価報告書," December 2020, https://www.data.jma.go.jp/cpdinfo/ccj/2020/pdf/cc2020_honpen.pdf
[5] United Nations, "The Paris Agreement," https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[6] UN environment programme, "Emissions Gap Report 2021," 26 October 2021, https://www.unep.org/resources/emissions-gap-report-2021
[7] WMO, "United in Science 2021," 16 September 2021, https://public.wmo.int/en/media/press-release/climate-change-and-impacts-accelerate

2013. This reduction goal was clearly stated in the Cabinet-approved Sixth Basic Energy Plan in October of 2021.[8] The plan calls for the complete introduction of renewable energy as the primary power source, and it raises the share of renewable energy in the power supply mix for FY2030 from 22-24% in the previous plan to 36-38%. Thermal power was lowered from 56% to 41%, ammonia and hydrogen power were newly added at 1%, and nuclear power was left unchanged at 20-22%.

However, there are many issues to be addressed to achieve the goal. For example, to reach the target ratio of nuclear power, more nuclear power plants will need to be restarted than were restarted in the ten years since the Fukushima Daiichi nuclear accident. Restarting nuclear power plants requires passing the Nuclear Regulation Authority's examination and obtaining local consent. Securing suitable land for the introduction of solar power and onshore wind power is also an issue. With its small land area, Japan is already the world's largest producer of renewable energy per square meter of land.[9] There are limited places to install large solar panels, known as mega-solar systems, and some residents and local governments oppose the construction of further expansion due to deforestation.

Under such circumstances, distributed energy systems are expected to be one of the most effective means of encouraging the use of renewable energy in each community as a distributed power source. Examples include solar power that can easily be installed on the roofs of homes and public facilities, wind power generation led by local communities, small-scale hydropower

[8] 経済産業省, 資源エネルギー庁, “エネルギー基本計画," October 2021, https://www.meti.go.jp/press/2021/10/20211022005/20211022005-1.pdf.
[9] 経済産業省, 資源エネルギー庁, “今後の再生可能エネルギー政策について,” 1 March 2021, https://www.meti.go.jp/shingikai/enecho/denryoku_gas/saisei_kano/pdf/025_01_00.pdf.

using agricultural water, small-scale geothermal power generation using hot spring resources, and biomass power generation using local resources.

Distributed Energy System MG

What is MG?

MG, a distributed energy system, is based on the concept proposed by the Coalition for Electricity Reliability and Supply Systems (CERTS)[10], established in 1999 by the Lawrence Berkeley National Laboratory under the US Department of Energy. In an emergency, the MG is independent of the power transmission and distribution network and energy self-sufficient within the grid (Figure 1). MG can efficiently utilize renewable energy as a distributed power source. By generating power near where demand is greatest, transmission losses due to long-distance power transmission can be reduced. In addition, by combining renewable energy sources such as local solar and wind power generation with other power sources such as storage batteries and generators, energy production can be diversified to facilitate risk dispersion in the event of power supply problems. This is also expected to enhance the energy supply's resilience during disasters and other emergencies.

Current Status and Challenges of MGs in Japan

The policy to efficiently use distributed energy and strengthen the energy system's resilience through the establishment and promotion of MGs is outlined in the Fifth Basic Energy Plan in 2018 and the Sixth Basic Energy Plan approved by the Cabinet in October of 2021. To promote MGs in Japan in the future, a joint study group, the Distributed Energy Platform, was

[10] "About CERTS," https://certs.lbl.gov/about-certs.html

launched in November of 2019 by the Ministry of Economy, Trade, and Industry (METI) and the Ministry of the Environment. The study group was attended by more than 240 participants from 190 companies and organizations, and it held four meetings to discuss the challenges of building MGs and other issues to promote distributed energy systems across different sectors. The meetings resulted in a list of issues to be addressed in constructing MGs, as described in "A Guidebook for the Construction of Regional Microgrids," published by METI in April of 2021. The guidebook identified the following six issues for the construction and diffusion of MGs:

- Disclosure of project information (maintenance costs and plans) for power transmission and distribution networks. Regional microgrids that utilize existing power distribution lines can reduce initial costs. However, the business information on power distribution networks owned by general transmission and distribution companies is not disclosed, making it difficult for private companies considering entry into the market to formulate a business plan.
- Incentive design to promote the introduction of regional MGs. The most significant barrier to commercializing regional microgrids is the difficulty in achieving economic viability. At present, private companies have little incentive to enter the business because profitability is not foreseeable.
- Presentation of regional issues by local governments. Whether or not a regional microgrid project can be established depends on the unique circumstances of each region. However, it is difficult for private operators alone to investigate what type of microgrid would be appropriate to solve the issues in each region.
- Clarification of rules and flexible institutional design for regional microgrid projects. Existing systems and regulations need to be improved to be suitable for the smooth

implementation of regional microgrid projects. It is also necessary to create an environment that facilitates the entry of private operators by disclosing the current grid constraints.

- Long-term planning and establishing a joint business model by the local government and private sector. Regional microgrid projects require cooperation with the local community. To this end, it is essential to increase the value of local MG and demonstrate how they can benefit the community.
- Establish a public-private consortium to implement the project. Establishing a regional microgrid will require establishing a promotion system in collaboration with major private operators, local officials, and power transmission and distribution companies. Local government leadership is required in this process.

In September of 2021, NTT announced the following three tasks for realizing MGs:[11]

- Microgrid business monetization. The most significant barrier for MG is the lack of revenue projections. In order to establish revenue prospects, information on the cost of maintenance of transmission and distribution networks is necessary. It is an urgent issue to clarify the prospects for continuous revenue while keeping costs low and promoting the efforts of private operators.
- Cooperation with local governments and stakeholders. In building a regional microgrid, which is also closely related to community development, it is necessary to build consensus with local governments, private businesses, and other local stakeholders. For

[11] NTT, "Beyond Our Planet," 27 September 2021, https://www.rd.ntt/se/media/article/0013.html.

smooth consensus building, it is necessary to develop a business plan that benefits the community and enhances its value.

- More effective use of renewable energy. Renewable energy is a variable power source whose generation is affected by weather conditions. In order to respond immediately to ever-changing power generation and further increase their efficiency, technology is needed to accurately manage the supply and demand of electricity.

As described above, there are still many issues to be addressed in Japan's establishment and diffusion of MGs. In particular, the MG business has high barriers to entry for the private sector because of the difficulty in generating revenue. In addition, there is a need to strengthen cooperation with local governments and other local stakeholders. On the other hand, the United States, the birthplace of MGs, is said to be making progress in their commercialization. According to Wood Mackenzie’s report, 546 new MGs were built in the United States in 2019. In addition, the US accounted for 38.5% of the total global MG capacity in 2019, and the market size is expected to grow steadily. Why has the commercialization of MGs in the US advanced to the point where it now accounts for more than one-third of the world's MG capacity? In the next section, we will analyze the US as a case study to research the reasons for the growth of MGs in the US and the measures the US is taking to further expand their use in the future.

Role of MGs in the US and Japan

MGs in the US

Why are MGs being put to practical use in the United States? This paper analyzes the roles and benefits of MG disclosed in the US and Japan to find out why and confirm their value. The US Department of Energy (DOE) defines MGs as having a role in supporting the progress of the nation's energy system as follows:[12]

- Microgrids are localized grids that can disconnect from the traditional grid to operate autonomously. Because they are able to operate while the main grid is down, microgrids can strengthen grid resilience and help mitigate grid disturbances, as well as function as a grid resource for faster system response and recovery.
- Microgrids support a flexible and efficient electric grid by enabling the integration of growing deployments of distributed energy resources such as renewables like solar. In addition, the use of local sources of energy to serve local loads helps reduce energy losses in transmission and distribution, further increasing efficiency of the electric delivery system.

The US National Renewable Energy Laboratory (NREL) describes the benefits of MG as follows:[13]

- A microgrid is a group of interconnected loads and distributed energy resources that acts as a single controllable entity with respect to the grid. It can connect and disconnect from

[12] Department of Energy, "The Role of Microgrids in Helping to Advance the Nation's Energy System," https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid/role-microgrids-helping.
[13] The National Renewable Energy Laboratory, "Microgrids," https://www.nrel.gov/grid/microgrids.html.

the grid to operate in grid-connected or island mode. Microgrids can improve customer reliability and resilience to grid disturbances.

- Advanced microgrids enable local power generation assets – including traditional generators, renewables, and storage – to keep the local grid running even when the larger grid experiences interruptions or, for remote areas, where there is no connection to the larger grid. In addition, advanced microgrids allow local assets to work together to save costs, extend the duration of energy supplies, and produce revenue via market participation.

The Center for Climate and Energy Solutions (C2ES), an environmental policy think tank, summarizes the benefits of microgrids in the following four points:[14]

- Microgrids offer the opportunity to deploy more zero-emission electricity sources, thereby reducing greenhouse gas emissions. The microgrid manager (e.g., local energy management system) can balance generation from non-controllable renewable power sources, such as solar, with distributed, controllable generation, such as natural gas-fueled combustion turbines. They can also use energy storage and batteries in electric vehicles to balance production and usage within the microgrid.
- Microgrids can make use of on-site energy that would otherwise be lost through transmission lines and heat that would otherwise be lost up the smokestack. When power has to travel long distances (e.g., from a centralized power station), line losses occur, requiring additional generation to ensure that far away demand is met. Since microgrid

[14] The Center for Climate and Energy Solutions, "Benefits of microgrids," https://www.c2es.org/content/microgrids/.

electricity is generated next to where it will be used (also known as distributed generation), line losses are minimized, and less power is required to meet the same level of demand. Also, when electricity is generated from specific centralized power sources (e.g., fossil fuels and nuclear power), a great deal of heat energy is created and typically released – unused – into the atmosphere. When power is generated close to the end users, it becomes economically feasible to use this heat energy productively, such as heating water or space in nearby homes and businesses, reducing greenhouse gas emissions.

- Microgrids can improve local management of power supply and demand, which can help defer costly investments by utilities in new power generation. When placed strategically within the electricity system, microgrids help reduce or manage electricity demand and alleviate grid congestion, lowering electricity prices and reducing peak power requirements. In this manner, microgrids may support system reliability, improve system efficiency, and help delay or avoid investment in new electric capacity (e.g., "peaker" plants, substations, transmission lines, energy storage, or other infrastructure). When connected to the local distribution network or transmission system, microgrids can also transact from a single node to export excess electricity or import imbalances from the surrounding system.
- Microgrids can enhance grid resilience to more extreme weather or cyber-attacks. Microgrids can continuously power individual buildings, neighborhoods, or entire cities, even if the surrounding microgrid suffers an outage. This concept of a microgrid functioning independently from the surrounding system is known as islanding. Microgrids can also indirectly help aid in their recovery from a system outage by sustaining services needed by restoration crews or helping to re-energize the microgrid.

METI further describes the role and benefits of MGs as such: [15]

The main benefits of introducing a regional microgrid are "improving resilience by ensuring energy supply in times of disaster," "improving the efficiency of energy use," and "revitalizing local industries by utilizing local energy." Distributed energy is the optimal use of a combination of various supply capacities (renewable energy, cogeneration) based on the characteristics of the region, which will "enhance resilience" by diversifying energy supply risks and supplying energy during emergencies and introducing "energy saving effects" by locally producing and consuming energy in the region. Energy-saving effects can also be expected through local production for local consumption of local energy. In 2018, the Fifth Basic Energy Plan mentioned that the construction of a distributed energy system using renewable energy would create new industries in the region and lead to "regional revitalization" by promoting the introduction of such a system in conjunction with urban development. The government's policy is to promote distributed energy systems.

NTT has touted similar benefits provided by MGs, as described in the following three points:[16]

- Strengthening resilience in the emergency energy supply. During emergencies, power will be supplied by combining diverse renewable and other energy sources based on local characteristics. In addition to renewable energy sources such as local solar and wind power, multiple power sources such as storage batteries and generators will be combined.

[15] 経済産業省, 資源エネルギー庁, “地域マイクログリッド構築のてびき,” 16 April 2021, https://www.meti.go.jp/shingikai/energy_environment/energy_resource/pdf/015_s01_00.pdf.
[16] NTT, “Beyond Our Planet,” 27 September 2021, https://www.rd.ntt/se/media/article/0013.html.

Distributing power sources makes it easier to diversify risks, such as using other power sources to supply power if one source experiences a problem. This is expected to enhance the energy supply's resilience during a disaster or other emergency.

- Reduction of transmission losses through local production and local consumption of renewable energy. Solar power, wind power, generators, and other forms of locally generated electricity are consumed within the same region, leading to the realization of local production for local consumption. It is believed that generating electricity near the place of demand can reduce transmission losses due to long-distance power transmission. Effective use of heat is also possible when using cogeneration systems that can produce both electricity and heat. Such efficient use of energy is expected not only to reduce transmission losses but also to reduce environmental impact.
- Regional revitalization integrated with urban development. Introducing a regional microgrid means building a system different from the conventional general power transmission and distribution system. Therefore, implementing a regional microgrid may bring about new industrial development. The integration of the construction of regional microgrids and community development is expected to lead to the region's revitalization.

Similarities and Differences between Japanese and US MGs

In confirming the information on the value, roles, and benefits of MG provisions disclosed in the US and Japan, it was found that the two countries have two points in common: "strengthening resilience" and "efficient use of renewable energy" in energy supply in the event of disasters and other emergencies. On the other hand, the two main differences between the US and Japan are as follows:

・In the case of the US, the "revenue and cost benefits" of implementing MGs are described.

・In the case of Japan, the "revitalization of local industry" is indicated as one of the possibilities expected from MGs.

Regarding resilience enhancement, every year, there are large-scale power outages due to hurricanes and wildfires. In Japan, Typhoon No. 15 in 2019 caused a prolonged power outage, and many people died from heat stroke due to a lack of air conditioning. Isumi City in Chiba Prefecture, where 70% of households experienced such prolonged power outages, is implementing a resilience-strengthening project by introducing MG. The US has direct experience with several MG that worked when Superstorm Sandy hit the northeastern US in 2012. It is said that this experience made state policymakers realize the importance of MG and led to the promotion of MG policies in the US.[17] However, power outages in the US are more severe than in Japan; comparative data from 2015 shows that the number of power outages in California is about seven times greater than in Japan as a whole, and the duration of power outages is about six times longer.[18] As of 2020, Texas, California, and New York are the top three states in terms of the number of outages per state.[19] Also in 2020, the top three states in terms of the capacity of installed MGs were Texas, New York, and California.[20] Although it is impossible to say for sure whether there is a clear correlation between the capacity of installed MGs and the number of power outages, the installation of MGs will likely increase to strengthen

[17] Feng, Wei, *A review of microgrid development in the United States–A decade of progress on policies, demonstrations, controls, and software tools*, Applied Energy, 15 October 2018, https://www-sciencedirect-com.ezp-prod1.hul.harvard.edu/science/article/pii/S0306261918309644.
[18] TEPCO Power Grid, "Top International Level of Quality," https://www.tepco.co.jp/en/pg/supply/quality/index-e.html.
[19] Chad Emery, "U.S. Power Outages in 2020: A State-by-State Analysis and Solutions for Homeowners," 10 March 2021, https://www.fixr.com/blog/2021/03/10/u-s-power-outages-2020-map-and-solutions-for-homeowners/.
[20] Statista, "U.S. penetration of microgrids by select state 2020," 21 January 2022, https://www.statista.com/statistics/1100458/-capacity-of-us-microgrids-by-state/.

resilience in the current environment of climate change, where natural disasters are becoming more severe. Regarding the more efficient use of renewable energy, both Japan and the US are accelerating their efforts to achieve carbon neutrality by 2050.

Monetization of MG projects is described as the main issue preventing their introduction in Japan. The question that this study poses, "Why is MG adoption in the US progressing?" will be investigated in terms of the revenues and costs perceived as beneficial in adopting MGs in the US. If we can identify MG cases in the US that have clear financial benefits, it may provide hints for the future diffusion of MGs in Japan. This study decided to proceed with a case study survey of MG projects that have been operated in the US over the medium to long term and that continue to be successful.

Research on MG Projects in the US

Research Projects

In proceeding with the case study of MG projects in the US, we first selected potential projects from states with the largest capacity of installed MGs, the top three of which, as of 2020, are Texas, New York, and California. Next, because Japanese MGs promote renewable energy as a distributed power source, we gave priority to New York and California, which are doing more to introduce and promote renewable energy and decarbonization efforts than Texas.[21] Finally, we compared New York and California's renewable energy adoption rates and per capita solar power

[21] Database of State Incentives for Renewables & Efficiency, "Renewable & Clean Energy Standards," https://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2020/09/RPS-CES-Sept2020.pdf.

generation capacity.[22] As both rates were higher in California, this research decided to prioritize California MG cases.

California passed Senate Bill (SB) 1339 to further develop MGs-related policies in 2018.[23] The bill directs the California Public Utilities Commission (Commission), the California Independent System Operator (CAISO), and the California Energy Commission (CEC) to jointly develop an MG policy framework. In SB 1399, the Commission states that it will take all of the following actions to "facilitate the commercialization of microgrids to the distribution customers of large electric utilities":

- Develop microgrid service standards necessary to meet state and local permitting requirements.
- Without shifting costs between ratepayers, develop methods to reduce barriers for microgrid deployment.
- Develop guidelines that determine what impact studies are required for microgrids to connect to the electrical corporation grid.
- Without shifting costs between ratepayers, develop separate large electrical corporation rates and tariffs, as necessary, to support microgrids, while ensuring that system, public, and worker safety are given the highest priority. The separate rates and tariffs shall not compensate a customer for the use of diesel backup or natural gas generation, except as either of those sources is used pursuant to Section 41514.1 of the Health and Safety Code, or except for natural gas generation that is a distributed energy resource.

[22] CleantTechnica, "Top Solar States per Capita," https://cleantechnica.com/2020/10/04/top-solar-power-states-per-capita-cleantechnica-report/.
[23] CALIFORNIA Public Utilities Commission, "Resiliency and Microgrids," https://www.cpuc.ca.gov/resiliencyandmicrogrids/.

・Form a working group to codify standards and protocols needed to meet California electrical corporation and Independent System Operator microgrid requirements.

・Develop a standard for direct current metering in Electric Rule 21 to streamline the interconnection process and lower interconnection costs for direct current microgrid applications.

Additionally, on September 19, 2019, the Commission issued a Regulatory Enactment (R. 19-09-009) under Senate Bill 1339 that will evaluate whether and how MGs will reduce greenhouse gas emissions, protect California taxpayers, and advance California's progressive environmental goals. As of this point, the California Late-Stage Business Commission is still working to strengthen microgrid rulemaking.[24]

Research Items

In this study, the following three research items will be used to examine solutions to the issues faced by the Japanese government and NTT's MG:

・Business model (financing, revenue streams)

・Value proposition (for communities)

・Technical features (renewable energy utilization)

Furthermore, in addition to these three items, “Criteria (environmental assessment)” will be added to the research items. This is because a significant objective of this research on MG dissemination is to accelerate the construction of a sustainable, decarbonized society. MG

[24] California Public Utilities Commission, “Microgrids Proceeding R.19-09-009 Track 5 Value of Resiliency,” https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/resiliency-and-microgrids/resiliency-and-microgrids-events-and-materials/rencat050722track5slidedeckfinal.pdf.

systems are made up of equipment such as solar and wind power, storage batteries, and MG control servers. As such, the construction of MGs produces carbon emissions and consumes energy as well as the earth's natural resources. It may therefore be necessary to identify the total environmental impact generated by the construction of MGs. Unless we do so, we will not know if MGs as a system can genuinely contribute to the creation of a sustainable, decarbonized society.

Life Cycle Assessment (LCA) is a method to evaluate and visualize such environmental impacts. An example of LCA is research on electrical vehicles (EVs).[25] EVs are said to be more environmentally friendly than gasoline-powered vehicles. However, according to this study, when carbon dioxide emissions of EVs and vehicles with internal combustion engines were compared over their entire life cycle using LCA methods, the carbon dioxide emissions of EVs with smaller battery sizes and vehicles with internal combustion engines were almost identical. Other studies have also shown that the environmental impact of EVs finally turns more negative than that of internal combustion engine vehicles after 70,000 km. Depending on conditions, some results indicate that the environmental impact of EVs does not turn negative. Moreover, since lithium in storage batteries requires a large amount of water for mining, the environmental impact of mining sites must also be evaluated. It is also necessary to consider where the electricity used for electric vehicles comes from, the resources used to build EV stations, and the source of electricity supplied by the stations.

The same issues exist for biomass energy and mega-solar power in Japan. Biomass energy has been actively introduced in Japan as a renewable energy source, but most wood pellets and palm oil used as fuel are imported from overseas. According to a report by an American

[25] Ryuji, Kawamoto, et al. *Estimation of CO2 Emissions of Internal Combustion Engine Vehicle and Battery Electric Vehicle Using LCA*. Sustainability 2019, 11(9), 2690; https://doi.org/10.3390/su11092690.

environmental NGO, exporting wood pellets for biomass power generation in Japan is causing large-scale deforestation and ecosystem destruction in the southeastern US.[26] In addition, palm oil used in Japan is 100% imported, primarily from Indonesia and Malaysia, with high carbon dioxide emissions associated with its transportation. In Japan, biomass energy is considered a renewable energy source that can lead to decarbonization, but in terms of overall LCA, it has a high environmental impact.

As mentioned in the previous section, mega solar in Japan faces similar challenges. Solar power generation is being actively promoted to achieve carbon neutrality. On the other hand, with its small land area, Japan already has the world's highest solar capacity per land area and solar capacity per flat land area.[27] Under these circumstances, there have been cases of mountains being cut down and forests being cleared to install mega-solar power plants. This is damaging the environment and ecosystems, affecting the livelihoods of local people, and has resulted in lawsuits by residents.

Furthermore, solar panels are said to have a lifespan of 15 to 20 years, so we must also consider the problem of their disposal that will occur worldwide in the near future. After all, solar panels contain toxic substances such as lead, selenium, and cadmium, depending on the panel type, and each has its appropriate disposal method. The disposal and replacement of solar panels has already begun, and, in many cases, the toxic substances are disposed of directly in landfills. This is because recycling used solar panels is still optional in Japan and the US.

[26] Mighty Earth, "SUMITOMO CORPORATION'S DIRTY ENERGY TRADE," http://www.mightyearth.org/wp-content/uploads/MIghty-Sumitomo-Report-English-Screen.pdf.
[27] 経済産業省, 資源エネルギー庁, "2030 年に向けたエネルギー政策の在り方," 13 April 2021, https://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/2021/040/040_005.pdf.

The above is an overview of the importance of LCA and the environmental impacts of EVs, biomass energy, solar panels, and mega solar. These evaluations depend on the criteria and input variables, but this paper does not intend to evaluate their merits or demerits. Rather, MG projects that promote renewable energy sources such as storage batteries, solar panels, and biomass need to be evaluated under appropriate criteria to determine whether they are genuinely systems that can lead to a sustainable, decarbonized society.

Previous Studies

Prior studies have been conducted of MG projects in California. One such study is the Microgrid Analysis and Case Studies Report published in 2018 by the California Energy Commission (CEC).[28] This study was conducted to promote MG projects in California, and it provided a holistic look at the technology, business model, size, and vendor landscape that support commercially viable MGs. It included a total of 26 MG case studies in California, North America, and other countries.

The present study will update the data on MG businesses that were the subject of the CEC's prior study in 2018. From those updated projects, we will continue to identify MG projects that are still successful and developing in the medium to long term as of 2022, and those MG projects will be the subject of this study. Furthermore, since METI and NTT expect from MGs the "revitalization of local industries," in addition to the 26 case studies in the California Public Utilities Commission's report, MG projects of the "Community Choice Aggregators,"[29] which are 25 organizations in California, were also surveyed and interviewed.

[28] California Energy Commission, "Microgrid Analysis and Case Studies Report," August 2018, https://www.energy.ca.gov/sites/default/files/2021-06/CEC-500-2018-022.pdf.
[29] California Community Choice Association's, "CALCCA Members," https://cal-cca.org/about/members/.

Case Studies

Of the 26 cases in the previous 2018 study, this study reexamined and updated the data, focusing on those cases that are commercially viable without government subsidies or operational support in building and operating MGs. Among them, the following is a summary of their characteristics, focusing on case studies in California, which are still ongoing in the medium to long term in 2022.

1. San Diego Zoo[30]

The San Diego Zoo, located in San Diego County, California, installed an MG in 2012 linked to solar panels and EVs. The total cost was approximately $1 million and was funded by San Diego Gas & Electric, which owns and manages the MG. The zoo received a license fee for the MG installation. It is estimated that 189,216 pounds of carbon dioxide emissions will be reduced through this project, which is equivalent to planting 2,788 trees that will grow for ten years.

In addition, the San Diego Zoo installed an additional 1 MW/4 MWh of battery storage in 2018 to absorb spikes in electricity use, using storage batteries provided by EDF Renewable North America. The installation of an MG saves the zoo money on utility costs, which means that the zoo only pays a usage fee. The zoo does not pay for the installation, meaning that all financial risks associated with the installation belong to EDF Renewable. (Table 1)

2. Inland Empire Utilities Agency (IEUA)[31]

IEUA is a sewer utility and water wholesaler in San Bernardino County that launched several distributed generation projects between 2008 and 2010, including wind and solar. The

[30] https://sandiegozoowildlifealliance.org/
[31] https://www.ieua.org/renewable-energy/.

MG project began in 2016. The goal was to connect and optimize distributed power sources that had previously operated independently. IEUA uses primarily on-site power generation, with grid power from Southern California Edison (SCE) as a supplement. Storage batteries also provide power when renewable energy is unavailable due to weather and other factors. IEUA has no invested capital in the MG project, which is installed, operated, and maintained by the developer Advanced Microgrid Solutions (AMS) under a 10-year energy management services agreement that sees it pay monthly fixed and variable costs with expected annual savings of $230,000. In September of 2019, IEUA was working to expand its existing solar and battery storage system to reduce energy costs further.[32] (Table 2)

3. Mission Produce[33]

MP is one of the world's leading avocado distributors, with facilities in five countries. Since operations are often shut down due to power outages, one of the main objectives of the MG was to improve the power supply's resiliency. Another primary objective is to save on electricity costs and develop sustainability management initiatives. The MG project was developed under a service agreement between MP and the Developer, Powerit Solutions, UniEnergy Technologies (UET). UET owns the battery storage system and receives a quarterly service fee from MP. In operating the MG, MP was able to save more than $2 million in electricity costs from 2008 to 2018. According to MP's 2020 ESG report, it is also moving forward with plans to add solar

[32] IEUA, "Inland Empire Utilities Agency and Inland Empire Regional Composting Authority Launch Award-Winning Battery and Solar Project," 24 September 2019, https://www.ieua.org/wp-content/uploads/2019/09/Press-Release-IEUA-and-IERCA_Award-Winning-Battery-and-Solar-Project-Dedication.pdf.

[33] https://missionproduce.com/sustainability.

panels at new farms in California and Peru to become self-sufficient in the electricity used on its farms.[34] (Table 3)

4. Alpha Omega Winery (AOW) [35]

AOW is a family-owned winery established in 2006. AOW was one of only three wineries in California with MGs as of 2022, and it has a seven-year lease with Blue Sky Utility, the developer of the MG. At the end of the lease, ownership of the MG will transfer to AOW. The project's environmental impact has been quantified as a reduction of 960,750 pounds of carbon dioxide per year (equivalent to planting 2,402 trees). According to a July 2022 Napa Green report, MGs installed at AOW in 2016 would generate almost 100% of the electricity they use (about 1 million kilowatts per year) and reportedly reduced energy bills from $15,000 per month to $1,000 per month.[36] (Table 4)

5. Montgomery County Public Safety & Correctional Facility[37]

Montgomery County installed an MG in 2018 to increase utility resiliency during disasters (the county has a history of significant and prolonged power outages due to severe storms), reduce environmental impacts, and lower costs to taxpayers. The government's goal was to reduce greenhouse gas emissions by 80% by 2027. As such, a public-private partnership was formed to build the MG at no upfront cost to Montgomery County through a new microgrid business model called Energy-as-a-Service (EaaS).[38] EaaS, provided by Schneider Electric,

[34] Mission Produce, "Environmental, Social & Governance Report 2020," 14 June 2022, https://issuu.com/missionavocados/docs/mis-esg-report-final
[35] https://www.aowinery.com/.
[36] Napa Green, "Meet the Napa Winery Using Solar Power to go "Off-Grid," https://napagreen.org/meet-the-napa-winery-using-solar-power-to-go-off-grid/.
[37] https://www.montgomerycountymd.gov/dgs-oes/Microgrids.html.
[38]Schneider Electric, "What is energy as a service," https://www.se.com/us/en/work/services/energy-as-a-service/.

allows private companies to provide public infrastructure, allowing the private sector to fund the infrastructure. (Figure 2) The MG project received the 2018 National Association of Counties (NACo) Achievement Award and has been touted as a model for improving local government resilience. The MG estimates that it will reduce greenhouse gas emissions by the same amount as planting 178,000 trees. (Table 5)

In addition, Montgomery County has started an MG project with Alpha Structure[39] that aims to power 70 electric buses by 2022. This project also does not involve any upfront capital investment by the county due to the EaaS contract. It is a long-term contract that guarantees predictable operating costs and performance. Over the next 25 years, the project is expected to reduce greenhouse gas emissions by more than 160,000 tons.[40]

Next, this study examined projects under California's Community Choice Aggregation (CCA) program, which allows entities authorized by local governments, called Community Choice Aggregator, to procure and generate electricity for residents and businesses in their jurisdictions. The CCA program is said to be a beneficial option for communities that want to have more local control over their power sources, choose greener power than the default power company provides, and lower their electricity rates, and it is currently authorized in California, Illinois, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Ohio, Rhode Island, and Virginia.[41]

[39] https://alphastruxure.com/.
[40] Maryland the daily record, "Montgomery County launches smart energy bus depot microgrid," https://thedailyrecord.com/2022/11/01/montgomery-county-launches-smart-energy-bus-depot-microgrid/.
[41] EPA, "Community Choice Aggregation," https://www.epa.gov/green-power-markets/community-choice-aggregation.

Since one of the issues facing the MG business in Japan is the "revitalization of local industries," a survey was conducted of 25 Community Choice Aggregators case studies [42] in California, revealing that four Community Choice Aggregators are specifically engaged in MG-related business (Table 6). This research conducted field interviews with Central Coast Community Energy (CCCE), the Community Choice Aggregator with the highest number of customers and participation rate, in January of 2022. CCCE serves customers in Monterey, San Benito, Santa Crux, and San Luis Obispo. It is controlled and managed by board members representing each community it serves. Because there are no investors or shareholders, the revenue generated by CCCE stays local and is reinvested in the community. Reinvestment takes the form of fair electricity rates, job creation, local economic and business support, and providing access to resources, rebates, and incentives.[43] Specifically, a portion of operating revenues is reinvested in the community each year, as shown in Energy Programs in Table 7.

Assessing US Microgrid Systems and Their Potential Application in Japan

Assessing US MGs

MGs, which have been commercially successful over the medium to long term without the support of government subsidies or operational funds, were investigated with a focus on cases in California. In addition, research and on-site interviews were conducted on Community Choice Aggregators' business, which contributes to the community by reinvesting a portion of its business profits into the community. We found several commonalities among MG cases that

[42] CALCCA, "CCAs: Mapping out a clean energy future," https://cal-cca.org/wp-content/uploads/2022/11/CalCCA-Clean-Energy-PPA-Map-11.10.2022-web.pdf.
[43] CCCE, "Annual Member Agency Update," 22 February 2022, https://ci.guadalupe.ca.us/wp-content/uploads/2022/02/5-CCCE-Annual-JPA-Update.pdf.

have been commercially successful over the medium to long term. The first is that developers and vendors, not users, own MGs. Users do not bear the initial cost but only pay a monthly fee. In some cases, users were found to receive license fees for MG installation from the operators. The monthly fee paid by the user is a business model known as lease and subscription, or EaaS (Energy as a Service). EaaS allows customers to use MGs as a service for a monthly fee. Regarding monthly fees, customers can also choose to pay based on the performance of the MG. This business model allows users to customize, build, and utilize MG connected to existing distributed renewable energy sources without the risk of initial costs. This EaaS-like business model for MG is also seen in the residential solar panel business. The solar EaaS model, called Solar as a Service, provides residents with electricity savings and environmental benefits without requiring them to purchase and maintain a solar power system. The solar provider retains ownership of the system and charges customers for the service. Service usage fees typically contribute to cost savings for users compared to retail electricity rates. Because providing efficient electricity generation is profitable, solar providers are incentivized to design and install systems best suited to the installation and usage environment. Customers and providers therefore have the same incentive.

The second common feature is the installation of storage batteries in the MG. By utilizing storage batteries, users save on their electricity bills and pay monthly fees to the service providers with the saved electricity bills. In other words, a win-win relationship has been established between users and service providers. Why is it that this MG business model in the US, which utilizes storage batteries, has not been widely adopted in Japan today? The following section discusses the possibility of its future application in Japan.

Through this survey and on-site interviews, a business model was also confirmed in which CCAs reinvest a portion of their business profits back into the community, thereby revitalizing local industries. Currently, there is no CCA system in Japan. However, elements of the CCA system and the regional profit-sharing business model of CCAs in California may provide hints for solutions to the problem of regional industry revitalization faced by MG operators in Japan. The following chapter will discuss this issue.

Regarding criteria, several projects were found to assess the reduction in carbon dioxide emissions from installed MGs. However, all projects only evaluated carbon dioxide emissions, and none of the projects mentioned life cycle assessment (multi-criteria). Criteria are also discussed in the next chapter (Table 8).

Potential Applications to Japan

This section discusses the following three points regarding the potential application of US MGs to Japan to promote Japan's MG business.

- Why is the MG storage battery business model, successfully monetized in the US, not catching on in Japan? Is it possible to apply this model to Japan?
- In Japan, where there is no CCA system, is it possible to realize a business that returns profits to the community, as the Community Choice Aggregator in California does?
- What are the ideal criteria for MG projects in Japan?

First, the MG storage battery business in the US will be discussed. The storage battery business mechanism that makes the MG business in the US monetizable is storing electricity during periods when electricity prices are low and utilizing that stored electricity during periods when electricity prices are high, as shown in Figure 3. By introducing this mechanism into MGs, the optimal use of renewable energy in the grid is realized. Since renewable energy output

fluctuates greatly depending on weather conditions and other factors, using storage batteries enables the construction of MGs with a more optimal balance between supply and demand. The cost of storage batteries has been declining every year, and the DOE has also published a report on the future growth of the storage battery business.[44]

Why is the MG storage battery business not popular in Japan? The reason can be inferred from the structure of this storage battery business. In other words, Japan has a low ratio of renewable energy and a high proportion of stable thermal power generation, which means that the fluctuation range of electricity is small, making it difficult to enjoy the benefits of the storage battery business. Of course, the low ratio of renewable energy is one of many reasons. Several factors are involved, including differences in electricity regulations and electricity markets between the US and Japan and renewable energy and regulations. At any rate, there is a strong possibility that the cost of storage batteries has yet to match the revenue from electricity fluctuations in Japan so far.

On the other hand, the storage battery business will likely grow as the ratio of renewable energy in Japan increases. In January of 2022, Nikkei Shimbun published an article on the expansion of renewable energy as a commercial opportunity for the storage battery business.[45] As the ratio of renewable energy is expected to increase toward the achievement of the Sixth Energy Plan, a mechanism to stabilize the fluctuating supply and demand of renewable energy is indispensable. The article suggests that commercial opportunities in the storage battery business will expand. Furthermore, Japan will launch the Feed-in premium (FIP) system in April of 2022.[46]

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[44] DOE, "Energy Storage Grand Challenge: Energy Storage Market Report," December 2020, https://www.energy.gov/sites/prod/files/2020/12/f81/Energy%20Storage%20Market%20Report%202020_0.pdf.

[45] 日本経済新聞, "蓄電池ビジネスとは再エネ拡大を商機に," 27 January 2022, https://www.nikkei.com/article/DGXZQOUA268RC0W2A120C2000000/.

[46] 経済産業省, 資源エネルギー庁, "FIP 制度について," 24 June 2022, https://www.meti.go.jp/shingikai/energy_environment/setsuden_dr/pdf/001_02_08.pdf.

Under this system, a certain amount of subsidies will be paid on top of the price at which electricity is sold. The advantage of this system is that renewable energy power producers will be aware of market prices, which fluctuate according to the supply and demand of electricity. They will be able to increase their earnings by selling electricity when market prices are high. This could lead to securing revenue for the storage battery business. The storage battery business model for MG projects in the US confirmed in this study, may serve as a reference for Japan in the future.

Next, this report discusses the feasibility of a business model that returns benefits to the community, as implemented by the Community Choice Aggregator in California, in Japan, where there is no CCA system. The best solution would be to introduce a CCA system in Japan, but there have yet to be any plans to do this from the Japanese government. Therefore, we would like to consider what mechanism would be needed to establish an MG business that can return benefits to the local community, such as a CCA system. Regarding the CCA system, the City of New York has systematically compiled information on its official website.[47] Below is an overview of the purpose of CCA and the system:

- The purpose of Community Choice Aggregation (CCA) is to allow participating local governments to procure energy supply service and distributed energy resources (DER) for eligible energy customers in the community. These customers will have the opportunity to opt out of the procurement, while maintaining transmission and distribution service from the existing Distribution Utility.
- CCA allows local governments to work together through a shared purchasing model to put out for bid the total amount of electricity and/or natural gas being purchased by eligible

[47] New York State, "Community Choice Aggregation," https://www.nyserda.ny.gov/All-Programs/Clean-Energy-Communities/How-It-Works/Toolkits/Community-Choice-Aggregation.

customers within the jurisdictional boundaries of participating municipalities. Eligible customers will have the opportunity to have more control to lower their overall energy costs, to spur clean energy innovation and investment, to improve customer choice and value, and to protect the environment, thereby fulfilling an important public purpose.

Based on this information from New York and California, the characteristics of the CCA can be summarized as follows:

- Selects energy sources on behalf of customers within its jurisdiction.
- Maintains and uses the services of existing distribution providers as well.
- Includes an opt-out method.
- Reduces customer energy costs.
- Promotes clean energy.
- Increases value and benefits to customers and local communities.
- Achieves public objectives and urban development.

With the exception of the opt-out method, these functions are considered feasible within the current Japanese system. Japan's electric power system consists of the "generation" of electricity, the "transmission and distribution" of electricity to consumers, and the "retail" of electricity for sale to consumers. Currently, the power generation and retail sectors are fully liberalized. In 2020, the "separation of power generation" was implemented, which, in principle, prohibits power generation companies from operating power transmission and distribution companies and retail businesses. In 2022, a new system was introduced to allow new entrants into the power distribution business. Under this system, new entrants are given licenses to operate "power distribution networks" that transmit electricity from substations to businesses and homes. In

other words, it will be possible to construct MGs on a regional community basis. In the future, this system may lead to technological advances in power distribution network management and encourage new power companies in the region to accelerate their efforts to produce and consume local energy. Taking a cue from California's CCA model of local profit sharing, we believe that revitalizing local industries based on MG projects could also progress nationwide in Japan.

Finally, the following discusses the ideal criteria for MG projects. Considering the criteria, it is essential to delve deeper into what "sustainable" means. The SDGs, adopted by the United Nations in 2015, is a set of 17 sustainable development goals to be achieved by 2030 to protect the future of the Earth and its people. They are one of the international lingua franca for the meaning of "sustainable" in our time. The SDG Indicators adopted by the UN General Assembly are used as indicators to measure the SDGs' achievement level. Each year, each country's achievement level is announced, as assessed by these SDG Indicators. In previous years, the five Nordic countries and the rich countries of Europe have topped the rankings. So, are the initiatives of these top-ranking countries "sustainable" models? Anthropologist Jason Hickel wrote an article entitled "The World's Sustainable Development Goals Are Not Sustainable" in 2020.[48] Hickel argues that if everyone on the planet consumed as much as Sweden, the top SDG-ranking country, the ecological and global environmental impact would triple the current level. He also says that the countries at the top of the rankings are far exceeding what is acceptable for each country relative to its population, not only in terms of resource consumption and greenhouse gas emissions but also in terms of land use and the amount of nitrogen and other chemicals released into the environment. The reason for this is that in the evaluation items of the SDG Indicators, the weight of development-related areas is high, exceeding the number of items

[48] Jason, Hickel. *The World's Sustainable Development Goals Aren't Sustainable*. Foreign Policy, 30 September 2020, https://foreignpolicy.com/2020/09/30/the-worlds-sustainable-development-goals-arent-sustainable/.

related to the environmental burden area. Furthermore, the evaluation calculations do not include environmental impacts generated by other countries for domestic consumption. In other words, the SDG indicators currently used around the world do not tell us the global environmental burden.

As the “Planetary boundaries” (Figure 4), the concept upon which SDGs are based, indicates, the systems beyond the Earth's limits or safety zone as of 2022 are climate change, biosphere unity, biogeochemical cycles, land use change, and new chemicals. All of these systems connect on Earth. For example, they directly impact climate change with respect to phosphorus and nitrogen. In other words, under the name of "achieving the 2030 Sustainable Development Goals" and "achieving a carbon neutral society by 2050," development that only evaluates greenhouse gas emissions or only evaluates projects or domestic environmental impacts and places the burden of environmental impacts on external parties cannot be called "sustainable" when evaluated on a global scale.

Only some businesses still evaluate and disclose information on multiple environmental impact indicators (LCA multi-criteria), such as resource consumption and carbon footprint. In the future, "sustainability" will require the pursuit of not only carbon footprints but also multi-criteria that enable visualization and internalization of the environmental impact of a business. Furthermore, with planetary boundaries reaching their limits, a comprehensive mechanism to quantitatively assess the environmental impact of the entire planet is needed. It is imperative to establish a systematic indicator as an international standard, such as the Global Commons Stewardship Framework,[49] under development by the Center for Global Commons (CGC) at the

[49] Center For Global Commons, “The Global Commons Stewardship Framework: Safeguarding the Global Commons for human prosperity and environmental sustainability,” May 2022, https://cgc.ifi.u-tokyo.ac.jp/wp-content/uploads/2022/05/Safeguarding-the-Global-Commons.pdf

University of Tokyo, which includes an index and monitoring system to measure environmental impacts on a global scale.

Conclusion

The common role of MGs in the US and Japan is to strengthen the resilience of energy supplies during emergencies and disasters and to utilize renewable energy efficiently. Particularly in the US, where many states suffer from frequent power outages, MGs are being introduced as countermeasures. For example, California has passed a bill to promote MGs, and the public and private sectors are working together in this regard.

In analyzing case studies in the US, where the installation of MGs is further along than in Japan, we identified two solutions to the MG promotion issues that Japan faces. The first is the commercialization of the MG business by introducing renewable energy and storage batteries to MGs and monetizing them by linking them to the electricity market. The second is a business model of returning profits to the community implemented by Community Choice Aggregators.

These two solutions have great potential if applied to Japan. Regarding the former, it is predicted that introducing renewable energy sources will lead to greater volatility in electricity prices in the energy market in Japan. Also, the cost of storage batteries may decrease. If these conditions are met, MG projects using storage batteries can be commercially viable in Japan. Furthermore, the FIP system that started in Japan in April 2022 will encourage these MG projects.

Regarding the latter, while it would be desirable to introduce a CCA system in Japan, it may be possible to build an MG business model that returns benefits to the community by utilizing Japan's current system and technology. Specifically, Japan will launch a system in 2022 allowing

new entrants into the power distribution business. By utilizing this system and the management technology of storage battery systems linked to the electricity market, it will be possible to construct an optimal MG system for local communities.

Since the deregulation of electricity retailing in Japan began in 2016, the number of local electric power companies has increased. However, most are structured in a competitive relationship with major electric power companies. Japan should learn from cases in the US to establish a business model in which major electric power companies, local governments, and regional electric power companies are integrated, as in the case of CCAs. By establishing this business structure and promoting technological improvements to optimize the supply of electricity within MGs in a particular region, a more competitive business model can be established to return profits to local communities.

However, this study did not provide a clear answer as to whether promoting MG projects would reduce the severity of climate change. Although MG projects that introduced renewable energy and quantitatively demonstrated their carbon reductions were identified, since no LCA assessment was conducted, it was impossible to quantitatively confirm the environmental impact of the MG project as a whole.

As of 2022, there are no standards for disposing of solar panels in Japan or the US, highlighting issues related to LCA for renewable energy. Currently, decarbonization projects are underway around the world to achieve a carbon-neutral society. In order to ensure that those projects are directing us towards a truly sustainable society, there is a need to strengthen efforts to evaluate them using multi-criteria LCA.

In addition, as the “Planetary boundaries” are approaching their limits, an index and monitoring system to measure environmental impacts on a global scale is needed. Currently, in

Japan, the CGC at the University of Tokyo is leading an effort to develop an internationally standardized mechanism that measures the degree and changes of each country's environmental impact. In addition to formulating such criteria for evaluating environmental impacts at the national level, it will also be necessary to establish evaluation criteria at the city level in the future.

There are two reasons why city-level evaluation criteria are needed. The first reason is that, today, the boundary between developed and developing countries is gradational. For example, China has the second-largest GDP in the world. However, they maintain their position as a developing country at the UN Climate Change Conference (COP) because of their per capita GDP and greenhouse gas emissions. While their claim of per capita data on a country-by-country basis may be valid, there is also a significant difference in CO2 emissions and consumption of natural resources between urban areas such as Beijing and Shanghai and rural areas such as Yunnan Province. In other words, despite the diversity of issues and countermeasures from city to city, setting international standards on a country-by-country basis will likely not lead to global-scale problem solving. Of course, this is true not only in China but also in Japan and the US.

The second reason is rapid urbanization. The ratio of the urban population to the total world population is expected to increase from 55% in 2018 to 68% by 2050.[50] The pace of urbanization is such that the world is building one New York City every month.[51] Moreover, each city is not

[50] United Nations, "World Urbanization Prospects, The 2018 Revision," https://population.un.org/wup/publications/Files/WUP2018-Report.pdf
[51] Gates, Bill, *How to Avoid a Climate Disaster.* Knopf, 2021, P.43.

uniform in terms of population density, the age structure of its citizens, and the rate of change in these factors.

Therefore, the evaluation criteria for environmental burdens to be set at the city level should not be based on administrative units but rather on area units determined by the nature of the city, such as population density and citizen age structure, and the evaluation criteria should be reviewed by the rate of change in these factors. By promoting initiatives in line with these realities, it will be possible to build a platform for sharing wisdom and collaboration among cities and citizens worldwide. Building this collaborative platform at the city/citizen level and operating it based on data from the field will lead to the creation of a better society for the benefit of the environment and people around the world.

Tables

Table 1: San Diego Zoo MG Project Features

Location	San Diego
Utility	San Diego Gas & Electric
Host Organization	San Diego Zoo
Developer/Vendor	SDG&E, EDF Renewables
Capacity	1MW/4MW
Project Overview	The storage project is expected to reduce energy costs at the zoo by using the battery to mitigate spikes in usage and lower demand charges, in addition to minimizing energy costs by recharging the battery when energy is at its lowest available rates, and then later discharging that power to the zoo when costs are highest.
Business Model	The San Diego Zoo uses EDF Renewables energy services and avoids all upfront costs. Payments are based on the Zoo's utility bills saved by the batteries.
Value Proposition	-Bill saving/ demand charge abatement -Renewable energy integration
Technical features	-1MW/ 4MW lithium -ion battery storage facility -solar power -wind power

Source: Author's summary, based on California Energy Commission, Microgrid Analysis and Case Studies Report (August 2018) and the Data researched by author.

Table 2: Inland Empire Utilities Agency MG Project Features

Location	San Bernardino County, California
Utility	Southern California Edison (SCE)
Host Organization	Inland Empire Utilities Agency (wastewater treatment facilities)

Developer/Vendor	Advanced Microgrid Solutions, Anaergia, Foundation Wind Power, SunPower, Evergreen, FuelCell Energy, Tesla, EnerNOC
Capacity	13.5 MW
Project Overview	IEUA is a regional wastewater utility and wholesaler of water. In this project, they are using MG to optimize the operation of the distributed energy they have built so far
Business Model	Under the Energy Management Services Agreement, MG will be implemented at no up-front cost; IEUA will pay AMS a monthly fee based on a 10-year contract; AMS will receive a performance-based fee based on cost savings; and IEUA will receive a monthly fee based on the amount of cost savings. Savings of $50,000 per year are guaranteed, with a cap estimated to reach $230,000.
Value Proposition	-Bill saving/ demand charge abatement -Provision of ancillary services -Renewable energy integration
Technical features	The DER listed below represent the portfolio across the six sites. -3.5 MW solar PV -1 MW wind turbine -2.8 MW fuel cell -3.65 MW Li-ion batteries -2.5 MW of back-up diesel generators -Load control and demand response software

Source: Author's summary, based on California Energy Commission, Microgrid Analysis and Case Studies Report (August 2018) and the Data researched by author.

Table 3: Mission Produce MG Project Features

Location	Oxnard, California
Utility	SCE
Host Organization	Mission Produce
Developer/Vendor	Powerit Solutions, UniEnergy Technologies (UET)

Capacity	1.5 MW
Project Overview	Mission Produce is an avocado company. The MG project, aims to strengthen resilience and save money on electricity bills.
Business Model	The MG was developed under a service agreement between Mission Produce and UET. UET owns the battery system and receives a quarterly service fee from Mission Produce.
Value Proposition	Bill savings / demand charge abatement -Reduction of carbon footprint
Technical features	-1 MW solar PV -0.5 MW / 2.0 MWh advanced vanadium redox flow batteries -Cloud-based demand management software platform

Source: Author's summary, based on California Energy Commission, Microgrid Analysis and Case Studies Report (August 2018) and the Data researched by author.

Table 4: Alpha Omega Winery MG Project Features

Location	Rutherford Bench, Napa Valley, CA
Utility	PG&E
Host Organization	Alpha Omega Winery
Developer/Vendor	Blue Sky Utility, Aquion Energy, Princeton Power Systems, BPi
Capacity	1.5 MW
Project Overview	The MG was built with a backup battery system with the goal of generating all of the winery's energy needs from solar power. In the future, an EV charging station will also be installed.
Business Model	The winery and MG operator have a 7-year lease agreement. The lease is designed to be less than the cost of utilities. After the lease ends, the winery owns the MG.
Value Proposition	Bill savings / demand charge abatement -Reduction of carbon footprint

Technical features	-400 kW solar PV -saltwater energy storage batteries -100 kW bi-directional inverters -EV charging stations (future)

Source: Author's summary, based on California Energy Commission, Microgrid Analysis and Case Studies Report (August 2018) and the Data researched by author.

Table 5: Montgomery County MG Project Features

Location	Montgomery County, Maryland
Utility	PEPCO
Host Organization	Montgomery County Public Safety Building and Correctional Facility
Developer/Vendor	Schneider Electric, Duke Energy Renewables
Capacity	7.6 MW
Project Overview	On site generation enables the system to operate independently from the electric utility during a grid outage. The microgrid initiative was prioritized due to the county's history with extended large-scale power outages due to major storms and the county government's goal of reducing greenhouse gas emissions by 80% by 2027.
Business Model	Duke Energy is the owner of MG. Funded through a PPA partnership with Schneider Electric, there is no initial outlay from Montgomery County; the PPA incorporated into the EaaS contract includes a capacity charge that covers MG capital expenditures in addition to the standard PPA base power charge.
Value Proposition	-Reliability -Resiliency -Renewable energy integration -Cybersecurity
Technical features	-2 MW solar PV - 2 MW continuous duty-rated natural gas generators -2.55 MW legacy diesel generators - 1 MW CHP

	-Critical Infrastructure Upgrades (i.e., medium and low voltage gear) - Advanced cybersecurity solution

Source: Author's summary, based on California Energy Commission, Microgrid Analysis and Case Studies Report (August 2018) and the Data researched by author.

Table 6: MG Project Overview by Community Choice Aggregators in California

CCAs	Number of customers (Participation Rate)	MG Project overview
Central Coast Community Energy[52] (Formerly MBCP)	296,000 (97%)	MBCP is in the process of developing a two part microgrid program focusing on local economic development and community resiliency. MBCP is currently negotiating a potential distributed energy resource in South Monterey county. MBCP is also fast tracking a community resiliency program where MBCP will provide financing to develop local energy resources for customers deemed critical facilities. MBCP is currently reviewing its service area and focusing on sites within Tier 3 and Tier 2 fire risk zones.
REDWOOD COAST Energy Authority[53]	63,000 (92%)	Redwood Coast Energy Authority is partnering with the Schatz Energy Research Center , PG&E, and the County of Humboldt to build a microgrid featuring a 2.2 MW solar array and battery energy storage at the California Redwood Coast – Humboldt County Airport. RCEA will own and operate the solar and battery systems, PG&E will operate the microgrid circuit, the County is hosting the microgrid, and the Schatz Center is the prime contractor responsible for the project design and technology integration. The system will be the first multi-customer, front-of-the-meter microgrid in PG&E's area of service.
LANCASTER ENERGY[54]	52,208 (90%)	Lancaster is working with the ZNE Alliance to develop an Alternative Energy Community, which includes two affordable ZNE residential home developments deployed as microgrid communities. The project team is designing renewable microgrids that enhance local resiliency, while remaining cost-competitive with traditional developments. The team will identify Distributed Energy Resource

[52] https://3cenergy.org/
[53] https://redwoodenergy.org/
[54] https://lancasterenergy.com/

		(DER) configurations (including an innovative flywheel energy storage system), microgrid system components, interconnection agreements, energy tariffs, and billing processes that will serve as prototypes for additional ZNE developments now being planned and built throughout the city, totaling over 1000 homes. These processes will also be organized into a toolkit for other California communities eager to develop affordable ZNE residential developments backed by renewable microgrids.
PIONEER COMMUNITY ENERGY[55]	95,548 (89%)	Working with developers and microgrid consultants on analyzing resiliency options involving integrated solutions that address PSPS events.

Table 7: FY 21/22 Central Coast Community Energy Energy Programs

Project	Amount	Date
Electrify Your Ride	$2.8 million	NOVEMBER 2021
School Bus Electrification	$1 million	OCTOBER 2021
Agriculture Electrification	$600k	OCTOBER 2021
Residential Electrification	$1.6 million	—
New Construction Electrification	$1.5 million	OCYOBER 2021
Reach Code	$60k	—
Battery Energy Storage Pilot	$350k	—
Summer Readiness	$400k	—
Energy Education, Workforce Development, and Innovation Grants	$1 million	—
Greenhouse Gas Inventory	$64k	—

Source: CCCE, Annual Member Agency Update (22 February 2022).

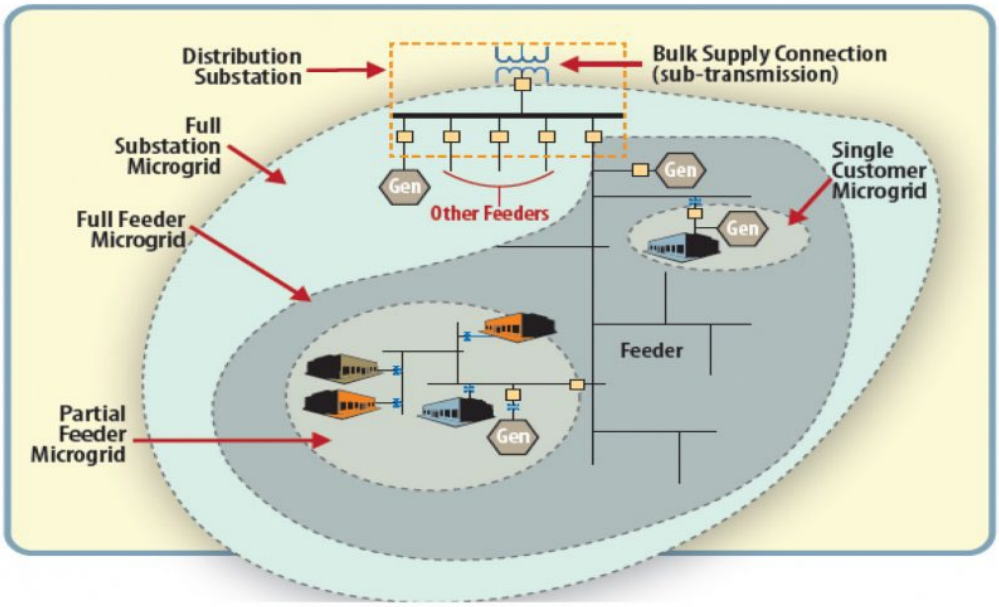
[55] https://pioneercommunityenergy.org/

Table 8: Summary of characteristics of commercially viable MGs using renewable energy

Business Model	-MG is owned by the developer and Vender. -No initial cost to the user. -The user pays a monthly fee. Or they receive a license fee for the MG installation. -Monthly fees are based on a lease and subscription model, Energy as a Service (EaaS). -CAAs return a portion of the revenue from community energy projects to the community.
Value Proposition	-Bill savings / demand charge abatement -Reduction of carbon footprint -Renewable energy integration
Technical features	-MG construction with storage batteries (lithium or lead) -Power supply and demand management using MG controller and storage batteries -Solar power generation (plus wind power and biomass)
Criteria	-The amount of carbon dioxide reduction has been quantified. -No case studies of life cycle assessment mulch criteria of the entire MG project (solar panels, storage batteries, controllers, etc.) were confirmed.

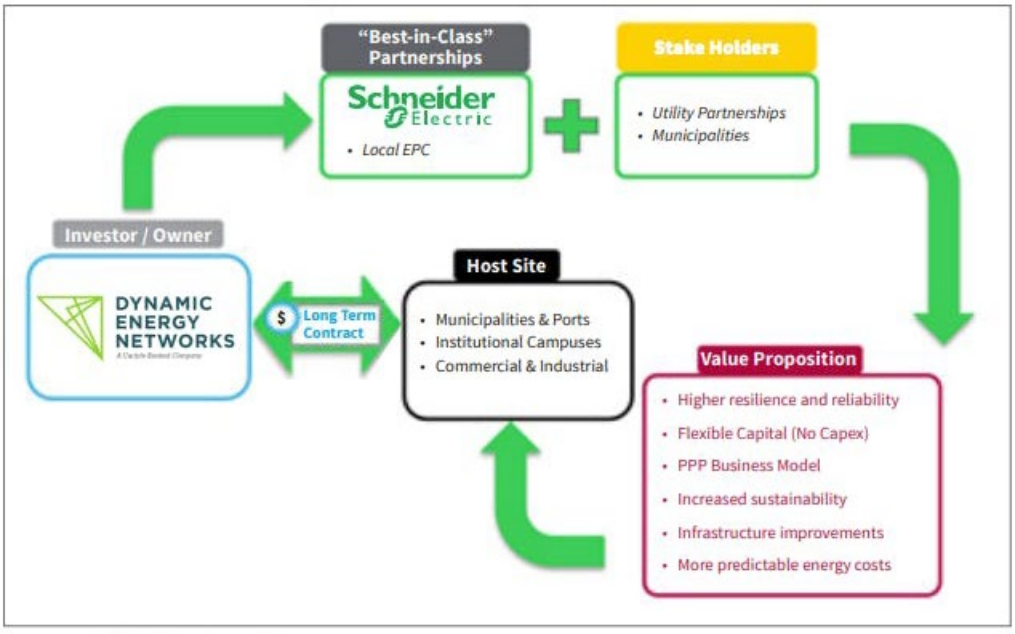
Figures

Figure 1: Microgrid typology by U.S. Department of Energy



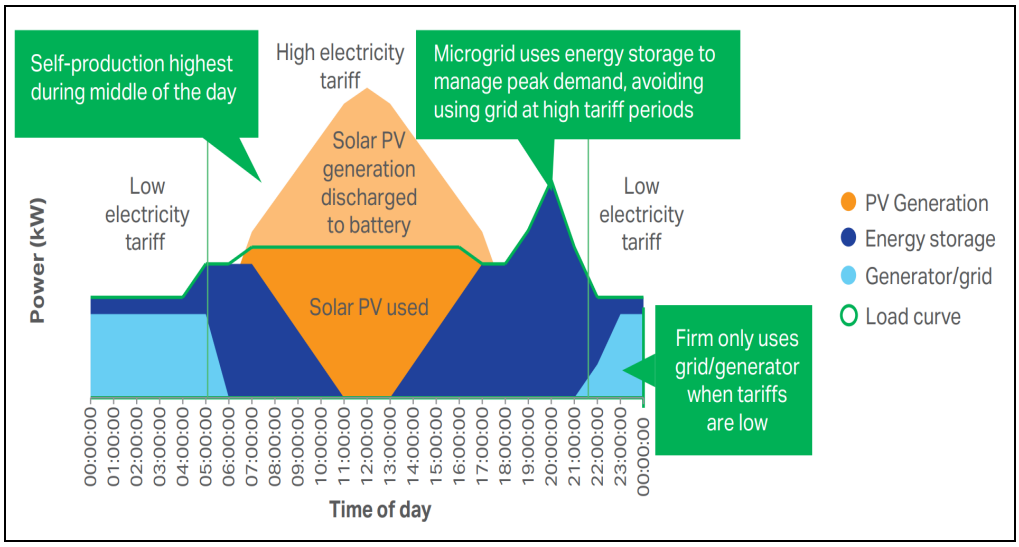
Source：DOE “DOE Microgrids Program Overview”6

Figure 2: Energy as a Service (EaaS)



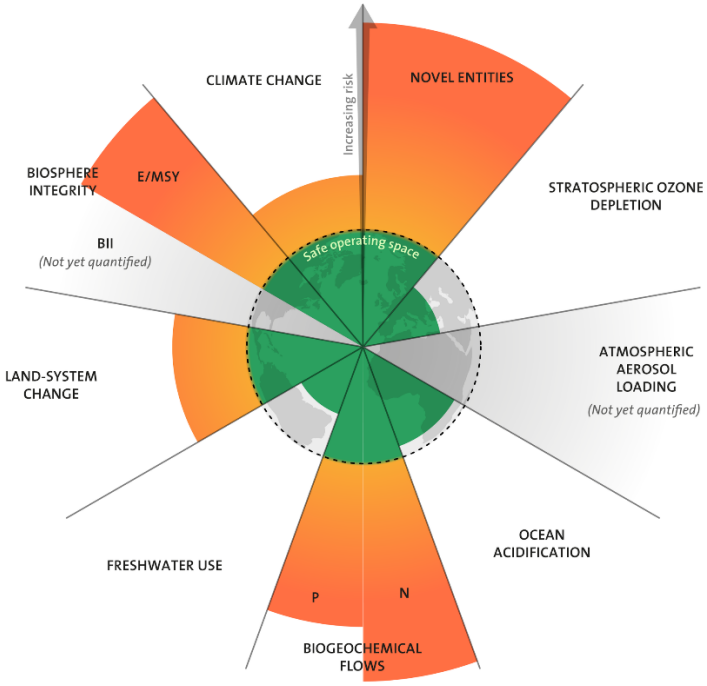
Source: Schneider Electric “Energy as a Service guide”

Figure 3: Schematic explanation of reducing time of use charges through energy storage



Source: WBCSD "Microgrid for commercial and industrial companies"

Figure 4: Planetary boundaries, 2022



Source: Stockholm Resilience Center "Planetary boundaries"

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