UNIVERSITY OF CALIFORNIA

Los Angeles

Producing Power, Producing Space:

The Geopolitical Economy of Japanese Electric Power Policy

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Geography

by

Hudson Douglas Spivey

2022

ABSTRACT OF THE DISSERTATION

Producing Power, Producing Space:

The Geopolitical Economy of Electric Power Policy in Japan

by

Hudson Douglas Spivey

Doctor of Philosophy in Geography

University of California, Los Angeles, 2022

Professor John A. Agnew, Chair

The Fukushima nuclear disaster of March 2011 provoked a profound reassessment by the Japanese public, political and business leaders, and civic organizations of their nation's reliance on nuclear power. In response to the disaster, the Japanese government passed sweeping administrative reforms to the prevailing institutions that governed the electric power sector over much of the postwar period. These reforms included a Feed-in Tariff (FIT) for renewable energy projects and the deregulation of the electric power sector, which opened both power generation and retail electricity sales to outside entrants. This dissertation examines how these changes to the regulatory regime governing Japan's electric power system are transforming socio-ecological relations in Japan. Bringing together literatures in Marxist state theory, science and technology studies, and geopolitical economy, it addresses the following questions: what role have the legal regimes of electric power policy played in shaping and stabilizing uneven power relations between the Japanese public and monopoly utilities, as well as between power producing and

power consuming regions, that characterize the geopolitical economy of the electric power system in Japan? How are these power relations changing as a result of regulatory reforms of Japan's electric power sector since 2011? And how do spatial, material, and political economic factors either permit or constrain these transformations? To answer these questions, it takes a hybrid approach, tracing both the historical geography of this system over the twentieth century and examining more narrowly the impact of recent regulatory reforms—particularly the widespread and rapid buildout of renewable energy since 2011—on the institutional, ecological, and material dynamics of this system. It begins by presenting a "geohistorical institutionalist" account of the development of state policy regarding the electric power system over the long twentieth century, which reorganized geopolitical economic relations across the territory of Japan and established relations of dependence between power producing and power consuming regions. It then traces the impact of post-2011 electricity sector reforms, which were responsible for a rapid buildout of solar photovoltaics across the country and made Japan one of the leaders of the global energy transition. While this rapid growth of renewables has increased competition and undermined the profitability of Japan's former regional monopolies, this dissertation further details how the utilities attempt to protect their fixed capital investments in centralized generation stations by appealing to the material limitations of Japan's power grid. As scholars and energy transition advocates argue for interventionist state action to produce the conditions for a transition to renewable energy, this dissertation reveals the political economic and geomaterial constraints that limit the potential of state action to bring about energy transitions.

The dissertation of Hudson Douglas Spivey is approved.

Kelly Ann Kay

Eric Stewart Sheppard

Katsuya Hirano

John A. Agnew, Committee Chair

University of California, Los Angeles

2022

TABLE OF CONTENTS

LIST OF FIGURES

ABBREVIATIONS

ANRE	Agency for Natural Resources and Energy
DBJ	Development Bank of Japan
DPJ	Democratic Party of Japan
FEPC	Federation of Electrical Power Companies of Japan
FIT	Feed-in Tariff
GDP	Gross Domestic Product
IPP	Independent power producer
ISEP	Institute for Sustainable Energy Policies
JAERI	Japan Atomic Energy Research Institute
KEPCO	Kansai Electric Power Company
LDP	Liberal Democratic Party
MAFF	Ministry of Agriculture, Forestry and Fisheries
METI	Ministry of Economy, Trade and Industry
MITI	Ministry of International Trade and Industry
MOE	Ministry of the Environment
OCCTO	Organization for Cross-regional Coordination of Transmission Operators
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
SCAP	Supreme Command for Allied Powers
TEPCO	Tokyo Electric Power Company
PV	Photovoltaic
RE	Renewable Energy
STS	Science and Technology Studies
VRE	Variable Renewable Energy

ACKNOWLEDGEMENTS

The fall of 2015 was both the best and worst of times to enter a doctoral program. It was best because, though we had no way of knowing it at the time, the Covid-19 pandemic would eventually shut the world—and the university—down for most of 2020, disrupting what it meant to undertake a Ph.D. for a whole cohort of students. In hindsight, it's clear that the mid-2010s may have been the zenith of global interconnectivity, which made conducting research in an international context easier than it had ever been in human history. Yet, in some ways, 2015 was already too late. Cases of Covid-19 were detected in Wuhan, China as early as December 2019, just three months after I had returned to Los Angeles from Tokyo, where I had conducted dissertation research over the prior year. What was supposed to be a leisurely—if rigorous—enterprise of combing through fieldnotes, interview recordings, and archival sources while writing over two years was suddenly disrupted. After UCLA shut down in March 2020, I found myself without access to the campus library or any of the sources I had hoped to obtain via inter-library loan. The sources I had brought back from Japan were packed away in boxes as my wife and I relocated to Northern California to wait out the approaching storm. Most importantly, any chance of returning to Japan in the summer of 2020 to tie up loose ends and conduct additional interviews was now lost. I would have to write my dissertation with what I had stored on my hard drive or could carry with me on the move north—which consisted of three boxes of printouts from the National Diet Library in Tokyo and 30 library books from UCLA.

Given the immense disruption of the pandemic, recalling my first years in the UCLA Department of Geography can feel like imagining a parallel universe. Yet I have no doubt that I benefited in countless ways, both personally and professionally, from the connections I made

during my time there. First and foremost, I am grateful for the counsel, encouragement, and unflagging support of my academic mentor, John Agnew. I went to John in my second year in the program when I was having doubts about my project, and he agreed to take me on as his advisee. His door was always open, and I will always cherish the many illuminating conversations we had in his office. I honestly cannot think of a more ideal scholar to have worked with and learned from while at UCLA.

Next, I am grateful for the support, feedback, and insight from my committee members. I was fortunate enough to take a course in urban theory with Eric Sheppard during my first year, and working with him, Helga Leitner, Jamie Peck, and fellow grad students on a collaborative book project was my first real experience of professional academic work. Eric's close readings of my drafts and targeted feedback were always incisive and helped me hone my arguments. Kelly Kay joined the geography department midway through my time at UCLA and joining her informal lab group to share writing was vital to keeping me grounded during the pandemic. Her feedback on my writing and conversations about the discipline were especially helpful for giving me the courage to keep going. Lastly, I don't know what would have come of my time at UCLA if I hadn't met Katsuya Hirano. Kats was kind enough to invite me to join him and Yoh Kawano in their regular meetings about Fukushima and to introduce me to his research contacts in Japan while still in my second year of studies. Without his support, I do not think I would have been able to obtain funding for doctoral research in Japan, nor would I have been introduced to my academic mentor in Japan, Shun Ishihara. While Kats bears no responsibility for the errors and omissions in this dissertation, this project simply would not exist if it weren't for him and his tireless support.

Thanks to a generous dissertation research fellowship from the Japan Foundation, I was able to conduct the research on which this dissertation was based. Shun Ishihara at Meiji Gakuin University was kind enough to agree to host me as a visiting researcher for a year, even though he was in the middle of completing a book project. I am deeply indebted to him for his generosity. The community of renewable energy advocates and researchers that agreed to meet with me and let me accompany them on excursions and to meetings were critical to the success of my dissertation research. Tetsunari Iida and Shota Furuya at the Institute of Sustainability Energy Policies (ISEP) in Japan met with me to explain Japan's renewable energy trends, and Iida was also kind enough to let me join him on two visits to Fukushima. I cannot thank them enough.

In Fukushima, I made the acquaintance of numerous residents to whom I will be forever indebted. On my first trip to Fukushima in the summer of 2017, I was given a tour of Iitate Village by local resident and political leader, Kenta Sato. Sato kindly freed up his schedule for me even though I was an unknown American researcher with halting Japanese and no real credentials. Hearing his family stories and personal reflections as we drove through his deserted ancestral village made a lasting impact, and I am still struggling to find the voice to tell this story. Early on in my trips to Fukushima I had the great fortune of staying with Akihiro Asami in his boarding house in Kitakata, who accompanied me on my first meeting with sake brewer and renewable power entrepreneur Yauemon Sato. Sato was kind enough to meet with me for an hour and tell me about his personal transition from running a sake brewery to starting community solar projects in the Aizu region. Kei Kondo of Iitate Denryoku was especially welcoming during one of my trips to Fukushima and allowed me to accompany him on a tour of his solar projects, even though he was being interviewed by a radio journalist from Tokyo on the ten-year

anniversary of 3/11. Without a doubt, this is only scratching the surface of those with whom I had the great fortune of spending time and talking with while I was in Japan and to whom I remain forever indebted.

Among my friends and colleagues from UCLA and other universities, I would like to thank the following: Kevin Richardson, Kenton Card, Alex Murphy, Adina Matisoff, Dan Abbe, Daniel Iwama, Teo Wickland, Lindsay King, Travis Bott, Clare Beer, Dian Irawaty, Sam Brandt, Dimitar Anguelov, Nerve Macaspac, and Emma Colven. Among UCLA faculty, I am grateful for the guidance and encouragement I received from Helga Leitner, Michael Shin, Sierra Burkhardt, Kyle Cavanaugh, Jared Diamond, Adam Moore, and David Rigby.

Two of the chapters in this dissertation were previously published as journal articles and I am grateful to these two journals for allowing me to reproduce them here. Chapter 3 was published as: Hudson Spivey (2020) "Governing the Fix: Energy Regimes, Accumulation Dynamics, and Land Use Changes in Japan's Solar Photovoltaic Boom", *Annals of the American Association of Geographers*, 110:6, 1690-1708, DOI: 10.1080/24694452.2020. 1740080. Chapter 4 was published as: Hudson Spivey (2021) "The Technopolitics of Energy Transitions: Materiality, Expertise, and Fixed Capital in Japan's Grid Disputes", *Environment and Planning E: Nature and Space*, 0:0, 1-17, DOI: 10.1177/25148486211006560.

Lastly, I would like to thank my wife, Adrianna, for giving me the strength and confidence to see this project through to the end. I could not have done this without you.

BIOGRAPHICAL SKETCH

Hudson Douglas Spivey

EDUCATION

M.S.	Environmental Studies	University of Montana	2011
B.A.	History (*summa cum laude*)	North Carolina State University	2004

PUBLICATIONS

2021 Spivey, Hudson. "The Technopolitics of Energy Transitions: Materiality, Expertise, and Fixed Capital in Japan's Grid Disputes." *Environment and Planning E: Nature and Space*.

2020 Spivey, Hudson. "Governing the Fix: Energy Regimes, Accumulation Dynamics, and Land Use Changes in Japan's Solar PV Boom." *Annals of the American Association of Geographers.* 110 (6):1690-1708. doi: https://doi.org/10.1080/24694452.2020.1740080.

2019 Spivey, Hudson. "Urban Nature/More-than-Human World." In *Urban Studies Inside-Out: Theory, Method, Practice.* Eds. Helga Leitner, Jamie Peck, and Eric Sheppard. Thousand Oaks, California: Sage Publications.

2019 Spivey, Hudson. "Right to the City." In *Urban Studies Inside-Out: Theory, Method, Practice.* Eds. Helga Leitner, Jamie Peck, and Eric Sheppard. Thousand Oaks, California: Sage Publications.

2019 Hasan, Nafis, Hudson Spivey, and Kenton Card. "Frustrated Encounters: On Ahmed Kanna's The City as Corporation." In *Urban Studies Inside-Out: Theory, Method, Practice.* Eds. Helga Leitner, Jamie Peck, and Eric Sheppard. Thousand Oaks, California: Sage Publications.

2019 Matthan, Tanya, Emma Colven, and **Hudson Spivey**. "Fluid Assemblages: On Lisa Björkman's Pipe Politics." In *Urban Studies Inside-Out: Theory, Method, Practice.* Eds. Helga Leitner, Jamie Peck, and Eric Sheppard. Thousand Oaks, California: Sage Publications.

GRANTS, AWARDS, AND FELLOWSHIPS

2021 Graduate Student Publication Award, Department of Geography, UCLA
2020 Department Distinguished TA Award, Department of Geography, UCLA
2020 Graduate Student Publication Award, Department of Geography, UCLA (declined)
2019 Hiroshi Wagatsuma Memorial Fellowship, Terasaki Center, UCLA
2018 Japan Studies Doctoral Fellowship, Japan Foundation, New York
2017 Graduate Research Mentorship, UCLA
2017 Graduate Summer Research Mentorship, UCLA
2017 Helin Research Travel Grant, UCLA
2016 Sasakawa Summer Language Fellowship, UCLA
2016 Foreign Language and Area Studies (FLAS), Summer Fellowship, UCLA
2015 Eugene V. Cota-Robles Fellowship, UCLA
2013 Richard Drake Writing Award, University of Montana
2012 Graduate Student Writing Award, University of Montana
2011 Cinnabar Climate Conservation Fellowship, University of Montana

ACADEMIC POSITIONS

Instructor of Record

2021	Summer	Geography 141: Cultural Geographies of the Modern World, UCLA
2020	Summer	Geography 7: Introduction to GIS, UCLA
2012	Winter	Writing 101: Freshman Composition, University of Montana
2011	Fall	Writing 101: Freshman Composition, University of Montana

Teaching Associate

2020	Spring	Geography 4, Globalization: Regional Development and World Economy
2020	Winter	Geography 153, Leadership in Organizations, UCLA
2019	Fall	Geography 5, People & Earth's Ecosystems, UCLA

Teaching Assistant

2017	Spring	Geography 6, World Regions, UCLA
2017	Winter	Geography 5, People & Earth's Ecosystems, UCLA
2016	Fall	Geography 3, Cultural Geography, UCLA

CHAPTER 1

Introduction:

The Geopolitical Economy of the Japanese Power System

In the days and months following the triple meltdown at the Fukushima Daiichi nuclear power plant in March 2011, Japan appeared to be in the midst of a collective reckoning with the energy future its leaders had been charting for it up until the eve of the disaster. Nearly four decades after the first oil crisis of 1973-74, Japan's electric power system had shed its once crippling dependence on petroleum imports for electric power generation and had built out a nuclear power plant fleet to displace oil as a baseload power source. Few people born in the 1970s or later had ever had much reason to think about the composition of the energy supply that generated the abundant and cheap electricity that powered Japan's households, factories, department stores, and nightlife districts. So long as the lights stayed on and the trains kept running, electricity receded into the background, a mere subtext or background for the more important activities of everyday life. Decades of pro-nuclear public relations outreach had also succeeded in convincing a broad swath of Japanese society of the benefits of nuclear power: not only was it a safe and secure baseload power source, but it was also the lynchpin of Japan's independence from Middle East oil and essentially carbon emissions-free.

The massive 9.0 magnitude earthquake that rocked Japan's northeastern prefectures at 2:46 p.m. on March 11, 2011, seemed to wake everyone from the dream that producing so much power could proceed without consequence. Although the earthquake's epicenter was off Japan's northeastern coast some 300 kilometers away from Tokyo (Figure 1.1), it was so large and so violent that it could be felt in the capital city, where it shook skyscrapers on their foundations.

The immediate effect in the Tokyo metropolitan area —an extensive urbanized zone that spans across the Kantō plain and is the most densely inhabited megaregion on the planet—was region-

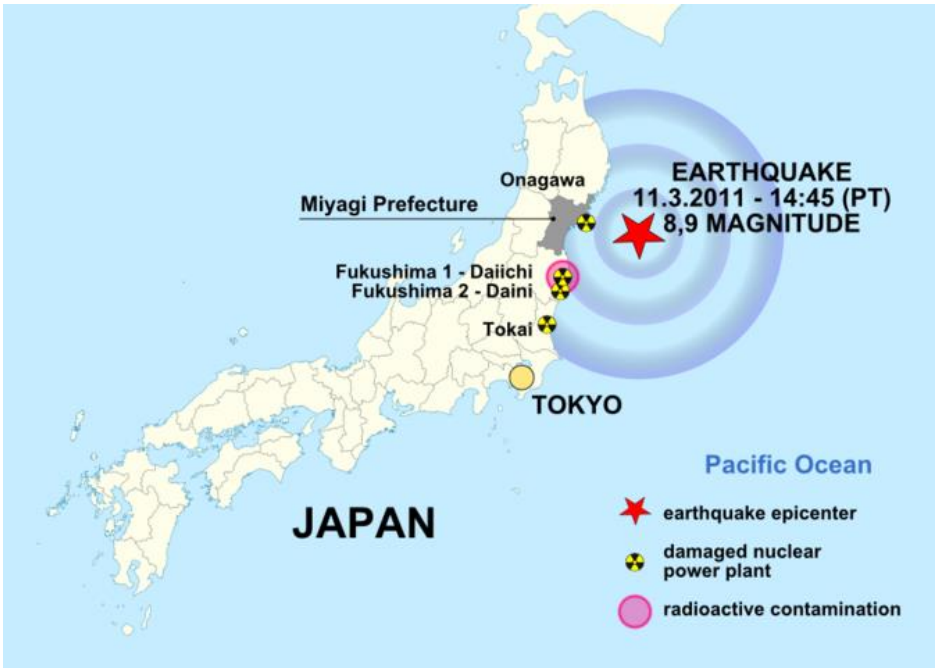

Figure 1.1: Map of the epicenter of the 8.9 magnitude Great East Japan Earthquake of March 22, 2011 (Source: Wikimedia Commons).

wide transit disruptions. As Tokyo's connections to the power plants situated far away in distant rural areas to its northeast and northwest were severed, the city's circulatory system of electric train lines came to a standstill. Trains stopped midway to their destinations and were emptied of passengers, who were forced to walk along the tracks to the nearest station. More than 700,000 workers who commuted into the city center for work each day were stranded on their return commutes. By nightfall, as it became clear that train service would not be restored to the city any time soon, some elected to walk the fifteen to twenty kilometers home along the pitch-black streets, lit only by the dim light from their smartphone screens as they scrolled through news feeds for information about the disaster (Figure 1.2).

Figure 1.2: Stranded commuters walk home past an idle commuter train on the evening of March 11th in Tokyo's Shinagawa Ward (Source: http://www.asahi.com/photonews/gallery/tsunami/tsunami1036.html).

Over the coming days, as the disaster at Daiichi unfolded, Japan's electric power grid was subjected to the most significant stress it had experienced since the immediate aftermath of World War II. Following the series of explosions that rocked the plant, the government of Japan under Prime Minister Naoto Kan ordered the shutdown of other plants in Japan's nuclear power fleet so that they could undergo stress tests to ensure they were fortified against future disasters. To cope with the loss of 20 percent of its generation capacity following the idling of its nuclear fleet, Tokyo Electric Power Company (TEPCO), the region's utility and owner of the beleaguered plant, initiated a series of rolling blackouts across the capital region (Jolly 2011)[1]. For weeks, residents of the capital had to plan for the scheduled power outages, which took place

[1]Although the Fukushima Daiichi nuclear power plant is located in the Tohoku region of Japan, it is owned and operated by TEPCO, which serves the Kantō region. While Japan's former regional monopolies were only able to sell power to customers in their service areas, some of them procured generation resources in neighboring regions.

in the evening hours when demand peaked as workers returned home from their offices and started powering on home appliances. Newspapers depicted eerie scenes of commuters returning home through the darkened streets of Shibuya and Ginza, two of Tokyo's most brightly lit urban shopping districts.

In the months following the disaster, Japan was wracked by extensive public debate on the fate of the country's nuclear power plants. By the summer of 2011, only 19 of Japan's 54 reactors were operating while the rest of them underwent safety inspections (McCurry 2011). Citizens' groups, echoed by then Prime Minister Kan, publicly advocated for the Japanese government to abandon nuclear power and pursue an energy policy that placed greater emphasis on renewable energy sources like wind and solar photovoltaics (PV). Critics of Japan's nuclear power policy charged that the risk of future earthquakes of a scale comparable to the Great East Japan Earthquake was too great to guarantee the future safety of Japan's idled nuclear plants. But with the defeat of Kan's Democratic Party of Japan and the return to power of the Liberal Democratic Party under Shinzō Abe, the cultural momentum behind abandoning nuclear power appeared to stall. Few were surprised when the Abe administration resurrected the government's support for nuclear power in its "Strategic Energy Plan" of 2014, which laid out an aggressive policy of re-starting (*saikadō*) the nuclear power plants. The plan forecast a national "energy mix" in 2030 featuring 20 to 22 percent nuclear power, down only 8 to10 percent from the 30 percent it had occupied prior to the disaster.

With Japan's power utilities complaining of record financial losses following the forced idling of their nuclear facilities for safety checks (The Japan Times Online 2012), and private firms threatening to relocate overseas in search of cheaper electric power rates (Kikkawa 2011), the Japanese government—led particularly by energy planners within the Ministry of Economy,

Trade and Industry (METI)—framed the re-starting of nuclear power plants as above all essential to Japan's economic security. This conflation of energy security *qua* economic security has been the consistent refrain of government nuclear power advocacy since the 1970s oil crises. Most recently, in March 2022, another earthquake off the coast of Fukushima that disrupted electricity service and produced power supply crunches in the Tokyo metropolitan region has reignited these debates. Adjusting their messaging strategy to accommodate safety concerns, business leaders in the Japan Business Federation (*Keidanren*) now publicly advocate for accelerating nuclear power plant restarts as a way to actually *prepare* for power shortages in the wake of future large-scale natural disasters (Lewis 2022).

Yet, despite this public relations push by the LDP and business elites, reactions to the central government's post-Fukushima nuclear ambitions have varied among the prefectures and local governing authorities that host Japan's 16 operational nuclear power facilities. By mid-2017, mayors of host communities in Kagoshima, Saga, and Ehime in southwest Japan, and Fukui in central Japan, along with their respective governors, had each approved the local power utility's applications to restart the reactors, citing in part the "necessity" of supplying Japan's energy needs as a justification (World Nuclear News 2018). On the other hand, the governor of Niigata prefecture—home to the Kashiwazaki-Kariwa power plant, the largest nuclear power installation in the world—refused Tokyo Electric Power Company's (TEPCO) application for a restart, staking his re-election campaign on his anti-nuclear platform (Urabe and Stapczynski 2017). Elsewhere, growing calls for "energy localism" (*enerugī chisan chishō*) and more regional autonomy in energy planning in communities across Japan have not been able to halt the central government's commitment to restarting Japan's idled nuclear fleet (Toyota 2016).

As the above examples demonstrate, "energy policy" in post-Fukushima Japan has become a much more fraught and contested enterprise than it was in the days of the hegemonic "nuclear village," the term scholars have used to describe collusive network of electric power utilities, government bureaucrats, career politicians, and academics that effectively nullified resistance to the state's nuclear ambitions since the 1970s (Kingston 2012). While from the early postwar period through the early 2000s energy policy was more of a top-down imposition by bureaucrats within the central government, in recent decades this once stable geography of consent has begun to fragment along a number of axes (Muramatsu 1997; DeWit and Ikegami 2010). Challenges from local self-governing bodies (*jichitai*), governors and mayors, activist lawyers, and renewable energy entrepreneurs in particular have grown in prominence since the Fukushima disaster. Regulatory reforms ratified in the Diet by the Democratic Party of Japan (DPJ) after the disaster have further undermined the prevailing status quo of Japan's electric power system, opening up generation capacity to renewable energy producers and unbundling the service territories from the former regional power monopolies so that they now face competition from upstart retail power firms.

What Japan is experiencing are the throes of socio-spatial upheaval that characterize the far-reaching transformation of energy systems that scholars have come to call "energy transitions." While the term denotes the replacement of conventional energy systems with renewable and distributed forms of power generation (Bridge and Gailing 2020), given the centrality of energy consumption to modern life the implications are much more profound. As geographers have recently emphasized, energy systems have played and continue to play a crucial role in constituting both social and spatial relations, and thus changing the ways that power is produced, distributed, and consumed will *ipso facto* thoroughly revolutionize the social

and spatial organization of society (Bridge et al. 2013; Calvert 2016). However, given that many energy transitions are in the earliest stages in our era—particularly the worldwide transition away from fossil fuels towards renewable energy in response to climate change—we do not yet have sufficient empirical data of precisely *how* these transitions will unfold, both in terms of what forms they will assume, and through what mechanisms they will gain momentum. How can societies undertake the wholesale transformation of their energy systems? What types of forces (political, economic, cultural) produce the conditions for energy transitions, and what types of forces resist them? What types of socio-spatial and socio-ecological transformations will result?

This dissertation is motivated precisely by the riddle of how recent changes to the regulatory regime that governed Japan's electric power system for much of the twentieth century are transforming socio-ecological relations in Japan. It aims to address the following empirical questions, which are informed by the more theoretical questions listed above: what role have the legal regimes of Japanese electric power policy played in shaping and stabilizing uneven power relations that characterize the electric power system in Japan? How are these power relations changing as a result of administrative reforms to Japan's electric power regulations since the 2011 Fukushima nuclear disaster? And how do spatial, material, and political economic factors either permit or constrain these transformations? By "power system," I am most interested in the power relations between the state, monopoly power utilities, and the public, which scholars have examined, as well as the geopolitical economic relations between power producing regions and power consuming regions, which they have largely neglected. To answer these questions, this dissertation takes a hybrid approach, tracing both the historical geography of the institutional elaboration of this system over the twentieth century and examining more narrowly the impact of

recent regulatory reforms—particularly the widespread and rapid buildout of renewable energy since 2011—on the institutional, ecological, and material dynamics of this system.

Japan's growth into one of the major economic powerhouses of the twentieth century was paralleled by the development of an elaborate piece of machinery that spans its four main islands of Honshū, Hokkaidō, Shikoku and Kyūshū: the power grid (Figure 1.3). While oil or nuclear

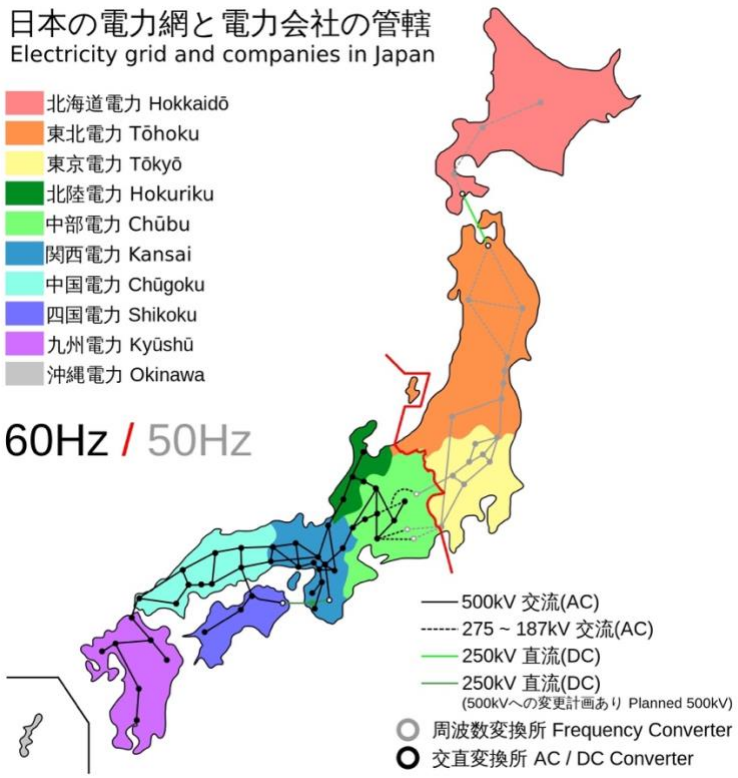

Figure 1.3: The Japanese electric power grid and regional utility service areas (Source: Wikimedia Commons).

energy are often given pride of place in discussions of Japanese energy policy, the success of Japan's development of a modern grid capable of transmitting gigawatts of power from its hydropower and nuclear power stations to its urban demand centers was critical to its successful transition into a highly developed nation after World War II. Yet despite its appearance as a technical artifact bereft of political content, the grid is social through and through, binding the

residents of Japan together in an invisible yet all-pervasive network of material and informational exchanges and flows. As a "socio-technical system" (Hughes 1983), the grid comprises a vast network of generation, transmission, distribution, and consumption, lighting factories and homes, and lending the glow to the ubiquitous lights that can be seen stretching across the archipelago from outer space on cloudless nights (Figure 1.4). At the same time that it is comprised of wires, pylons, inverters, and transformers, the grid is embedded in legal and political institutions that govern access to this critical infrastructure by a variety of

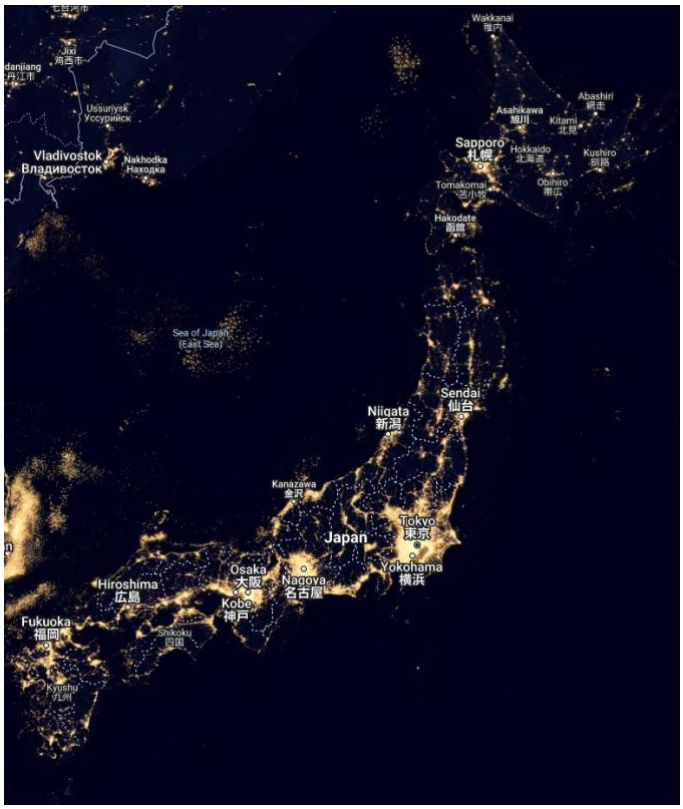

Figure 1.4: A satellite image of the Japanese archipelago at night (Source: Blue Marble Navigator).

constituencies. While the grid only forms the primary object of investigation of one of the chapters of this dissertation, its networked geography offers the perfect metaphor for conceptualizing how power is distributed both literally and metaphorically between urban and rural sites within the nominal territory of Japan. To attend to the politics of "the grid," I pay

special attention to both the social and the material aspects of the power system and seek to understand how the two are inter-related.

This introductory chapter provides a thematic and theoretical overview to the chapters that follow. It begins by situating the research questions and empirical material gathered here within the emerging transdisciplinary field of energy studies and explains how the research differs from conventional analyses of Japanese energy policy. It then proceeds to explicate more precisely the theoretical framework of "geopolitical economy" that informs its empirical chapters and reviews the methods used to conduct the research and analysis. Lastly, it concludes with an overview of the material and arguments presented in the three main empirical chapters, which constitute the core of the dissertation.

Electric Power, Regulation, and the Administrative State

In recent years, the relationship between energy and politics has seen increasing attention from scholars working in the transdisciplinary field of energy studies. Noteworthy studies have examined connections between energy nationalism, fossil fuel extraction, and forms of "petro-citizenship" in Peru (Valdivia 2008: 457), as well as how fossil fuel-driven suburban growth in the U.S. contributed to the rise of neoliberal forms of entrepreneurial subjectivity (Huber 2013a). Yet most of this work continues to focus on fossil fuels, a thematic blind spot Jones (2016) terms "petromyopia". To be sure, this petrocentric bias is understandable, given the substantial spatial footprint of fossil fuel-based infrastructures in many parts of the globe (Urry 2014), their influence on forms of cultural production (Wilson et al. 2017), the relationship of oil production to political violence and dangerous forms of labor (Watts 2004; Appel 2012), and its role in sustaining contemporary modes of capital accumulation (Altvater 2009). However, as Jones

(2016) notes, electricity has arguably played an equal, if not more substantial, role in re-configuring the geographies of production, sociality, and everyday life since its development in the late 19th century and is thus deserving of more intense critical scholarly investigation.

This dissertation responds to calls by scholars in energy studies to examine the connections between electric power systems—the whole socio-technical ecosystem encompassing generation, transmission, and distribution—and the organization of systems of social power. As Gupta (2015: 563) has argued, "how electricity is generated, transmitted, distributed, and consumed is fashioned by existing social arrangements, but also profoundly shapes political and social structures." The chapters included here attempt to build on this observation by exploring more explicitly the spatial and political economic dimensions of these structures, which in turn shape the potential trajectories for future energy system transformation. Electricity, as a flow resource that cannot be stockpiled for future use, has certain intrinsic, material limitations that shape the geographies it produces and the types of social arrangements it affords. As one of the most capital-intensive sectors of the global economy (Mazur 2013), it requires the organizational capacities of large-scale enterprises, states, and increasingly quasi-governmental organizations like regional transmission organizations to mobilize the capital, materials, labor, and expertise ("know-how") to maintain grid functionality. Despite forming the infrastructural basis of the "networked flows" of information and currency that characterize the global economy (Swyngedouw 2004), generation facilities like hydropower dams, nuclear power plants, and the transmission lines linking them to urban centers and households remain stubbornly immobile. Over the twentieth century, this tension between fixity and mobility, between geographically dispersed economic relations and centralized power systems, has played a profound role in shaping the spatiality of political and economic power within societies.

The three chapters that comprise the body of this dissertation build in part on calls to bridge the gap between political ecology and political geography (e.g., Robbins 2007; Harris 2017) by examining the role of government policymaking related to electric power in remaking socio-ecological landscapes and metabolisms across the Japanese archipelago. The broad scope of this framing is methodologically aligned within recent studies in geography that examine socio-ecological transformations at large spatial and temporal scales (Moore 2015; Sneddon 2015). Geographical studies of state-led infrastructural projects have highlighted how, at some level or another, all political projects "invariably rely on transforming environmental conditions and relations and imply the production of new socio-natural assemblages and constellations" (Swyngedouw 2015). However, while recent scholarship has outlined the effects of states in certain places —and even the state itself as an "effect" of infrastructure projects (Harris 2012)— there is still less known about the relatively sequestered world of policy production ("policymaking"), which constitutes a black box in critical scholarship. By opening up the black box of administrative bureaucracy and energy policymaking, this dissertation attempts to show how worlds often described as "socio-technical"—like nuclear power plants, electricity grids, and the intellectual labor of policy makers and government administrators—are both constitutive of and constituted through socio-ecological relations.

In the literature on Japanese energy policy, the state (or one of its agencies) is often represented as a coherent actor, reified into a unified apparatus animated by certain coherent institutional logics (like promoting nuclear power development) and contained within its territorial borders (e.g., Samuels 1987; Aldrich 2008). This reified projection of coherence and unity is what Mitchell (1991) called "the state effect," which mistakes the effect of state activities for the state itself. Mitchell's Foucauldian critique challenged the prevailing

substantive view of the state that was emerging in scholarship that sought to "bring the state back in" (Evans et al. 1985). While Mitchell's insight was perhaps a necessary corrective to work that attributed too much autonomy to "the" state, this dissertation attempts to bypass the substantivist-deconstructionist debate by attempting to decenter "the state" as an object of theoretical interest altogether. Instead, I attempt to investigate more directly the real-world, mundane functioning of the Japanese administrative state, particularly its economic and energy bureaucracy, which I distinguish from the theoretical concerns with the properties and imperatives of "the state". One benefit of this approach is that there exists a substantial literature on the Japanese bureaucracy and on the agencies most responsible for setting national energy policy goals during the postwar era. As Japan's economic "pilot agency," the Ministry of International Trade and Industry (MITI) (which became METI after administrative restructuring in 2001) and its energy planning bureau the Agency for Natural Resources and Energy (ANRE) were responsible to an uncommon degree among governmental agencies for the composition of Japan's energy supply and the configuration of its electric power system. By examining the operations of the state bureaucracy charged with designing policy for governing the Japanese energy system, we can derive greater insights about the structural political-economic constraints within which energy transition initiatives unfold. Additionally, we can glimpse the possibilities and limits of pursuing energy transition strategies through the state organization itself, which is increasingly recognized by even progressive advocates of renewable energy as the critical fulcrum for changing the global energy system towards a more equitable and sustainable arrangement (Klein 2015).

The empirical chapters presented here differ from conventional social scientific studies of Japanese energy policy by beginning from the premise that the policy priorities of the Japanese

bureaucracy are shaped to a profound degree by the accumulation dynamics of capitalism. I draw on the core theoretical insight from the French Regulation School and other Marxist state theorists (Aglietta 1979; Lipietz 1988; Altvater 1993) that capitalist reproduction is not an autonomous, self-driven process, but requires active institutional—that is, political—intervention to achieve periodic and temporary stability. Given capitalism's endemic crisis-tendencies, particularly the conflict between capital and labor, the riddle remains precisely how these tendencies are kept in check. However, while Regulationists focused primarily on the role of the state in obtaining a "Fordist" compromise between labor and capital through setting wage floors and other working condition standards, regulating public utilities like the electric power industry have also been critical to securing the conditions for production and social reproduction in capitalist societies. As scholarship focusing on MITI has shown, the Japanese economic planning bureaucracy played a critical role over the twentieth century in stabilizing inter-capitalist relations and preventing ruinous competition among Japanese firms (Johnson 1982; Gao 1997; Okimoto 1989; Sasada 2012). A crucial, though under-examined, aspect of MITI's economic and electric power policymaking is that it has also played a central role in materially producing the "state space" of Japan (Brenner and Elden 2009), a lacuna I attempt to address by approaching these questions through the theoretical lens of geopolitical economy.

Geopolitical Economy as Theory and Method

Given that the avowed focus of this dissertation is the electrical power policy of a single nation-state, rather than the terrain of international relations, it would be reasonable to wonder at my use of the term "geopolitical economy" in the title. "Geopolitical economy" has had a somewhat uneven tenure in geography over the decades and its usefulness as either a concept or

a theory remains in some dispute (Glassman 2018). Originally coined by Agnew and Corbridge (1989: 268), the term was developed to "incorporate both the processes of economic and political change and the rhetorical understanding that gives a geopolitical order its appeal and acceptability." While their work sought to highlight the inter-penetration of the political and the economic by focusing on the ways economic policies and instruments (like trade deficits) function as novel tools for expanding the hegemony of geopolitical actors, there was also an obvious emphasis on the scale of world politics (Corbridge and Agnew 1991). A decade later, Ó Tuathail (1998: 38) foregrounded the global scale even more explicitly by describing geopolitical economy as "a hybrid of geopolitics and political economy." Recently, Glassman (2018: 412) has attempted to reinvigorate scholarly engagement with the term, arguing for a hybrid definition that merges two common definitions of the term: an abbreviation of "geographical political economy" and "geopolitics plus political economy". He helpfully criticizes the conflation of the "geo-" with the global, arguing that work in this vein should attend "the socio-spatial variegation and complexity of political economic processes, not simply emphasis on the importance of the global scale" (Glassman 2018: 408). Yet elsewhere he appears to slip easily into privileging the global, defining geopolitical economy as the study of the "interrelation of political economy and geopolitics" (Lee, Wainwright, and Glassman 2018).

In contrast, my usage is more expansive, operating as a succinct and convenient abbreviation of both "historical-geographical materialism" (Swyngedouw 2000) and "geographical political economy." Like this latter term, geopolitical economy attends first and foremost to the "geographical": the variegated geographies that comprise the capitalist space economy (Sheppard 2011). It highlights the fact that all political-economic relationships—the worlds of production, social reproduction, and exchange—are both conducted in space, operating

across territories and places, and are also actively generative of space(s), in that these relations produce new landscapes and new relationships between and within specific places. In the long arc of capitalist economic development, this spatiality has been characterized by uneven development: at the macro-scale between different nation-states in the world economy, at the meso-scale between cities and regions within individual nation-states, and at the micro-scale within specific urban regions. Among the three, the meso-scale relationship between cities and regions within nation-states, what Soja (1989: 86) described as the "town-countryside antithesis" has received far less attention from critical geographical scholarship, despite recent theoretical overtures calling for greater examination of the relationship of urban areas to their hinterlands (Neel 2018; Brenner and Katsikis 2020).

The "political" aspect of "geopolitical economy" further draws attention to the differential distributions of power that shape and infuse economic relations, which in liberal economics are too often depicted as relations of exchange among parties that are otherwise equal. These power relations can take the form of relations between states in the world system, as described by Corbridge and Agnew (1991), while within individual nation-states they take the form of relations between classes and other demographics. More importantly, emphasizing the "political" in political economy responds to Agnew's (2012) critique that economic geography has relied on a naturalized conception of economic activity, which evacuates the role of political processes in co-determining how economic processes (and crises) unfold. Drawing on Agnew's critique and the observation of early Marxist state theorists (O'Connor 1973; Poulantzas 2000), my conceptualization of the "political" hearkens to the role played by political institutions like governments, with their domains of formal law, policy, and litigation, in regulating the types of economic activities—which encompass everything along the spectrum of production, social

reproduction, and exchange—that obtain both between and within different territories in the world economy.

Lastly, the "economy" of geopolitical economy highlights how certain social relations that are intrinsic to the capitalist mode of production—particularly commodity production for exchange, competition between firms, and the antagonism between labor and capital—provide a unitary, motivating force to the transformations of social and physical space in capitalist society (Hudson 2016). Moreover, my conceptualization of what specific activities comprise the "economy" draws on conceptions of social metabolism that are common to Marxian conceptions of production (Swyngedouw 2000) and green political economy, which views the economy primarily "in terms of its biophysical stocks and flows" (Fischer-Kowalski and Haberl, 2015). In addition to the circulation of money-capital and generation of symbolic wealth, the production of commodities and reproduction of social life and labor under capitalist social relations entails the application of human labor and technology to the raw materials of the natural world, resulting in what Smith (2008) famously called "the production of nature". Any economy is more than the dollar sum total of goods and services exchanged but is rather a way of "organizing nature" (Moore 2015), which involves the transformation of both natural landscapes and the built environment. In short, as my theoretical and methodological framing, "geopolitical economy" seeks a comprehensive approach to analyzing the inter-operation of political and economic forces in producing the spatial and scalar organization of modern socio-ecological metabolisms.

In this framing of "geopolitical economy", therefore, no methodological preference is granted to a specific scale of social, political, or economic organization. Rather, it seeks to de-stabilize our inherited assumptions of what precisely counts as "geopolitical," which need not take place exclusively at the global scale. The different scales commonly listed by theorists of

geographical political economy—including the local, the urban, the regional, and the global (Brenner et al. 2003)—are seen as co-constitutive of the spatiality of political-economic relations under capitalism. Further, in contrast to some work on the "capitalist production of space" (Harvey 2001) that has become a mainstay in critical geographic scholarship, focusing analytical attention on the political aspects of how economic relations are coordinated, stabilized, and regularized within and between territories allows us to avoid falling prey to the kind of "capitalocentrism" first identified by Gibson-Graham (2006: 35). In arguing for the constitutive role that the changing dynamics of the capitalist economic system have in transforming the spatial and scalar organization of societies, geographers of a Marxian bent have at times granted too much primacy to a reified conceptualization of Capital-with-a-capital-C, as though it operated autonomously within, between, and across territories. Drawing on Marx's depiction of Capital as a force which must inexorably "strive to tear down every spatial barrier to intercourse, i.e., to exchange, and conquer the whole earth for its market" (Marx 1973: 538), geographers have often depicted Capital (or the Law of Value) as operating sui generis, the un-moved mover behind the incessant unmaking and remaking of landscapes and spatial relations that characterize the geography of modernity (cf. Smith 2008; Moore 2015). While this work often recognizes the need for "state intervention" (Harvey 1982: 232, 282) in smoothing space for capitalist development and market extensification, the state itself remains a "black box" and its emergence reduced to a mere function for the accumulation of capital (Agnew 2012). As I propose here, attending to the role of the state's legal-regulatory apparatus in producing the spatial conditions for expanded capitalist production, particularly in its ability to facilitate the growth and development of energy resources, can reveal crucial yet under-examined dynamics of the capitalist production of space.

Therefore, in terms of methodology, this project has relied on close readings of Japanese laws related to the energy industry to analyze the geographical imaginaries and territorial ambitions of the Japanese policymaking apparatus. This is true especially for Chapter 2, which presents a linear historical narrative of laws and policies related to the electric power industry as they have been elaborated over the twentieth century with the rise of large-scale centralized power generation facilities. While Chapters 3 and 4 also rely on a close reading of laws, policies, and policy reports, these were also supplemented with field investigations to examine the geographic impacts of changing policies—especially those promoting renewable energy development—on the ground. During visits to Japan in the summers of 2016, 2017, and the year of 2018-2019, I also conducted 46 semi-structured interviews with a variety of Japanese citizens with both direct and indirect connections to the energy industry and energy policy. These interview participants included current and former regional public utility employees, owners of renewable energy businesses and retail power companies, anti-nuclear activists living near the restarted Genkai nuclear power plant in Saga prefecture, residents of areas impacted by the Fukushima nuclear disaster, five central government bureaucrats, and two executives from a major regional public utility (who agreed to the interview on conditions of anonymity). Although not all of these interviews and field site visits were drawn upon in my empirical arguments, they formed a critical basis of knowledge that informed my analysis and my sense of how Japan's energy system is transforming in the wake of 3.11. The field site visits in particular impressed upon me how rapidly solar panels were appearing in the Japanese countryside and made it exceedingly clear to me that the decisions made in deliberation council meetings in Tokyo have palpable socio-ecological ramifications far out in rural areas.

Outline of Chapters

Following this introduction, this dissertation consists of three empirical-analytical chapters and a concluding chapter. Each of the empirical chapters have been written as standalone research articles and thus each consists of its own particular set of theoretical questions and empirical data with which they seek to answer them. Although Chapter 2 has a much more historical focus than Chapters 3 and 4, it provides a critical background context for the changes to Japan's electric power policy since 2011, which are covered in greater detail in the latter two chapters.

Chapter 2 presents what I call a "geohistorical institutionalist" account of the development of state policy regarding the electric power system over the long twentieth century. In contrast to conventional depictions of the historical political economy of Japanese energy policy, which often ignore the socio-spatial implications of institutional decision-making, this chapter examines the role of energy policy production and implementation in re-organizing geopolitical economic relations across the territory of Japan over the long twentieth century. By reviewing primary sources related to the institutional history of Japanese electric power regulation, it seeks to trace how energy policy emerged as a discursive and material technology of power in conjunction with the growth of infrastructural networks for electric power production and distribution. Lefebvre's (1977) theory of the role of the state in the capitalist production of space is especially useful here, as it provides a theoretical basis for analyzing how state laws and regulations also revolutionize socio-spatial relations between rural zones of provision and urban zones of consumption within a given territory. The chapter traces the role of state policy in the organization of the electric power industry across four phases, each of which corresponded to deepening relations of uneven development between Japan's rapidly urbanizing and industrializing core and its rural areas. These relations of uneven development between

Japan's core and periphery formed the critical backdrop for the agitation for rural energy autonomy (自治, *jichi*) and greater distributed renewable energy production that emerged after the Fukushima nuclear disaster.

Chapter 3 begins with the Fukushima disaster and elaborates the sweeping changes to Japan's energy governance regime since then. It examines the role of recent reforms to Japan's "energy regime"—its predominant institutions governing the electric power sector—in stimulating fixed capital investments in solar photovoltaic (PV) systems. It then analyzes the investment trends and land use changes that are emerging after these reforms. Following the Fukushima disaster, the Japanese government passed a Feed-in Tariff (FIT) to incentivize renewable energy production, followed by the liberalization of the small-scale retail power market. By attending to the role of the METI's energy policy in generating the conditions for this massive renewable energy buildout, this chapter offers a corrective to recent geographical scholarship that argues that fixed capital investments in renewable energy might function as a "socioecological fix" for stagnating capital accumulation (McCarthy 2015). Analyzing Japan's electric power regulatory reforms through the lens of institutional political economy reveals a crucial limitation facing investors seeking renewed accumulation through a socioecological fix: METI, as the extra-economic agent charged with sustaining accumulation at the national scale, maintains the capacity to shape conditions of profitability in the electric power sector and thus retains the capacity to intervene in the market if the former monopoly utilities are imperiled in a way that undermines the overall security of the electric power system.

Additionally, this article offers a typology of investment patterns and land use changes that have resulted from the growing market in renewables. The guaranteed return on investment offered by the FIT has stimulated demand for space to site solar projects. This demand, coupled

with Japan's strict farmland protections, has led investors to pursue projects in novel configurations that challenge established geographic assumptions that the lower power density of solar PV will increase pressure for development in rural areas (Huber and McCarthy 2017). By bringing the insights of neo-Marxian state theory to bear on the political ecology of fixed infrastructure, this chapter contributes an empirical analysis of the political ecological dimensions of state action in governing renewable energy transitions.

Chapter 4 follows the impact of renewable energy on Japan's power grid by looking at attempts by Japan's former regional power monopolies to restrict access to the grid by renewable power producers, a phenomenon known as "grid curtailments". This chapter complicates the optimistic views of renewable energy advocates that increased renewables generation on its own will transform Japan's power system by looking at the types of hidden politics that inhere in fixed infrastructures like the electric power grid. Since the passage of Japan's FIT, a growing number of renewables advocates in Japan have claimed that distributed power generation offers the opportunity for rural, peripheral communities to transform Japan's power system and claim autonomy from their financial dependency of Japan's regional public utilities and central government subsidies. However, recent moves by the central government's Organization for Cross-regional Coordination of Transmission Operators (OCCTO), an organization housed within METI, to curtail solar PV generation on days with high sunlight and low demand reveals the persistent dependence of renewable power producers on the centrally managed electric power grid to remain financially viable. The material properties of the electric power grid, which require that power generation and power consumption—supply and demand—must be in constant balance, exerts a disciplining force on renewable power producers that cannot be undone by legislative action alone. As Langdon Winner (1980) pointed out long ago, artifacts

have politics and form a hidden, unremarked structural background that is far more material than the "structures" of theoretical Marxism. The "technostructure" of the capitalist state itself (Lefebvre 1977) is bound up with the grid, and state authorities can appeal to the material constraints of this infrastructure as a way to maintain the hegemony of monopoly capital.

The fifth and concluding chapter summarizes the major findings of dissertation and attempts to synthesize the insights on the relationship between energy policy, politics, and economy in modern capitalist societies that runs through the three empirical chapters preceding it. After reviewing the major findings of each chapter and how they speak to one another, it proceeds to lay out remaining questions regarding the political economy of energy transitions and potential research pathways that remain to be explored.

CHAPTER 2:

Territorial Metabolism:

Japanese Energy Policy and the Ecology of the Developmental State

Introduction

The production of energy is closely tied to that of political space, that is, state space.

- Henri Lefebvre (1977; 2004: 90)

If asked which resource was most decisive in the constitution of political power in the twentieth century, few would say electric power. While countless studies have been written about the centrality of oil to domestic and international politics, from Daniel Yergin's (1990) seminal depiction of oil as "the prize" sought by competing nation-states to Timothy Mitchell's (2011) examination of the tumultuous transition from oil to coal, very little has been written about the centrality of electric power to modern politics. Part of this may be due to what Jones (2016) calls the "petromyopia" of energy studies, given the Anglophone bias of much of the scholarship produced in this subfield. Yet it is also doubtless due to the fact that electric power is not readily categorized as a "natural resource," a designation reserved for more tangible materials like timber, coal, or ore. These latter more readily evoke the raw materials labeled "factors of production" by economists, which are only valuable insofar as they serve as feedstocks to industrial processes (Hanink 2000). Electric power, which relies on a technical process to convert natural resources into energy, would not appear to be a natural resource under this definition, nor would it seem "natural" at all.

Unlike so-called “natural resources”, which economists long have held to be “free gifts of nature” ready for the taking, electric power is both an input and an output of industrial processes. In this sense, the various energy feedstocks that serve as inputs to energy production classified by energy scholars as “primary energy sources,” whereas electric power—as the output of this production—is considered a “secondary energy source”. For this reason, nation-states that feature prominently in our popular geographical imaginaries as those endowed with abundant natural resources are precisely those with large stores of “primary resources”—think Nigeria or Saudi Arabia with their subterranean oil reserves, Canada with its timber and oil shale, or Russia with its natural gas. The hallmark of nation-states said to suffer from a “resource curse” (Ross 1999) is that they possess an over-abundance of primary resources without the tertiary resources—technology, capital, and expertise—required to make efficient use of them for achieving “take-off” to autonomous economic development.

Among modern nation-states, Japan has long been considered to suffer from a situation inverse to the resource curse: rather than over-abundance, Japan has a scarcity of the critical raw materials essential to sustaining a modern, industrial economy. This is particularly acute in terms of energy resources. Unlike the U.S., Japan claims no significant domestic reserves of oil and gas; its coal fields, particularly those in Hokkaido, central Kyushu and the Jōban region of Fukushima, produce coal of inferior quality for steel or electric power production; and there are no significant domestic uranium deposits, despite hopes in the 1950s for reserves in Ningyō Toge in Western Japan. Over the twentieth century, as Japan transitioned from a late-developing country with a primarily agricultural economy to an urban-industrial superpower with the second largest economy in the world, this “inverse resource curse” has rendered Japan overwhelmingly dependent on imports of critical natural resources for Japan’s industrial development. It has also

led the Japanese state to place a greater emphasis on electric power—its cost-efficient production and most efficient allocation to uses with the highest return—as the bedrock concern of its resource policy and strategies.

In contrast to the U.S. (Huber 2013a), one can argue that in Japan it has not been oil but rather electric power that has served as the indispensable "lifeblood" of the economy. Electricity is the invisible force that allows Japan's trains to run on time, that keeps the elevators moving and the lights on late in high-rise office buildings, that replaces labor in the home and powers the whole phantasmagoria of desire that characterizes the urban landscapes of Tokyo, Osaka, and other zones of the sprawling Tokkaido Megalopolis (Figure 2.1). Of course, there is no doubt

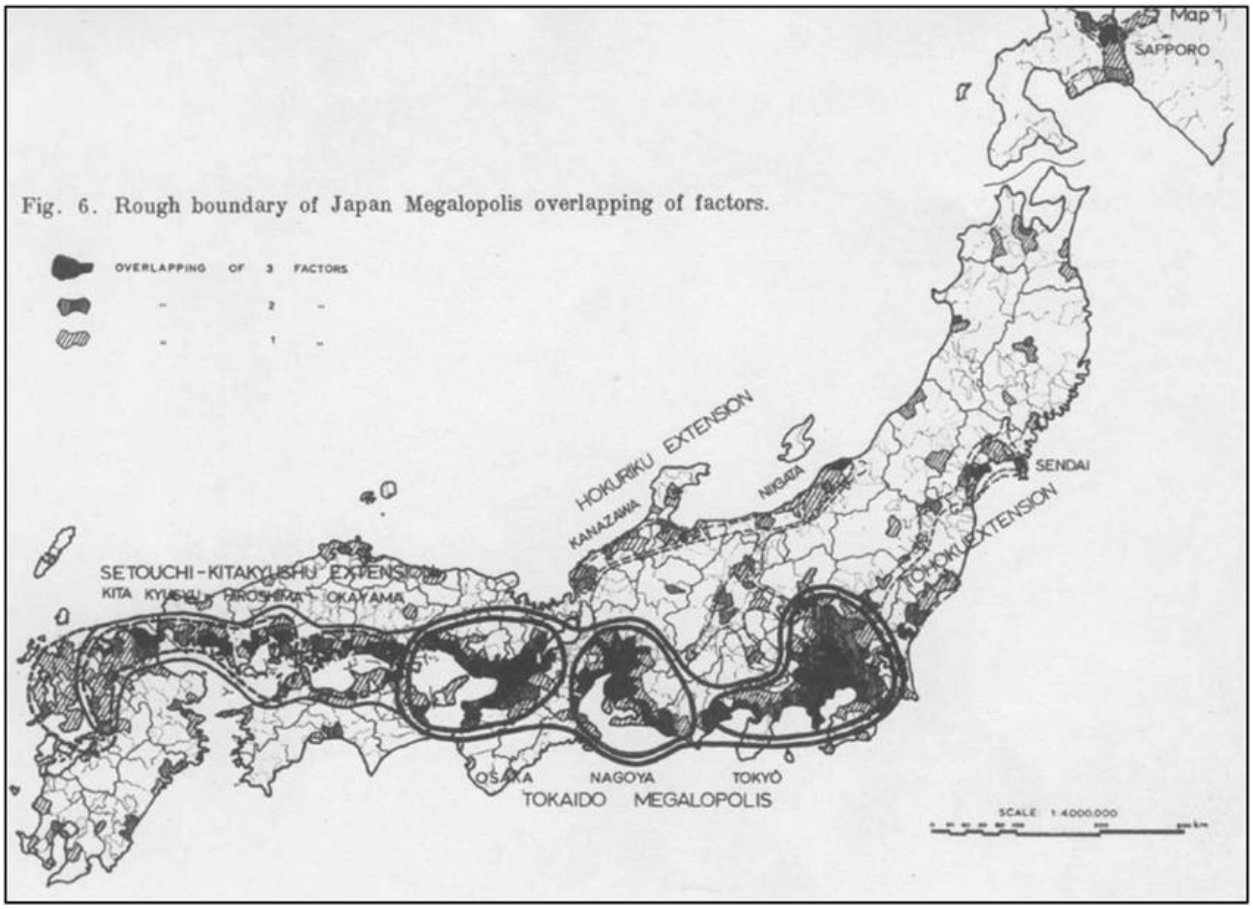

Figure 2.1: Japan's Tokkaido Megalopolis, which stretches from Tokyo in the east to Fukuoka in the West (Source: Doi 1968).

that maintaining access to fossil fuels from overseas has served as a major animus in Japanese government policy and planning over the twentieth century (Samuels 1987) and remains so today. Until the end of the Pacific War[2], fossil fuels were the primary concern for state officials seeking industrial and military supremacy in the struggle for global conquest among the Great Powers. After the war's end, the rapid adoption of automobiles within and beyond urban centers increased the demand for oil, as did the rise of the petrochemical industry and the transition of Japan's electric power generation fleet towards oil-fueled generation in the 1960s. This latter point, however, underscores that it has hardly been mere *possession* of oil that was the animating factor behind the resource security strategies of the Japanese government, but rather its ultimate use—which, as the twentieth century advanced, was significantly directed towards electric power production (Tsuru 1993: 152). Producing power, in turn, served simultaneously as *the* critical input to Japan's transition away from heavy industry to light consumer durables production (Toshi to Denka Kenkyūkai 2015) and as a major factor revolutionizing domestic spaces to incorporate the electric commodities that were the hallmark of Japan's postwar consumer revolution (Partner 1999).

This enterprise of obtaining resources on world markets and converting them into domestic productive power was, in essence, a metabolic relation, one that lay at the foundations of the startling year-on-year expansion of the Japanese economy in the 1950s and 1960s and its emergence as a "highly developed country" on the world stage. To be sure, this metabolic relation spanned beyond the networks of electric power lines; it crisscrossed the archipelago in a webwork of social and material infrastructures, running along new train lines and expressways, etching its way into the landscape as bulldozers flattened ex-urban hillsides for new housing

[2] I use the term "Pacific War" to denote the war between the U.S. and Japan that was waged from 1941-1945, which is the most commonly used term in Japanese to refer to World War II (*Taiheiyō Sensō*).

developments and cranes rose to fill Tokyo's skyline with glittering office towers and exclusive multi-story apartment buildings developers dubbed "mansions" (*manshion*). This metabolic relation also extended through the international ports that grew to fill what little coastline remained in dense conurbations like the Tokyo-Yokohama and Osaka-Kobe regions, which siphoned off large portions of the global ecological surplus to produce disposable goods for consumer-citizens and generate new wealth for Japan's multinational conglomerates (or *sogo-sosha*) (Dauvergne 1997).

Yet behind and beneath this tangled new geography of rapid economic growth lay the critical bedrock infrastructure of the electric power system. This power network formed a meso-scale geography, sandwiched between the macro-scale of global trade, finance, and banking and the micro-scale of the urban or rural region, that constituted an intimate, though hardly visible, linkage between the Japan's cities and its rural periphery. This invisible linkage between urban core and rural hinterland has defined what I term the "territorial metabolism" of the modern Japanese economy for more than half a century. With the rise of electric power's centrality to the postwar (and post-Imperial) Japanese political economy came a whole host of state-led interventions into the territory (国土, *kokudo*, or "national land") of the Japanese archipelago to produce this power. The perceived need for these interventions—particularly the need to secure cheap, stable supplies of baseload electric power generation to fuel Japan's postwar economic reconstruction—gave rise to new modes of territorial knowledge production, new mechanisms for surveying and inventorying the productive capacity of Japanese landscapes, and new legal mechanisms for rigidifying financial and infrastructural inter-dependencies between the power-producing core and the power-consuming periphery. Domestic energy policy, which pertained particularly to increasing the scale of electric power production by developing Japan's latent

"electric power resources" (電源, *dengen*), gave rise to a new territorial logic to Japanese governmental policy. This new territorial logic was a constitutive element in the evolution of a state-form that was to ascend to prominence among many resource-scarce, late-developing economies in East and Southeast Asia—the developmental state.

The connection between the need for state administrators to produce the conditions for economic growth in a context of national resource scarcity and the emergence of capacities termed "developmental" is a relatively unexamined dynamic in literature on the developmental state. Beginning with early literature on this topic (Johnson 1982), the focus has often centered on industrial or financial policy, with comparatively less attention devoted to the socio-natural context in which these capacities emerged. While a resource-rich state like the federal government of the United States did acquire some developmental characteristics at certain points in history, such as the Tennessee Valley Authority (TVA), these developmental projects were piecemeal, short-lived, and hotly contested. The overall trajectory of government policy towards land and resource development was laissez-faire, as resource abundance permitted relatively haphazard and uncoordinated development. In resource-scarce nations like Japan, however, the need to achieve a delicate balance between limited domestic resources and the demands of industry, especially in the context of military defeat after the Pacific War, provided a context in which developmental capacities could flourish. In the absence of a massive pool of domestic resources, private industry not only tolerated, but at times openly supported, the use of more overtly interventionist state approaches to economic and resource development. As the case of electric power shows, state policy gradually emerged as a necessary ingredient to ensure stable, coordinated development of technological resources that would serve as the basis of economic growth.

This chapter presents a historical-institutional mapping of how these relationships of power within Japan between the power-consuming core and the power-producing periphery developed over the long twentieth century and how they coalesced into the territorial strategies of the developmental state. In so doing, it seeks to answer the following questions: how did energy policy emerge as a primary locus of governmental practice for the Japanese state over the long-twentieth century? And how did the inventorying and development of what Japanese bureaucrats and planners called "electric power resources" (電源, *dengen*) transform geopolitical economic relations between urban areas and rural regions in the Japanese archipelago?

Rather than presume "energy policy" to be a pre-existing domain of strategic interest that merely needed to be discovered by government bureaucrats, this inquiry is grounded in the Foucauldian insight that new modes of administrative knowledge production (or "policy") actively constitute new domains of governmental intervention—that is, the practice of policymaking simultaneously constitutes both its object of interest—"energy resources"—and its instrument—the interventionist, developmental state. Tracing the emergence and evolution of these forms of administrative knowledge production and their geo-material impacts (or "knowledge/power" in Foucauldian parlance) requires an approach that is attuned to both institutional change over time and its elaboration over space. To do this, this chapter takes an approach to geopolitical economy that might be characterized as "geohistorical institutionalism" to chart the development of law and policy related to energy and electric power and the impact these developments had on urban-rural relations in Japan.

The chapter begins by briefly introducing the theoretical and methodological underpinnings of this inquiry. It builds on insights from Lefebvre's (1977) theories of state space to show how attending to the legal-policy productions of the administrative state can enrich our

understandings of the production of space in the capitalist mode of production over the longue durée. The next sections then examine four major phases of the emergence energy policy and electric power regulation in Japan, beginning with the earliest regulation in the 1890s and proceeding to the ministerial reorganization of the Japanese government in 2001. Through a close reading of Japanese archival and secondary sources, I present a longue dureé overview of how particular ministries of the Japanese state gradually developed spatial strategies for facilitating the development of electric power resources (*dengen*) in the form of hydroelectric dams and nuclear power, which reified relations of financial dependency between the urban core and rural periphery. Finally, the chapter concludes with a review of the spatial outcomes of this form of territorial development, particularly the growing disparity between rural zones of power provision and urban zones of consumption. I also offer brief reflections on how, following the 2011 Fukushima nuclear disaster, the rise of renewable and decentralized forms of electric power production may present challenges to this pre-dominant territorial metabolism of electric power production, themes which are taken up at greater length in Chapter 3.

Energy Policy and the Production of State Space

Henri Lefebvre's late writings on the topic of the state and its role in the production of space offer useful general theories for conceptualizing how domestic energy policies in the postwar period generated new social metabolisms at the territorial scale. Lefebvre's (1977) core insight—which constituted a heterodox challenge to the prevailing economism of Marxist political economy at the time—was that capitalism had become so entangled with the planning and regulatory functions of the modern state that this economic form was more accurately described as a "state mode of production," or SMP. For Lefebvre, the need for capitalist

production to constantly revolutionize the spatial organization of economic activities—which spanned a variety of scales, from the household, the city, to the region and the globe—generated more than just the social contradictions (such as between capital and labor) examined in Marxist thought. Rather, the need to introduce capitalist social relations and practices into new spheres also generated the *spatial contradictions* of uneven development, as the accumulation of capital in rapidly urbanizing areas outpaced development in rural areas. In its ability to mold a spatially disparate citizenry into a political community unified by ideology and a common territorial imagination, the state provided an indispensable support to a process of modernization that might otherwise lead to the breakdown of social bonds, potentially undermining general social consent towards capitalism:

> The state provides the *relations* (that is, the social relations of production) with a calibrated spatial *support*; it clashes with the pre-existent economic space that it encounters – spontaneous poles of growth, historic towns, commercialized fragments of space that are sold in "lots." It tends to renew not only the social relations inherent in industrial production, but also the relations of domination inherent in the hierarchy of groups and places… The economy is thus recast in spatial terms—flows (of energy, raw materials, labor power, finished goods, trade patterns, etc.) and stocks (of gold and capital, investments, machines, technologies, stable clusters of various jobs, etc.). The state tends to control flows and stocks by ensuring their coordination (Brenner et. al. 2003: 85, emphasis in original).

In addition to the state's ability to provide an ideological gloss of common purpose to a system built on social relations of unlimited competition between atomized individuals and firms, Lefebvre's quote also points to the *coordinating* role of the state in securing the supply of resources—"flows" and "stocks"—for market actors. Especially pronounced in the early postwar decades, this coordinating function required the state not merely to intervene in times of crisis, but rather "incessantly, by means of diverse organizations and institutions devoted to the management and production of space" (Ibid: 86). By bringing space into the realm of social

production, Lefebvre sought to denaturalize common perceptions of state administrative labor. While state bureaucrats might appear "to administer, to manage and to organize a *natural space*," in truth "they *substitute* another space for it," a space that is simultaneously rendered both homogenous (as one parcel of land can be exchanged for another) and fragmented (as each place is assigned a particular role in a hierarchized "division of labor within a territory") (Ibid: 87; 84).

For Lefebvre, the production of state space proceeded most plainly through the construction of large-scale infrastructures. Although he never stated so explicitly, his writings are full of references to the large-scale socio-technical networks that both provide a circulatory system to capitalism and make up the fabric of everyday life in the modern world—"roads, canals, railroads, commercial and financial circuits, motorways and air routes, etc." (Ibid: 84)—what architectural theorist Keller Easterling (2014) has recently termed "infrastructure space". The involvement of the state in these ventures was necessary because of the observational and organizational capacities of the state, which allowed it to oversee "the management of space 'on a grand scale'" (Lefebvre 1977: 90). Energy production, too, offered a potent example of the role of the state in producing space, as it depended upon the "surveillance" of technicians to coordinate the flow of energy (he specifies electricity and oil) across vast distances and between disparate places. Moreover, the production of energy facilitated the expansion of other infrastructure networks that characterized the "dominant space" of modernity, a space "demarcated by motorways, canals, and railroads" (Ibid.).

Left unexamined in his mostly conjectural remarks about the role of the state in the production of space, and its deep entanglements in the development of capitalism, is precisely how—through what mechanisms—the state developed "the techniques permitting the management of space on a large scale" (Ibid.). How did its "technostructure" lay claim to

"energy questions" as an operating logic, and what types of space did this produce? Lefebvre's discussion of *the* state should not be taken to speak to all states in all places and times, but rather to a particular state form that Galbraith (1967) called the "new industrial state" (Galbraith also coined the term "technostructure" that Lefebvre deploys to describe the state's planning apparatus). As Galbraith argued, two decades after the end of the Second World War, the growth of monopoly capital and the development of increasingly sophisticated large-scale technological systems had brought about a new fusion of the state's planning apparatus and the coordination needs of large-scale industrial sectors. While Lefebvre seemed to draw his characterizations of this new state form from the postwar French state and its policies of economic coordination, or *dirigisme*, and nuclear power production (Brenner and Elden 2009), similar tendencies towards a top-down spatial coordination of economic activities by state officials could be witnessed in East Asia. Japan in particular fostered the emergence of an interventionist state form later termed the "developmental state" by Anglophone scholars (Johnson 1982), as economic planners in various state bureaucracies sought to use industrial policy to guide Japan along a path towards import-led growth and rapid industrialization following military defeat (O'Bryan 2009).

In the remaining sections below, I detail how as the Japanese state acquired an increasing array of calculative and spatial planning tools for electric power development over the twentieth century that one might term "developmental", it also acquired a capacity to productively intervene in socio-spatial relations. In fact, the two were inseparable—the production of power for economic development entailed the production of space. Through their electric power development policies and comprehensive development plans of the postwar period, economists and planners at the Ministry of International Trade and Industry (MITI, or *tsusanshō*) played an outsized role in shaping the production of space and generating successive revolutions of socio-

ecological metabolisms at the territorial scale, between Japan's urban core (*chūō*) and rural periphery (*chihō*). By tracing the emergence of these laws, policies, plans, and regulations and their influence on the organization of the Japanese electric power industry, I attempt to demonstrate both how territorial planning emerged as a core logic of Japanese policy and the constitutive role it played in producing the Japan's territorial metabolism.

The Geopolitical Economy of Electric Power Development in Japan

Part I: The Character of the Japanese Bureaucracy

To understand the role of state policies in shaping socio-ecological metabolisms in Japan, it is important to first understand the peculiarities of Japanese political institutions, which grant significantly more decision-making authority to the bureaucracy than Western legal traditions. In contrast to the U.S. and the U.K., which feature common law traditions, during the Meiji period (1868-1912) the Japanese government developed a civil law tradition influenced by French and especially German legal systems (Pyle 1974). This legal framework gave government bureaucrats (not legislators or the courts) an outsize influence in determining the content of legislation and the specific methods of its implementation. It also contributed to a general, society-wide attitude against the litigiousness so prevalent in common law traditions, as law was generally viewed as "an instrument of constraint that the State uses when it wishes to impose its will" (Noda 1976, cited in Oda 2009: 3). Prewar bureaucrats were not regarded as "civil servants" in thrall to the shifting demands of public opinion, but rather "officials of the Emperor" (*tennō no kanri*) whose power derived from intrinsic, rather than extrinsic, authority (Johnson 1982: 38). Despite successive pressures to democratize Japan, which included the brief period known as "Taisho Democracy" (1912-1926) and later intensive efforts to re-design Japanese

government by U.S. technocrats during the postwar Occupation of Japan (1945-1952), the hold of Japan's bureaucrats on governing power proved strikingly resilient over the twentieth century. This has resulted in a political system characterized by what one observer described as "administration through law" rather than "rule of law" (Isomura and Kuronomura, 1974: 18).

Parallel to this centralization of ruling authority within the bureaucracy, the central government also exerted overwhelming authority over local governing authorities at the sub-national level, including prefectures (県,*ken*) (akin to U.S. states or French *départements*), counties (郡, *gun*), and municipalities (市町村, *shi-chō-son*, literally "cities, towns, and villages") (Figure 2.2). Until the passage of the Local Autonomy Act (*chihō jichi hō*) of 1947, prefectural governors were appointed by the Home Ministry and dispatched from Tokyo to govern areas to which they often had no prior personal connection. The governor was in charge of the prefectural office, which was "staffed by an extensive bureaucracy supported by powerful new national laws" (Lewis 2000: 107). This governor served as a centrally appointed bulwark against popular demands for public participation and reserved the right to *not* enact legislation even if it was passed by the prefectural assembly (Ibid: 109). Even after the democratization of this institution during the U.S. Occupation, localities remained politically subordinate to the center in part due to financial reasons, a condition Kenichi Miyamoto (2005) described as "san-wari jichi" or "thirty percent autonomy". This percentage refers to the annual transfers of wealth from the central government to localities, which comprise on average seventy percent of local government budgets. According to Onitsuka (2012:2), "it is through this budget transfer that central government controls local governments, and local governments court the patronage of central government."

Figure 2.2: The Prefectures and Regions of Japan (Source: www.worldatlas.com).

In terms of energy policy, these dynamics have contributed to an overwhelming capacity for central government bureaucrats to undertake unilateral policymaking that had far-reaching socio-ecological implications for Japan's rural regions. Through the close of the twentieth century, while other advanced industrial societies were transitioning away from "spatial Keynesianism" towards more neoliberal models of territorial governance (Brenner 2004), Japan's bureaucrats maintained a pronounced capacity for independent legislative and planning action, largely insulated from challenges from private industry, legislators in the Diet, popular political movements, or local resistance. As Yoshioka Hitoshi (2011) argues in his seminal

history of Japanese nuclear power policy, Japan's system of unilateral policy design and deployment can be described as a "State Policy Complex" (*kokusaku kyōdōtai*), which bears similarities to the "military-industrial complex" used to describe the U.S. political system. In this complex, real control over the policy-making process resides with the "administrative organization" (*gyōsei kikan*); the legislature is often overruled by administrative agencies and lacks the ability to make independent decisions (Yoshioka 2011: 23-24). Rather than drawing their directives from the Prime Minister's office (the nominal executive authority in Japan's parliamentary system), the various central government ministries set policy priorities that later receive authorization from the Prime Minister. Paid favors (*dangō*) from inside bidders in private industry are common and play a role in determining which projects find legislative backing from the ministries and which founder (Woodall 1993). Critics of central government policies, including intellectuals and experts, are usually silenced by being excluded from what few venues remain for public participation in the policy-making process, like deliberation committees (*shingikai*). Once an administrative agency secures funding or incentive measures for a particular project as an objective of "national policy" or "state policy" (国策, *kokusaku*), these projects are exceptionally difficult to halt or reverse mid-stream.[3] Instead, the agencies lobby tirelessly to obtain local "understanding" (*rikai*) and "consent" (*gōi*) (two terms that Yoshioka attests are peculiar to Japanese public administration-speak), which local populations have very little political or financial leverage to resist (Yoshioka 2011: 27).

[3] The term "kokusaku" can be translated a number of ways given the multiple possible translations of the root term "koku" or "kuni" (国). In other parts of this dissertation, the term is translated as "national policy," but "koku" can also be translated as "state" or "government". The Japanese government is often colloquially referred to as "kuni," which has the same character (国). Throughout this chapter I translate "kokusaku" as "state policy" because it signals the top-down and centralized character of these types of policy decisions. In other instances where English-language translations are well established in existing scholarship, I use the more generic term, "national policy," as in "National Policy Research Association" (*kokusaku kenkyūkai*) and "national policy corporation" (*kokusaku kaisha)*.

Yet while the blueprint for the unilateral power of the bureaucracy over "state policy" (*kokusaku*) was entrenched in the design of political institutions after the Meiji Restoration, their entanglement with energy policy was not pre-given, but emerged over decades with the increasingly complex elaboration of electric power networks. For purposes of analysis, we can breakdown Japanese power regulation over the twentieth century into four phases. This project of periodization is inherently a fraught enterprise, for by imposing a temporal framework it risks suggesting that the transitions between historical phases was abrupt and definitive, rather than characterized by both continuity and divergence. My use of periodization is therefore as an analytical tool to try to pinpoint some of the major conjunctures and to help make sense of processes that are far more complex both historically and geographically. The earliest phase was from 1891-1931, when jurisdiction for electric power regulation was granted to the Ministry of Communications (逓信省, *Teishin-shō*). The second was from 1931-1951, when excessive competition and consolidation in the industry resulted in the emergence of 5 large electric power companies, followed by wartime nationalization of the industry under Prime Minister Konoe Fumimaro in 1938. The third period, 1952-1973, began with the reorganization of the electric power industry (電力業再編成, *denryoku-gyō saihensei*) by the postwar U.S. Occupation, a period that saw the most rapid growth of power output before the Oil Crisis. The fourth phase, which followed the 1973 Oil Crisis, featured growing state emphasis on nuclear power production and ended with the restructuring of government ministries in 2001 (中央省庁再編, *Chūō shōchō saihen*). The following sections examine in detail how increasingly complex power production and distribution networks called forth new developmental capacities in the Japanese state across these four phases.

Part II: 1891-1931: Early Electric Power Policy Under the Prewar Ministry of Communications

Despite its late beginnings on the path to modernization, Japan was an early adopter of electricity. The first notable public use of electric power came only ten years after the Meiji Restoration, on March 25, 1878, when a French-made arc light illuminated the opening ceremony for the Central Telegraph Bureau, a date which was later commemorated and celebrated annually as "Electric Power Day" (Figure 2.3). The first recorded generation of power for consumer use in Japan came in 1887, only five years and ten months after the world's first power plant for consumer use started operating in London (Kikkawa 2012: 4). The newly

Figure 2.3: Tokyo residents gather to see the first public demonstration of arc lighting in the Ginza District, 1882 (Source: https://mainichi.jp/articles/20160923/k00/00e/040/233000c).

incorporated Tokyo Electric Lighting Company (*Tōkyō Dentō*) used an Edison Electric-made thermal power plant to generate DC power for use at the Japan Mail Shipping Line (*Nippon Yūsen Gaisha*) and the Tokyo Central Post Office (Takeno 2015). From 1888 to 1891, electric service arrived in other Japanese cities, including Kobe, Kyoto, Osaka, Nagoya, Yokohama,

Kumamoto, and Sapporo, using small thermal generators that had a limited geographic reach. Power was also generated and transmitted to industrial installations in rural areas like Fukushima prefecture, where in 1890 Koriyama Textile Company generated 300 kilowatts (kW) at Inawashiro Lake and sent it 24 kilometers over an eleven kilovolt (kV) transmission line to its textile mills in Koriyama City. But in its early years, locally generated thermal power predominated in Japan's power supply, as the concentration of consumers on urban blocks made it easier to achieve returns on investment and long-distance transmission was not yet technically feasible. By 1891, just 13 years from the first recorded instance of electric power generation, 11 electric lighting companies and 26,237 electric lightbulbs were recorded in the country (Takeno 2015: 827).

Given the rapid growth of the industry, the Meiji state issued its first electric power regulations soon after the creation of cabinet ministries in 1885. Jurisdiction over the industry was vested in the Ministry of Communications (or Telegraphs, 逓信省, *Teishin-shō*), which had been newly created to regulate posts, telegraphs, electric power, and other communications and transit networks. The Electric Enterprise Regulations (電気営業取締規則, *Denki Eigyō Torishimari Kisoku*), ratified in 1891, were passed in response to a fire at the new Imperial Diet's temporary lecture hall (*kari-gijidō*), which was attributed to an electrical short circuit. The new regulations established the first national standards to ensure the safety of DC power systems and prevent fires (Kimura 2018: 14). The Ministry of Communications was also in charge of the Denki Shikenjō, Electro-Technical Laboratory, which also undertook research & development projects for new industrial applications of electric power (Morris-Suzuki 1994: 82).

New developments in power generation and transmission technology following the Russo-Japanese War (1904-1905) initiated far-reaching transformations of Japan's power system

and called forth new planning powers from the state. As Kokaze (1980: 486) argues, after the war the Ministry of Communications transitioned from administrative measures to regulate technologies (*gijutsu torishimari-teki hōan gyōsei*) to one of genuine industrial administration (*honkaku-teki sangyō gyōsei*) of the type practiced by MITI after the war. The period from 1883 to 1906 was characterized by enterprise-led development, as entrepreneurs sought to develop small-scale thermal power plants with some hydropower dams thrown into the mix (Kikkawa 2012). The expansion of hydropower dams during the war, however, significantly reduced the price of electric power, as dams had near zero marginal costs (like fuel inputs) and round-the-clock power production cheapened power rates during periods with low overall electricity demand. Government and business elites were quick to realize the promise cheap hydropower held for the success of Japanese commodities on international markets. In 1906, Mitsubishi Bank President Hatano Shōgorō celebrated the new technology, as it would "make power abundant, lower costs, advance the development of mechanized industry, reduce the need for labor power, and reduce the overall costs of production" (quoted in Kokaze 1980: 488). The completion in 1907 of Tokyo Electric Lighting's 15,000kW Komahashi Power Plant in Yamanashi Prefecture, which delivered power along 76 kilometers of transmission lines from the mountainous region to the capital, initiated a new phase of hydropower development when long-distance high-voltage transmission was now feasible (Kikkawa 2012: 7). In 1914, this was succeeded by a new record for long-distance transmission when power was sent along 227 kilometers of high-voltage transmission from a hydroelectric power plant at Lake Inawashiro in Fukushima to Tokyo (Nishino 2014: 303). By 1911, hydroelectric power exceeded thermal power generation for the first time in Japan's history and maintained this predominance until the 1960s (Kokaze 1980: 489).

Gotō Shinpei, who served as Minister of Communications from 1908-1911 in the second Cabinet of Prime Minister Katsura, was an early proponent and architect of government regulation of the burgeoning hydropower industry. In his writings on hydropower policy, Gotō called for the state to "guide (*yūdō*) the development of electric power industry from the perspective of the national economy" (Kokaze 1980: 490). To mitigate the potential for haphazard or uneconomic development of Japan's river basins by private firms, Gotō called for state-funded surveys of every river basin throughout the territory of Japan (*naichi*) that was potentially suitable for hydropower development. In 1910, at the cost of 1.5 million yen, the government ratified a plan to conduct hydropower surveys over five years, which would measure the slope, average rainfall, average water levels and water volumes across these river basins. Although these surveys were a significant boon to private industry, they also signaled a growing state interest in overseeing the development and management of the power industry for purposes of national economic development.

In 1911, the first Electric Power Industry Law (*Denki Jigyō Hō*) was passed, the most major piece of legislation of the prewar period. The law signified state recognition of electricity's growing importance as an essential public good for economic and social life in Japan's rapidly urbanizing society. It moved beyond the technical standards of the earlier regulations to create provisions for government oversight of the management and operation of electric power companies. In addition to the hydropower survey provisions and the right to settle power line right-of-way disputes, the law granted the government the right to regulate power rates to ensure that electricity was provided in a way that enhanced the public good (Kokaze 1980: 494).

The period from World War I through the 1920s saw a major acceleration of these trends towards growing urban power consumption and was facilitated by the growing use of long-distance high-voltage power transmission. While private industry was mostly responsible for the development of hydropower dams in distant, rural river basins, the state at this time worked as the handmaiden of capital, in a sense smoothing space for private development by facilitating flows of more accurate information (in the form of hydrological surveys) and helping to settle disputes with local residents who resisted the siting of long-distance transmission lines. In fact, the large-scale production of hydropower only became economical once transmission technology had reached a stage where it could reliably transmit that power to distant urban centers with minimal efficiency losses. Through this enrollment of distant river basin ecologies into systems of urban power provision, private firms that combined engineering expertise and managerial prowess were able to grow into some of the biggest *non*-zaibatsu corporations of the prewar period. By the end of the 1920s, the growing dominance of large firms able to marshal the capital and resources for developing hydropower dams led to a wave of mergers and consolidation in the industry, known as the "Electric Power War," until five electric power companies came to dominate the market—Tokyo Electric Lighting, Toho Electric Power, Ujigawa Electricity, Daido Electric Power, and Nippon Electric Power (Kikkawa 2012).

Part III: 1931-1951: Wartime Controls and the Birth of National Power Policy

The era of market competition between the five major electric power firms came to a close in 1932 with the founding of the Federation of Electric Power Companies (FERC) in April and the enactment of the revised Electric Power Industry Law, which established supply area monopolies (Kikkawa 2012: 12). This period also saw growing calls by technocrats and planners

in the Japanese state to nationalize the industry as part of a project to rationalize production the sake of national defense. The 1930s and 1940s marked the high tide of Japanese technocratic planning and paralleled trends in the U.S., the U.S.S.R., and continental Europe towards greater state intervention into everyday life and the organization of agrarian and industrial production that James Scott (1998) called "authoritarian high modernism" (Garon 1997; Mimura 2011). Beginning in the late 1920s, technocrats in the Japanese state noted the characteristics of ruinous competition that seemed to prevail among the electric power firms, which undermined the ability of the industry to effectively respond to the ebbs and flows of power demand. This volatility led to initiatives by Ministry of Communications bureaucrats for public rather than private management of the industry, as state control of the industry would better align with electric power's status as an essential public good (Sataka 2011: 41). The wartime period also marked the beginnings of a recognition by state authorities that electric power was essential for the security and viability of the Japanese economy, and thus the state deepened its involvement in surveying river basins that had good prospects for development as "electric power resources" (電気資源, *denki shigen,* which in the postwar era would be commonly abbreviated as "power sources," 電源, or *dengen*).

An early development in the Japanese state's growing attention to resource adequacy policies came in 1927 with the creation of the Resources Bureau. The Resources Bureau sponsored the Resources Survey Law (*Shigen Chōsa Hō*), which required private enterprises to report on their financial and productive capabilities to central government (Johnson 1982: 118). The work by the Resources Bureau was a pioneering development towards the later materials mobilization plans of the wartime era and created much of the administrative capacity for both devising and implementing resource management policies by civilian technocrats in the Japanese

Imperial state. While the Bureau's policies and reports never obtained the status of law, according to Mimura (2011: 20), in its work the Bureau "set a precedent for policymaking by which economic planning was undertaken almost exclusively by technocrats and then forced on the Diet for approval in the form of mobilization laws."

As the scale and technical complexity of economic activities increased over the 1930s, particularly as the Japanese Imperial Army became more embroiled in conflicts and state-building projects in its Imperial holdings in Manchuria, there were growing calls for the technocratic management of Japan's domestic and international affairs. As described by Mimura (2011: 13-14), prominent wartime technocrats known as "reform bureaucrats" (*kakushin kanryō*) sought to use the instruments of the state—"the military, bureaucracy, police, and courts"—to challenge "the prerogatives of capitalists by assuming increased control over the access to and distribution of the means of production." Groups like the National Policy Research Association (*kokusaku kenkyūkai*) advocated for the technocratic planning of a wide sphere of economic and social arenas. Central to all of this was their use of law, or "state policy" (*kokusaku*), which codified plans and granted them authority over individuals, private firms, and local governments. As the above quotes from Yoshioka (2011) demonstrate, the term "kokusaku" would have far reaching implications well into the postwar period for the state's ability to enforce its planning goals for developing electric power plants.

A major watershed in the regulation of the electric power industry occurred in 1938, when the State Management of Electric Power Law (電力国家管理法, *Denryoku Kokka Kanri Hō*) was passed by the Imperial Diet, which nationalized the electric power industry (Sataka 2011: 62). This law was passed along with the National General Mobilization Law (国家総動員法, *Kokka Sōdōin Hō*), which ratified the wholesale restructuring of the Japanese economy by

the state to place the nation on a wartime footing. At the time, despite all of the consolidation the industry had seen during the "Electric Power Wars," 731 different power companies still operated in Japan—610 of which were privately owned, and 121 of which were publicly owned, usually at the prefectural or municipal level (Nishino 2014: 306). On the basis of this law, the assets of these 731 electric power firms were absorbed by the newly created national policy corporation, Nippon Hassōden (the Japan Electric Generation and Transmission Company, or Hassōden), which was created by the Ministry of Communications to manage the development and deployment of power generation and transmission infrastructure. By April 1941, Hassōden had control of all major electric power generation and transmission facilities in the country. For distribution, the government established nine regional electric power distribution companies (配電, or Haiden) in 1942, which were granted monopolies over retail power sales and were allowed to operate semi-privately in nine regions of Japan: Hokkaido, Tohoku, Kanto, Chubu, Hokuriku, Kansai, Chugoku, Shikoku, and Kyushu (Okamoto 2017: 185). As a state-owned corporation, Hassōden was beholden to centralized directives by bureaucrats in Tokyo, while the Haidens were able to operate partially autonomously with their own regional managers (many of whom were taken from the five big private companies that preceded them), ensuring stable, reliable power distribution to end-use customers.

This organizational arrangement realized the designs of Okumura Kiwao, a Ministry of Communications bureaucrat and architect of the control law. It embodied the principle of what he termed "private ownership, public management" (*minyū-kokuei*) in an early draft of the law in 1935 (Mimura 2011: 119). Okumura's views were later articulated in a report issued by the Cabinet Research Bureau (内閣調査局, *Naikaku Chōsa Kyoku*), which argued that state management of electric power was critical to "overseeing the enactment of plans to develop

Japan's undeveloped electric power resources with the utmost efficiency" (*mikaihatsu denki shigen no saikō nōritsuteki kaihatsu keikaku no shikō wo tanto*) (Denryokuchō 1942: 14). With the unified development planning provided by the state, "electric power resources will be developed economically and power will be distributed rationally throughout the national transmission network, aligning the overall demand in all areas with generation in all areas and allowing for the balancing of supply and demand, which will ensure the complete use of installed infrastructure" (*denki shigen no keizaiteki kaihatsu to gōriteki naru sōdenmō ni yoru zenkokuteki kyūden soshiki toni yori, kakuchi no juyō wo sōgō shi kakuchi no hatsuden wo gōsei shi, motte juyō to kyōkyū to no kinkō wo tokushime, setsubi no kanzen naru riyō wo ki suru*) (Ibid.) The ultimate aim of the nationalization law was to supply power at the cheapest possible cost by making "effective use of hydropower sites and the rational and economic development of national resources with the utmost efficiency" (*suiryoku hatsuden chiten no yūkō riyō ni yoru gōriteki oyobi keizaiteki ni yori kokka shigen no saikō nōritsu hakki*) (Ibid.). During its period of operation 1939-1951, Hassōden surveyed several domestic river basins for hydropower development, focusing particularly on areas that were too remote or technologically challenging for privately operated firms to develop with their limited capital and resources.

In the wartime period, conducting surveys for hydropower development assumed a new territorial logic, informed by a growing ambition for state-led comprehensive territorial planning (国土計画, *kokudo keikaku*, or "national land planning") that was overtaking Japan's technocratic elite. Okumura, the architect of the 1938 electric power nationalization law, was also a founding member of the Total War Research Institute, a research and training institute created in 1940 to create national plans. This type of planning "sought to determine the most efficient distribution of the various facilities of the economy, population, culture, and society in

order to promote the comprehensive development, use, and preservation of the native land in accordance with the state's goal" (Mimura 2011: 192). Among the many domains listed by reform bureaucrats in the Cabinet Planning Board in their "Outline for the Establishment of National Land Planning" (*kokudo keikaku settei yōkō*) was "comprehensive power planning (including fuels)" (*sōgō-teki dōryoku keikaku)* (Okubo 1986: 169-172). By taking electric power resource planning (especially the planning of dams on Japan's river basins) under its domain, Hassōden was fulfilling a major goal of territorial planning. While resource and labor shortages prevented Hassōden from completing its ambitious dam projects during the war, its river basin surveys would serve as blueprints for the most iconic large-scale dam projects of the postwar period.

Part IV: 1951 – 1973: Postwar Dam Development and the Energy Revolution

By the end of the Pacific War on August 1945, the major institutional architecture for the state-led development of electric power resources across the Japanese archipelago had been put in place. Despite the efforts by U.S. Occupation administrators to democratize Japanese political institutions, postwar historians have argued that the decade of the 1940s is characterized by continuity rather than rupture. Johnson (1982: 195), for instance, argued for viewing the 1940s as "one continuous era: the period of the high tide of state control." With the forced disbanding of Japan's military and the breakup of its massive industrial and banking cartels (*zaibatsu*) by Occupation authorities in the Supreme Command for Allied Powers (SCAP), many reform bureaucrats that presided over the controversial wartime control legislation could now operate relatively unimpeded by external institutional constraints. Noguchi (1995), too, later argued that the institutions that would see Japan's economy achieve double-digit growth rates in the late

1950s and 1960s should be viewed as the "1940 System." His thesis challenged the prevailing idea of the "1955 system," which political analysts typically pinpointed as the critical year for Japan's postwar political evolution, when major conservative political forces merged to form the Liberal Democratic Party (LDP). For Noguchi, the 1940s were a far more critical decade, as several institutions of technocratic oversight and economic planning developed during the wartime era would not only persist but obtain greater intransigence after the war.

Evidence for this view of institutional continuity can be gleaned from the early postwar policy directives issued by bureaucrats in the newly pacified Japanese state. Woven into these plans were concerns with resource and land limitations in a country with a population approaching 80 million, which now repatriate millions of soldiers and emigrants returning from its former colonial holdings in Taiwan, Korea, and Manchuria. In September 1945, the National Land Bureau issued its Basic Principles for National Land Planning (*kokudo keikaku kihon hōshin*), which essentially modified the imperatives of wartime territorial planning to fit the needs of peacetime: housing development, population re-distribution, and urban reconstruction (Dinmore 2013: 20). The Economic Stabilization Board (*Keizai Antei Honbu*, or ESB), formed in August 1946, was a successor to the wartime Cabinet Planning Board and immediately set about drawing up Priority Production Policies for various industries it deemed essential to Japan's economic reconstruction, primarily steel, coal, fertilizer, and electric power. As Hein (1990: 120) writes, the ESB's work "drew on the extensive allocative and rationing powers that the state had acquired during the war, although it was based legally on the Temporary Materials Supply and Demand Control Law (*Rinji Busshi Jukyū Chōsei Hō*) of 30 September 1946."

Viewed in terms of continuity rather than rupture, electric power development of the immediate postwar decades maintained the trend towards greater state oversight of the

development of electric power resources. State planning of electric power development was further enhanced by new technologies and financing opportunities from the U.S. and a much more refined territorial planning apparatus. In June 1950, Japanese industry began a rapid rebound with the start of the Korean War and the "special procurements" contracts from the U.S. military to supply the war effort on the Korean Peninsula (Tsuru 1993: 57). By summer 1951, however, with the Korean War boom in full swing, the nine Haidens (electric power distribution companies) began rationing electric power as a severe drought that year crippled power output from Japan's hydroelectric dams (Hein 1990: 252). Prominent newspapers, trade journals, and periodicals were filled with calls to develop Japan's electric power system to meet the growing demand. Attention turned in particular to Japan's under-developed "electric power resources" (電源, *dengen*, literally "power sources"), echoing earlier calls during the war by the Ministry of Communications to develop Japan's "undeveloped electric power resources" (未開発電気資源, *mikaihatsu denki shigen*). These were found especially in Japan's remotest mountain valleys, including those that had been surveyed by Hassōden during the war years like the Tadami River Valley in Fukushima, which local newspapers promoted as "Tadami Dengen" in a series of articles in 1950 (Figure 2.4). When the electric power system was re-privatized through legal action initiated by SCAP administrators in 1951, however, and the nine wartime Haidens became nine regional private power monopolies, the newly created companies did not have the capital reserves sufficient to develop these river basins (for additional background on the reorganization of the electric power industry, see Chapter 3). To address this shortfall, the Diet passed the Electric Power Resources Development Law (*Dengen Kaihatsu Sokushin Hō)* in 1952.

Figure 2.4: A special feature in the Fukushima Daily News in 1950 promotes the Tadami Valley with a headline that reads: "Greeting the Dawn: Tadami Dengen" (Source: Tadami Machishi Shuppan Kai 1970).

The law created a national policy corporation (*kokusaku kaisha*), the Electric Power Resources Development Corporation (*Dengen Kaihatsu Kabushiki Kaisha*), or "Denpatsu". The creation of this national policy corporation maintained certain characteristics of wartime electric power governance but also diverged from them in important ways. While each of the nine regional monopoly utilities had far more autonomy in terms of power resource development and day-to-day operations than their wartime predecessors, after the war they faced significant capital limitations that inhibited their ability to undertake large-scale dam construction and meet the growing demand of the rapidly expanding postwar economy (Miwa 2005). Denpatsu was designed to fill this financing gap, by undertaking expensive large-scale hydropower dam projects and delivering the wholesale power to the regional power monopolies for retail sales. As

a hybrid public-private entity, Denpatsu preserved some of the institutional characteristics of Hassōden, particularly the "private ownership, public management" that was so broadly endorsed by wartime technocrats like Okumura Kiwao. Thus, Denpatsu can be viewed as a continuation of state ambitions from the wartime era, as it provided state planners in the newly created Ministry of International Trade and Industry (MITI) and its Electric Power Resources Development Coordination Committee (*Dengen Kaihatsu Chōsei Shingi* Kai) with authority to identify river basins most suited to hydropower development in their Electric Power Resources Development Five-Year Plans and undertake those projects indirectly through the newly formed public policy corporation.

The creation of Denpatsu and MITI's Electric Power Resources Development Coordination Committee coincided with the growing emphasis by economic planners in the Japanese government on the importance of comprehensive territorial development planning (*kokudo sōgō kaihatsu*) to balance development between Japan's urban and rural regions. In the tumultuous days of the Occupation (1945-1952), as Japanese analysts and commentators sought ways of fuse the ideals of democratization brought by the U.S. Occupation with the pressing need for economic development, their attention turned towards the Tennessee Valley Authority (T.V.A.). In the late 1940s and 1950s, study groups were convened by prominent economists like Shigeto Tsuru at Hitotsubashi University (who played a prominent role in economic reconstruction policy) to analyze the role of the T.V.A. in promoting "comprehensive development" as a form of targeted area development (*chiiki kaihatsu*) of economically depressed regions. By combining hydroelectric power with land reclamation, farmland improvement, reforestation, flood mitigation, and rural livelihood enhancements, the T.V.A. appeared to offer rural Japanese "steady employment, productive farmland, and a more

‘enlightened’ way of thinking about their relationship with their landscape” (Dinmore 2013: 18). It also provided a real-world case study for Japanese planners for how to meld their ambitions for technological modernization with the need to facilitate rural economic development.

Despite the rhetoric around “comprehensive development,” however, in practice Denpatsu’s work damming Japan’s remote river valleys served more to enhance the economic productivity of Japan’s urban areas than it did to elevate rural livelihoods. The 1950s and 1960s witnessed the construction by Denpatsu of some of the largest hydroelectric stations in East Asia. With support from the U.S. consulting firm Overseas Consultants, Incorporated (OCI), Denpatsu updated the surveys Hassōden had conducted during the war. In 1956, Sakuma Dam was completed on the Tenryu River in Shizuoka Prefecture. With four turbines of 96,000 kilowatts each, it was the largest dam in East Asia at the time (Miwa 2005: 429). This was followed in the late 1950s by three large-scale gravity dams, Okutadami, Tagokura, and Miboro dams, known collectively as “OTM”, each of which exceeded Sakuma in terms of power output (Figure 2.5). The unleashing of the electric power contained in the snowfall in what official reports called Japan’s remote “electric power resource regions” (電源地帯, *dengen chitai*) was a massive stimulus to Japan’s expanding urban economy and a major precondition for the double-digit growth rates that lasted from 1955 to about 1972, a period known in Japan as “the era of high-speed growth” (*kōdō seichō ki*).

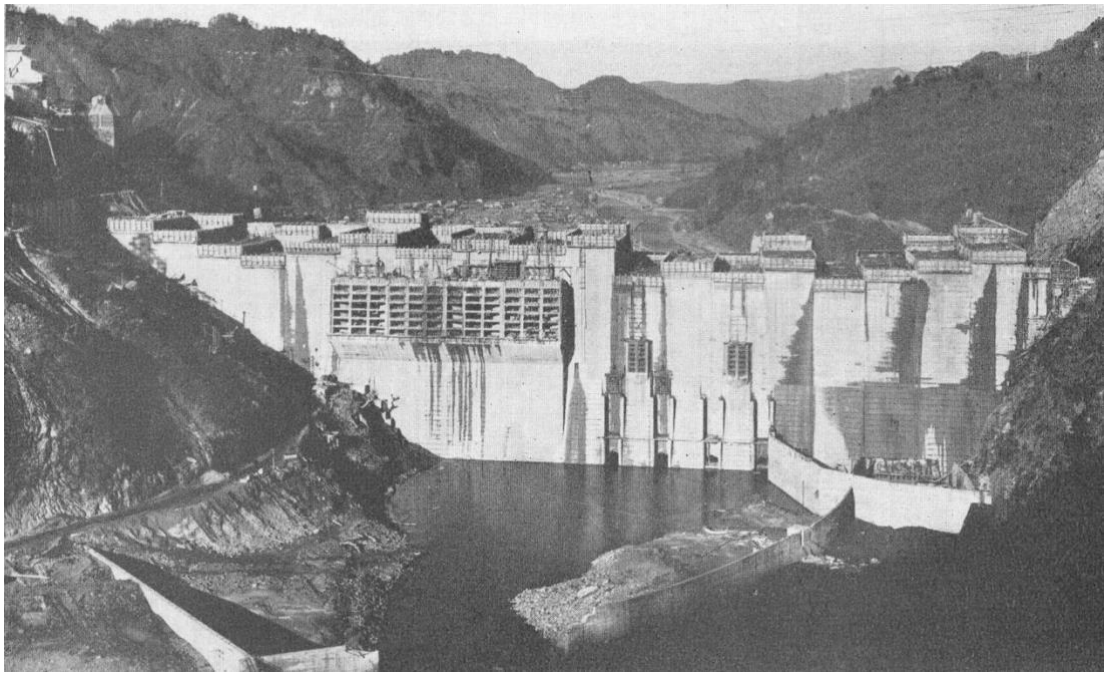

Figure 2.5: Construction of the Tagokura Dam nears completion on the Tadami river, Fukushima Prefecture circa 1959 (Source: http://www.jcinet.or.jp/photo/archive/detail_db.php?i d=16&page =19).

As the 1960s wore on, however, major transformations in both the structure of power demand and the composition of power generation occurred that would have massive implications for the energy policy landscape of the 1970s and beyond. As the Japanese economy expanded rapidly in the late 1950s and 1960s, urban populations swelled. Tokyo, Nagoya, and Osaka each saw year-on-year population growth rates ranging from ten to twenty percent, with much of this driven by in-migration from economically depressed rural areas (Yorimitsu 1987: 17). As more Japanese urban residents acquired greater purchasing power, they sought to purchase high-end consumer appliances to outfit their apartments in the buildings that were swiftly rising to fill the skylines of these emerging megacities. During the 1950s, in particularly high demand were what were known as the "three sacred treasures" (*sanshu no jingi*): the electric washing machine, the refrigerator, and the black and white television (Yoshimi 1999). These were followed by the "three Cs" of the 1960s: car, room cooler, and the color television (Partner 1999: 138). The swift

growth of urban domestic consumption increased national electric power demand through the 1960s. Demand for air conditioning in urban areas during the summer in particular led to an inversion of what the power industry calls "peak demand"—the day of maximum power demand. In 1968, for the first time national peak summer demand exceeded peak winter demand, as Japan's urban households, office buildings, retail spaces, and factories drew on 37,391 megawatts of power for cooling and illumination (Kikkawa 2004: 227).

Japan's regional power monopolies struggled to meet this unprecedented acceleration of power demand. Every year, annual demand forecasts were exceeded, driven primarily by urban domestic and industrial consumption. As double-digit GDP growth rates became the norm during Prime Minister Ikeda Hayato's "Income Doubling Plan" of the 1960s, there seemed to be no end to the growth of Japanese power consumption. Early in the decade, economic planners such as Arisawa Hiromi were already sounding the alarms of an impending energy crunch as demand threatened to exceed the output of hydropower dams, even as many of them were yet to come fully online and had been viewed as massive when they were planned a decade earlier. In a highly influential text of the period, Arisawa noted a global transition away from hydropower and coal towards petroleum for baseload electric power supply and called for Japan to join this transition (Arisawa 1963). Both the relative cheapness of petroleum-based thermal power and their swelling earnings as a result of accelerating demand meant that the nine regional utilities were capable of undertaking this transition through private investment. However, there is little doubt that the role of Denpatsu and centralized planning in transforming Japan's mountain watersheds into "electric power resource regions" was significant factor smoothing the way for urban economic expansion during the 1950s and early 60s.

Part V: 1973-2000: Territorial Strategies to Promote Nuclear Power Development

By 1970, state administrative control over the electric power industry was at its postwar nadir. With the passage of the Electric Power Industry Law (*Denki Jigyō Hō*) of 1964, MITI finally formalized the governance structure of the electric utility industry, which had been in place since 1951. MITI's reluctance to introduce the bill to the Diet was due in part to the fact that the law unambiguously limited MITI's administrative oversight and granted operational autonomy to the nine regional utilities (Okamoto 2017: 186). Beyond the five-year plans created by MITI's Electric Power Resources Development Coordination Committee and its periodic review and approval of the nine firms' rate structure and transmission coordination (Chapter 3), MITI administrative guidance of the power industry waned over the 1960s. With their ledgers flush with capital from annual power sales, the nine regional firms each expanded their generation and transmission infrastructure with little central government coordination. In essence, the state now played a less substantial role directing the development or management of the industry, much in the same way it had during the prewar period.

This was to change with the start of the "oil shocks" of 1973 (*sekiyu shokku*). With the "energy revolution" to greater reliance on oil-based thermal power production in the 1960s, Japan's dependence on fuel imports from overseas had swelled. Between 1960 and 1971, the total energy consumed in Japan increased twelve percent annually, a rate more than double than the global average of five percent. By 1971, Japan was the second largest energy consumer after the United States, despite its relative dearth of domestic petroleum reserves (Japan Institute of International Affairs 1975: 161). On the eve of the Oil Crisis, Japan relied on oil for over 70 percent of its total energy needs, and three-quarters of the oil consumed went to industrial uses. Because of this absolute dependence on foreign imports, when OPEC instituted a 25 percent

reduction of crude oil exports in October 1973, prices skyrocketed, and the economy entered a tailspin (Tsurumi 1975: 113).

The effect on MITI administrators was galvanizing. Along with the Ministry of Finance (MOF), MITI was the agency charged with securing the conditions for the overall growth of the Japanese economy and treated the threat of protracted fuel price spikes with alarm. The spike in petroleum prices hit a variety of industrial sectors and commodities, including gasoline, home heating fuel, and electric power. While prior energy supply constraints like the electric power rationing during the Korean War had primarily affected industrial sectors, the influx of high energy lifestyles during the 1960s meant that people from all walks of life felt the energy crunch in intimate ways, including in lines for gasoline and scrambles in grocery stores for sugar and toilet paper (Figure 2.6).

Figure 2.6: Shoppers in Tokyo Line Up for Toilet Paper During the 1973 Oil Crisis (Source: https://yomidr.yomiuri.co.jp/article/20210901-OYTEW890607/).

MITI responded rapidly with two pieces of emergency legislation in December 1973: the Emergency Measures Law for the Stabilization of the People's Livelihood (*Kokumin Seikatsu Antei Kinkyū Sochi Hō*) and the Petroleum Supply and Demand Normalization Law (*Sekiyu Jukyū Tekiseika Hō*) (Johnson 1982: 298; Tsuru 1993: 100). The petroleum law can be viewed as a return of the state controls initiated when the foreign trade control law passed in 1937 by MITI's prewar predecessor, the Ministry of Commerce and Industry (Nakamura 1974: 169-173), which had been an important development towards the state economic management by wartime technocrats. According to Johnson (1982: 298), the new emergency energy laws "legalized MITI's administrative guidance and formally recognized that administrative guidance was in the national interest." The Emergency Measures Law for the Stabilization of the People's Livelihood marked a new articulation of governmentality in Japan, as MITI administrators now configured their interventions at the level of the macroeconomy (including the coordinating of supply and demand) as critical to securing the livelihood of individual citizens (The Japan Institute of International Affairs 1975: 199). This law would be succeeded by future emergency measures, like the Law Concerning the Rational Use of Energy of 1979, which "encouraged efficiency on the part of Japanese consumers" (Stewart 2009: 178). While these laws did not represent a wholesale reversion to the era of strict wartime controls and technocratic interventionism, they did significantly tip the balance from the "self control" that prevailed in the high-growth heyday of the 1960s back towards "state control" (Johnson 1982: 298).

The state response to the 1973 Oil Crisis also spurred renewed bureaucratic interest in territorial planning for electric power development. The need to rapidly transition away from oil-fired power plants enhanced the status of nuclear power in the eyes of bureaucrats and utility managers, a technology that demanded additional government planning and coordination

capacity. MITI created a new sub-agency, the Agency for Natural Resources and Energy (*Shigen Enerugī Chō,* or ANRE), tasked with developing national level strategies for resource and energy security, within which expanding nuclear power as a proportion of Japan's electricity supply came to occupy a privileged position. ANRE succeeded MITI's Comprehensive Energy Committee (*Sōgō Enerugī Bukai),* which had been created in 1962 to secure supplies of petroleum and coal and was later renamed the Comprehensive Energy Investigation Committee (*Sōgō Enerugī Chōsa Kai*) in 1965 (Yoshioka 2011: 182-184). While energy policy was viewed primarily through the lens of industrial policy during this period, the effect of the Oil Crisis was to lead policymakers to revise this view to consider it a national policy issue of the highest order. As an issue of "state policy" (*kokusaku*), decision makers within MITI and the Prime Minister's Cabinet now obtained the power to ratify energy policy priorities for the nation for purposes of national security.

MITI-authored legislation in response to the Oil Crisis of 1973-74 was critical in developing spatial strategies for siting nuclear power plants across the Japanese archipelago. Siting nuclear power plants had already begun in the 1960s, led in part by the Japan Atomic Energy Research Institute (JAERI) and later by the two largest regional utilities, Tokyo Electric Power Company (TEPCO) and Kansai Electric Power Company (KEPCO). After JAERI demonstrated the commercial viability of nuclear power in 1963 with the successful operation of its Japan Power Demonstration Reactor (JPDR) in Tōkai Village, Ibaragi Prefecture, both TEPCO and KEPCO set about creating their own nuclear power development plans. Japan's first two privately operated power plants were sited and developed by these companies through negotiations with local village leaders, with KEPCO's Tsuruga Power plant in Fukui Prefecture starting in 1970 and TEPCO's Fukushima Daiichi Power Plant starting the following year. To

facilitate the development of nuclear power plants in Japan's rural regions, MITI introduced the Three Power Sources Development Laws (*Dengen Kaihatsu Sokushin Hō*, also known as the *Dengen Sanpō*), which were implemented in June 1974 (Yoshioka 2011: 151). The three laws were essentially a package of targeted, large-scale subsidies for communities that agreed to host a nuclear power plant and applied retroactively to towns where such plants were already sited. The laws also guaranteed the local government would receive property taxes for the plant. For example, the remote coastal town of Ōkuma, where Fukushima Daiichi was sited, received 1.92 billion yen in tax revenues in 1978, 88.5 percent of which was attributed to the nuclear power plant (Onitsuka 2012: 5). The scale of these funds was so considerable that host communities and prefectures—all of which were remote, rural areas connected to distant urban centers by high-voltage transmission lines—became economically dependent on the revenues from hosting these plants.

As the 1970s wore on, however, coastal communities across Japan showed increasing resistance to hosting nuclear power plants. While the state's "national policy" approach carried considerable weight in overwhelming local resistance, the primary fulcrum of state control over securing land for development hinged solely on obtaining the consent of constituencies with property or fishing rights directly in the way of the project, an aspect of siting law that is unique to Japan (Yoshioka 2011: 149). While this narrowed the scope of constituencies that needed to be won over, it also meant that if local property owners or fishermen's unions refused to relinquish their property rights, the regional utility and MITI had few tools at their disposal to overcome this resistance. Beginning in the late 1960s, a few sparse local resistance movements succeeded in pressuring regional utilities to cancel their nuclear power plant siting plans, such as Tsu Island in Ehime Prefecture in 1968 and Nachikatsuura in Wakayama Prefecture in 1971.

Through the 1970s, resistance movements reached a crescendo and became better organized, which had great consequences for the ability of MITI and the nine regional utilities to site power plants. Eventually, more than 50 different nuclear power plants sites would have to be withdrawn due to citizen resistance (Hirabayashi 2013: 37), and among Japan's 18 total nuclear power plants sites, 16 were announced in the 1960s and only two (Ikata Power Plant in Shikoku and Sendai Power Plant in Kagoshima) were announced in the 1970s (Figure 2.7).

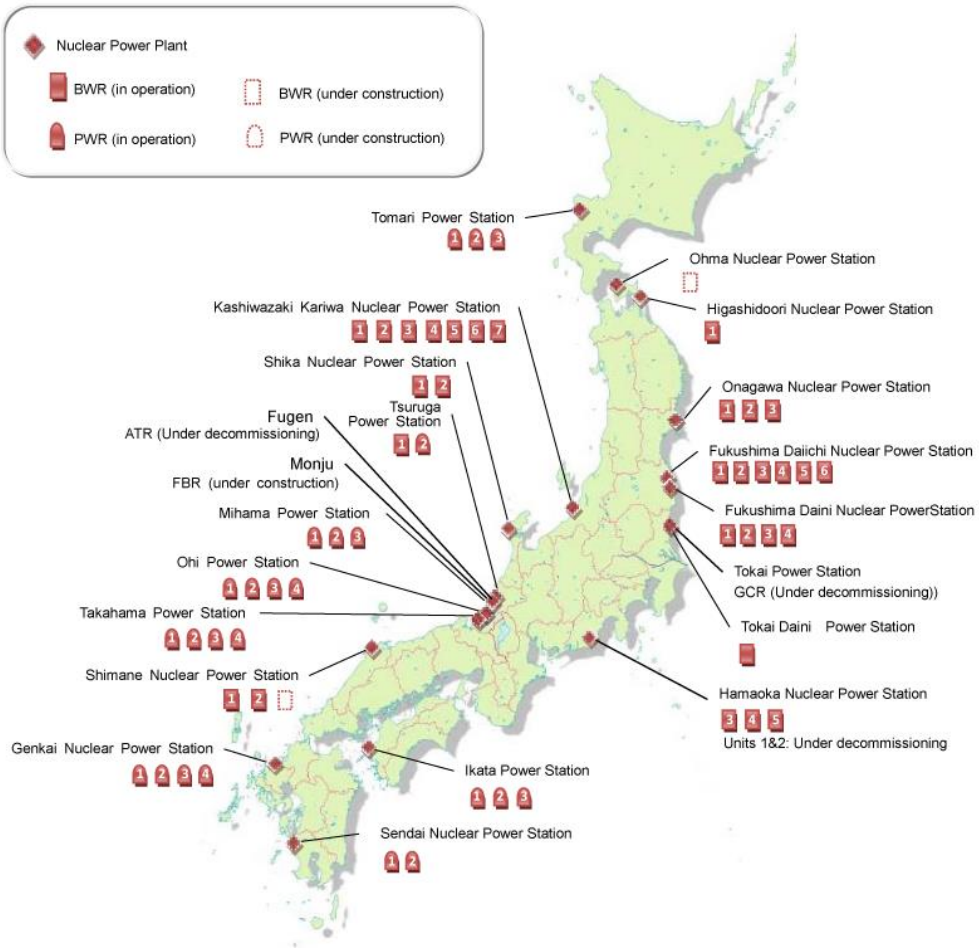

Figure 2.7: Map of Japan's nuclear power plant fleet circa 2010 (Source: National Report of Japan for the Fifth Review Meeting of the Convention on Nuclear Safety, September 2010, Government of Japan).

In response to this resistance, MITI developed an assortment of "soft social policy instruments" (Aldrich 2008: 126) that functioned as spatially targeted interventions to win over recalcitrant communities. In 1976, the Prime Minister's office established the Ministerial Council for Promoting a Comprehensive Energy Policy (*Sōgō Enerugī Taisaku Suishin Kakuryō Kaigi*). In addition to designating power plants as Important Electric Power Resources Requiring Special Measures (*Yō Taisaku Jūyō Dengen*), which enhanced the Dengen Sanpō subsidies, the council also set up liaison meetings in potential host communities involving representatives from the regional bureau of MITI, local ministerial offices, the prefectural governor, and mayors of relevant towns (Ibid: 135). After the Three Mile Island accident in the United States in March 1979 further turned public opinion against nuclear power, MITI intensified their local spatial targeting strategies for power plant siting. MITI officials conducted site visits—rare for elite bureaucrats in Tokyo—to make presentations on Japan's energy policy priorities and "warn of coming power shortages if nuclear power plants were not constructed" (Ibid: 137). In 1983, MITI created the Citation Ceremony for Electric Power Sources-Siting Promoters (*Dengen Richhi Sokushin Kōrōsha Hyōshō*), which presented mayors of towns where power plants were sited with the opportunity to meet the prime minister at his Tokyo residence and receive accolades in front of the national media (Ibid: 149). Continuing with the trend of local economic development promotion to maintain local consent, in 1990 MITI established the Center for the Development of Power Supply Regions (*Dengen Chiiki Shinkō Sentā*), which publishes a monthly bulletin promoting local products from host communities and hosts an annual symposium on regional development.

Throughout the 1980s and 1990s, MITI administrators in ANRE remained focused on enhancing the proportion of nuclear power in Japan's energy mix by creating targeted subsidies

for host communities. By 1985, nuclear power surpassed oil-based thermal power as a proportion of Japan's power supply (Okamoto 2017: 188) and eventually grew to about 30 percent by 2010. To accelerate this transition, in 1992 MITI increased electricity discounts for host communities from 10 to 15 percent to 30 to 50 percent and in 1994 MITI began eliminating the ceiling on subsidies offered to host communities (Aldrich 2008: 137). While these subsidies did little to secure new sites for nuclear power development, they did succeed in obtaining consent for additional power plants in host communities. This led to the intensive spatial concentration in some sites, each of which came to hold a significant proportion of Japan's 54 nuclear reactors by 2010. For instance, the coast of Fukui prefecture hosted four nuclear power plants with 13 reactors for the Kansai area and the coastline of Fukushima prefecture hosted two plants and 10 reactors for powering Tokyo. This overwhelming concentration earned both areas the nickname "Genpatsu Ginza" (Onitsuka 2012: 1), a term which hearkened to Tokyo's bustling upscale fashion district. Some 360 kilometers up the coast from Fukui's plants, the seven reactors on the site of TEPCO's Kashiwazaki-Kariwa Power made it the largest nuclear power station in the world.

Conclusion

Across the latter half of the twentieth century, as MITI administrators developed spatial targeting strategies for siting power plants and maintaining social consent to their operation, the economic conditions in Japan's rural regions began a slow decline, due in part to declining populations. Scholars of Japanese urbanization even coined a term to describe the vacuum-like draw that Tokyo exerted over the surrounding rural prefectures: *ikkyoku shūchū,* or "unipolar concentration". As in-migration to Tokyo and other hubs of the Tokkaido Megalopolis continued

apace, electric power resources, particularly nuclear and thermal power, were developed to meet skyrocketing urban power demand as Japan catapulted to the second largest GDP after the United States at the end of the Cold War. The spatial outcome of this wave of ongoing urbanization and electric power development was the production of a rigidified geography that was striated between power producing regions and power consuming regions, a geography that was given tacit state recognition with MITI's creation of quasi-public organizations and publications developing and promoting Japan's "power supply regions" (*dengen chitai* or *dengen chiiki*). In essence, Japan's rural regions (*chihō*) were financially, politically, and culturally subordinated to its urban centers (*chūō*) as sources of energy for continued urban economic growth. Even after the Japanese government underwent administrative restructuring in 2001, when MITI was renamed METI (the Ministry of Economy, Trade and Industry), the fundamentals of this administrative and spatial architecture remained intact. Not until the Fukushima Nuclear Disaster in March 2011 would local citizens movements in both the center and the periphery begin to obtain the political traction needed to challenge this structure of regional dependency.

As this review of Japanese energy policy changes over the long twentieth century shows, electric power was not an object of strategic interest for Japan's developmental state in its earliest days. It was first treated as another network infrastructure like radio or telegraphy and placed under the Ministry of Communications. The earliest regulations by the Ministry of Communications were geared towards improving the safety of power lines and interior wiring. But with Goto Shinpei's tenure as Communications Minister, there was a growing interest in the significance of electric power for the cost competitiveness of Japan's commodities on global markets. While this interest appeared to reach its zenith with the nationalization of electric power

industry during the wartime period, this state's interest in electric power continued to grow in peacetime, from the postwar period when Japan faced power shortages to the 1970s when spiking oil prices made electrifying as many commercial and industrial sectors as possible a strategic priority. The growing strategic importance of electric power to the Japanese state remained consistent regardless of changes in ministerial jurisdiction over the power industry, and reflected a long-standing strategic interest in providing stable, low-cost power sources in both wartime and peacetime. The transfer of regulatory jurisdiction of the electric power industry from the Ministry of Communications to the Ministry of Munitions in 1941 grew from the recognition that cheap power was a crucial asset for wartime production. Following Japan's disarmament in 1945, the wartime Ministry of Munitions was recast as MITI and maintained its oversight of the power industry for ensuring the conditions for Japan's economic recovery after defeat. Viewed from the vantage point of world politics, the end of the Pacific War may have marked a major shift in Japan's political economy away from militarism, but from the perspective of regulation of the electric power industry the era was marked as much by continuity as change.

In order to secure a stable baseload of cheap electric power, the Japanese state engaged in a number of territorial strategies for resource discovery and development. Chief among these was the use of land surveys that were funded by the central government to identify suitable sites for power plants. These included Goto Shinpei's hydropower surveys of the 1910s, Hassōden's surveys for large-scale dams in the 1940s, and Denpatsu's surveys of undeveloped river basins in the 1950s and 1960s. In the 1960s, MITI also engaged in a series of topographical and geographical surveys of suitable sites for nuclear power plant development, which included evaluating a variety of technical criteria, including proximity to demand centers, bedrock

suitability, frequency of earthquakes, proximity to the sea, and a small local population (Aldrich 2008: 126). A second territorial strategy included targeted financial assistance for host communities. This ranged from one-time payouts to mountain communities displaced by the flooding caused by dam construction or annual subsidies for coastal governments agreeing to host nuclear power plants. Even though the state had nominal jurisdiction over the full territory of Japan, projecting that power over remote communities in mountain watersheds or on rocky coastlines required developing territorial strategies for obtaining social consent to MITI's electric power development ambitions.

Viewed in terms of a territorial metabolism, the electric power system that emerged in Japan over the twentieth century tied urban demand centers to rural zones of power production. Until the mid-1960s, hydropower was Japan's primary electric power source, and involved metabolizing the snowfall of Japan's remotest interior valleys into electric power for urban factories and high-rise office buildings. As nuclear power stations came online, increasingly Japan's remotest coastal locations were drawn into this networked ecology as well, supplying power to Japan's major urban centers in the Kantō, Kansai, and Kinai plains. While hidden from view when a Tokyoite turned on an electric air conditioner to cool their apartment on a hot July day, the electric power system tied rural zones of provision to urban zones of consumption in intimate ways. In return for sending electric power to Japan's urban centers, rural regions received state subsidies for public facilities and local employment opportunities, which provided a metabolic basis to the territorial unity of the Japanese economy.

With the Fukushima Nuclear Disaster in 2011 and the passage of bills reforming the monopoly structure of the electric power industry and subsidizing renewable energy production, some residents of host communities and local development advocates have begun clamoring for

an opportunity to undo the relationship of structured dependency between Japan's urban core and rural periphery (see Chapter 3). Their belief is that by unbundling the territorial structure of Japan's electric power system, especially by moving away from centralized generation stations like nuclear power towards distributed energy sources like solar and wind, they will also be able to undo the ties of dependency and subordination that keep rural communities in thrall to the authors of "national policy" in Tokyo. The challenge for some of these aspiring renewable energy producers is that they still must find connections to the electric power grid, which is still centrally governed and has its own spatially bound limitations (see Chapter 4). While it is not possible to review the full scope of policy developments and their spatial ramifications in this chapter, it has set out to review the major components of the Japanese territorial metabolism as it evolved over the twentieth century and the center-periphery relations that it both produced and was produced by. It is these spatial dynamics that have become increasingly unmoored as the regional power monopolies have lost their designated monopoly status and the grid has had to accommodate a growing proportion of renewable energy, a transformation that has been initiated and managed by the energy planning administrators within the Japanese state.

CHAPTER 3:

Governing the Fix:

Energy Regimes, Accumulation Dynamics, and

Land Use Changes in Japan's Solar PV Boom

Introduction

Energy systems around the world are in the midst of a large-scale transition towards renewable energy. In recent years, solar photovoltaic (PV) systems in particular have expanded rapidly, and the plummeting cost of PV technology has spawned predictions that renewables could soon achieve grid parity with conventional fuels (WEF 2017). In 2016, more solar PV capacity was added to the world energy portfolio than any other energy source, a first since national energy data began being collected on a global scale (IEA 2017). The same year also saw more solar PV installations than the previous five years combined (REN21 2017). Global energy observers predict the solar buildout will continue accelerating in coming years, with world PV capacity tripling to 800 gigawatts by 2022 (IEA 2017).

Japan has emerged as an important locus of this global energy transition. Following the March 2011 Fukushima Daiichi nuclear disaster, the Japanese government passed a generous Feed-in-Tariff (FIT) to incentivize investment in renewable energy, with solar PV surpassing all other sources (Figure 3.1). In 2016, Japan added 8.6 million kilowatts (kW) in solar PV capacity, bringing the cumulative total to 42.8 million kW (ISEP 2018a: 3). This rapid expansion catapulted Japan beyond Germany in terms of cumulative installed solar PV capacity, placing it second only to China in global rankings (Figure 3.2) (REN21 2017). Japanese environmental groups, anti-nuclear activists, and renewables advocates welcomed the solar expansion as a way

of weaning the country off of nuclear energy, which critics consider too risky in the earthquake-prone archipelago. Documentary films like *Japan and Renewables (Nihon to Saisei)* and *Peaceful Revolution (Odayaka na Kakumei)* also highlighted the potential for solar and wind technologies to generate social wealth in rural areas already registering the effects of depopulation and regional economic decline.

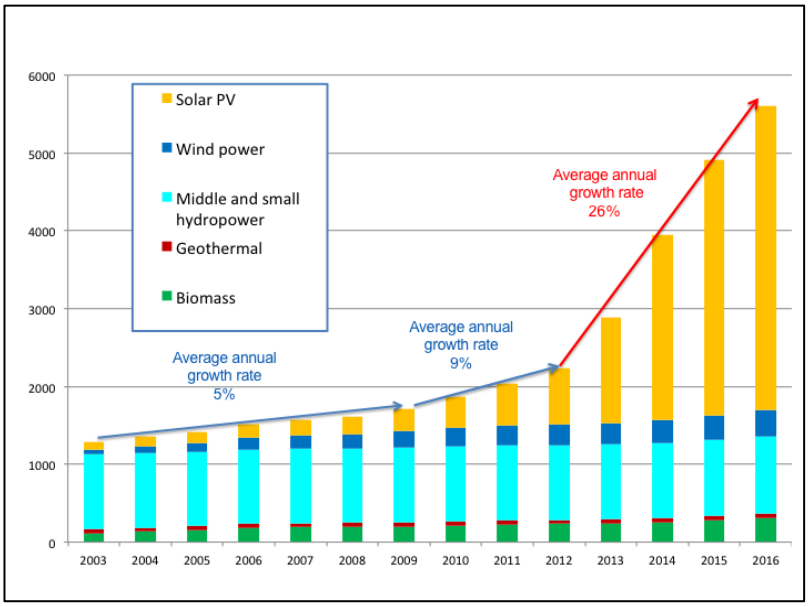

Figure 3.1: Renewable energy expansion in Japan, 2003-2016 (Data Source: METI).

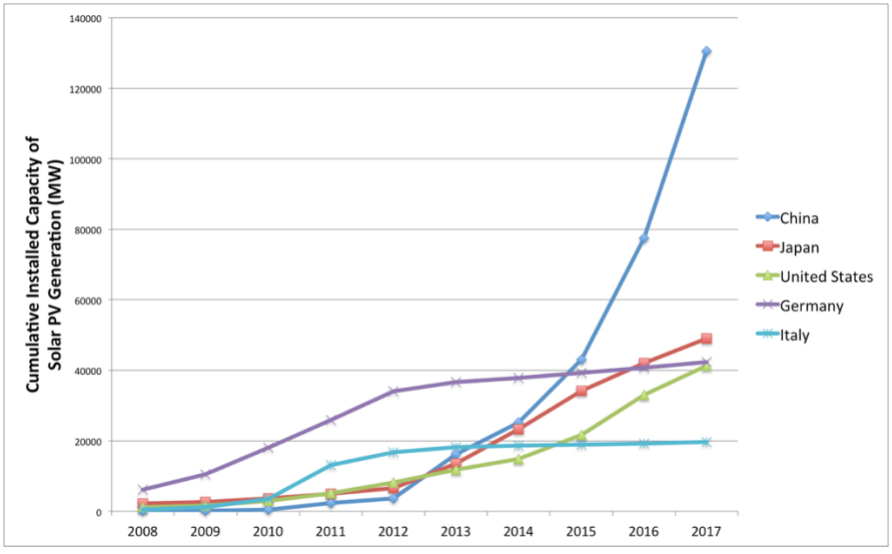

Figure 3.2: Rankings of top five countries for installed solar PV capacity (by author).

Despite the prevalence of such utopian depictions, however, geographers have recently called for more critical assessments of renewable energy transitions. “Green technologies” like solar PV are far from environmentally or socially benign (Mulvaney 2013). Moreover, land use footprints of renewables are much larger than conventional systems powered by fuels with greater energy density like coal, natural gas, or uranium (Huber and McCarthy 2017; Walker 1995). These land requirements, coupled with the uneven distribution of areas with enough sunshine or wind activity to generate sufficient returns in kilowatts or income, have fueled concerns that a broad-scale renewables buildout could disproportionately impact rural areas, which offer relatively abundant, inexpensive land (Woods 2012; McCarthy 2015).

Additionally, geographers have begun to investigate the potential of renewable energy transitions to create new avenues for capital accumulation in an era of climate instability and global ecological decline. The capital requirements for reconfiguring the infrastructure of global energy systems to accommodate the mass introduction of renewables are significant and could constitute a major investment frontier for global capital (Sayre 2010; Castree and Christophers 2015). Recognizing this financial dimension to energy transitions has led to speculations that a large-scale deployment of utility-scale solar plants and wind farms may offer a “socioecological fix” (Ekers and Prudham 2015, 2017, 2018) to economic and environmental crises by providing “both opportunities for the reinvigoration of capital accumulation on a global scale and a biophysically significant response to climate change” (McCarthy 2015, 2495).

This article examines the recent boom in solar PV construction in Japan as a case of the socioecological fix. In particular, it focuses on two key reforms to Japan’s energy governance regime since 2011—the FIT and the liberalization of the small-scale retail power market— to understand the role of state legal and regulatory action in producing the conditions for secure

investments in renewable energy infrastructure. Analyzing the logic behind Japan's recent energy governance reforms through the lens of institutional political economy reveals a crucial limitation facing investors seeking renewed accumulation through a socioecological fix: the state, as the extra-economic agent charged with sustaining capital accumulation at the national scale, maintains the capacity to shape the conditions of profitability in the electric power sector. Government administrators in charge of regulating Japan's electric power sector must maintain a careful balance between the interests of renewables investors seeking new pathways for capital accumulation, firms seeking low electricity rates, and regional power companies seeking to protect their fixed assets from devaluation, as failing to do so might undermine the conditions of capital accumulation for the Japanese economy as a whole. By bringing Marxian theories of the state to bear on the political ecology of fixed infrastructure, this article contributes an empirical analysis of the political ecological dimensions of state action in governing renewable energy transitions.

Beyond analyzing the changing institutional dynamics regulating Japan's power sector, this article also offers a typology of the land use changes that have emerged as a result of solar PV investments. This approach highlights how "energy regimes" (Huber and McCarthy 2017) are simultaneously social and spatial, comprised of both the legal-regulatory frameworks governing an energy system and the material footprint of energy infrastructure on the landscape. The guaranteed return on investment offered by the FIT has stimulated demand from a variety of actors for space to site solar PV projects and has empowered new constituencies to participate in Japan's formerly closed energy system. At the same time, strict legal protections for farmland are compelling investors to pursue projects in novel spatial configurations that challenge

assumptions about the types of land transformations that will result from the lower "power density"—"power produced per unit area"—of renewables (Huber and McCarthy 2017, 657).

The data informing this study was gathered during sixteen months of fieldwork between 2017 and 2019 and entailed thirty-two semi-structured interviews with state and civil society actors involved with Japan's energy transition. Participants included representatives from the Ministry of Economy, Trade and Industry (METI) [4], the Ministry of Agriculture, Forestry and Fisheries (MAFF), the Ministry of the Environment (MOE), regional power utilities, industry trade associations, solar power investors, small-scale retail power producers, renewables policy advocates, and local government. Interviews were supplemented with attendance at three renewable energy policy and investment seminars in Tokyo; site visits to six solar PV projects of varying sizes; and document analysis of legal statutes, government policy briefs, deliberation committee minutes, company annual reports, and press releases.

The next section elaborates on the concept of an energy regime using Marxian state theory, which provides a useful framework for analyzing the mediating role of institutions and state policy in producing conditions for a socioecological fix through investment in renewable energy infrastructure. The third section traces the historical-geographical constitution of Japan's energy regime after World War II and analyzes the relationship between electric power regulation and the spatiality of the energy system until the collapse of the bubble economy in 1991.[5] The fourth section examines the influence of the FIT and the liberalization of the retail power market since 2011 in stimulating investment in renewables and undermining the security

[4] The Ministry of International Trade and Industry (MITI) was re-organized as the Ministry of Economy, Trade and Industry (METI) as part of a re-organization of government ministries in 2002. Both acronyms are used to refer to the main government ministry involved in energy governance after World War II.

[5] The "bubble economy" was a massive asset price bubble in Japan from 1986 to 1991 driven by speculation in stocks and real estate. Since its collapse, the Japanese economy has experienced decades of stagnation and low (or negative) growth. For more on the bubble economy, see Vogel (2006).

of fixed capital investments of Japan's nine regional power monopolies.[6] The fifth section surveys the types of investment patterns and solar PV projects that have followed these institutional reforms, particularly large-scale, "mega-solar" installations; community-based solar systems and rooftop solar; and "solar sharing" (or "agrivoltaic") installations on working agricultural land. The article concludes by reviewing the types of administrative tools states might wield to govern a socioecological fix through renewables and highlights the need for scholarship to attend to the role that different institutional contexts play in shaping the land use pressures attending renewable energy transitions.

Theorizing the State in the Socioecological Fix

Recent approaches to the political ecology of renewable energy draw on historical-geographical materialism to emphasize that energy systems are a form of fixed capital, which introduces path dependencies and structural constraints into the possible trajectories of energy transitions. More than simply the result of idealism or political will, transforming energy systems to less carbon-intensive configurations is a socio-metabolic process entailing the wholesale transformation of infrastructure, landscapes, and socio-spatial relations that developed over the past century of fossil-fuel driven growth (Huber and McCarthy 2017; Bridge et. al. 2013). The lower power density ("power produced per unit area") of renewables means that "any large-scale shift to renewable energy sources would require huge areas of land; enormous inputs of raw materials for construction, labour and capital; and the production of dramatically reconfigured sociospatial relations" (Huber and McCarthy 2017, 657, 665). Transitioning energy systems away from more energy dense, subterranean resources like fossil fuels or enriched uranium

[6] The nine regional monopolies expanded to ten with the reversion of Okinawa to Japanese control in 1972. For purposes of simplicity, this article deals only with the nine monopolies of the Japanese mainland.

would likely require geographically significant transformations of land use, as "vertical" energy regimes are replaced by the "horizontal" energy regimes of technologies like solar PV and wind.

Given the high capital requirements of transforming energy systems, scholars have drawn attention to the potential of finance capital to both drive and profit from a broad-scale transition to renewables (McCarthy 2015; Kennedy 2018; Knuth 2018). Harvey's (1978, 1982) seminal argument that fixed capital investment serves as a "spatial fix" to capitalist crises has been used to conceptualize the coupled financial and ecological aspects of green infrastructural transformations through the lens of an ecological or socioecological fix (Ekers and Prudham 2015, 2017, 2018; Bok 2019). Reconfiguring contemporary built environments with the scale and rapidity required to respond significantly to climate change will require "a massive capital switch," which would entail diverting investment and capital flows from existing uses into low-carbon infrastructures (Castree and Christophers 2015, 380; Sayre 2010). Although "capital switching" originally described short-term strategies pursued by capitalists seeking new avenues of profit in response to an accumulation crisis (Harvey 1978), a capital switch in response to climate change would be socially, not economically, determined, and more long-lasting. Diverting capital into renewable energy systems could constitute a socioecological fix by providing fractions of capital with the opportunity for massive returns on investment in the infrastructural components of the new energy regime, while also decoupling capital accumulation from high carbon emissions (McCarthy 2015). On the other hand, firms holding un-amortized investments in conventional or more carbon-intensive infrastructure have a vested interest in maintaining the current configuration of the energy regime, and are prone to resist through political or financial means any transition that might result in the premature devaluation of their fixed assets (Sayre 2010; Knuth 2017).

While the figure of the state and the necessity of state action loom large in accounts of the socioecological fix, the relationship of state policy to fixed infrastructure investment has yet to receive explicit, sustained theorization. Castree and Christophers (2015) cite the example of the U.S. Rural Electrification Administration to demonstrate how state action has historically been instrumental in stimulating investment into the built environment, noting that finance capital is capable of responding to the need for a capital switch "given the right incentives by governments" (381). McCarthy (2015, 2498) also notes that implementing any large-scale buildout of renewable energy would likely require "highly active, interventionist, developmentalist states" to make their territories "available as sites for investment in renewables, subsidizing the transition, and coordinating policies and movements of investment and energy alike across national borders." While the ascendance of market-based modes of governance in many national contexts has made such interventionism increasingly rare, East Asian states that have only selectively embraced the neoliberal trend still retain the capacity to deploy policy instruments described as "developmental" to spur renewable energy development (Kim and Thurbon 2015; Chen and Lees 2016; Hung 2019).

A useful framework for analyzing the rationales and limitations of state action to secure socioecological fixes is offered by Marxian state theory, which has theorized the necessary role states play in managing the contradictions of the capitalist mode of production to ensure the stable and regular accumulation of capital (cf. Clark and Dear 1984; Jessop 1990). This approach emphasizes that capital alone is not sufficient to guarantee its own expanded reproduction but requires a state to secure conditions of accumulation and legitimation for the prevailing system of production (O'Connor 1973). State action is thus constrained by the contradictory imperative of maintaining a "balance between capital's need for valorization and the achievement of popular

consent" (Altvater 1993, 27). While failure to secure the conditions of accumulation can lead to an economic crisis, failure to secure political legitimacy can produce a broader legitimation crisis (Habermas 1975; O'Connor 1973). Emphasizing this dual character of crises under capitalism points to the possibility that socioecological fixes might serve to resolve political as well as economic crises. It also extends recent explorations of the role of political contestation in shaping the trajectory of fixes (Ekers and Prudham 2018) by drawing attention to the institutional frameworks of capitalist states—including law, regulation, and policy—as a crucial zone where struggles for power and hegemony are waged.

State action has historically been instrumental in providing incentives to stimulate private investment into the physical infrastructures that comprise "the general preconditions of production" (Marx 1973, cited in Harvey 1982, 226). Despite the dependence of individual firms on reliable shared infrastructures like roads, electric grids, and communications networks for the production and circulation of commodities, associated risks and delayed returns disincentivize firms from "reproducing the environmental conditions of their own accumulation" (Ekers and Prudham 2017, 1382). Risks include the long time-horizon for project initiation and completion; delays due to weather, supply interruptions, or fluctuations in labor availability; and uncertainty over the realization of profits due to long turnover times and the ever-present risk of devaluation (Harvey 1982, 224-226). State action mitigates such risks by excluding infrastructure investment from the prevailing rules of inter-firm competition. Designating certain sectors "natural monopolies," providing subsidies and tax benefits for fixed capital investment, and offering amortization guarantees to protect incumbent firms from devaluation all serve to minimize risks and incentivize firms to invest in fixed infrastructure.

As a public utility vital not only for general economic production but also social reproduction, electric power has long been an object of state interest and has been subject to varying modes of regulation to ensure its relative stability (e.g. Hughes 1983). Borrowing loosely from French regulation theory, which is concerned with the institutional conditions for capital accumulation across broad territorial scales across several economic sectors (Aglietta 1979; Jones 1997), we can usefully extend the concept of "energy regimes" to encompass the institutional ensembles that stabilize accumulation within the energy sector and produce the conditions for secure fixed investments in energy infrastructure. While institutional ensembles vary across specific national-political contexts, from state ownership, private ownership of regulated monopolies, to de-regulation, the legal-regulatory regime governing electric power has played a central role in shaping the fiscal and socioecological spatiality of energy systems. Attending to the influence of state legal and regulatory action on investment patterns in electric power infrastructure is thus critical to understanding the precise mechanisms through which the conditions for socioecological fixes are produced and stabilized in different historical-geographical contexts.

As the following case of Japan's successive "energy regimes" demonstrates, the institutional arrangements governing accumulation are not determined in advance but emerge as "chance discoveries" (Lipietz 1986; Huber 2013b) through state and firm responses to accumulation or legitimation crises, both real and anticipated. The next two sections examine electric power regulation and re-regulation in postwar Japan as a case for understanding the role of the state legal-regulatory apparatus in producing the conditions for fixed capital investments in renewable energy. After first surveying the historical-geographical constitution of Japan's postwar energy regime, I then examine how two major reforms of the regime of electric power

governance since 2011 are stimulating rapid investment into the built environment and disrupting the dynamics of capital accumulation for Japan's regional power monopolies.

The Institutional Architecture of Japan's Postwar Energy Regime

Japan, as the state that served as the prototype for the "developmental state" (Johnson 1982; Woo-Cumings 1999) and only selectively embraced aspects of neoliberal governance (Hill and Fujita 2000), provides an optimum locus for evaluating the role of the state in producing the conditions for a socioecological fix. The main institutions governing Japan's electric power sector emerged after World War II and were not subject to serious reforms until after the collapse of the bubble economy in 1991. Tracing the history of this period is critical for understanding how inter-dependencies between state policy, fixed capital investment, and the socioecological production of space are being transformed in the wake of recent institutional reforms. The four main characteristics of this structure—privately held firms, an integrated distribution system, division into regional service areas, and monopoly ownership (Kikkawa 2004)—provided the institutional context for secure investments by Japan's regional power monopolies in fixed infrastructure for power generation, transmission, and distribution. This investment in turn laid the foundation for an immense accumulation of capital not only among regional power firms, but also across the whole economy, which depended on cheap, abundant electricity to reduce the costs of value-added production that formed the core of Japan's postwar industrial strategy.

The re-organization of the Japanese electric power system into nine regional monopolies occurred during the Allied Occupation of Japan (1945-1952). U.S. occupation authorities ordered the dissolution of the state-controlled power monopoly, Nippon Hassōden, and divided the Japanese territory into nine regions—Hokkaido, Tohoku, Kanto (Tokyo), Chubu, Hokuriku,

Kansai, Chugoku, Shikoku, and Kyushu—with each power company constituted as a privately owned, vertically integrated "natural monopoly" within its host region (Hein 1990) (Figure 3.3). Designating utilities natural monopolies was widely considered necessary to prevent the occurrence of "ruinous competition" and ensure stable power rates for consumers (Hughes 1983, 59). This limit to inter-firm competition provided relatively secure conditions for constructing large-scale, capital intensive infrastructure for power generation and delivery, including hydroelectric dams, thermal and nuclear power plants, and high-voltage power lines to transmit power from remote sources to centers of industrial activity (Okamoto 2017).

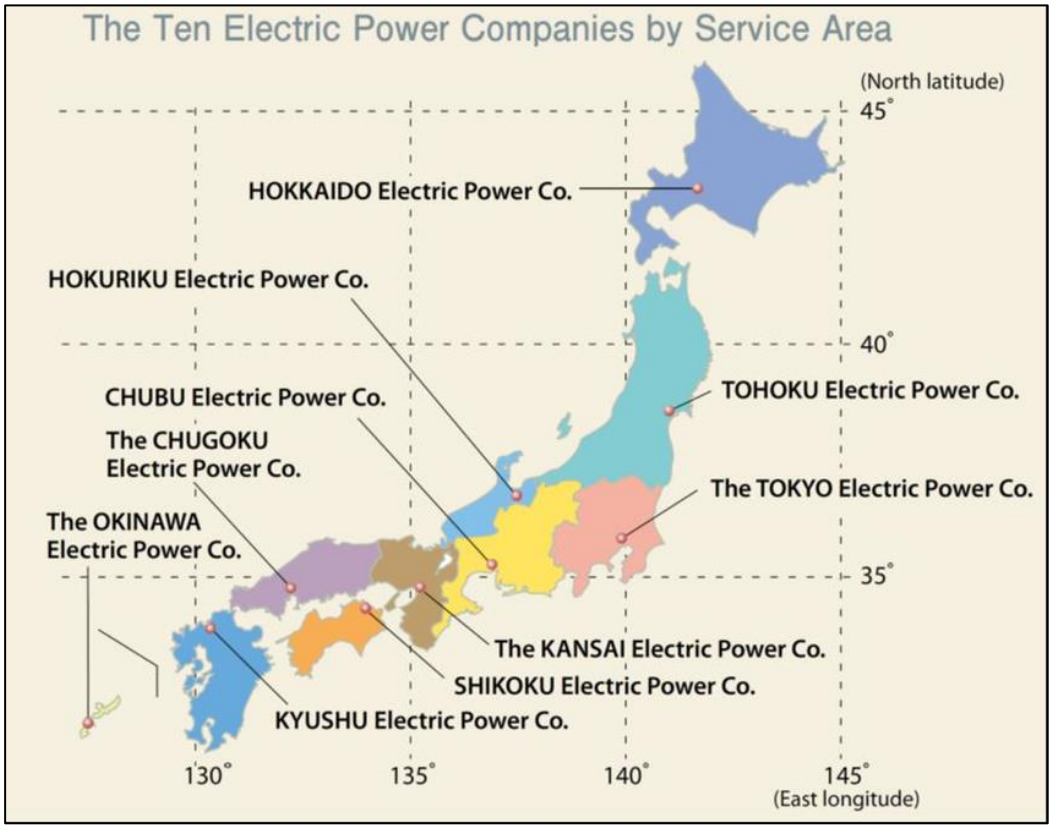

Figure 3.3: Service area map of Japan's regional power monopolies (Source: The Federation of Electric Power Companies of Japan).

After a brief experiment with a U.S.-style Public Utilities Commission, regulatory oversight of the electric power and gas utilities was transferred to the newly created Ministry of

International Trade and Industry (MITI) (Hein 1990, 274). As the Japanese government's economic "pilot agency," MITI was the chief architect of the institutions of the "developmental state" (Johnson 1982), and it regulated the electric utilities with a blend of centralized economic coordination and free market competition that are the hallmarks of this state form. By designating the electric power sector a "strategic industry," MITI provided special subsidies, depreciation exemptions, financing guarantees, delayed interest payments, and other benefits that allowed regional power monopolies to operate outside of the framework of normal market competition (Johnson 1982, 29). Along with the first allocation of foreign development assistance from the U.S. (Hein 1990, 278), these exemptions and subsidies provided enough operating capital that regional monopolies could invest in new generation facilities without having significantly to raise electricity rates, which might otherwise hinder the recovery of key manufacturing sectors (Johnson 1982, 220). Regional power monopolies also benefited from public funding for the Electric Power Development Corporation, a "national policy corporation" created in 1952, which constructed hydropower dams throughout the Japanese archipelago and sold power wholesale to the regional firms (Hein 1990).

Japan's postwar energy regime, and thus the dynamics governing fixed capital formation and accumulation dynamics within the power sector, was underwritten by formal laws and informal institutional arrangements between the nine electric power monopolies and MITI. The Electric Power Industry Law (*Denki Jigyō Hō*), first passed in 1964 and not revised until 1995 (Kikkawa 2004, 493), ratified the basic framework for industry regulation that MITI had pursued on an ad hoc basis since 1952. The law formalized MITI's power to approve or deny proposed changes to electricity rates (ANRE 2011) and required firms to submit applications for rate changes to MITI's Public Utilities Bureau (*Kōeki Jigyō Kyoku*). This allowed bureaucrats to

monitor the firms' financial situations—income and expenses, wages and capital investments—without having to nationalize the industry outright. Article 19 of the law also stipulated that administrators must ensure utilities receive a "proper return" for provisioning a public good. Indeed, economic bureaucrats at MITI had an incentive to assure regional monopolies of profitability, as that would allow additional fixed capital investments, further expanding the supply of electricity to Japan's booming urban-industrial centers.

MITI's regulatory mandate required a delicate balancing act between the need for profit in the Japanese power sector—dependent primarily on the volume of electric power sales—and the need for cheap electricity rates among large-scale industrial users, like heavy chemical and steel firms (Samuels 1987). Rate increases among the nine firms were coordinated through their trade association, the Federation of Electrical Power Companies of Japan (FEPC). Fractions of capital from other sectors advocated for cheap electricity rates through regional Chambers of Commerce and the national business association, the Japan Business Federation (*Keidanren*) (of which the nine power monopolies were also prominent members). MITI hosted public-private deliberation sessions within the important Electric Power Industry Council (*Denki Jigyō Shingikai*), where various stakeholders, including representatives from large industry, small and medium enterprises, and other power consumers, could share their opinion on proposed rate increases with a panel of MITI bureaucrats (Samuels 1987, 164). Deliberation through such "advisory councils" assisted MITI in determining the optimum rate at which both private power producers and private power consumers would obtain maximum profitability, thus securing legitimacy for MITI's governance of the electric power system and an overall positive growth trajectory for the Japanese economy (Johnson 1982, 36).

For the first two decades after reorganization, the institutional dynamics of this energy regime worked exceedingly well. The combination of market competition and government coordination provided the right combination of incentives for firms to transition away from a reliance on hydropower towards constructing more advanced and energy dense thermal power stations fueled by imported oil—a transition so rapid that contemporary observers called it an "energy revolution" (Miwa 2005). This new, subterranean energy regime powered by imported hydrocarbons was essential to Japan's postwar economic "take off" and eventual inclusion into the OECD. By the early 1970s, Japan's nine electric power firms were flush with cash, and Tokyo Electric Power Company (TEPCO) was the largest public utility on the planet (Hein 1990, 272).

Changing conditions in both the world system and the domestic political economy gradually transformed institutional relationships between the regional monopolies and the Japanese state (for a deeper exploration of these changes, see Chapter 2). The first oil shock of 1973-74 revealed the vulnerabilities of the energy system's newfound dependence on imported oil. Prices of imported goods skyrocketed along with the cost of heating fuel and electricity, sparking runs on everything from kerosene to toilet paper. MITI responded to the altered world situation by replacing the Public Utilities Bureau with a new Agency for Natural Resources and Energy (ANRE) (*Shigen Enerugī Chō*), which as an "agency" had a bigger budget, more brainpower, and more administrative clout (Johnson 1982, 296-298). Recognizing the precarious position in which dependence on foreign oil imports for 70% of electricity generation placed the Japanese economy (Samuels 1987, 163), the government also ratified the Three Electric Power Sources Laws (*Dengen Sanpō*), which promised lavish subsidies and public facilities to communities agreeing to host new nuclear power plants (Aldrich 2008).

As a result of the "trauma" of the oil shocks, MITI planners were single-minded in their pursuit of nuclear power as the linchpin of Japan's energy regime (Electric power industry representative interview, 21 July 2019). Nuclear power plant construction accelerated after the oil crisis, with the nine utilities constructing a total of thirty-nine reactors across the Japanese archipelago by 2011 (for a total of fifty-four) (Sklarew 2018). Implementing nuclear power policy required new institutional relationships between the state and the nine monopolies in terms of how the state provided additional research and development funds and financing guarantees for this infrastructural buildout. With Japan's "national policy" (*kokusaku*) now centered on pursuing energy security through nuclear power, MITI supported the nine firms in building nuclear infrastructure with amortization guarantees and helped them acquire land title in rural communities with inexpensive land (Former mayor of Tokai Village, Ibaraki Prefecture, interview 26 July 2017). However, the state's dependence on privately held utilities for constructing this infrastructure also gave the utilities significant leverage over national energy policy options, particularly any that might threaten to strand their fixed capital investments in nuclear energy (Sklarew 2018).

After Japan's bubble economy collapsed in 1991, many institutions widely regarded as crucial ingredients for Japan's double-digit growth rates in the early postwar decades were increasingly viewed as sources of stagnation and thus in need of reform (Vogel 2006). Japan's electricity rates came under increasing scrutiny, which at the time were the highest in the industrial world. From the 1990s to the mid-2000s, MITI administrators initiated several phases of liberalization of Japan's retail power market in the hope that competition would reduce electricity rates (ANRE representative interview, 10 July 2019). Yet MITI maintained the system of vertically integrated regional monopolies out of concern that too much competition might hurt

the profitability of the companies and undermine their ability to continue making investments in nuclear power infrastructure (Sklarew 2017).

The crisis of Japan's electric power system following the Fukushima nuclear disaster in March 2011, however, provided reform-minded bureaucrats and de-regulation proponents in the Abe administration with the opportunity to enact a much more thorough liberalization of the electricity retail market, bringing Japan in line with global trends. Moreover, it offered renewable energy proponents a chance to incentivize renewables construction through the passage of a Feed-in Tariff. Both reforms have undermined the security of the regional monopolies' fixed capital investments in nuclear power infrastructure and have unleashed new waves of investment that are already transforming the financial and socioecological spatiality of Japan's energy regime.

Re-regulating the Japanese Energy Regime: Passage of the FIT and Electricity Market Liberalization

The triple meltdown at the Fukushima Daiichi nuclear power plant occurred after a 9.0 magnitude earthquake and tsunami struck the northeastern coast of Japan on 11 March 2011. Beyond the immediate crisis of assessing the damage at the plant and evacuating residents out of the path of radiation, the disaster also signaled a crisis for Japan's prevailing energy governance regime. Observers noted that opposition movements in Japan viewed the crisis as an opportunity to transform dominant political and economic arrangements, including the collusive relationship between government and business that characterized the nuclear power lobby (Samuels 2013). For business elites in *Keidanren*, bureaucrats in METI, and the nine regional power monopolies, however, the prospect of a future without nuclear power constituted a grave threat not only to

Japan's energy security, but to the overall competitiveness of Japanese capitalism (Kikkawa 2011).

De-nuclearizing Japan's electric grid represented a crisis for economic bureaucrats and power utility executives in part because it would result in the immediate, socially produced devaluation of the utilities' fixed investments in nuclear power plant infrastructure, as well as the human labor and expertise required to operate and maintain those plants (Electric power industry representative interview, 21 July 2019). Large-scale industrial consumers, already coping with rolling blackouts across eastern Japan after the disaster, feared any electricity rate increases that might result from drastic changes to Japan's energy mix. As activists and high-profile public figures called for the immediate suspension of operations at Japan's fifty-three remaining nuclear power facilities, *Keidanren* representatives began publicly discussing the prospect of rapid capital flight overseas in search of lower power rates (Kikkawa 2011). For METI, the major policy imperative was to devise a way of restoring the stability of Japan's electric power system without raising rates so precipitously that it triggered a broader accumulation crisis.

If the March 2011 crisis had a fiscal component, it also constituted a legitimation crisis for METI's forty-year commitment to nuclear energy. Social consent for Japan's nuclear power policy had been largely secured through the propagation of trust in the expertise of the scientists and planners in charge of Japan's nuclear facilities and the allocation of financial subsidies to communities hosting these facilities. As the debacle at Fukushima unfolded, the social consensus behind Japan's nuclear power policy began to fray (Scalise 2012). Prime minister Naoto Kan of the Democratic Party of Japan (DPJ) seized this legitimation crisis to order the shutdown of all nuclear power plants and mandated that each plant undergo rigorous safety inspections before they could be restarted.

While utilities scrambled to compensate for the loss of nuclear facilities by firing up idled thermal power stations, the ruling DPJ also passed the Feed-in Tariff as its final legislative act. Although the utilities opposed this measure, few politicians were willing to risk being associated publicly with them by voting against it (ANRE representative interview, 10 July 2019). After convening an expert committee featuring economists, members of the business community, renewable energy analysts, and consumer advocates (a panel from which power utility representatives were notably absent), ANRE established a generous 42 yen per kWh FIT for solar power supplies in July 2012 (ANRE 2012). This was more than double the FIT rate offered in Germany, triple that of China (Muhammad-Suki et. al. 2014, 638), and far above the average unit cost of 8.8 yen per kWh (Matsuo 2013). This new FIT built on a 2009 FIT for rooftop solar and required utilities to purchase power from all registered renewable energy producers in their service area, giving renewables priority access to the power grid. If this measure contained any compromise, it was that utilities would pass the cost of the FIT on to customers by charging higher power rates. The only real threat to utilities' standing was the entry privilege to the grid granted to renewables, which might create redundancy for thermal power plants on days with low power demand. For any registered renewable energy producer, the FIT rate was guaranteed for a contract period of twenty years, which ensured fixed returns well beyond the retrieval of upfront installation costs (Ayoub and Yuji 2012; Muhammad-Sukki 2014).

The second institutional reform, which constituted perhaps a greater threat to the long-term viability of the regional monopolies' fixed capital investments, was the liberalization of the retail power sector (ANRE 2013). Initiated in stages beginning in April 2016, "Electricity System Reform" promised to liberalize fully the small-scale retail power market, which was valued at 8 trillion yen (US$76 billion) (ANRE 2015). An amendment to the 1964 Electric

Power Industry Law in 1995 had already partially liberalized the wholesale market by allowing new entrants, dubbed "independent power producers" (IPPs), to bid on wholesale power contracts with large-scale industrial consumers. In 2000, recommendations from METI's Electric Utility Industry Council led to the deregulation of retail sales to customers over 2000kW (Asano 2006), followed by the liberalization of sales over 500kW (in April 2004) and over 50kW (in April 2005), which represented a liberalization of 62 percent of the retail market (ANRE 2015) (3.4). However, longstanding relationships of cooperation and interdependence between the utilities and large-scale consumers, as well as concerns about stability of supply, prevented many firms from switching their contracts to new entrants (Kikkawa 2004). METI officials now sought a more total liberalization as a means to counteract the rate hikes that would inevitably result from the FIT (ANRE representative interview, 10 July 2019). Liberalization also aligned with the Abenomics platform, which aimed to revive the Japanese economy by eliminating developmental state institutions that insulated the health care, agriculture, and energy systems from market competition (Prime Minister's Office of Japan 2014).

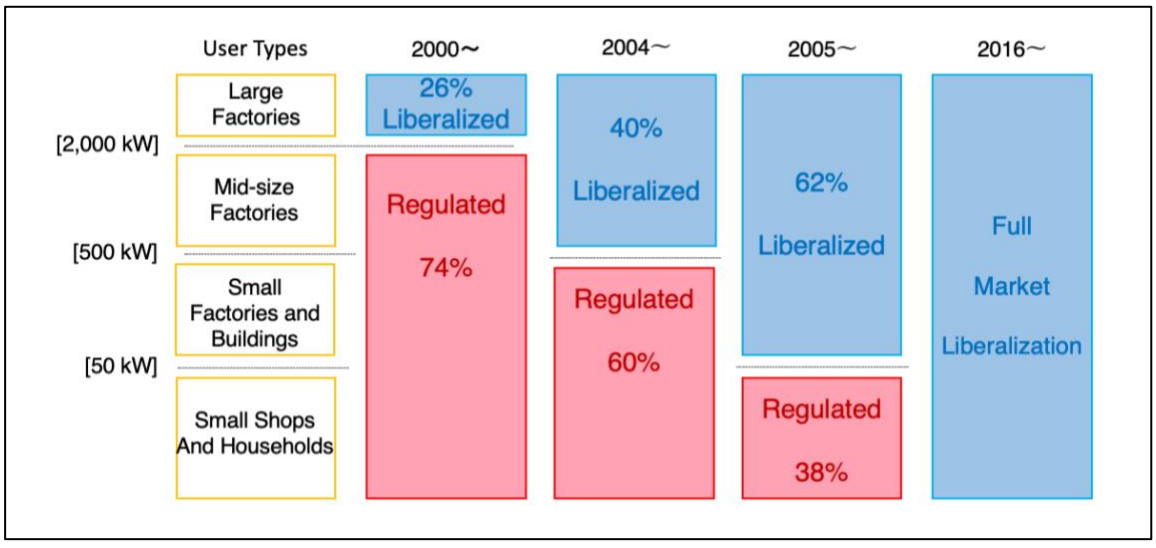

Figure 3.4: Timeline of electricity market liberalization (by author).

Statistics on switching rates from METI suggest that the impact of this most recent liberalization initiative has surpassed previous efforts, resulting in a shrinking customer base and fewer sales receipts for the nine regional utilities. By the end of March 2017, one year after the market was liberalized, approximately 8.8 percent of utility customers nationwide had switched their contracts with utility providers—4.7 percent of these to new companies (ANRE 2017). By June 2018, a total of 18.3 percent of contracts had switched (ANRE 2018). Disaggregating national statistics reveals significant variation between regions, with consumers in the large power markets of the Tokyo-Yokohama (Kanto) and the Osaka-Kobe (Kansai) regions accounting for the greatest percentages of contract switching to new providers (Figure 3.5). The former regional monopolies for these two areas, Tokyo Electric Power Company (TEPCO) and Kansai Electric Power Company (KEPCO), have lost 15.5 percent and 14.8 percent, respectively, of their customer base to outside entrants. Areas with smaller populations, and a smaller number of new entrants, have seen much lower switching ratios; the Kyushu region was just over 7 percent and Hokuriku, Chugoku and Shikoku were near 3 percent. TEPCO and two other utilities with large urban markets, KEPCO and Chubu Electric Power Co. in Nagoya, have reported continuing power sales losses due to customers switching to a different power retailer (Tsukimori 2017, 2018).

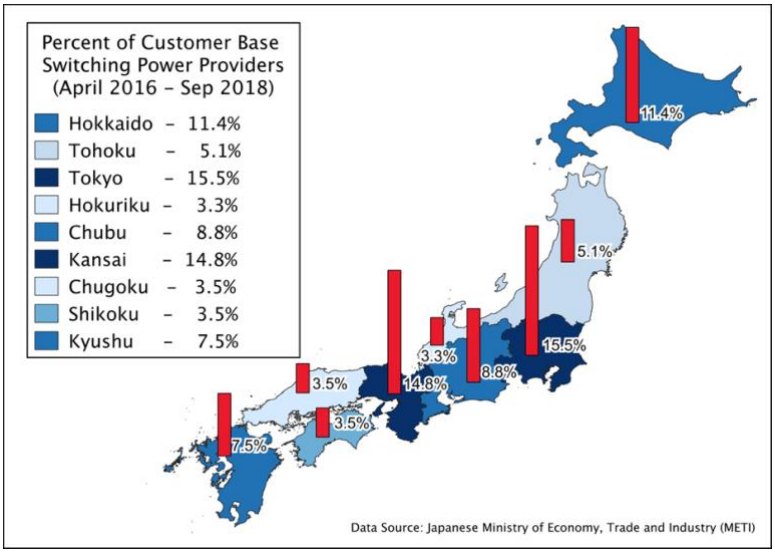

Figure 3.5: Switching rates among regional power monopolies (by author).

Whether or not these two reforms will continue to drive a capital switch from conventional fuels to renewables and from incumbent firms to new entrants over the long term depends on two conditions whose trajectory remain uncertain. The first pertains to the viability of smaller entrants into the power sector, which are currently competing over a still tight retail market. New entrants are handicapped by the unwillingness of Japanese consumers to switch power suppliers. Surveys of more than 2,000 electric power consumers across Japan found that more than 55 percent of customers intended to stay with their same power provider after liberalization (McLellan, Chapman, and Aoki 2016). Certainly, the loss of anywhere close to 45 percent of their customer base would threaten the operations of the large, incumbent firms. With the opening up of former monopoly territories to outside competition, however, customers now have the ability to simply switch from one large regional firm to another in search of cheaper rates. Additionally, in order to protect large-scale power consumers from unstable power rates during the early period of liberalization, METI required major utilities to maintain their standard,

regulated rates until at least March 2020 (METI 2015), which means we have yet to see how large consumers will perform in a fully liberalized market.

Second, and more importantly, it is not clear how close the Japanese state would allow any of the large incumbent utilities to approach insolvency as a result of socially produced devaluation through a renewable energy transition. Already the government has purchased a majority share in TEPCO after its bankruptcy crisis in 2011, in effect constituting the first nationally owned utility in Japan since the Electric Power Development Corporation was privatized in 2003 (Morita 2012). In unleashing new rounds of investment and market activation with the FIT and electricity market liberalization, it is possible that the state has only delayed the broader legitimation and accumulation crisis signaled by the past three "lost decades." Now that these forces have been unleashed, politicians in the Liberal Democratic Party and METI have gradually returned to a more openly pro-nuclear stance, including it as a pillar baseload source in the first post-Fukushima Basic Energy Plan (METI 2014). Analysts in Japan point to recent grid restrictions imposed by utilities on renewable power producers during periods of low consumer demand as a METI-sanctioned strategy to protect the nuclear power assets of incumbent firms, which are given priority access to the grid even on sunny days (ISEP 2018b).

Solar PV Investments and the Spatial Constitution of the Fix

While the FIT and liberalization of the small-scale retail power market have transformed the institutional conditions of accumulation in Japan's electric power sector, the impact of these reforms has not been limited to the spatiality of economic networks between and within firms, the state, and consumers. By spurring accelerated investments in solar PV installations, an energy source with much lower power density than conventional fuels, they are also having

direct, material impacts on the socioecological production of space. In particular, the high returns on investment offered by the FIT have made it financially feasible for a variety of actors to pursue investments in solar PV, ranging from Japanese and foreign venture capital firms and large industrial firms like Mitsui to rural communities impacted by population decline, economic stagnation, or even nuclear disaster. This section draws on interviews and publicly available data to provide a rough typology of solar PV projects in Japan according to their scale (or relative size), their prevalence, and their ownership structure, with the aim of revealing how both material landscapes and power relations are being reconfigured through Japan's socioecological fix.

Perhaps the most geographically prominent type of land use change resulting from the passage of the FIT is represented by "mega-solar" PV installations. The term "mega-solar" derives from "megawatt" and designates installations with 1MW or greater in output capacity. According to industry estimates, 1MW installations can provide enough electricity to power on average anywhere from 180 to 340 Japanese homes.[7] As of June 2019, approximately 6091 mega-solar projects have been constructed since 2012 and 2611 (roughly 40 percent) of those are greater than 2MW in capacity (Electrical Japan 2019). A large proportion of the institutional investment into Japan's solar PV market has been directed at these types of installations, with large firms bundling multiple mega-solar projects into PV portfolios to maximize returns (Institute for Sustainable Energy Policy employee interview, 19 March 2019). The land use footprints of these portfolios are considerable. As of March 2019, the holders of the top three largest solar PV portfolios in Japan, Orix, Softbank (SB Energy), and Mitsui, each held 520MW,

[7] Based on the author's calculations from estimated output from mega-solar projects and the Federation of Electric Power Companies of Japan (FEPC), which estimates average household demand in Japan as 3,600 kWh/year.

390MW, and 336.6 MW respectively (Solarplaza 2018) —equating to roughly 608 ha, 456 ha and 394 ha of land or water surface converted to solar PV by each firm.[8]

The high rates of return promised by the FIT's twenty-year purchase guarantee brought Japan's PV market significant attention from global investors. In 2016, the U.S. Chamber of Commerce rated Japan the second-best renewables market (ITA 2016). Investors, eager to reduce the costs of long lead times, contractor negotiations, land acquisition, and grid connection applications, continue to pursue projects of greater and greater scales. U.S.-based GE Energy Financial Services (GEEFS) has invested in the largest—by area and output—mega-solar project, the 235MW Kirei Megasolar Project in Okayama, Japan (Clover 2014). Built on 500 hectares of reclaimed land that once supported a local salt production industry, the project promised to generate ninety-four million dollars' worth of tax revenues for the local municipality leasing the land and would produce fixed returns for investors over the twenty-year contract (Asada 2016). In June 2017, GEFS also announced the launch of a seventy-five billion yen (710 million dollars) solar investment fund, the largest in Japan, which it will invest in a portfolio of 500MW to 600MW of utility-scale solar projects. The Development Bank of Japan's (DBJ) participation in the fund as an anchor investor suggests that solar PV continues to attract the attention of both domestic and international financial players (DBJ 2017).

In the short term, strict legal protections at the national and municipal levels for agricultural land (MacDonald 1997) have largely prevented working or abandoned farmland from being overtaken by mega-solar projects (MAFF Renewable Energy Office representative

[8] Average land-use footprints for solar PV installations in Japan were calculated from data on a variety of projects featured on Japanese solar developer websites. Area (ha) / Power Capacity (MW) yields an average of land-use footprint 1.1 ha/MW to 1.7 ha/MW for solar PV installations. For instance, the Kirei Megasolar Plant has 235MW capacity on 260ha of land (http://www.setouchimegasolar.com/en/business/index.html), and Renovac's Itako Solar Plant in Ibaragi Prefecture has 14.7MW capacity on 18ha of land (http://www.renovainc.jp/business/ power_ plant/suigo-itako-solar).

interview, 31 May 2019). Investors in mega-solar installations have instead sought to develop projects on forested land with fewer protections, on underutilized land in rural areas, or declining former industrial areas that have few alternatives for re-utilizing land (Institute for Sustainable Energy Policy employee interview, 04 April 2019), as with Pacifico Energy's 96.2 MW mega-solar project on an abandoned golf course in rural Miyazaki (financed by GE EFS and Virginia Solar Group) (Clover 2015). Following the collapse of the bubble economy, large swaths of the countryside that had been purchased to develop golf courses, or coastline areas that had been reclaimed for constructing industrial installations, were rapidly devalued, stranding these assets for both investors and the communities that anticipated increased tourism and tax revenues. The result is that Japan—a country notorious for having an exceptionally low ratio of developable land-to-population—now has numerous areas that are considered eligible for re-development by local governments facing fiscal downturns due to population decline. MAFF, which regulates agricultural land use, even actively advises rural local governments to lease under-utilized land to renewable energy projects to boost tax revenues (MAFF Renewable Energy Office representative interview, 31 May 2019).

Moreover, as rural depopulation intensifies, the amount of land open for re-development for solar PV installations is expected to increase. Recent studies on land tenure transformations in the wake of population decline from the Home Ministry suggest nearly 25 percent of Japan's territory (nearly the size of the southern island of Kyushu) is vacant, un- or under-utilized, and with unclear title status following the death of the owner (Yoshihara 2017). Additionally, the approximately 8,900 ha (89 km^2) of working farmland irradiated to potentially unsafe levels by the Fukushima nuclear disaster (MAFF 2012) are now open for siting solar PV projects. The largest operating community-financed solar project in Japan, the 33MW Tomioka Revitalization

Solar Project in Tomioka, Fukushima, is one such project (Yamashita 2018), but private developers have also targeted local land owners across Fukushima with offers of lucrative deals in exchange for land leases to site PV projects (Iitate Electric Power Company executive interview, 10 March 2019). In the short term, at least, the remaining supply of abandoned golf courses, resorts, and unused land zoned for industrial projects means that rural agricultural land is not immediately threatened by an invasion of mega-solar installations. However, if the government were to prioritize a transition to 100% renewables, pressures from developers would likely increase on forestland, which is subject to fewer protections than farmland and has been the subject of most local conflicts over solar PV development (Institute for Sustainable Energy Policy employee interview, 04 April 2019).

The FIT has also spurred a rapid expansion in the number of community-financed or community-based renewable energy companies, 200 of which existed by the end of 2016. These are generally smaller scale renewable energy providers ($\leq$1MW) that are either the product of community-based finance, or provide dividends to host communities, or both (Institute for Sustainable Energy Policy employee interview, 19 March 2019). While such community-based financing schemes (such as owning a solar PV installation as a neighborhood, municipality or village) do not necessitate a specific form of land-use (such as smaller-scale PV operations), the heavy capital requirements of mega-solar installations mean that 1MW is often the upper-limit for these types of projects. Instead, community-owned solar operations consist of a patchwork of several smaller projects of 50kw to 500kw sited on land owned by or leased from local residents. Financing is secured through a variety of sources, such as private investments, local banks, municipal governments, community-based investment funds, or government programs, like the MOE's Japanese Green Fund. Income from the sales of electricity to the regional utility are paid

out as dividends to community investors (Iitate Electric Power Company executive interview, 10 March 2019).

Aizu Electric Power Company ("Aipower") in Fukushima prefecture is a prototypical community-based solar company and one of the earliest formed to take advantage of the FIT (Institute for Sustainable Energy Policy employee interview, 19 March 2019). Using primarily community-based financing, it has constructed PV installations throughout the prefecture, primarily of 500kW or less. In 2014, it also built the 1MW Oguni mega-solar installation with debt financing from Jonan Shinyo Bank, which was a landmark undertaking for a community-based operator. The remainder of its PV installations, however, are situated on the margins of working farmland or forestland and distribute income gained from selling power to the regional utility (Tohoku Electric Power Company) in the form of a dividend to either the landowners or the residents of the towns where the panels are sited (Aipower executive interview, 18 July 2017). With the liberalization small-scale retail power market, Aipower is now able to sell power from its solar installations directly to consumers in Tokyo through a partnership with a consumer advocacy group, Seikatsu Club Energy (Aipower executive interview, 7 March 2019).

Smaller, community-based solar investment initiatives have also emerged in urban areas as a result of the FIT. Municipal and prefectural governments attracted by the opportunity of generating revenues through PV projects hosted bidding contests for access rights to rooftops and unused portions of public facilities (Nakagawa 2012). After the contract period of the lease expires, ownership of the solar installations—and revenues from the FIT—passes on to the municipality. Other programs have sought to benefit residents directly through FIT revenues or lower electricity costs. Tokyo's Setagaya Ward received much attention in 2014 with the launch of its *yanenerugii* program (a portmanteau of the terms for "rooftop" and "energy"), which

generates electricity from solar rooftop installations and returns the dividends to residents on their electric power bill (Setagaya Ward 2016). Although comprehensive data on the current prevalence of municipal rooftop leasing projects do not exist, by 2015 at least 50 percent of Japan's forty-seven prefectures featured such programs, including large urban prefectures like Kanagawa, Osaka, Aichi, and Fukuoka (Japan for Sustainability 2015).

Given the land constraints of the Japanese archipelago, smaller-scale investors and ecology-minded designers have sought ways to expand solar systems without encroaching on agricultural land. One innovation is "solar sharing," or "agrivoltaics," which proponents consider a recent Japanese innovation, but which may have a longer, more international history (Majumdar and Pasqualetti 2018). These installations are arranged to allow sunlight to hit the ground beneath the solar panels—thus "sharing" the energy of the sun between both plants and the grid (Figure 3.6). Akira Nagashima developed Japan's first solar sharing installation in 2003

Figure 3.6: Solar sharing installation on cultivated farmland in Fukushima, Japan (photo by author).

as a way for farmers to generate electricity without having to displace agricultural crops with solar panels (Solar Sharing Federation representative interview, 17 October 2018). Some estimates claim as much as fifty percent of Japan's annual electricity demand could be covered by solar sharing installations on only 20 percent of its working farmland (Solar Sharing 2015). This suggests that the search for viable land for siting PV projects need not necessarily produce a zero-sum scenario pitting rural agriculturalists against an urban-driven solar invasion. However, the same strict agricultural land protection laws that prevent mega-solar projects and the reluctance of local agricultural unions to allow mixed-use development on working farmland have made the process of siting such installations on farmland exceptionally difficult (Iitate Electric Power Company executive interview, 10 March 2019). At the national level, MAFF has sponsored several solar-sharing pilot projects as a way of boosting rural incomes but does not regard the widespread conversion of farmland to solar sharing installations a realistic pathway to decarbonizing Japan's energy grid (MAFF Renewable Energy Office representative interview, 31 May 2019).

Conclusion: The Limits to Renewable Capitalism?

In tracing the components of the solar PV boom in Japan through the lens of the socioecological fix, this article has attempted a double move, both analyzing the regulatory changes in the governance regime of the electric power sector and offering a typology of the landscape transformations that are emerging as a result. Moving beyond theoretical assertions that all changes to infrastructural systems are of a socioecological character, it has sought to draw out empirically the influence of institutional conditions, including laws, regulation, and policy, on the pathways of infrastructure investment and land use.

The reforms undertaken by METI following the shutdown of Japan's nuclear capacity reconfigured the institutions of Japan's vertical energy regime and stimulated accelerated investment into the horizontal regime of solar PV. Yet, in producing the conditions for a socioecological fix, the Japanese state did not yield its administrative capacity to steer or "pilot" investment and accumulation dynamics in the electric power sector. METI administrators, like administrators in all capitalist states, must walk the tightrope between accumulation and legitimation. In the case of Japan's energy regime, this has involved tailoring incentives to ensure that the revenue of firms in other sectors are not jeopardized by higher electricity rates, and that the fixed assets of large, incumbent power utilities are not too rapidly devalued by increased market competition. Indeed, METI has deployed a variety of policy instruments to govern the market forces unleashed by these institutional reforms, including setting strict timelines for liberalization to protect incumbent firms, introducing renewable power auctions to reduce electricity rates, and revising the FIT rate downward several times to temper the rapid rate of solar PV expansion (ANRE representative interview, 10 July 2019). This suggests that capitalist states are limited in their ability to pursue a socioecological fix through renewables by the need to balance the competing (and contradictory) interests of diverse fractions of capital to achieve a growth trajectory for the economy as a whole.

The case of Japan's solar PV boom also highlights that the power of capital to reconfigure existing socioecological relations through fixed capital investments in renewable energy is not unlimited but remains embedded in specific national-political contexts with specific institutional and geographic conditions. While regulatory reforms produced the market conditions for a rapid PV buildout, they did not determine the pattern that these investments would take once materialized (or "fixed") as infrastructure on the landscape. Instead, these

landscape transformations have been shaped primarily by three conditions, both social and material: one, the capitalist imperative among PV investors to maximize returns on investment; two, the materiality of solar PV, which, as an energy source with low power density, is land intensive; and three, existing land use regulations, which in Japan are exceptionally prohibitive of agricultural land development. These conditions have led firms like Pacifico and institutional investors to prioritize projects on unused or abandoned land rather than developing mega-solar farms on farmland. More importantly, the combination of strict agricultural land protections with an energy source that is by nature spatially extensive has resulted in solar PV installations that economize space, including rooftop lending and solar sharing. While the profitability of these systems pales in comparison to larger conventional systems, they suggest that the potential impacts of solar PV deployment on rural land are not pre-determined by the materiality of the energy source itself, but rather proceed from the capitalist social system in which the use value of electricity is subordinated to the production of surplus value.

Lastly, this article has revealed some of the ways in which institutional knowledge production—the types of laws, regulations, and policies that emerge out of METI—can both directly and indirectly transform socioecological metabolisms at the landscape scale. This suggests that political ecologists should continue to expand the empirical boundaries of the field to consider how forms of governance explicitly framed as "non-environmental"—such as the regulation of market participation in the electric power sector, or the pricing of electricity generated from renewable sources—can have far-reaching socioecological implications (Huber 2013b). While popular environmentalist discourse often recognizes (if only implicitly) the ecological import of economic policies, laws, and regulations, scholars have yet to detail fully the ways in which such forms of knowledge serve to both structure and concretize socio-

metabolic relations more broadly, particularly in the industrialized or industrializing parts of the world with strong state apparatuses. Political ecological scholarship can only be further enriched by expanding the notion of "environmental governance" to include administrative forms, agencies, and policies that are coded as "non-environmental" but which have socioecological ramifications nevertheless.

CHAPTER 4:

The Technopolitics of Energy Transitions:

Materiality, Expertise, and Fixed Capital in Japan's Power Grid Disputes

Foregrounding the grid in renewable energy disputes

Like many of the networked infrastructures essential to reproducing modern life, the electric power grid is not a common topic of political controversy. Only in times of interruption, breakdown, or spectacular failure—instances now growing more commonplace with the increased frequency of extreme weather events in a changing climate—does the grid emerge from the veil of "fetishization" (Kaika and Swyngedouw 2000) that normally screens it from view to become an object of public dispute. As recent events like the power outages in Texas in February 2021 or California's rolling blackouts during late summer heatwaves attest, a stable, functioning power grid is critical to sustaining a variety of services on which many of us depend, from medical care and sanitation to air conditioning, home heating, and food preservation. In such instances, the grid is revealed to be a thoroughly political object, the governance and management of which is vital for the provisioning and security of everyday life.

This invisibilization of the grid may account in part for why critical scholarship on energy transitions has largely neglected the material politics of electricity and the role the grid plays in shaping emergent energy futures. Notwithstanding much important work on the politics of smart grids and localized power distribution networks (Bulkeley et al. 2016; Franklin and Osborne 2017), research has instead tended to emphasize the conflicts and socioecological impacts of changing the types of resources that fuel energy systems. Prominent studies have focused on fossil fuels (Willow and Wylie 2014; Healy and Barry 2017), biomass and biofuels

(Baka 2017), wind (Siamanta 2019), solar (Rignall 2016; Kennedy 2018), small hydropower (Harlan 2019; Kelly-Richards et al. 2017), or waste-to-energy (Behrsin 2019), with decidedly less attention given to the networked infrastructures that are essential for conveying the energy produced from those resources to sites of consumption. Much as in our everyday life, the grid has remained unremarked and under-examined.

In this paper, I explore how analyzing disputes over low-carbon energy transitions requires greater attention to the materiality of the networked infrastructures through which those transitions are elaborated, negotiated, and ultimately contested. How might we approach the political ecology of the grid? Networked infrastructures like the power grid present conceptual and methodological hurdles distinct from those of land-based or aquatic resources typically investigated in political ecology. While significant research in urban political ecology (e.g., Heynen et al. 2006; Silver 2015; Newell et al. 2017) has examined the infrastructures that undergird life in urban-industrial societies, to date much of this work has avoided explicit theorization of technology and the role it plays in both shaping and mediating environmental politics and disputes. Theories of the "production of nature" and "urbanization of nature" (Smith 1984; Fitzsimmons 1989; Swyngedouw 2006) likewise have had much more to say about the theoretical categories of *nature* and *society* (and their mutual imbrication) than about *technology*, the socio-material force that mediates between the labor of human bodies and social systems and the more-than-human world (Kirsch and Mitchell 2004).

Exploring the relevance of a political theory of technology to political ecology resonates with earlier calls to adapt political ecology's methodological toolkit for analyzing resource disputes in so-called "First World" societies (now commonly referred to as the Global North) (McCarthy 2002, 2005). While ensuing scholarship has amply demonstrated political ecology's

relevance to Global North contexts, the prominence of socio-technical infrastructures in mediating socio-ecological metabolisms in societies with high infrastructural penetration (which may or may not correspond to a Global North/South binary) demands a more explicit engagement with analytical frameworks from Science and Technology Studies (STS) for assessing the politics of socio-technical systems (Furlong 2011). Such politics, I posit, may be fruitfully conceptualized as *technopolitics*. This formulation calls attention to both the ability of material artifacts to shape, generate, or co-determine political outcomes (Winner 1980; Bennett 2005; Braun and Whatmore 2010) and the central role that technical expertise plays in formulating, mediating, and adjudicating these conflicts (Barry 2001; Mitchell 2002).

Empirically, this paper turns to recent controversies in Japan over the capacity of Japan's regional power grid network to integrate power generated by variable renewable energy sources, particularly solar photovoltaics (PV). During sixteen months of fieldwork in Tokyo and the Tohoku region of northeastern Japan between 2016 to 2019, I attended seminars and conducted thirty-two interviews with advocates and developers of community-scale renewable energy projects, who expressed concern that Japan's former regional power monopolies were gradually restricting the number and size of solar PV projects that could connect to the grid. These advocates pinpointed the challenges of integrating more renewables into the grid, and the technical question of grid capacity, as critical to reducing Japan's dependence on nuclear power, which they considered too risky after the 2011 Fukushima nuclear disaster. In analyzing controversies over the exclusion of renewables from Japan's grid, I detail how incumbent power utilities marshal expert claims about the technical limitations of the grid to reserve capacity for idled nuclear power plants and protect their fixed capital investments from devaluation. I further

highlight how renewables advocates mobilize counter-expertise through policy advocacy to contest these claims.

In the next section, I elaborate how fusing the analytical prism of technopolitics with an attention to the political economy of power utilities can illuminate new dynamics in renewable energy conflicts, particularly the agency of non-human materials and the central role of experts and expertise in adjudicating these conflicts. I further provide an overview of the ways in which the particular resource materiality of electricity and the grid elevates the role of fixed capital investment as a dynamic shaping conflicts over energy futures. The third section examines the Japanese situation in detail and analyzes how these technopolitical dynamics are influencing recent struggles over grid management and access. The article concludes with reflections on how a deeper theorization of technology is particularly relevant to analyzing the political ecology of renewable energy and offers some of the ways that a deeper mutual engagement stands to enrich both political ecology and STS.

The Matter of the Grid

Recent analyses of electric power grids draw on object-oriented approaches to describe them as assemblages, hybrid entities composed of "a volatile mix of coal, sweat, electromagnetic fields, computer programs, electron streams, profit motives, heat, lifestyles, nuclear fuel, plastic, fantasies of mastery, static, legislation, water, economic theory, wire, and wood" (Bennett 2005: 448; Harrison and Popke 2011). Such descriptions highlight the diversity of forces—human and more-than-human, social and material, technical and organic—that must be enrolled to produce the apparent stability, reliability, and functional coherence of networked infrastructures. Despite their descriptive complexity, however, studies emphasizing the agency of more-than-human

actants have been criticized as "depoliticized and ahistorical" for obscuring (or outright avoiding) how political economic logics of capital accumulation and inter-firm competition also shape the design and governance of science and technology (Arboleda 2017: 362; Hornborg 2014; Kirsch and Mitchell 2004). While attending to the material agency of non-humans is critical to understanding the positive political force exerted by artifacts in disputes over energy transitions, theories of technology from STS stand to be enriched by political ecology's tradition of examining the influence of multi-scalar institutional dynamics and political economy on the politics of socio-environmental regulation.

One way of approaching disputes over energy transitions in a way that fuses political ecology with the theoretical insights of artifactual politics from STS is by attending to the technopolitics that emerge from how they are designed, constructed, operated, and governed. Early formulations of "technopolitics" denoted how material artifacts and expertise have become entangled with contemporary politics (Hecht 1998; Mitchell 2002). Hecht (1998: 15) defines it as "the strategic practice of designing or using technology to constitute, embody, or enact political goals." Technopolitics involves the use of appeals to expertise and technological necessity to pursue political ends. Mitchell's (2002) use of the term is more disparate and capacious than Hecht's, emphasizing the role of hybrid agencies in constituting among experts a sense of mastery over human and non-human world.

> Techno-politics is always a technical body, an alloy that must emerge from a process of manufacture whose ingredients are both human and nonhuman, both intentional and not, and in which the intentional or the human is always somewhat overrun by the unintended. (Mitchell 2002: 42-43)

Although Mitchell never offers a more precise definition, his use of the term in other contexts makes clear that it pertains to "the politics of technical expertise" (Ibid.: 42) and the anti-political

authority granted to expert knowledge with the rise of technocratic governance after the World War II.

Both formulations highlight two dynamics of technopolitics that are relevant for analyzing the political ecology of the grid. The first is that "artifacts have politics" (Winner 1980). This is true not merely in the sense that technological artifacts—like hydropower dams, nuclear power plants, or solar panels—are *political,* serving as objects of social controversy, but also in the sense that artifacts themselves exert a lived, material influence over how social life is imagined and conducted. Acknowledging this does not require subscribing to an ahistorical technological determinism, attributing an irrefutable logic to how technological innovation unfolds or the impacts it has on societies. Rather, it means recognizing that a kind of hidden legislative work takes place in the design and material construction of those systems that shapes the contours of social, political, and economic life and conditions "the framework for public order that will endure for many generations" (Winner 1980: 128). While non-human agency influences how artifacts can or cannot be designed, appeals to the non-negotiable needs of the technological system can serve as a convenient "way out of the apparent irresolvability of political controversies—as an anti-political instrument" (Barry 2001: 7). In this way, technopolitics conceals its political (and economic) origins.

The second is that technopolitical disputes often revolve around the claims of expertise. Appeals to artifactual complexity or system requirements are simultaneously appeals to the technical expertise capable of identifying these characteristics, diagnosing issues, and prescribing appropriate responses. Such appeals also have a distinctly anti-political timbre (Sadowski and Levenda 2020), as they constitute the realms of technological governance and decision-making as outside the boundaries of political dispute. Experts, in performing their often mundane,

intellectual labor, engage in "structuring decisions," in which "different people are situated differently and possess unequal degrees of power as well as unequal levels of awareness" (Winner 1980: 127). Approaching the technopolitics of energy transitions calls for a methodology of "studying up" (Nader 1972), tracing how government regulators or incumbent power utilities rely on technical expertise to formulate energy policies and neuter opposition, as well as how non-dominant social groups mobilize counter-expertise (Williams and Moore 2019) to contest, upend, or reform official policies.

While technopolitics highlights the politics of expertise and the agency of non-humans in disputes over energy transitions, it is important not to overlook how these elements operate within the economic logics of producing energy in a capitalist economic system. The particular resource materiality (Bakker and Bridge 2006) of electricity centers the power grid as a crucial arena of conflict, calling for greater analytical emphasis on the intersections of technopolitics and political economy. For one, the electricity that flows along transmission lines does not pre-exist its generation, but rather emerges from a technical process of metabolic conversion, rendering energy in one form—flowing water, combusting coal, splitting atoms, sunlight, or wind—into a stream of electrons. Indeed, unlike most biophysical resources examined in political ecology, electricity as an object-in-itself cannot exist in the absence of its mediating infrastructure; the mode of delivery and transmission—the grid—is integral to the resource. As with other technogenic resources that emerge from complex industrial production processes, electric power depends on infrastructures with a high organic composition of capital, which in capitalist societies are developed through investment by private firms with the express purpose of generating a profit (Barca and Bridge 2015).

The fact that every power plant and grid is simultaneously a form of fixed capital investment undertaken by private firms introduces path dependencies that shape how and by whom power grids are managed (Harrison 2013). In the twentieth century, private power companies in the U.S., Western Europe, and Japan pursued massive fixed capital investments in grid infrastructure, as their ability to sell the electric power that was produced at any new generation facilities depended on the infrastructure to convey that power to consumers. In return for providing a public service, states eventually designated these private companies "natural monopolies" and granted them monopoly control over generation, transmission and distribution, and retail power sales in specific geographical areas to prevent the inefficiencies that might result from too many firms competing over a single region (Hughes 1983). Until the late 1980s, when utility deregulation became an international trend, power utilities were assured the amortization of their long-term, fixed capital investments in both generation and transmission and distribution infrastructure in part through their monopoly control of regional power grids. Liberalizing power generation markets to allow participation by outside entrants—as Japan did in 2013 after the Fukushima nuclear disaster—eliminated this monopoly power and meant that an increasing number of generating sources would compete over a limited capacity on the grid to transmit that power.

A second way that electricity's material properties influence the technopolitics of the grid is that it cannot be stored but must be consumed within seconds of production. This need to constantly balance the amount of electricity (or "load") entering and exiting the grid to prevent catastrophic failure means that there are actual material constraints in terms of how much given capacity a grid can allocate to different generation sources. Although grid managers have an increasing array of techniques for trading or storing excess quantities of power, including

pumped hydro and batteries, the present limitations of storing power at grid-scale forces power producers to compete over a limited amount of "grid capacity" that must be met and cannot be exceeded (Martinot 2016). This provides a real limitation on the number of power sources that can generate returns on investment by selling power to consumers through the grid. As I elaborate below using details from Japan's grid, a given grid's capacity is partly contingent on the number of users and the number of power plants operating at a given moment, which means grid managers must constantly find ways to balance loads that account for geographical and temporal variation. Instances where power demand overwhelmingly exceeds supply, or supply exceeds demand, can lead to blackouts (Bakke 2016), such as those that struck grids in the northeastern U.S. in the summer of 2005 (Bennett 2005) or Texas in the winter of 2021. This ever-present risk of catastrophic failure necessitates a delicate balancing of the load entering the grid with the amount exiting it, down to the slightest variation over seconds (Martinot 2016: 227).

In the following section, I detail how the material necessity of balancing the load on the grid requires not only that grid managers account for geographical and temporal differences, but it also includes hidden political and economic considerations about which power sources are the most stable and viable for grid security. While renewable energy sources and grid liberalization introduce additional complexity to an already complicated socio-technical system, appeals to the need for maintaining grid stability can also indirectly permit grid operators to prop up forms of power production that are viewed as politically or economically more preferential.

The Technopolitics of Japan's Grid Disputes

Until the Fukushima nuclear disaster of 2011, Japan produced upwards of 30% of its electricity from nuclear power and each of the mainland nine regional power companies managed at least one plant (Figure 4.1). After the disaster, however, the Japanese government

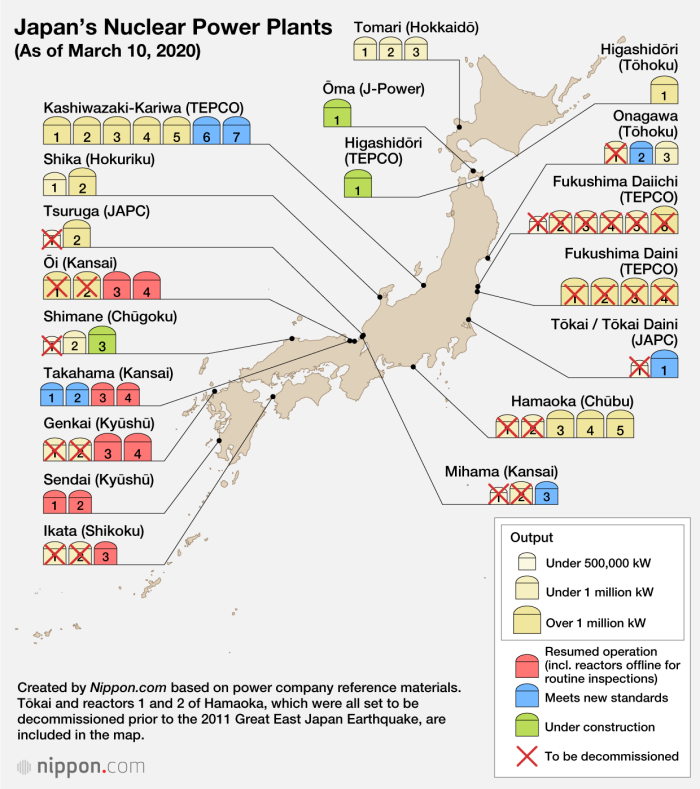

Figure 4.1: Map showing the status of Japan's nuclear power plants since 2011 (Source: Nippon.com).

ordered the shutdown of all 54 nuclear plants nationwide while they updated their safety protocols and underwent rigorous inspections. Both to make up for some of this lost power generating capacity and to respond to growing popular agitation for transitioning away from nuclear energy, in 2012 the government also enacted a generous Feed-in Tariff (FIT) to boost renewable energy production. Designed using Germany's 2004 FIT legislation as a model, the Japanese FIT essentially liberalized the power generation market in Japan by guaranteeing subsidized rates for power generated from renewable sources and granting renewables priority access to regional power grids. The government's Agency of Natural Resources and Energy

(ANRE), which regulates the power industry, initially set an exceptionally high FIT (42 yen/kwh) to account for the high costs of solar PV and wind generation technologies, but as solar PV prices began falling worldwide throughout the decade it was subsequently revised downward to reflect the decline in development costs (see Chapter 3).

There were concerns within Japan that eliminating nuclear power as a baseload power source would jeopardize the overall stability of the grid (Kikkawa 2012). Since the 1970s, debates over the feasibility of variable renewable energy sources like wind or solar PV had centered on the instability they would introduce to the transmission and distribution network (Bakke 2016). Whereas conventional baseload power sources like hydroelectric dams, nuclear, or coal-fired power plants operate at a constant voltage, the output of variable power sources changes depending on whether the sun is shining or the wind is blowing. Such variations range from micro-scale changes over seconds or hours (e.g., a cloud briefly passing over the sun) and meso-scale (e.g., sunset in the evening) to macro-scale (e.g., rainy seasons or a succession of years with anomalously low rates of sunshine) (Martinot 2016). While some variations are cyclical and more predictable, as hours of sunlight vary according to the time of day or season of the year, others can be more erratic, making reliable calculation and anticipation difficult. Both environmental and technical factors present challenges to grid integration, including "voltage swings, sudden weather-induced changes in generation, and legacy protective devices designed with one-way power flow in mind" (Hill et al. 2012). Given these operational challenges, a long dominant assumption among power utilities worldwide was that increasing the proportion of VRE in the power supply would unavoidably result in an increased risk of blackouts and brownouts.

By 2012, when the Japanese government passed Feed-in Tariff (FIT), the impacts of VRE on grid instability had been clarified for engineers and grid managers, who could draw on the experiences of nations with large proportions of VRE on their grids like Denmark (Bakke 2016). New technologies made achieving grid stability in response to micro-scale load variations more feasible, including "visualization tools, maps, trending displays, real-time analytics [that] inform an operator of problems that previously were too subtle to detect" (Cohn 2017: 223). Meso-scale variations were more challenging. As is common with most urban electricity consumers (Powells et al. 2014), the rhythms of everyday life in Japan produce a predictable ramping up of power consumption in the evenings as people turn on lights, air-conditioners, televisions and home appliances, a phenomenon known as "peak demand". This means that demand peaks just as the sun sets and output from renewables declines precipitously. A macro-scale issue was that certain regions of the country had sunny weather during parts of the year with low power demand. Sunny or windy days during spring or fall, when mild temperatures reduced demand for air-conditioning or home heating, would lead to large power surpluses, which would force grid managers to find ways to shift or curtail the load from generation stations or else risk catastrophic grid failure.

By 2016, Japan's generous FIT was so effective in stimulating a rapid growth in the proportion of VRE in Japan's electricity supply, particularly solar PV, that it was also generating regulatory conundrums for policy makers and grid managers (Chapter 3). By the end of 2019, VRE accounted for 8.2% of Japan's annual power generation, with solar PV accounting for the majority at 7.4% (ISEP 2020). According to one early career bureaucrat at the Ministry of Economy, Trade, and Industry (METI), whose team was responsible for revising the FIT in subsequent legislative sessions, the overwhelming response from developers had created a host

of problems for grid operators and regulators, who were already dealing with the nationwide shutdown of nuclear power. Chief among these was the creation of a "solar bubble." Lured by the promise of lucrative returns from renewables investments, too many developers had secured licensing and grid access early on to lock-in high FIT rates but were delaying completing the projects. With solar technology costs falling rapidly, waiting promised even higher returns from the excessively high FIT (Interview, METI employee, 26 October 2017). This presented significant challenges for both utilities and renewables developers; while the former had to reserve grid capacity for non-existent solar projects, the latter risked being denied approval for a new solar project because of the phantom capacity reserved by these non-existent projects.

Further challenges resided in the material configuration of Japan's power grid itself. In three different interviews, power utility executives attributed the challenges of grid integration in part to Japan's geological configuration as an "island nation" (*shima guni*), which resulted in Japan having a grid that was "shaped like a skewer" (*kushi-gata,* a term for the skewers used in grilled meat dishes), rather than the geographically expansive, continental-scale grids of the EU and the U.S. (Figure 4.2). Unlike continental systems in the U.S. and continental Europe, which can transfer power freely between distant regions to balance supply and demand, island power grids "cannot rely on the inertia of a neighboring system to maintain frequency stability" but "must be self-sufficient, in terms of having enough frequency stabilizing capability" (Kuwahata et al. 2018: 1250). Inter-island connections, particularly those tying the island of Honshu to Hokkaido in the north and to Kyushu in the south, constituted critical bottlenecks in the transmission network that inhibited the ability of regional grid managers facing a power surplus to sell to regions with high demand. An even greater—and geographically peculiar—bottleneck existed due to Japan's grid being divided into eastern and western zones that ran at different

frequencies, with the western segment running at 60 hertz and the eastern segment running at 50 hertz. Transferring power between these two regions requires routing power through three frequency conversion stations (shown in red in Figure 4.2), which can only handle around one million kilowatts each (Gordenker 2011) and constitutes a hard material limit on how excess power can be distributed across the country.

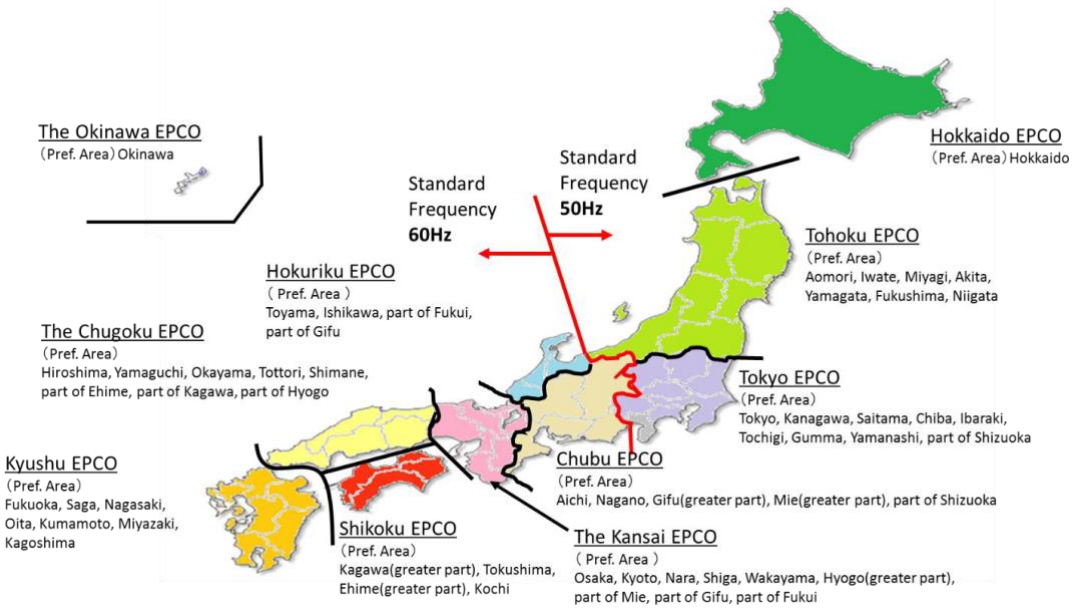

Figure 4.2: The Ten Regional Service Areas in Japan and Frequency Division (Source: OCCTO).

As the decade wore on, disputes erupted over how access to the grid was being managed, with renewable energy advocates voicing concern that the utilities and ANRE bureaucrats seemed partial in how they allocated the technically determined "grid capacity." Despite having granted renewables a policy victory with the passage of the FIT, particularly in the granting of priority grid access, the seemingly technical designation of grid capacity could allow incumbent utilities to withhold additional capacity for the eventual restart of their nuclear power plants. Under the 2013 revisions to Japan's Electric Power Industry Law (*Denki Jigyō Hō)*, electric power generation, transmission and distribution, and retail sales had been "unbundled," meaning

they were no longer invested in vertically integrated regional power monopolies. Although the regional power firms still existed, they were now forced to compete with independent power producers (IPPs) for access to the grid and with retail power companies for sales to consumers (Spivey 2020). Transmission and distribution—the grid—remained the only domain of the power system still under their control. Although regulatory oversight of the grid had been invested in the Organization for Cross-regional Coordination of Transmission Operators (OCCTO), a watchdog agency created in 2015 to facilitate the transition to an economically liberalized and nationally integrated grid, the agency was nested in METI, which had a long history of propping up Japan's nuclear power industry through R&D support for corporations and subsidies for acquiring land for power plant development in rural communities (Aldrich 2008).

The first sign of a strategy to exclude renewables from the grid appeared in 2014, when Kyushu Electric Power Company (KEPCO) in southwestern Japan became the first utility to use claims of limited grid capacity (*aki-yōryō ga nai*) to slow applications from solar developers for grid access, claiming they lacked the capital necessary to upgrade their grids to accommodate the surge in new connections (Topham 2014). In October 2018, KEPCO began its first grid curtailments, ultimately restricting the access of renewables—particularly solar PV—to the grid for a total of 26 days (Kuwahata et al. 2018; Tsukimori 2018). The utility said curtailments were necessary due to a combination of environmental circumstances and techno-material constraints, including a succession of sunny days with mild temperatures and low regional demand, insufficient storage capacity, and network bottlenecks that inhibited power transfers to neighboring grids with similarly low demand. The western portion of Japan's grid was essentially overflowing with solar power with no way of transferring it efficiently farther east to other markets. KEPCO had restarted its nuclear power plant at Sendai in southern Kyushu and its

Genkai plant was in the middle of safety inspections, having received consent for restarts from the local community. To the question of whether claims of limited grid capacity in the present could serve KEPCO's interest of reserving future capacity for its still-idled nuclear power plants, a METI official replied that these were technical, not political, decisions, based solely on the grid's material limitations. Pointing to the challenges presented by the country's island geography and under-developed inter-island connections, he said: "Japan's grid was not built for distributed energy" like wind and solar PV (Interview, METI employee, 26 October 2017).

Utilities in other parts of Japan have also relied on technical claims of limited grid capacity to stem the growth of renewables as a proportion of the regional generation mix. As part of my research on Japan's evolving energy imaginaries and policies in the wake of the Fukushima nuclear disaster, I met with several small-scale solar power operators who were eager to make a grassroots transformation of Japan's energy system. The passage of the FIT spurred a rapid growth in renewables development by small-scale entrepreneurs, who saw an opportunity to revitalize agricultural communities by selling power to the grid. Iitate Electric Power (*Iitate Denryoku*), a community power company in Fukushima founded in one of the villages evacuated due to radiation from Daiichi, is one such company, led by a former Fukushima farmer who lost his livelihood after the disaster and found a new one in renewable energy (Figure 4.3). As we drove past abandoned farmsteads in Iitate Village, I asked why there weren't more solar projects, given that they seemed to promise so many benefits to residents still suffering the after-effects of mandatory evacuation orders and agricultural decline. Given the extent of vacant land, why were there so few projects? He replied:

> The first hurdle is the local agricultural union. They decide which uses to allow on farmland and are skeptical about allowing land to be used for non-agricultural purposes, even if it is 'solar sharing' [agrivoltaics]. But the bigger hurdle is Tohoku Electric Power

> Company's recent mandate that they will only allow projects of 50 kilowatts or less to connect to the grid (Interview, 9 March 2019).

This 50-kilowatt mandate forced their small company to pursue numerous small projects instead of focusing on larger projects, which multiplied the administrative overhead required for negotiating with the agricultural union, obtaining solar project permitting from METI, and applying for grid connections with Tohoku Electric. Given what I had heard from the METI employee about the solar bubble, I asked him if the utility might have legitimate reasons for slowing down development. He answered:

> Sure, but if that's the case, why make the requirement so small, at 50 kilowatts? Why not 100 or 500? It seems to me like they are actively trying to slow down solar development in order to reserve more of the grid for their nuclear power plants, which they are still hoping to restart (Interview, 9 March 2019).

Defining not only grid capacity, but the extent of projects that were "manageable" from a grid integration perspective, allowed Tohoku Electric to halt the pace of solar PV development and maintain some reserve capacity for restarting the Onagawa nuclear power plant in Miyagi prefecture, which was undamaged from the earthquake and tsunami of March 2011.

Figure 4.3: Iitate Power executive, Kei Kondo, with one of the company's solar installations in Iitate Village, Fukushima, Japan (photo by author).

The denial that anything other than the technical constraints of grid configuration, grid capacity, or grid stability might be involved in decisions to ration or curtail grid access was a common refrain among the utility and regulatory experts with whom I spoke, many of whom agreed to sit down with me only on conditions of anonymity. A representative of the Japan Electric Association (*Nihon Denki Kyokai*) told me in his high-rise office in the Ginza district of central Tokyo that suggestions that renewables were being unjustly excluded from the grid in Kyushu were unfounded, given that KEPCO diligently followed all required protocols before ordering grid curtailments. Opening a pamphlet on effective grid management created by the Association, he proceeded to walk me through these protocols step-by-step in an almost painstaking fashion. Grid managers first had to try to use any excess power by pumping water behind hydropower dams ("pumped hydro"), transferring power to neighboring grids, and ramping down output from thermal power plants. Then, only if a power surplus still existed after taking these three measures, could operators order the curtailment of renewables. He dismissed the idea that nuclear power was being unfairly prioritized as likewise absurd, again appealing to

material constraints of the energy source: a nuclear power plant cannot simply be turned on and off like a thermal power plant. For this representative, and for the industry of which he is a prominent member, the commitment to maintaining nuclear power as the premier baseload power source of Japan's grid was framed as emerging not from the political economic interest of minimizing the devaluation of sunk assets, but from the necessity of doing what was technically required to prevent blackouts and produce a stable supply of electricity at the lowest possible cost. The risk of a blackout was the specter that stalked these techno-economic considerations: "For human lives and livelihoods, and for economic activity, electricity is indispensable" (Interview, Japan Electric Power Association representative, 8 August 2019). The power utilities in charge of managing the grid were simply operating under the disinterested goal of securing a "stable supply" of power (*antei kyōkyū*) and pursuing this goal within the boundaries that the material characteristics of the system—both power sources and the grid—had set for them.

Yet, the composition of Japan's electric power supply had long been fraught with political and economic implications. Renewables proponents in Japan often framed their dream of a Japan powered by one-hundred percent renewables not simply as a technical approach to energy security, but also as a categorical rejection of nuclear power and the monopoly power of the regional utilities. For their part, regional utilities and the nuclear industry had also long engaged in political lobbying and public relations campaigns to sway Japanese public opinion in favor of nuclear power, succeeding only after the oil shocks of the 1970s revealed the vulnerabilities of relying on imported fossil fuels (Aldrich 2008). The attempt by the utilities to restart their nuclear power plants after the Fukushima nuclear disaster remains a hot button political issue, with many popular public figures—including former Prime Ministers Koizumi Junichiro, Hatoyama Yuichiro, and Kan Naoto—publicly expressing their support for a nuclear-

power-free Japan. Japan's regional utilities also had economic incentives to restrict access to the transmission and distribution grid to both simplify grid management and reserve capacity for their still idled nuclear power plants. Since the 1970s, the utilities had gone on a building spree of nuclear power plants, which after the high upfront costs promised at minimum three decades of low-cost electric power. The rapid growth in renewables and the liberalization of the power industry in 2016 undermined this long-term strategy. Regional power utilities were now posting record losses and some executives even privately expressed concern about the long-term financial viability of their firms if they were unable to recoup their large-scale fixed capital investments in nuclear power (Interview, power utility executive, 27 July 2019).

While utilities and regulators in METI and the OCCTO position policies related to grid curtailments and designations of grid capacity as neutral procedures determined through the technical requirements of power network stability, other stakeholders have contested these designations through the mobilizations of counter-expertise. Counter-expertise is expertise that is not officially sanctioned and consists of knowledge or observations that are marginalized or excluded by official institutions (Williams and Moore 2019). Although Japan's grid counter-experts have PhDs and experience managing complex technical systems, their insights are neglected because it does not align with the central government's policy priorities. The Institute for Sustainable Energy Policies (ISEP), a non-governmental organization led by former nuclear engineer and staunch renewables advocated Iida Tetsunari, has been a leading institutional actor promoting counter-expertise critical of prevailing grid management criteria. In a report that critically assesses KEPCO's grid curtailments, ISEP pointed out that the curtailments appeared to contravene METI's own FIT legislation, which mandated that grid managers give renewables "priority access" to the grid (ISEP 2018). On the surface, OCCTO's procedures attempted to

preserve this priority status by making renewables curtailment the last option to keep supply and demand in alignment, as the Japan Electric Power Association representative explained to me. However, ISEP's policy brief noted that while OCCTO's guidelines allow for adjusting the proportion of renewables and thermal power on the grid, the baseload occupied by KEPCO's Genkai and Sendai nuclear power plants was never in dispute, in part because it aligned with government targets—outlined in the 2018 Energy Basic Plan—for restoring nuclear energy to 20 to 22% of Japan's primary energy supply by 2030.

Despite the success of renewables proponents after the 2011 nuclear disaster in securing economic stimulus for renewables investment through the FIT, the stipulation—unremarked at the time—of requiring feeding-in to regional power grids inadvertently gave regional power utilities a mechanism for inhibiting the ascendance of renewables to the status of Japan's baseload source. The decisions of the transmission and distribution wings of the former regional power monopolies to restrict grid applications or curtail grid access are articulated technopolitically, and center on the technical specifications of grid stability, grid capacity, and the geographical configuration of Japan's grid. These arguments meld the material requirements of stable grid operation, technical arguments based on ideal power mixes to ensure low cost and efficient power, and moral arguments about how best to secure the households and corporations of the Japanese nation. They also serve simultaneously to conceal the economic incentive for former regional monopolies, who oversee transmission and distribution infrastructure, to restrict renewables and reserve future capacity for their idled nuclear power plants.

While materiality plays a significant role in shaping the possible trajectories for Japan's energy future and the management of the grid, how it is invoked by experts within both government and industry can produce asymmetries of power and inequalities in outcomes. For

official experts, the requirements of a stable grid seemed to dictate above all else a power supply with minimal variability and intermittency, which could imperil the Japanese economy. These economic perils were reasoned to be greater than the peril lived by people in the pathway of Fukushima Daiichi's radiation plume. "Stable supply" (*antei kyōkyū*) was invoked as frequently in their speech as in the PR pamphlets I gathered in waiting rooms and nuclear power museums, and formed a kind of anti-political watchword, as though the technology itself determines what policy, and what energy mix, is best. On the other hand, counter-experts in the renewables community downplayed the risks inherent in balancing the load on a grid with a high proportion of variable renewables. For them, the ideal power mix for Japan proceeded logically from their belief that nuclear power is simply too risky on such a tectonically active archipelago, and from an almost teleological faith that a distributed energy future will necessarily replace the centralized grids of the present. In the short term, the dependence of renewables on the centrally administered grid for power transmission if it is to be financially viable has rendered renewables producers also dependent on the experts and technocrats that manage it. Whether or not Japan will ultimately reduce its dependence on nuclear power and imported fossil fuels depends not just on public awareness campaigns or the power of political parties, but on the outcome of these kinds of mundane technopolitical disputes waged over the management of the grid.

Conclusion: Towards a Technopolitical Ecology

An early definition of political ecology held that the field combined "the concerns of ecology with a broadly defined political economy... [which] encompasses the constantly shifting dialectic between society and land-based resources" (Blaikie and Brookfield 1987: 17). As subsequent scholars have noted, this formulation was fraught with ontological assumptions and

geographical imaginaries that over-determined the types of societies and resources scholars were willing to examine (McCarthy 2005). One assumption was that this socio-natural dialectic was more apparent in so-called "Third World" settings, where peasants, herders, or landless laborers engaging in hunting, subsistence agriculture, or primary production were the ideal subjects of research. A second was that the proper object of research was "land-based resources." Attention was given primarily to "biophysical resource systems" with little attention given to the "technological resource systems" (Bauwens 2017) that were so predominant in the urbanizing and industrializing societies of the Global North and South. Technology was thereby constituted as political ecology's other, and though often a prominent factor in environmental disputes, it was rarely the object of explicit analysis or theorization.

A primary aim of this paper has been to explore the conceptual and methodological implications of treating disputes around technological resources as subjects of political ecological research. Using the power grid as an example to think through these questions, I argue that such networked infrastructures have material properties that render them distinct from other resources and change both the sites and character of political disputes. In the case of Japan's power grid, conflicts have unfolded in a rarefied arena of board rooms, government offices, and operating centers, which contrasts with more visible sites of struggle seen in popular movements against oil pipelines, hydropower dams, or solar power plantations. The conduct of these disputes is also less spectacular, revolving around questions over which expert claims of grid capacity are privileged in the policymaking arena. Researching these instances of technopolitics requires "studying up" (Nader 1972), tracing how different forms of expertise become hegemonic, allowing them to exercise social power over the management of the resource.

Another point is that for networked infrastructures, the materiality of the system plays a significant role in determining how the resource can be managed. In their discussions of grid capacity, public utilities can use appeals to the technical requirements for grid stability as a way of shielding other political economic determinations of their policy from scrutiny. Grid capacity, or other technical factors that might be appealed to in the case of other technological resources, is only determined in part by the material properties of the system. Choosing how to allocate that capacity, and under which priorities, is also a decision infused with technopolitical implications, as it is determined in part by political economic and technocratic rationales about which energy sources best ensure the stability of the power grid. As yet these questions are still significant topics of dispute, both in Japan and internationally.

A secondary, and broader, aim of this paper has been to demonstrate the relevance of theories of technological politics from STS for analyzing the political ecology of large-scale technological systems. Although scholarship in urban political ecology and political-industrial ecology have broadened the empirical foci of the field to encompass networked infrastructures and urban systems, political ecology still largely lacks a theory of technology. As Huber (2015) argues, studies of infrastructure often resort to relying on some biophysical resource to serve as a stand-in for "nature", neglecting the hybrid enviro-technical systems of production, circulation, and consumption in which a more-than-human nature is always-already embedded. Political ecology has much to gain from foregrounding the role of technological systems in mediating social metabolisms at a variety of scales beyond the urban, tracing networks beyond city limits to encompass everything from rural-urban linkages and trans-regional infrastructure politics, to global supply chains and international policy disputes. Critical studies of technological politics, too, stand to be enriched by political ecology's attentiveness to uneven power relations and the

multi-scalar dynamics of political economy, not to mention feminist political ecology's commitments to examining more local and embodied socio-ecological impacts. Lastly, scholarship on the political ecology of renewable energy likewise stands to benefit from sustained attention to the anti-political forces exerted by artifacts of power production and distribution on the trajectory of energy transitions and how struggles over energy futures often center on disputes over technical expertise.

CHAPTER 5:

Conclusion

In recent years, scholars working in the emerging "academic borderland" of energy geographies (Baka and Vaishnava 2020) have made major inroads to understanding the relationship between energy systems and systems of social power. This work has ranged across a wide array of theoretical approaches, including noteworthy studies of the relationship between Foucauldian biopolitics, subjectivity, and energy systems (Boyer 2011) and the linkages between the materiality of fossil fuels and modern political systems (Mitchell 2011). Given the centrality of energy consumption to contemporary social life, the supposition is that transforming energy systems to accommodate greater proportions of renewable energy will require a revolution of all spheres of human activity, including those conventionally described as the cultural, the political, and the economic.

This dissertation has examined Japan's post-Fukushima energy transition through the lens of geopolitical economy. Drawing on the expansive definition of geopolitical economy outlined in the introduction, the articles gathered here have sought to identify the intersections of political and economic forces in Japan's rapid buildout of renewable energy, and has focused on how law, policy, and mundane administrative labor by state bureaucrats have transformed the institutional dynamics of Japan's electric power system. More than simply analyzing institutional changes, however, it has also detailed how changes to electric power policy to allow more renewable energy on Japan's grid has also transformed the geography of energy production in Japan, with more distributed forms of generation participating in the wholesale energy market and a more complicated geography of economic actors selling retail power to consumers. In this

demonstration of geopolitical economy at work, transforming systems of electric power production also has implications for land use and for geographies of consumption, as electric power utilities are unbundled from regional territories over which they once had monopoly jurisdiction and dispersed rural solar cooperatives are able to generate power and income by selling power to the grid.

The current energy transition from fossil fuels and nuclear energy to renewables is not the first in human history (Smil 2016). As the history charted in Chapter 2 of this dissertation shows, societies like Japan's underwent energy transitions at several times in their history during the modern period. In Japan's case, this involved a transition after the Meiji Restoration of 1868 from a feudal agrarian economy powered by wind and wood to a modern economy powered by coal. After the Russo-Japanese War of 1905-06, this early coal complex was supplemented, and in some sense succeeded, by a transition towards greater electric power use that was generated by hydropower dams. The period of "hydropower-first, thermal power second" (Kikkawa 2012) lasted from the 1920s until about the 1960s, when Japan underwent what analysts and commentators called an "energy revolution" towards greater reliance on oil for power generation (Miwa 2005). After the oil crisis, the Japanese government promoted a transition away from fossil fuels and towards greater reliance on nuclear energy. While this did not completely replace the fossil fuel complex that dominated the globe after the Second World War, it did supplement it considerably. Until the eve of the Fukushima nuclear disaster in 2011, Japan's energy policy focused on a "balanced mix" that incorporated a variety of primary energy sources to enhance the Japanese power system's ability to withstand any exogenous shocks in the form global resource shortages, such as were experienced during the 1970s oil crisis.

Yet the current energy transition since the Fukushima nuclear disaster differs from those that preceded it in significant ways. First, many of the earlier transitions relied to an overwhelming degree on entrepreneurial activity in response to market incentives, rather than state action to stimulate the transition, a dynamic reviewed in Chapter 2. This was true particularly for the hydropower boom of the 1920s and the rapid expansion of oil-fired thermal generation in the 1960s. Only once private development became haphazard or inefficient did the state step in. Today, as a variety of scholars and energy transition advocates have remarked, state action is indispensable to produce the conditions for a transition to renewable energy. Fixed investments in conventional powerplants that have yet to amortize remain a financial disincentive to the transition, as utilities already hold power generation sources that have low marginal costs. These marginal costs are lowest for nuclear power plants, which do not require recurrent purchases of fuel on global markets to operate like natural gas or coal-fired power plants. Until the middle of the 2010s, when the cost of renewables began to plummet worldwide due to increased Chinese production, state action was seen as an important tool to reduce the high costs of solar PV panels and wind turbines, which further inhibited the incentive to transition.

Second, unlike previous transitions, power utilities are among the largest private corporations in the world and constitute a substantial impediment to the transition. For much of the twentieth century, Tokyo Electric Power Company was the largest public utility on the planet, and it still manages the world's largest nuclear power plant at Kashiwazaki-Kariwa in Niigata Prefecture. As noted in Chapter 3, utility reluctance to transition away from conventional generation sources is due in part to the immense costs of retiring coal, natural gas, or nuclear power plants before they have reached their end of life, a process energy transition scholars call

"green devaluation" (Knuth 2017). Incumbent power utilities—those that have dominated the landscape of energy generation, transmission, and distribution in their respective service territories—thus constitute "vested interests" with a substantial financial stake in maintaining the energy status quo (Moe 2012). The complexity and high capital costs of new generation infrastructure also constitute significant barriers to entry for independent power producers, another aspect of the current energy landscape that state action can be used to address.

Third, there is the problem of current infrastructure configurations, which co-evolved with the development of large-scale, centralized generation stations over the twentieth century. This infrastructure—the material, rather than financial, aspects of "fixed capital"—constitutes a physical impediment to rapidly deploying and integrating distributed renewable power generation into the energy mix. As Chapter 4 details, foremost among this infrastructure is the power grid itself, which is the crucial component for conveying electricity from generation sources to end-use customers. Prior to 2011, managing Japan's grid was a relatively straightforward affair. The nine regional power monopolies managed a portfolio comprised primarily of large-scale generation stations. Nuclear power provided stable baseload power but were incapable of varying their output; once turned off, it can take weeks or months to safely restart them. Hydropower dams could vary their output somewhat to meet daily changes in demand, and although their output waned through the year as snowmelt dwindled and Japan's early summer rainy season tapered off, this decline was predictable. Natural gas played the role of "peaking plants" that could be turned on at certain periods of the day when demand spiked abruptly and turned off just as quickly. Increasing the proportion of renewable sources on the grid, which varied in output depending on the time of day or the season, in both predictable and

unpredictable ways, promised to eliminate much of the control that grid operators and utilities had during the era of centralized power.

In Japan's case, initiating an energy transition while addressing the three challenges listed above has depended to a great degree on state action, particularly in the form of legal action and regulatory reforms initiated by METI. First, to address the issue of high costs, Japan's Feed-in Tariff (FIT) was designed to stimulate a market in renewables and essentially reduce the overhead costs of developing energy projects. The financial stimulus provided by the FIT operated in two ways: the guaranteed premium paid to developers seeking to interconnect their renewables projects to the grid minimized the once substantial barriers to entry in the generation sector, and the subsequent expansion of demand for solar panels also initiated a virtuous circle, whereby the cost of solar itself declined year over year. Second, to overcome the veto power of vested interests, represented by TEPCO and the other regional utilities and *Keidanren*, METI both mandated that regional utilities give renewables priority access to the grid and simultaneously undertook the reform of the electricity sector through revisions to the Electric Power Industry Law (*Denki Jigyō Hō*). These regulatory reforms initiated the process of "unbundling" the three phases of power supply—generation, transmission, and distribution/retail sales—and allowed new entrants to compete with the former monopoly utilities over generation and retail sales. As detailed in Chapter 3, these electricity sector reforms were responsible for a rapid buildout of solar photovoltaics across the country in the mid-to-late 2010s, during which Japan became one of the leaders of the global energy transition.

Lastly, to manage the growing complexity of Japan's grid and facilitate its management under the newly deregulated conditions, METI created the Organization for Cross-regional Coordination of Transmission Operators (OCCTO). This independent agency reviews the grid

operation plans of the former ten regional power monopolies, which now remain the sole organizations responsible for managing the operation of Japan's grid. As Chapter 4 shows, maintaining monopoly control over the transmission network has provided incumbent power utilities with a backdoor way to slowdown the precipitous growth of renewables across the country. By pointing to grid capacity constraints, grid operators—that is, the former regional power monopolies—are able to justify curtailing solar power output on days with high production and low demand. On this grounds, regional utilities have also been able to deny interconnection rights to renewables project developers, despite the mandate under the FIT legislation that such projects be given priority access to the grid. While such constraints do exist and are bound up with the material properties of the grid, grid operators often fail to disclose certain portions of the grid capacity that have been withheld from their calculations to allow them to maintain capacity for future nuclear power plant restarts. Incumbent power utilities are thus provided with a technopolitical means of circumventing legislative constraints mandating the expansion of renewable energy.

What all of this means for the future of Japan's energy transition is uncertain. Even before research for this dissertation began, the Government of Japan released the 2014 Basic Energy Plan, which called for accelerating nuclear power plant restarts in order to secure a stable and reliable electric power supply. The consensus among industry leaders, both within and outside the power utility sector, remained that nuclear energy was a significant pillar of Japanese energy security strategy. Kyushu Electric Power Company, whose service territory was farthest from the epicenter of the Great East Japan Earthquake, succeeded in restarting both the Genkai and Sendai nuclear power plants while I was conducting research. As one of my contacts at METI pointed out, METI administrators had also become concerned, too, that FIT valuations

were too high and had contributed to a distorted generation market. In 2017, METI introduced an auction system to address this distortion and bring down wholesale power prices, which was set up to allow renewable developers to bid competitively into the wholesale power market. The goal was to abandon a more developmentalist approach to renewable development and rely on more neoliberal, market-oriented strategies for securing renewable generation at the lowest price. A recent near miss of a Tokyo-wide blackout due to power supply shortfalls during an early spring cold front, and the prospects of decreased liquified natural gas (LNG) imports from Russia in response to the Ukraine crisis, have re-ignited debates about whether Japan should accelerate the restart of nuclear plants (Lewis 2022). As far general trends are concerned, it appears most likely that renewable energy will be viewed as but one pillar in Japan's overall energy strategy, along with coal, natural gas, and nuclear. Renewables advocates continue to push for more development, but it remains difficult to argue against the weight of fixed capital with low marginal costs sitting idle when it could otherwise be producing power. Public opinion against nuclear has also gradually ebbed as memories of the Fukushima crisis dissipate with each year.

Beyond the empirical arguments about the institutional dynamics of Japan's energy transition, this dissertation has also touched on two primary theoretical takeaways, which would benefit from further exploration in future studies. The first is that the power dynamics that inhere in energy systems operate not simply socially—as in, say, a conflict between a public utility and a community targeted for dam construction—but spatially, at a variety of scales. Chapter 2 reviews how the elaboration of Japan's energy system over the twentieth century involved an enterprise of deepening territorial intervention by the Japanese state, which sought ways to maximize the power output from Japan's limited territorial landbase. What emerged from this

process was an intensified territorial division of labor (or "territorial metabolism") between power producing regions (*dengen chitai* or *dengen chiiki*) and power consuming regions, which were the urbanized areas that fueled Japan's rapid economic growth at the world stage. This meso-scale interaction between urban and rural areas—what Soja (1989: 86) once called the "town-countryside antithesis"—is a crucial yet largely unremarked spatial context for global energy transitions. The relations of dependence that evolved between Japan's power producing regions and its power consuming regions paralleled relations of uneven development that are too often examined solely at the macro-scale of the world economy or the micro-scale of the gentrifying urban neighborhood. As Chapter 3 examines at some length, transitioning towards distributed forms of energy generation promises to upend these dynamics, as growing revenues from local renewable energy projects reduces rural fiscal dependency on power subsidies from the center. However, given that rural renewable energy projects still depend on the centralized grid and state-mandated FIT to generate income, it is not yet clear how easy it will be to achieve local economic independence.

How an energy transition involves not merely changing the technologies of generation, but also the spatial footprint and distribution of energy production and consumption, continues to call for more fine-grained analysis. Is it possible that the centralization of political power that characterized many modern states parallels the centralization of power generation technologies and transmission infrastructure? In the case of Japan, the "unbundling" of power generation, transmission, and distribution has also accompanied an unbundling of regional power utilities from their monopoly service territories. This fragmentation of a formerly stable geography has generated additional calls from residents of Japan's regions (*chihō*) for regional autonomy from the center (*chūō*), like Satō Yauemon, a sake brewer from the Aizu region of Fukushima that

owns the Aipower solar energy company referred to in Chapter 3. To what extent centralized infrastructures are tied up with centralized systems of social power, and whether the transformation of one will influence transformations of the other, remain under-examined dynamics of energy transitions that will benefit from further research.

Second, another significant takeaway from this dissertation is that any description of economic trends within a given sector of the economy—especially in a sector as heavily regulated as electric power, but not exclusively—must always include a discussion of the institutional and legal frameworks governing that sector. This goes farther than simply affirming that the economic is political. Rather, it calls scholars to examine more directly how legal and political systems are bound up with systems of production, distribution, and exchange and play a crucial role in how they are structured both socially and spatially. Attending to how specific laws and policies shape socio-ecological metabolisms, rendering one form of production more profitable than another, or one location for a production facility more attractive than another, reveals an often-overlooked context to the capitalist production of space. As this dissertation has set out to demonstrate, tracing the socio-spatial elaboration of policies construed as fundamentally economic is one important and useful way of putting politics (and ecology) back into economic geography.

BIBLIOGRAPHY

Agency for Natural Resources and Energy (ANRE). 2011. Denki ryōkin seidō no keii to genjō ni tsuite [Background and current situation of electric power rates]. Accessed February 25, 2019. http://www.meti.go.jp/committee/kenkyukai/energy/denkiryoukin/ 001_06_00.pdf.

———. 2012. Denki ryōkin seidō unyō no minaoshi ni kakaru yūshokusha kaigi hōkokusho [Report of the expert committee on revising the electricity rate system]. Accessed February 24, 2019. http://www.meti.go.jp/committee/kenkyukai/energy/denkiryoukin/ report_001_ 02a.pdf.

———. 2013. Denryoku kouri shijō no jiyūka ni tsuite [On the liberalization of the small-scale retail power market]. Accessed March 17, 2018. http://www.enecho.meti.go.jp/category/ electricity_and_gas/electric/pdf/ seido1206.pdf.

———. 2015. Denryoku no kouri zenmen jiyūka no gaiyō [Overview of the full liberalization of the small-scale retail power market]. Accessed March 17, 2018. http://www.enecho.meti. go.jp/category/electricity_and_gas/electric/electricity_liberalization/pdf/summary.pdf.

———. 2017. Denryoku kouri zenmen jiyūka no suishin jōkyō [Status update on the full liberalization of the small-scale retail power market]. July 7. Accessed March 17, 2018. http://www.meti.go.jp/committee/sougouenergy/denryoku_gas/denryoku_gas_kihon/pdf/ 004_03_00.pdf.

———. 2018. Denryoku kouri zenmen jiyūka no suishin jōkyō [Status update on the full liberalization of the small-scale retail power market]. September 18. Accessed November 18, 2018. http://www.meti.go.jp/shingikai/enecho/denryoku_gas/denryoku _gas/pdf/011 _03_01.pdf.

Aglietta, M. 1979. *A Theory of Capitalist Regulation: The US Experience*. London: Verso.

Agnew, J. 2012. Putting politics into economic geography. In *The Wiley-Blackwell Companion to Economic Geography*, eds. T. Barnes, J. Peck, and E. Sheppard, 567-580. Malden, MA and Oxford: Blackwell Publishing, Ltd.

Agnew, J., and S. Corbridge. 1989. The new geopolitics: The dynamics of geopolitical disorder. In *A World in Crisis? Geographical Perspectives*, eds. R. Johnston and P. Taylor, 266-288. Oxford: Blackwell.

Aldrich, D. P. 2008. *Site Fights: Divisive Facilities and Civil Society in Japan and the West.* Ithaca: Cornell University Press.

Altvater, E. 1993. *The Future of the Market: An Essay on the Regulation of Money and Nature After the Collapse of "Actually Existing Socialism."* London: Verso.

———. 2009. The social and natural environment of fossil capitalism. *Socialist register* 43: 37–59.

Appel, H. 2012. Offshore work: Oil, modularity, and the how of capitalism in Equatorial Guinea. *American Ethnologist* 39 (4):692–709.

Arboleda, M. 2017. Revitalizing science and technology studies: A Marxian critique of more-than-human geographies. *Environment and Planning D: Society and Space* 35 (2):360–378.

Arisawa, H. 1963. *Nihon no enerugī mondai [Energy Issues in Japan]*. Tokyo: Iwanami Shoten.

Asada, I. 2016. Shioden sekichi ni mega-sōrā gyakufū norikoe, shimin no hokori mezasu – Setouchi-shi. *Nikkan Kōgyō Shinbun* 5 July. Accessed March 20, 2018. https://newswitch.jp/p/5250.

Asano, H. 2006. Regulatory reform of the electricity industry in Japan: What is the next step of deregulation? *Energy Policy* 34 (16):2491–2497.

Ayoub, N., and N. Yuji. 2012. Governmental intervention approaches to promote renewable energies—Special emphasis on Japanese feed-in tariff. *Energy Policy* 43: 191–201.

Baka, J. 2017. Making space for energy: Wasteland development, enclosures, and energy dispossessions. *Antipode* 49 (4):977–996.

Baka, J., and S. Vaishnava. 2020. The evolving borderland of energy geographies. *Geography Compass* 14(7):12493.

Bakke, G. 2016. *The Grid: The Fraying Wires Between Americans and Our Energy Future*. New York: Bloomsbury Publishing.

Bakker, K., and G. Bridge. 2006. Material worlds? Resource geographies and the "matter of nature." *Progress in Human Geography* 30 (1):5–27.

Barca, S., and G. Bridge. 2015. Industrialisation and environmental change. In *The Routledge Handbook of Political Ecology*, eds. T. Perreault, Gavin Bridge, and J. McCarthy, 366–377. London: Routledge.

Barry, A. 2001. *Political Machines: Governing a Technological Society*. London and New York: The Athlone Press.

Bauwens, T. 2017. Polycentric governance approaches for a low-carbon transition: The roles of community-based energy initiatives in enhancing the resilience of energy systems. In *Complex Systems and Social Practices in Energy Transitions*, ed. N. Labanca, 119–145. London: Springer.

Bebbington, A. 2012. Underground political ecologies: The second annual lecture of the Cultural and Political Ecology Specialty Group of the Association of American Geographers. *Geoforum* 43 (6):1152–1162.

Behrsin, I. 2019. Rendering renewable: Technoscience and the political economy of waste-to-energy regulation in the European Union. *Annals of the American Association of Geographers* 109 (5):1362–1378.

Bennett, J. 2005. The agency of assemblages and the North American blackout. *Public Culture* 17 (3):445–466.

Blaikie, P., and H. Brookfield. 1987. *Land Degradation and Society*. London and New York: Routledge.

Bok, R. 2019. By our metaphors you shall know us': The 'fix' of geographical political economy. *Progress in Human Geography* 43(6):1087-1108.

Boyer, D. 2011. Energopolitics and the anthropology of energy. *Anthropology News* 52 (5):5–7.

Braun, B., and S. Whatmore eds. 2010. *Political Matter: Technoscience, Democracy, and Public Life*. Minneapolis: University of Minnesota Press.

Brenner, N. 2004. *New State Spaces: Urban Governance and the Rescaling of Statehood*. Oxford: Oxford University Press.

Brenner, N., and S. Elden. 2009. *Henri Lefebvre: State, Space, World: Selected Essays*. Minneapolis: University of Minnesota Press.

Brenner, N., B. Jessop, M. Jones, and G. Macleod. 2003. *State / Space: A Reader*. Malden, MA and Oxford: Blackwell Publishing.

Brenner, N., and N. Katsikis. 2020. Operational landscapes: Hinterlands of the Capitalocene. *Architectural Design* 90 (1):22–31.

Bridge, G., S. Bouzarovski, M. Bradshaw, and N. Eyre. 2013. Geographies of energy transition: Space, place and the low-carbon economy. *Energy Policy* 53: 331–340.

Bridge, G., and L. Gailing. 2020. New energy spaces: Towards a geographical political economy of energy transition. *Environment and Planning A: Economy and Space* 52 (6):1037–1050.

Bryant, R. L., and S. Bailey. 1997. *Third World Political Ecology*. London: Routledge.

Bulkeley, H., P. M. McGuirk, and R. Dowling. 2016. Making a smart city for the smart grid? The urban material politics of actualising smart electricity networks. *Environment and Planning A: Economy and Space* 48 (9):1709–1726.

Calvert, K. 2016. From 'energy geography' to 'energy geographies' Perspectives on a fertile academic borderland. *Progress in Human Geography* 40 (1):105–125.

Castree, N., and B. Christophers. 2015. Banking spatially on the future: Capital switching, infrastructure, and the ecological fix. *Annals of the Association of American Geographers* 105 (2):378-386.

Chen, G. C., and C. Lees. 2016. Growing China's renewables sector: A developmental state approach. *New Political Economy* 21 (6):574–586.

Clark, G., and M. Dear. 1984. *State Apparatus: Structures and Language of Legitimacy*. Boston: Allen and Unwin.

Clover, I. 2014. GE throws weight behind 230 MW Japanese PV plant. *PV Magazine*. Accessed March 17, 2018. https://www.pv-magazine.com/2014/03/31/ge-throws-weight-behind-230-mw-japanese-pv-plant_100014667/.

———. 2015. GE Energy Financial invests in 96.2 MW solar plant in Japan. *PV Magazine*. Accessed March 17, 2018. https://www.pv-magazine.com/2015/04/02/ge-energy-financial-invests-in-96-2-mw-solar-plant-in-japan_100018895/.

Cohn, J. A. 2018. *The Grid: Biography of an American Technology*. Cambridge, MA: MIT Press.

Corbridge, S., and J. Agnew. 1991. The US trade and budget deficits in global perspective: An essay in geopolitical-economy. *Environment and Planning D: Society and Space* 9 (1):71–90.

Dauvergne, P. 1997. *Shadows in the Forest: Japan and the Politics of Timber in Southeast Asia*. Cambridge: MIT Press.

Denryokuchō ed. 1942. *Denryoku kokka kanri no tenmatsu [A Detailed Account of State Management of Electric Power]*. Tokyo: Nippon Hassōden.

Development Bank of Japan (DBJ). 2017. Press release, June 29. Accessed January 27, 2019. https://www. dbj.jp/en/topics/dbj_news/2017/files/0000027694_file1.pdf

DeWit, A., and T. Ikegami. 2010. Back on the agenda: Decentralization and the Japanese political economy. *Social Science Japan Journal* 13 (1):143–148.

Dinmore, E. 2013. Concrete results? The TVA and the appeal of large dams in Occupation-era Japan. *The Journal of Japanese Studies* 39 (1):1–38.

Doi, T. 1968. Japan megalopolis: Another approach. *Ekistics* 26 (152):96–99.

Easterling, K. 2014. *Extrastatecraft: The Power of Infrastructure Space*. London: Verso.

Ekers, M., and S. Prudham. 2015. Towards the socio-ecological fix. *Environment and Planning A* 47 (12):2438–2445.

Ekers, M., and S. Prudham. 2017. The metabolism of socioecological fixes: Capital switching, spatial fixes, and the production of nature. *Annals of the American Association of Geographers* 107 (6):1370–1388.

———. 2018. The socioecological fix: Fixed capital, metabolism, and hegemony. *Annals of the American Association of Geographers* 108 (1):17–34.

Electrical Japan. 2019. Map and rankings of mega-solar power stations across Japan. Accessed February 28, 2019. http://agora.ex.nii.ac.jp/earthquake/201103eastjapan/energy/electrical-japan/type/8.html.ja

Evans, P. B., D. Rueschemeyer, and T. Skocpol eds. 1985. *Bringing the State Back In*. Cambridge: Cambridge University Press.

Fischer-Kowalski, M., and H. Haberl. 2015. Social metabolism: a metric for biophysical growth and degrowth. In *Handbook of Ecological Economics*, eds. J. Martínez-Alier and Roldan Muradian. 100–138. Cheltenham, UK and Northampton, MA: Edward Elgar Publishing.

Fitzsimmons, M. 1989. The matter of nature. *Antipode* 21 (2):106–120.

Franklin, R. S., and T. Osborne. 2017. Toward an urban political ecology of energy justice: The case of rooftop solar in Tucson, AZ. *Journal of Political Ecology* 24: 1055–1076.

Fraser, T., and A. J. Chapman. 2018. Social equity impacts in Japan's mega-solar siting process. *Energy for Sustainable Development* 42: 136–151.

Furlong, K. 2011. Small technologies, big change: Rethinking infrastructure through STS and geography. *Progress in Human Geography* 35 (4):460–482.

Galbraith, J. K. 1967. *The New Industrial State*. Boston: Houghton Mifflin.

Gao, B. 1997. *Economic Ideology and Japanese Industrial Policy: Developmentalism from 1931 to 1965*. Cambridge: Cambridge University Press.

Garon, S. M. 1997. *Molding Japanese Minds: The State in Everyday Life*. Princeton, NJ: Princeton University Press.

Gibson-Graham, J. K. 2006. *The End of Capitalism (as We Knew It): A Feminist Critique of Political Economy*. Minneapolis: University of Minnesota Press.

Glassman, J. 2018. Geopolitical economies of development and democratization in East Asia: Themes, concepts, and geographies. *Environment and Planning A: Economy and Space* 50 (2):407–415.

Gordenker, A. 2011. Japan's incompatible power grids. *The Japan Times*. Accessed July 15, 2020. https://www.japantimes.co.jp/news/2011/07/19/reference/japans-incompatible-power-grids/

Gupta, A. 2015. An anthropology of electricity from the global south. *Cultural Anthropology* 30 (4):555–568.

Habermas, J. 1975. *Legitimation Crisis*. Boston: Beacon press.

Hanink, D. M. 2000. Resources. In *A Companion to Economic Geography*, eds. E. Sheppard and T. J. Barnes, 227–241. Oxford: Blackwell Publishing.

Harlan, T. 2019. Conservation or Decarbonization? Small Hydropower and State Logics of Green Development in China. *Annals of the American Association of Geographers* 110 (5):1464-1482.

Harris, L. M. 2012. State as socionatural effect: Variable and emergent geographies of the state in southeastern Turkey. *Comparative Studies of South Asia, Africa and the Middle East* 32 (1):25–39.

———. 2017. Political ecologies of the state: Recent interventions and questions going forward. *Political Geography* (58):90–92.

Harrison, C. 2013. ‘Accomplished by methods which are indefensible’: Electric utilities, finance, and the natural barriers to accumulation. *Geoforum* 49: 173–183.

Harrison, C., and J. Popke. 2011. “Because you got to have heat”: The networked assemblage of energy poverty in Eastern North Carolina. *Annals of the Association of American Geographers* 101 (4):949–961.

Harvey, D. 1978. The urban process under capitalism: A framework for analysis. *International Journal of Urban and Regional Research* 2 (1–3):101–131.

———. 1982. *The Limits to Capital*. Chicago: University of Chicago Press.

———. 2001. *Spaces of Capital: Towards a Critical Geography*. Edinburgh: Edinburgh University Press.

Healy, N., and J. Barry. 2017. Politicizing energy justice and energy system transitions: Fossil fuel divestment and a “just transition.” *Energy Policy* 108: 451–459.

Hecht, G. 1998. *The Radiance of France: Nuclear Power and National Identity after World War II*. Cambridge: MIT press.

Hein, L. E. 1990. *Fueling Growth: The Energy Revolution and Economic Policy in Postwar Japan*. Cambridge: Harvard University Press.

Henderson, D. F. 1975. *Foreign Enterprise in Japan: Laws and Policies*. Tokyo: Tuttle.

Heynen, N. C., M. Kaika, and E. Swyngedouw. 2006. *In the Nature of Cities: Urban Political Ecology and the Politics of Urban Metabolism*. London and New York: Routledge.

Hill, C. A., M. C. Such, D. Chen, J. Gonzalez, and W. M. Grady. 2012. Battery energy storage for enabling integration of distributed solar power generation. *IEEE Transactions on smart grid* 3 (2):850–857.

Hill, R. C., and K. Fujita. 2000. State restructuring and local power in Japan. *Urban Studies* 37 (4):673–690.

Hirabayashi, S. 2013. “Genpatsu okotowari” chiten to hangenpatsu undō [Sites that refused nuclear power and anti-nuclear movements]. *Ōhara Shakai Mondai Kenkyūjo Zasshi* (661):36–51.

Hornborg, A. 2014. Technology as fetish: Marx, Latour, and the cultural foundations of capitalism. *Theory, Culture & Society* 31 (4):119–140.

Hornborg, A., G. Cederlöf, and A. Roos. 2019. Has Cuba exposed the myth of “free” solar power? Energy, space, and justice. *Environment and Planning E: Nature and Space* 2 (4):989–1008.

Hosoe, N. 2006. The deregulation of Japan’s electricity industry. *Japan and the World Economy* 18 (2):230–246.

Huber, M. T. 2013a. *Lifeblood: Oil, Freedom, and the Forces of Capital*. Minneapolis: University of Minnesota Press.

———. 2013b. Fueling capitalism: Oil, the regulation approach, and the ecology of capital. *Economic Geography* 89 (2):171-194.

———. 2015. Energy and social power: From political ecology to the ecology of politics. In *The Routledge Handbook of Political Ecology*, eds. T. Perreault, G. Bridge, and J. McCarthy, 481–92. London: Routledge.

Huber, M., and J. McCarthy. 2017. Beyond the subterranean energy regime? Fuel, land use and the production of space. *Transactions of the Institute of British Geographers* 42 (4):655–668.

Hudson, R. 2016. *Approaches to Economic Geography: Towards a Geographical Political Economy*. London and New York: Routledge.

Hughes, T. P. 1983. *Networks of Power: Electrification in Western Society, 1880-1930.* Baltimore: Johns Hopkins University Press.

Hung, P.Y. 2020. Placing green energy in the sea: Offshore wind farms, dolphins, oysters, and the territorial politics of the intertidal zone in Taiwan. *Annals of the American Association of Geographers* 110 (1):56–77.

Institute for Sustainable Energy Policies (ISEP). 2018a. Kyūshū Denryoku ga sai-ene shutsuryoku yokusei no mae ni subeki muttsu no koto [Six things Kyushu Electric Power Company should do before restricting renewable power production]. Accessed January 18, 2019. https://www.isep.or.jp/archives/library/11321.

———. 2018b. *Renewables 2017 Japan Status Report (Summary).* Tokyo: Institute for Sustainable Energy Policies.

———. 2020. Share of renewable energy electricity in Japan, 2019 (Preliminary report). Accessed July 3, 2020. https://www.isep.or.jp/en/879/.

International Energy Agency (IEA). 2017. *Renewables 2017*. Paris: International Energy Agency.

International Trade Administration. 2016. *Renewable Energy Top Markets Report*. Washington, D.C.: U.S. Department of Commerce. Accessed March 9, 2018. https://www.trade.gov/topmarkets/pdf/Renewable_Energy_Japan.pdf.

Isomura, E., and M. Kuronuma. 1974. *Gendai Nihon no gyōsei [Contemporary Japanese Administration]*. Tokyo: Teikoku Chihō Gyōsei Gakkai.

Japan for Sustainability. 2015. “Yanegashi” taiyōkō hatsuden jigyō, zenkoku ni kakudai chū [“Rooftop leasing” solar power projects expanding nationwide]. Accessed September 20, 2019. https://www.japanfs.org/ja/news/archives/news_id035241.html

Jessop, B. 1990. *State Theory: Putting Capitalist States in their Place*. Cambridge: Polity.

Jessop, B., N. Brenner, and M. Jones. 2008. Theorizing sociospatial relations. *Environment and Planning D: Society and Space* 26 (3):389–401.

Johnson, C. 1982. *MITI and the Japanese Miracle: The Growth of Industrial Policy: 1925-1975*. Palo Alto: Stanford University Press.

Jolly, D. 2011. Japan’s Electricity Shortage to Last Months. *The New York Times* 28 March. Accessed April 30, 2022. https://www.nytimes.com/2011/03/29/business/global/29 power.html.

Jones, C. F. 2016. Petromyopia: Oil and the Energy Humanities. *Humanities* 5 (2):36.

Jones, M. R. 1997. Spatial selectivity of the state? The regulationist enigma and local struggles over economic governance. *Environment and Planning A* 29 (5):831-864.

Journal, T. A. P. Why worry? Japan’s nuclear plants at grave risk from quake damage. *The Asia-Pacific Journal: Japan Focus*. Accessed April 23, 2022. https://apjjf.org/-Ishibashi-Katsuhiko/2495/article.html.

Kaika, M., and E. Swyngedouw. 2000. Fetishizing the modern city: The phantasmagoria of urban technological networks. *International Journal of Urban and Regional Research* 24 (1):120–138.

Kelly-Richards, S., N. Silber-Coats, A. Crootof, D. Tecklin, and C. Bauer. 2017. Governing the transition to renewable energy: A review of impacts and policy issues in the small hydropower boom. *Energy Policy* 101: 251–264.

Kennedy, S. F. 2018. Indonesia's energy transition and its contradictions: Emerging geographies of energy and finance. *Energy research & social science* 41: 230–237.

Kikkawa, T. 2004. *Nippon denryoku sangyo hatten no dainamizumu [Dynamism of Development in the Japanese Electric Power Industry]*. Nagoya: Nagoya University Press.

———. 2011. *Genshiryoku hatsuden wo dō suru ka: Nihon no enerugī seisaku no saisei ni mukete [What Should Be Done About Nuclear Power? Towards the Revitalization of Japanese Energy Policy]*. Nagoya: Nagoya Daigaku Shuppan Kai.

———. 2012. The History of Japan's Electric Power Industry before World War II. *Hitotsubashi journal of commerce and management*: 1–16.

Kim, S. Y., and E. Thurbon. 2015. Developmental environmentalism: Explaining South Korea's ambitious pursuit of green growth. *Politics & Society* 43 (2):213-240.

Kimura, H. 2018. Senzen Matsumoto chihō no denki jigyō: denki jigyō seisaku to chihō denki jigyō sha [Prewar electric power enterprises in the Matsumoto region: Electric power industry policy and regional electric power entrepreneurs]. *Matsumoto Daigaku Kenkyū Kiyō* 16: 1–31.

Kingston, J. 2012. Japan's nuclear village. *The Asia-Pacific Journal: Japan Focus* 10 (37:1). Accessed April 7, 2018. https://apjjf.org/2012/10/37/Jeff-Kingston/3822/article.html.

Kirsch, S., and D. Mitchell. 2004. The nature of things: Dead labor, nonhuman actors, and the persistence of Marxism. *Antipode* 36 (4):687–705.

Klein, N. 2015. *This Changes Everything: Capitalism vs. the Climate*. New York: Simon & Schuster.

Knuth, S. 2017. Green devaluation: Disruption, divestment, and decommodification for a green economy. *Capitalism Nature Socialism* 28 (1):98–117.

———. 2018. "Breakthroughs" for a green economy? Financialization and clean energy transition. *Energy Research & Social Science* 41: 220–229.

Kokaze, H. 1980. Nichi-Ro Sengo ni okeru denryoku seiasaku no tenkai: dainiji Katsuura naikaku to denki jigyō hō [The development of electric power policy after the Russo-Japanese War: The Electric Power Enterprise Law and the second Katsuura cabinet]. *Shigaku Zasshi* 89 (4):486–504.

Kuwahata, R., P. Merk, T. Wakeyama, D. Pescia, S. Rabe, and S. Ichimura. 2020. Renewables integration grid study for the 2030 Japanese power system. *IET Renewable Power Generation*. 14 (8):1249-1258.

Lawhon, M., and J. T. Murphy. 2012. Socio-technical regimes and sustainability transitions: Insights from political ecology. *Progress in Human Geography* 36 (3):354–378.

Lee, S.-O., J. Wainwright, and J. Glassman. 2018. Geopolitical economy and the production of territory: The case of US–China geopolitical-economic competition in Asia. *Environment and Planning A: Economy and Space* 50 (2):416–436.

Lefebvre, H. 1977. *De L'Etat: Le Mode de Production Etatique.* Paris: Union Generale d'Editions.

Lewis, L. 2022. Japan dodges the nuclear question as it struggles to keep the lights on. *Financial Times* 2 April. Accessed April 24, 2022. https://www.ft.com/content/f2bd636c-71db-477c-9b26-f2aceb0d7b59.

Lewis, M. 2000. *Becoming Apart: National Power and Local Politics in Toyama, 1868-1945*. Cambridge, MA: Harvard University Asia Center.

Lipietz, A. 1986. New tendencies in the international division of labor: Regimes of accumulation and modes of social regulation. In *Production, Work, Territory: The Geographical Anatomy of Industrial Capitalism*, ed. A. Lipietz, 16–40. Boston: Allen and Unwin.

———. Reflections on a tale: The Marxist foundations of the concepts of regulation and accumulation. *Studies in Political Economy* 26: 7-37.

Majumdar, D., and M. J. Pasqualetti. 2018. Dual use of agricultural land: Introducing 'agrivoltaics' in Phoenix Metropolitan Statistical Area, USA. *Landscape and Urban Planning* 170: 150–168.

Martinot, E. 2016. Grid integration of renewable energy: Flexibility, innovation, and experience. *Annual Review of Environment and Resources* 41: 223–251.

Marx, K. 1973. *Grundrisse: Foundations of the Critique of Political Economy*. Harmondsworth: Penguin.

Matsuo, Y. 2015. The Rise in Cost of Power Generation in Japan after the Fukushima Daiichi Accident and Its Impact on the Finances of the Electric Power Utilities. *The Institute of Energy Economics, Japan.* Accessed March 2, 2019. https://eneken.ieej.or.jp/data/5252.pdf.

Matsuura, S. 1998. Senzen no denryoku kokka kanri to kasui tōsei jigyō [State management of electric power and river control projects before World War II]. *Suiri kagaku* 42 (5):67–85.

Mazur, A. 2013. *Energy and Electricity in Industrial Nations: The Sociology and Technology of Energy*. London: Routledge.

McCarthy, J. 2002. First World political ecology: Lessons from the Wise Use movement. *Environment and planning A* 34 (7):1281–1302.

———. 2005. First World political ecology: Directions and challenges. *Environment and Planning A* 37 (6):953–958.

———. 2015. A socioecological fix to capitalist crisis and climate change? The possibilities and limits of renewable energy. *Environment and Planning A* 47.

McCurry, J. 2011. Japan nuclear reactors must pass tsunami test before reopening. *The Guardian* 11 July. Accessed April 30, 2022. https://www.theguardian.com/world/2011/jul/11/japan-nuclear-reactors-tsunami-test.

McDonald, M. G. 1997. Agricultural landholding in Japan: Fifty years after land reform. *Geoforum* 28 (1):55–78.

McLellan, B. C., A. J. Chapman, and K. Aoki. 2016. Geography, urbanization and lock-in: Considerations for sustainable transitions to decentralized energy systems. *Journal of Cleaner Production* 128: 77–96.

Mimura, J. 2011. *Planning for Empire: Reform Bureaucrats and the Japanese Wartime State*. Ithaca: Cornell University Press.

Ministry of Agriculture, Forestry and Fisheries (MAFF). 2012. Nōchi dojō no hōshasei busshitsu nōdo bunpuzu no sakusei ni tsuite [On the production of maps showing the distribution of radiation on agricultural land.] Accessed March 2, 2019. http://www. affrc.maff.go.jp/ docs/map/h24/120323.htm.

Ministry of Economy, Trade and Industry (METI). 2014. *Strategic Energy Plan*. Accessed November 24, 2018. https://www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/ 4th_strategic_energy_plan.pdf.

———. 2015. Denki ryōkin no suijun [Standards for electricity rates]. Accessed February 25, 2019. http://www.meti.go.jp/shingikai/enecho/denryoku_gas/denryoku_kihon/pdf/002_ 04 _02.pdf

Mitchell, T. 1991. The limits of the state: Beyond statist approaches and their critics. *American political science review* 85 (1):77–96.

———. 2002. *Rule of Experts: Egypt, Techno-politics, Modernity*. Berkeley: University of California Press.

———. 2011. *Carbon Democracy: Political Power in the Age of Oil*. London: Verso.

Miwa, M. 2005. The energy revolution. In *A Social History of Science and Technology in Contemporary Japan: Road to Self-reliance, 1952-1959*, eds. S. Nakayama, K. Gotō, and H. Yoshioka, 391–413. Melbourne: Trans Pacific Press.

Miyamoto, K. 2005. *Nihon no chihō jichi: Sono rekishi to mirai* [The History and Future of Regional Self-Government in Japan]. Tokyo: Jichitai Kenkyusha.

Moe, E. 2012. Vested interests, energy efficiency and renewables in Japan. *Energy Policy* 40: 260–273.

Moore, J. W. 2015. *Capitalism in the Web of Life: Ecology and the Accumulation of Capital*. London: Verso.

Morita, H. 2012. Rescuing victims and rescuing TEPCO: A legal and political analysis of the TEPCO bailout. *Zeitschrift für japanisches Recht/Journal of Japanese Law* 34: 23–41.

Morris-Suzuki, T. 1994. *The Technological Transformation of Japan: From the Seventeenth to the Twenty-First Century*. Cambridge: Cambridge University Press.

Muhammad-Sukki, F., S. H. Abu-Bakar, A. B. Munir, S. H. M. Yasin, R. Ramirez-Iniguez, S. G. McMeekin, B. G. Stewart, N. Sarmah, T. K. Mallick, R. A. Rahim, M. E. Karim, S.

Ahmad, and R. M. Tahar. 2014. Feed-in tariff for solar photovoltaic: The rise of Japan. *Renewable energy* 68: 636–643.

Mulvaney, D. 2013. Opening the black box of solar energy technologies: Exploring tensions between innovation and environmental justice. *Science as Culture* 22 (2):230–237.

Muramatsu, M. 1997. *Local Power in the Japanese State*. Berkeley: University of California Press.

Nader, L. 1972. Up the anthropologist: Perspectives gained from studying up. In *Reinventing Anthropology*, ed. D. Hymes, 284–311. New York: Pantheon Books.

Nakagawa, T. 2012. Taiyōkō hatsuden he no yanekashi, 10 tōken ga sannyū chūkai [10 prefectures and designated cities join or facilitate rooftop leasing agreements for solar energy]. *Asahi News*, November 18. Accessed February 18, 2019. http://www.asahi.com/special/energy/TKY201211170771.html.

Nakamura, T. 1974. *Nihon no keizai tōsei: Senji-sengo no keiken to kyōkun [Japan's Economic Controls: Experiences and Lessons from the Prewar and Postwar Periods]*. Tokyo: Nihon Keizai Shinbunsha.

Neel, P. A. 2018. *Hinterland: America's New Landscape of Class and Conflict*. London: Reaktion Books.

Newell, J. P., J. J. Cousins, and J. Baka. 2017. Political-industrial ecology: An introduction. *Geoforum* 85: 319–323.

Nishino, T. 2014. Tōkyō no denki jigyō to dengen kaihatsu [The history of electric utility companies and power supply development in Tokyo since the Meiji Era]. *Chigaku Zasshi* 123 (2):298–314.

Noda, Y. 1976. *Introduction to Japanese Law*. Tokyo: University of Tokyo Press.

Noguchi Y. 1995. *1940-Nen Taisei* [*The 1940 System*]. Tokyo: Tōyō Keizai Shinbunsha.

Ó Tuathail, G. 1998. Postmodern geopolitics? The modern geopolitical imagination and beyond. In *Rethinking Geopolitics*, eds. S. Dalby and G. Ó Tuathail, 16–38. London and New York: Routledge.

O'Bryan, S. 2009. *The Growth Idea: Purpose and Prosperity in Postwar Japan*. Honolulu: University of Hawaii Press.

O'Connor, J. 1973. *The Fiscal Crisis of the State*. New York: St. Martin's Press.

Oda, H. 2009. *Japanese Law*. Oxford: Oxford University Press.

Okamoto, T. 2017. Reorganization, deregulation, and liberalization: Postwar development of the Japanese electric power industry and its change after 11 March 2011. *Technology and Culture* 58 (1):182–193.

Okimoto, D. I. 1989. *Between MITI and the Market: Japanese Industrial Policy for High Technology*. Palo Alto: Stanford University Press.

Okubo, T., ed. 1986. *Shōwa shakai keizai shiryo shūsei dai 11 maki [Collected Sources on the Society and Economy of the Shōwa Period, Volume 11]*. Tokyo: Taitō bunka daigaku tōyō kenkyūjo.

Onitsuka, H. 2012. Hooked on nuclear power: Japanese state-local relations and the vicious cycle of nuclear dependence. *The Asia-Pacific Journal: Japan Focus* 10 (3:1):1–12.

Osaki, T. 2018. Junichiro Koizumi-led group pitches bill calling for 'immediate halt' to Japan's reliance on nuclear power. *The Japan Times Online*, 10 January. Accessed March 7, 2018. https://www.japantimes. co.jp/news/2018/01/10/national/politics-diplomacy/junichiro-koizumi-led-group-pitches-bill-calling-immediate-halt-japans-reliance-nuclear-power/.

Partner, S. 1999. *Assembled in Japan: Electrical Goods and the Making of the Japanese Consumer*. Berkeley: University of California Press.

Poulantzas, N. A. 2000. *State, Power, Socialism*. London: Verso.

Powells, G., H. Bulkeley, S. Bell, and E. Judson. 2014. Peak electricity demand and the flexibility of everyday life. *Geoforum* 55: 43–52.

Prime Minister's Office Japan. 2014. Japan revitalization strategy. Accessed March 21, 2018. https://www.kantei.go.jp/jp/singi/keizaisaisei/pdf/honbunEN.pdf.

Pyle, K. B. 1974. Advantages of followership: German economics and Japanese bureaucrats, 1890-1925. *Journal of Japanese Studies* 1 (1):127–164.

Renewable Energy Policy Network for the 21st Century (REN21). 2017. *Renewables 2017 Global Status Report*. Paris: REN21 Secretariat.

Rignall, K. E. 2016. Solar power, state power, and the politics of energy transition in pre-Saharan Morocco. *Environment and Planning A: Economy and Space* 48 (3):540–557.

Robbins, P. 2002. Obstacles to a First World political ecology? Looking near without looking up. *Environment and planning A* 34 (8):1509–1513.

———. 2007. Political ecology and the state: A postcard to political geography from the field. In *The SAGE Handbook of Political Geography*, eds. K. Cox, M. Low, and J. Robinson, 205–218. London: SAGE.

Ross, M. L. 1999. The political economy of the resource curse. *World Politics* 51 (2):297–322.

Sadowski, J., and A. M. Levenda. 2020. The anti-politics of smart energy regimes. *Political Geography* 81:102202.

Samuels, R. J. 1987. *The Business of the Japanese State: Energy Markets in Comparative and Historical Perspective*. Ithaca: Cornell University Press.

———. 2013. *3.11: Disaster and Change in Japan*. Ithaca: Cornell University Press.

Sasada, H. 2012. *The Evolution of the Japanese Developmental State: Institutions Locked In by Ideas*. London: Routledge.

Sataka, M. 2011. *Denryoku to kokka [Electric Power and the Nation]*. Tokyo: Shueisha.

Sayre, N. F. 2010. Climate change, scale, and devaluation: The challenge of our built environment. *Washington and Lee Journal of Energy, Climate, and the Environment* 1 (1):93–105.

Scalise, P. J. 2012. Hard choices: Japan's post-Fukushima energy policy in the twenty-first century. In *Natural Disaster and Nuclear Crisis in Japan: Response and Recovery after Japan's 3/11*, ed. J. Kingston, 140–155. London and New York: Routledge.

Scott, J. C. 1998. *Seeing like a State: How Certain Schemes to Improve the Human Condition Have Failed*. New Haven: Yale University Press.

Setagaya Ward. 2016. Shizen enerugī ni yoru jichitai-kan renkei [Municipal cooperation through renewable energy]. Accessed March 21, 2018. http://www.city.setagaya.lg.jp/static/ oshirase2016 1015/p01_001.html.

Sheppard, E. 2011. Geographical political economy. *Journal of Economic Geography* 11 (2):319–331.

Siamanta, Z. C. 2019. Wind parks in post-crisis Greece: Neoliberalisation vis-à-vis green grabbing. *Environment and Planning E: Nature and Space* 2 (2):274–303.

Silver, J. 2015. Disrupted infrastructures: An urban political ecology of interrupted electricity in Accra. *International Journal of Urban and Regional Research* 39 (5):984–1003.

Sklarew, J. F. 2018. Power fluctuations: How Japan's nuclear infrastructure priorities influence electric utilities' clout. *Energy Research & Social Science* 41: 158–167.

Smil, V. 2015. *Power Density: A Key to Understanding Energy Sources and Uses*. Cambridge: MIT Press.

Smil, V. 2016. *Energy Transitions: Global and National Perspectives*. Santa Barbara, CA: Praeger.

Smith, N. 2008. *Uneven Development: Nature, Capital, and the Production of Space*. Athens and London: University of Georgia Press.

Sneddon, C. 2015. *Concrete Revolution: Large Dams, Cold War Geopolitics, and the US Bureau of Reclamation*. Chicago: University of Chicago Press.

Soja, E. W. 1989. *Postmodern geographies: The reassertion of space in critical social theory*. London and New York: Verso.

Solarplaza. 2018. Top 30 Japanese Solar PV Portfolios. Accessed February 24, 2018. https://www.solarplaza.com/channels/top-10s/11774/top-30-japanese-solar-pv-portfolios/.

Solar Sharing: Made in Japan. 2015. What is solar sharing? Accessed March 29, 2018. https://solar-sharing-japan.blogspot.com/p/the-system-is-called-solar-sharing-in.html.

Spivey, H. 2020. Governing the fix: Energy regimes, accumulation dynamics, and land use changes in Japan's solar photovoltaic boom. *Annals of the American Association of Geographers* 110 (6):1690–1708. DOI: 10.1080/24694452.2020. 1740080.

Stewart, D. 2009. Japan: The power of efficiency. In *Energy Security Challenges for the 21st Century: A Reference Handbook,* eds. G. Luft, G. and A. Korin, 176–190. Santa Barbara, CA: Praeger Security International,

Swyngedouw, E. 2000. The Marxian alternative: Historical-geographical materialism and the political economy of capitalism. In *A Companion to Economic Geography*, eds. E. Sheppard and T. J. Barnes, 41–59. Oxford: Blackwell Publishing.

———. 2004. Globalisation or ‘glocalisation’? Networks, territories and rescaling. *Cambridge Review of International Affairs* 17 (1):25–48.

———. 2006. Circulations and metabolisms: (Hybrid) natures and (cyborg) cities. *Science as Culture* 15 (2):105–121.

———. 2015. *Liquid Power: Contested Hydro-modernities in Twentieth-century Spain*. Cambridge, MA: MIT Press.

Tadami Machishi Shuppan Kai. 1970. *Zusetsu Aizu Tadami no rekishi [An Illustrated History of Aizu Tadami]*. Sendai: Tadami Machi Yakuba.

Takeno, S. 2015. Waga kuni no denki jigyō no hensen. [The transition of Japan electricity business]. *Denki setsubi gakkai shi* 35 (12):827–830.

The Japan Times Online. 2012. Eight of 10 Japanese utilities with reactors incur net April-September loss. The Japan Times Online. 1 November. Accessed May 18, 2018. https://www.japantimes.co.jp/news/2012/11/01/news/eight-of-10-japanese-utilities-with-reactors-incur-net-april-september-loss/

The Japan Institute of International Affairs. 1975. *White Papers of Japan, 1973-74: Annual Abstract of Official Report and Statistics of the Japanese Government*. Tokyo: The Japan Institute of International Affairs.

Topham, J. 2014. Japan’s Kyushu Electric shuts off renewable suppliers from grid. *Reuters* 25 September. Accessed July 14, 2020. https://www.reuters.com/article/us-japan-renewables-rejection-idUSKCN0HK0WY20140925.

Toshi to Denka Kenkyūkai ed. 2015. *Nippon denkashi 3: Mirai he tsumugu denkashi [A History of Electrification in Japan 3: An Electrification History to Assemble the Future]*. Tokyo: Nihon Denki Kyōkai Shinbunbu.

Toyota, Y. 2016. Shimin-chiiki shutai ni yoru saisei kanō enerugii fukyū no torikumi “shimin-chiiki kyōdō hatsudensho” no dōkō to tenbō [Trends and developments of citizens’ co-owned renewable energy power plants]. *Hosei University Institute for Sustainability* 6: 87–100.

Tsukimori, O. 2017. Power sales decline for Japan’s top utilities amid market liberalization. *Reuters* 31 October. Accessed May 19, 2018. https://www.reuters.com/article/us-japan-electricity/power-sales-decline-for-japans-top-utilities-amid-market-liberalization-idUSKB N1D01F8.

———. 2018a. Japan’s Kyushu Elec restricts renewable energy supplies for first time. *Reuters* 15 October. Accessed July 14, 2020. https://www.reuters.com/article/japan-nuclear-renewables-restrictions-idUSL4N1WS390.

———. 2018b. Japan's top power utilities see power sales decline. *Reuters*, April 27. Accessed January 18, 2019. https://www.reuters.com/article/us-japan-electricity/japans-top-power-utilities-see-power-sales-decline-idUSKBN1HY1I1.

Tsuru, S. 1993. *Japan’s Capitalism: Creative Defeat and Beyond*. Cambridge: Cambridge University Press.

Tsurumi, Y. 1975. Japan. *Daedalus* 104 (4):113–127.

Urabe, E., and S. Stapczynski. 2017. Niigata governor Ryuichi Yoneyama stands firm against restart of Kashiwazaki-Kariwa plant. *The Japan Times Online* 1 February. Accessed May 18, 2018. https://www.japantimes.co.jp/news/2017/02/01/national/niigata-governor-ryuichi-yoneyama-stands-firm-against-restart-of-kashiwazaki-kariwa-plant/.

Urry, J. 2014. The problem of energy. *Theory, Culture & Society* 31 (5):3–20.

Valdivia, G. 2008. Governing relations between people and things: Citizenship, territory, and the political economy of petroleum in Ecuador. *Political Geography* 27 (4):456–477.

Vogel, S. K. 2006. *Japan Remodeled: How Government and Industry are Reforming Japanese Capitalism*. Ithaca: Cornell University Press.

Walker, G. 1995. Energy, land use and renewables: A changing agenda. *Land Use Policy* 12 (1):3–6.

Watts, M. 2004. Resource curse? Governmentality, oil and power in the Niger Delta, Nigeria. *Geopolitics* 9 (1):50–80.

Willow, A. J., and S. Wylie. 2014. Politics, ecology, and the new anthropology of energy: Exploring the emerging frontiers of hydraulic fracking. *Journal of Political Ecology* 21 (1):222–236.

Wilson, S., A. Carlson, and I. Szeman. 2017. *Petrocultures: Oil, Politics, Culture*. Montreal: McGill-Queen's Press.

Winner, L. 1980. Do artifacts have politics? *Daedalus* 109 (1):121–136.

Woo-Cumings, M. ed. 1999. *The Developmental State*. Ithaca: Cornell University Press.

Woodall, B. 1993. The logic of collusive action: The political roots of Japan's Dangō system. *Comparative Politics* 25 (3):297–312.

Woods, M. 2012. Rural geography III: Rural futures and the future of rural geography. *Progress in Human Geography* 36 (1):125-134.

World Economic Forum (WEF). 2017. *Renewable Infrastructure Investment Handbook: A Guide for Institutional Investors.* Geneva: World Economic Forum.

World Nuclear News. 2018. Seventh Japanese reactor restarted. *World Nuclear News* 23 March. Accessed April 1, 2018. http://www.world-nuclear-news.org/C-Seventh-Japanese-reactor-restarted-2303185.html.

Yamashita, N. 2018. Learning from local conflicts over solar PV to promote local projects. *Kagaku* 88 (10):1015–1022.

Yergin, D. 1991. *The Prize: The Epic Quest for Oil, Money & Power*. New York: Simon and Schuster.

Yorimitsu, M. 1987. A review of recent population changes in Japan. *Hitotsubashi Journal of Social Studies* 19 (1):15–30.

Yoshihara, S. 2017. *Jinkō genshō jidai no tochi mondai [Land Issues in the Era of Population Decline]*. Tokyo: Chuō Kōron Shinsha.

Yoshimi, S. 1999. "Made in Japan": the cultural politics of "home electrification" in postwar Japan. *Media, Culture & Society* 21 (2):149–171.

Yoshioka, H. 2011. *Genshiryoku no shakaishi: Sono Nihonteki tenkai. [A Social History of Nuclear Energy Development in Japan]*. Tokyo: Asahi Shinbun Shuppan.