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Contracting for Geothermal in Japan

By J. Mark Ramseyer*

Abstract: Although Japan has the third largest deposit of geothermal energy in the world, its total installed generation capacity remains paltry. In part, development has been stymied by contractual problems involving promissory credibility. By the common law of property, hot springs hotels in many areas can potentially shut down geothermal projects. Geothermal developers would make the projects worth the hotels' while if they could, but cannot credibly assure them that they (the developers) will compensate them for any damages ex post. Conversely, by the basic logic of collective action, hot springs hotels cannot credibly promise to negotiate in good faith. Because each hot springs owner may potentially have a right to enjoin the entire geothermal project, the developer faces sequential negotiations, each of them a bilateral monopoly -- and no one owner can credibly promise that all subsequent owners will negotiate in good faith.

These problems are not necessarily insolvable. And the few geothermal plants that exist are disproportionately those where the hotels and developers created ways to solve these twin contractual problems. Some geothermal developers overcame their credibility problem by piping hot water to the hotels directly. Some hotels overcame their collective action problem by negotiating through their trade association or town government.

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"As the locomotive pulled out of the long tunnel separating the two worlds, the base of the night turned white."

From Nobel laureate Yasunari Kawabata's Snow Country, the sentence is one of those opening lines every literate Japanese knows. Think of it as the Japanese equivalent to "It is a truth universally acknowledged," or "Happy families are all alike."

Kawabata set his 1930s elegy to time, transience, and the fading beauty of age in what was then the small hot springs community of Yuzawa. Located in Niigata prefecture (see Figure 1) along the Japan Sea coast, Yuzawa is no longer quite the small town. It has become instead a booming hot springs and skiing resort. It has over 30 hotels and inns, and maybe more. Despite the abundant heat underground, it does not host a geothermal plant. Barely 90 km away, however, the fading city of Kashiwazaki contains the largest nuclear power complex in the world.

[Insert Figure 1 about here.]

Japan is itself a chain of 100 active volcanos. Hot molten rock sits just below the surface. In turn, that heat has given rise to a thriving hot springs hotel industry. It is an industry that has effectively kept the geothermal program at bay. Until the 2011 Fukushima melt down, nuclear development had thrived. Geothermal development had stalled.

Hot springs hotel owners worry that geothermal wells might run their wells dry. The geothermal developers argue that this cannot (or at least usually will not) happen, and can point to some solid science behind their claims. By Japanese law, however, in many communities the hot springs owners potentially have the power to enjoin a geothermal plant. If geothermal energy generates larger returns than the risk it poses to hot springs, the two groups ought to be able to negotiate prices and terms that let the developers proceed.

In fact, though, two reciprocal contracting problems rooted in basic game theory (both involving difficulty in making credible commitments) have sometimes stymied the industry. First, geothermal developers cannot credibly promise incumbent hot springs owners that they (the incumbent owners) can collect expectation damages in case the geothermal wells do damage the hot springs. The hot springs industry is over-developed in Japan, and existing wells randomly go dry on a regular basis. Because of the resulting "noise," owners know that if a geothermal developer were to harm a well, they would find it hard to prove causation in court. For exactly the same reason, geothermal developers do not want to agree to compensate hotels for all wells that go dry.

Second, although each hotel owner might want to negotiate a mutually beneficial arrangement with a geothermal developer, no one owner can credibly promise that all subsequent owners will also negotiate in good faith. Japanese hot springs owners do not just have a (only probabilistically enforceable, in practice) right to damages. In many communities, they have a customary right (probabilistically enforceable, for exactly the same reason) to enjoin a hotel that exhausts their steam and hot water. Because each owner has a potential right to hold up the entire geothermal project, the geothermal developer effectively faces sequential negotiations, each of them a bilateral monopoly, and each of them a potential hold-up.

The few geothermal plants in operation disproportionately involve cases where the developer and the hotel owners were able to solve these twin contractual problems. Sometimes, the geothermal developer made the promise of ex post compensation credible by piping hot water to the springs directly from the geothermal plant. Unfortunately, many (if not most) geothermal projects lack the volume of hot water to cut this deal.

Sometimes, the hotels solved their offsetting collective action problem by negotiating through their trade association or town government. Apparently, they expect to control would-be deviants through threats of social ostracism (Ramseyer & Rasmusen, 2020). Necessarily, however, this requires levels of cohesion and social capital that many villages (especially those in the steadily deteriorating rural countryside) no longer have.

I begin by noting the lack of geothermal development in Japan (Sec. I). I explain the technology behind geothermal energy (Sec. II), trace the property law of hot springs (Sec. III), and summarize the government promotional measures for the geothermal industry (Sec. IV). Finally, I turn to the contractual problems behind the slow pace of geothermal growth (Sec. V).

I. The Puzzle

As the first decade of the 21st century closed, Japan generated about a quarter of its electricity each from coal (27.8 percent, in 2010), natural gas (29.0), and nuclear power (25.1; METI 2019, Fig. 214-1-6). That situation stopped abruptly, of course. In March of 2011, a magnitude 9.0 earthquake hit the northeast. It battered the coast with a 38.9-meter-high tsunami, destroyed the coastal Fukushima nuclear complex, and shocked three reactors into melt-down mode.

The Japanese government had turned to nuclear power in the wake of the 1973 OPEC embargo. That year, mid-eastern oil-producing nations decided to boycott countries that supported Israel. The group included Japan. Because it produces almost no oil itself, Japan had relied instead on OPEC oil, and the boycott now slammed GDP growth into negative territory (Ramseyer 2012).

Rather than let OPEC dictate its foreign policy, the Japanese government moved quickly to diversify its energy sources away from petroleum. It had long since tapped out its rivers for hydro-electric power. It had exhausted its coal mines decades earlier. That left nuclear power.

The 2011 tsunami crashed this policy and forced Japan to shut down its nuclear plants. By 2017, the country had slashed electricity use by about a tenth, and nuclear power constituted only 3.1 percent of the remainder. Coal produced 32.3 percent of its electricity, and natural gas 39.8 percent (METI 2019, fig. 214-1-6; Kankyo 2020).

Could Japan produce its electricity from geothermal sources? Iceland famously does, but only 364,000 people live there. Japan has 126 million. With its long chain of volcanos, Japan (with 23,000 MW) has geothermal potential third only to the U.S. (39,000 MW) and Indonesia (27,000 MW).[1] Yet the U.S. has installed geothermal capacity of 2,511 MW, the Philippines has 1,916 MW, and Indonesia 1,534 MW. Iceland has 665 MW, while Japan ranks 10th in the world with only 533 MW (Table 1 Panel A; IRENA 2017). Those 533 MW barely produce 0.2 percent of its electricity (Table 1 Panel B).

[Insert Table 1 about here.]

The question is why Japan does not produce more.

[1] Nagashima (N.D.); Geothermal (2014); Nihon onsen (N.D.); Fukuda (2019); Yamazaki (2019).

II. The Technology

A. The Plants:[2]

1. General. -- Geothermal plants tap the energy radiating from the core of the earth. That core lies 2,900 km below the crust. It has a temperature of some 5000 C, primarily generated by radioactive decay. When rocks reach temperatures of 700 to 1300 C, they melt and form magna. That magna heats other rocks and aquifers. And when magna surfaces during a volcanic eruption, it takes the form of lava.

2. Steam. -- The most (conceptually) straightforward way to transform underground heat into electricity is through a "dry-steam" plant. Under this approach, a developer drills a set of wells into an underground steam deposit. He pipes the steam to a turbine, generates electricity, and returns the condensed steam into the ground through a second set of wells. If straightforward in theory, the method is also rare. In the U.S., only the Geysers (in California) and Yellowstone National Park (in Wyoming) have the deposits necessary to support dry steam plants. In Japan, only the Matsukawa plant in Iwate prefecture runs on dry steam (Science 2012).

3. Flash. -- More commonly, geothermal engineers turn to underground deposits of pressurized high-temperature (over 182 C) water. Through one set of wells, they pump the high-pressure water to the surface. Once that water enters a lower pressure container, it evaporates (it "flashes"). The engineers separate the steam from the remaining water and drive a turbine.

In pumping the water out of the underground cavity, geothermal engineers lower the pressure of the water that remains; with its mix of arsenic, fluoride, boron and heavy metals, the pumped water is itself something of a biohazard. For both reasons, after generating the electricity the engineers pump the water back into the earth. The process is not simple. They use a second set of wells for this, but the silica and calcite in the water can precipitate and easily clog the pipes. In turn, to prevent this from happening the geothermal plants typically mix sulfuric acid -- a deadly risk in its own right -- into the already toxic water they pump into the earth.[3]

4. Enhanced Geothermal Systems. -- Most areas underground do not contain accessible layers of the water and steam necessary to transport the underground energy to the surface. To extract that heat anyway, geothermal engineers turn to the new "enhanced geothermal" technique. They first fracture the underground rock by pumping high-pressure liquid into the dry, hot rock. Sometimes, they use explosives as well. After the rocks crack, they pump in additional water to absorb the heat. Through a set of extraction wells, they bring the heated water back to the surface and drive a turbine (NEDO N.D.; Shin 2016).

The EGS fracturing technique closely resembles the "fracking" used to extract natural gas. Necessarily, it creates analogous environmental risks (Kondo 2012; Kondo 2015). Sometimes, EGS causes earthquakes. Sometimes, it can cause land to sink. In the process, it sometimes damages highways, pipelines, and so forth.

5. Binary. -- Even when water underground is too cool for flash, modern geothermal developers can sometimes still generate electricity by piping it past a second liquid flowing in a

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[2] See generally Kondo (2015); National (2020); Irena (2017); U.S. Dept. Energy (2008).

[3] Wanner et al. (2017); Rajvanshi (2018); Gunnlaugsson, et al. (2014); Takahisa (N.D.); Jinetsu (2015).

closed loop. For that second liquid, they use something with a lower boiling point than water (e.g., ammonia-water mixtures, or a butane or pentane hydrocarbon). The heat in the extracted water causes the second liquid to evaporate and drive a turbine. As with flash and EGS, the developers then pipe the cooled water back underground.[4]

B. The Welfare Caveat:

Table for purposes of this article whether geothermal plants advance social welfare. They may, but scientists disagree and for these purposes the question does not matter. Hydrocarbon emissions harm the environment, but how much they harm it remains a scientifically contested question. Nuclear power poses small risks of extraordinarily large harm, but the size of the small risk remains similarly contested.

Geothermal plants may not be as clean as its proponents have hoped. The massive plants straightforwardly degrade national parks. They may (or may not) threaten the centuries-old hot springs industry. And EGS plants bring all the (scientifically contested) risks associated with the fracking industry. For the rest of this study, however, I assume that geothermal development does raise net public welfare, and explore the contracting problems that have plagued developers in Japan.

C. The Cost:

Geothermal plants are expensive to build. Glacier Partners (2009) specializes in geothermal consulting. In 2009, it concluded that a 35 MW binary plant in Nevada would cost $161 million. It would provide electricity for about 44,000 households (see Ishida 2015; Nihon 2019).

To estimate drilling costs, Glacier Partners posited a cost per well of $4.5 million. If each well produced 4.5 MW, a 35MW capacity plant would need 8 production wells. It would need another 7 injection wells to pump the water back into the ground after running the turbine. Given that about a fifth of drilled wells are unusable, it reasoned that the developer would need to drill 18 wells. At $4.5 million per well, it calculated a drilling cost of $81 million.

Glacier Partners (2009) estimated that the plant itself would cost $2.0 million per installed MW. Given a 35MW plant, it calculated a $70 million cost. Glacier Partners budgeted another $5 million for the transmission lines necessary to connect the plant to the grid. Located as they are in volcanic areas, some Japanese geothermal plants will require long transmission lines and access roads.

Note that this estimate excludes costs and subsidies specific to a given political and geographic environment. Glacier Partners excludes the cost of exploring for the wells, for example, the cost of the environmental assessments, the costs of negotiating with the community, and the costs of any other regulatory restrictions. One Japanese consulting firm estimates that the early exploratory wells have a success rate of about 20 percent (Deloitte 2016).

Geothermal plants do not last forever. Almost inevitably, they instead lose pressure and temperature.[5] In Table 2, I give the decline over time in energy production at the major Japanese geothermal plants. From 1997 to 2010 only one plant continued to produce water at the rate at which it had initially produced; only one produced water as hot as it had initially produced. Half

[4] NEDO (N.D., 7); Kondo (2015); Baba (2015); Kawanami (2013).

[5] Ohyama (2014, 341, 346); Kankyo (2017, 4.5); Ehara (2014, 314).

of the plants produced less than 2/3 what they had initially produced. At three of the plants, water temperature had fallen more than 10 degrees.

[Insert Table 2 about here.]

III. The Rival Industry

A. The Industry:

Hot springs resorts are a booming business in Japan. In 1962, there were 1,500 hot springs resorts, with 9,200 hotels and inns. By 2011, there were 3,100 hot spring resorts with 13,800 hotels and inns. In 1962, about 500,000 people worked in the industry. By 2011 about 1.4 million did. In a given year, Japanese make about 120 million over-night visits to the hot springs resorts (this in a country with a population of 126.5 million). They make another 10 million one-day visits (Nihon onsen, N.D.).

B. The possible Conflict:

The trade association of hot springs hotels vehemently opposes new geothermal plants. Allow the plants, it argues, and their springs may lose temperature, lose volume, and possibly even run dry. The Ebino plateau in Kyushu straddles the line between Kagoshima and Miyazaki prefectures. Near Mt. Kirishima and several other active volcanos, it was home to many geysers and an outdoor bath that attracted 39,000 people a year. In 1996, Kyushu Electric built a 30 MW flash plant nearby. Soon, the geysers started to wilt, and the water to the bath cooled and receded. Over time, the geysers in one field stopped entirely, and in 2006 the famous outdoor bath permanently closed its doors.[6] Nor is it only Ebino. Hot springs operators tie geothermal plants to lower water volume or temperature in Fukushima prefecture, in Oita, in Iwate, in Akita, in Miyagi.[7]

Geothermal developers insist this cannot happen. Hot springs wells go 100 to 200 meters below the surface. Geothermal wells extend 1 to 3 km below the surface, and a non-permeable "caplock" membrane separates the two deposits.[8] Industry spokesmen quote scholars like Kyushu University professor Sachio Ebara:[9]

> Despite more than 40 years of geothermal electrical generation, no geothermal project has ever so harmed a hot springs firm as to drive it out of business.

And the Environmental Ministry routinely claims the same (Zenkoku 2013, 242). Nonetheless, when they choose places to drill, developers tend to avoid areas with an extensive hot springs industry anyway (Hymans & Uchikoshi 2020).

From time to time, hot springs wells run dry. In 1977, the Environmental Ministry found that 3,800 of the country's 22,000 hot springs no longer produced water. When a well stops producing, hotels and bath operators usually just drill a new one (Jinetsu N.D.). About Ebino and the other springs that went dry when a geothermal plant opened, geothermal developers simply assert coincidence: the geothermal plant could not have caused the hot springs to go dry, because the two underground deposits simply do not connect (Zenkoku 2013, 247).

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[6] Jinetsu (N.D.).

[7] Oyama (2016); Matsuzaki (2016); Endo (2016); Kondo (2012).

[8] Fukuda (2019); Ohyama (2014, 344); Kondo (2015).

[9] Kondo (2012); see also (Science 2012) (quoting Hirosaki Univ. professor).

Japanese have heard this all before. Prior to 2011, the government had adamantly insisted that the nuclear reactors were safe too. A large corps of scholars did the same. So predictably enthusiastic about nuclear development were they that the press took to calling them the "nuclear power tribe." Scientists did not all back the nuclear tribe before 2011. And scientists are not all as certain as the industry and the government that the hot springs and geothermal deposits never connect.

C. The Law.

1. Early common law. -- Based closely on the German model, the late 19th-century Japanese Civil Code[10] said little about water. It said even less about underground hot springs. It did provide that fee simple ownership extended below the surface (Sec. 207). From that premise, the new Supreme Court declared in 1896 that fee simple owners held an absolute right to percolating water: own the land and the owner could use the percolating water as he pleased.[11] The plaintiffs in the case were farmers who had been using water from the defendant's land to irrigate their rice paddies. When the defendant built new paddies, he left them insufficient water to farm as they had been doing. The plaintiffs claimed a customary right to the water, and the defendant claimed a fee simple interest in his land. The court held for the defendant: title to land extends to water flowing under the land.

That very year, however, the Supreme Court made clear that the rule applied only to percolating water: disputes over water flowing above ground it would decide according to a rule that resembles a "prior appropriation" regime: riparian farmers had a right to use water only to the extent of custom.[12] "By ancient custom," the court explained, the downstream farmers had a right to continue to use the water. An upstream riparian owner could increase the water he used only to the extent that he did not interfere with downstream customary use. Three years later, the court explained:[13].

> By established national custom, [riparian owners] may not use [flowing] water freely if other established users already use that water to irrigate rice paddies. On the contrary, they may use it to develop new paddies only if they do not thereby damage the existing use of the downstream riparian users. This custom is one we recognize in this court.

About percolating hot springs, the courts enforced a customary prior appropriation regime close to the rule it used for riparian rights. To be sure, they did not reach the rule immediately. In 1905, the Supreme Court instead held that Section 207 of the Civil Code gave fee simple owners a right to exploit any underground steam.[14] Yet even there, it left room for custom to the contrary. Landowners held that right to underground steam, it noted carefully, only "absent any custom to the contrary."[15]

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[10] Minpo [Civil Code], Law No. 89 of 1896 and Law No. 9 of 1898.

[11] Nakanobo v. Yoneda, 2 Daihan minroku 3-1111 (Sup. Ct. Mar. 27, 1896).

[12] See Smith (2008, 446, 452); Smith (2016, 206-07); Yoshida v. Komori, 2 Daihan minroku 9-19 (Sup. Ct. Oct. 7, 1896).

[13] Kasuga v. Miyahara, 5 Daihan minroku 2-1 (Sup. Ct. Feb. 1, 1899).

[14] Kiyono v. Takauchi, 11 Daihan minroku 1703 (Sup. Ct. Dec. 20, 1905).

[15] Kiyono v. Takauchi, 11 Daihan minroku 1703 (Sup. Ct. Dec. 20, 1905).

The Tokyo High Court explained the logic in 1935 (p. 6):[16]

> Cold water that percolates from the ground is attached to the ownership of that land. It is rare that the right to that water is treated as a right separate from that of the land. Hot springs water, however, is much more economically valuable than cold water. Hence it is often transferred independently of the land from which it flows.

The court seemed almost to anticipate Harold Demsetz (1967; see Smith 2016, 207): the more valuable the resource, the more people will develop clearly enforceable private rights to it.

Whether custom required the prior appropriation regime turned on local facts. The village of Kinosaki lay on the Japan Sea coast near Kyoto, and touted six outdoor medicinal baths.[17] To cater to the visitors, residents operated over sixty bath-less inns. Visitors would stay at an inn, and rest in the public baths. It was a quiet town. Novelist Shiga Naoya stayed there to write.

In 1910, the railroad arrived. Increasingly, it brought vacationers from metropolitan Kobe, Kyoto, and Osaka. The wealthier of the new visitors wanted hot springs baths in their villas. They wanted hot springs baths in their hotels. And to cater to the new demand, entrepreneurs began to build hotels with indoor baths.

The new indoor facilities threatened to run the public baths dry, and the sixty bathless inns out of business. Local residents ostracized the owner of one of the new hotels. They boycotted merchants who did business with him. Their children harassed his children. They cut the electricity to the town and used the chaos to storm his hotel.

And the villagers also sued. By custom, they argued, no one could pump the hot water indoors. They lost: whatever the custom in the distant past, the town no longer had such a custom. By the time the inn-keepers sued, reasoned the court, so many residents had pumped water indoor that any customary ban had long since vanished.

Yet if Kinosaki no longer gave prior users a customary right to the hot springs, many of the most prominent resort towns did. If they had that custom, the courts enforced it. Wrote the Supreme Court:[18]

> Owners may use underground water that flows through the land they use. They may use that underground water even if it is part of a hot springs. This right, however, is conditional: it holds only when there is no law to the contrary. And [in the presence of such a custom,] it gives the land owner usage rights only to the extent that his use does not infringe the rights of others to use the water.

About the hot springs in Matsumoto, a few-hour train ride from Tokyo, the Tokyo High Court explained in 1939:[19]

> The rights to the hot springs in the Matsumoto area of Nagano prefecture constitute a type of real rights. They are independent of the ownership rights to the land from which they flow. By the customary law of the area, parties may transfer these rights to hot springs through a simple meeting of the minds.

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[16] Furihata v. Okamura, 3872 Horitsu shimbun 5 (Tokyo High Ct. July 17, 1935).

[17] Ramseyer (1989, 63-64); Kinosaki Village v. Kataoka, 4249 Horitsu shimbun 5 (Kobe D. Ct. Feb. 7, 1938); Kawashima, Shiomi & Watanabe (1964).

[18] Japan v. Masaki, 3453 Horitsu shimbun 15 (Sup. Ct. Aug. 10, 1932).

[19] Nagano shogyo K.K. v. K.K. Nihon kangyo ginko, 4517 Horitsu shimbun 12, 13 (Tokyo High Ct. Oct. 16, 1939):

2. Post-war. -- (a) The statutory overlay. On this common law of property, the Japanese government added an administrative overlay in 1948.[20] The new statute -- the Hot Springs Act -- added a requirement that one who would dig a well obtain an advance permit from the prefectural government (Sec. 3). The governor was to deny the permit if the existing well would interfere with existing hot springs or otherwise with the "public welfare" (Sec. 4). Absent such interference, he was to approve the application.[21] He was to maintain a hot springs council, and consult with it about any drilling application he might receive (Kondo 2015, 9; Kawanami 2013, 51).

Some prominent hot springs communities did not trust their governor. Rather than leave the legal regime as is, they added local regulations of their own. The Oita town of Kokonoe, for example, required applicants to obtain the approval of the village mayor, and to take any steps necessary to avoid harm specifically to the local hot springs resources and more generally to the local environment. The town also required potential geothermal developers to consult with a specifically geothermal committee (Kokonoe 2015, sec. 5, 6). The larger Oita city of Beppu deliberately introduced municipal requirements so onerous that it hoped developers would decide to dig elsewhere just to avoid the paperwork (Yamane 2018).

(b) The common law, again. The post-war courts continued the earlier common law of hot springs. "Absent a special rule or custom to the contrary," wrote one district court in 2002, title to land carried with it the right to exploit hot water underground.[22] With that custom to the contrary, however, ownership of the surface land was separate from ownership of the hot water below.[23] When a developer petitioned for a drilling permit under the Hot Springs Act, the outcome turned in part on the presence or absence of such a custom. Wrote the Fukuoka District Court:[24]

> When we consider the import of Section 4 of the Hot Springs Act regarding the drilling permit, in some areas, by long years of custom, the owner of a hot springs has the exclusive right to the water at stake. In these areas, the rights relating to the hot springs are separate from the ownership rights in the land. The right to use the hot springs is itself a distinct form of customary real rights."

Major hot springs resorts often maintained exactly that custom. Take the city of Beppu within Oita prefecture. Of the 27,400 hot springs in the country, Oita has 4,381, and Beppu has 2,291. Of the 2.63 million liter/minute produced in Japan, Oita produces 279,000, and Beppu produces 87,360. Crucially, Beppu has a customary tradition that treats the underground steam and hot water as an interest from the land.[25]

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[20] As Smith (2008, 455) notes has happened with the prior appropriation regime in the U.S. Onsen ho: Law No. 125 of 1948. See generally Onsen ho seko kisoku [Implementation Rule for the Hot Springs Act], Rei. No. 35 of 1948 (general implementation order).

[21] See Ishikawa ken v. Onsen kaihatsu K.K., 1311 Hanrei taimuzu 104 (Kanazawa D. Ct. Nov. 28, 2008), aff'd, 1311 Hanrei taimuzu 95 (Nagoya High Ct. Aug. 19, 2009) (reversing a denial of an permit on grounds that evidence was too vague).

[22] [No names given], 2002 WLJPCA 10319014 (Gifu D. Ct. Oct. 31, 2002).

[23] Kigyo kumiai Higashiyama onsen v. Sako, 888 Hanrei jiho 107 (Kochi D. Ct. Jan. 26, 1978), aff'd, 1044 Hanrei jiho 383 (Takamatsu High Ct. Dec. 7, 1981).

[24] Kokusai baiyaa shitei hoteru v. Shizuoka ken chiji, 5 Gyoshu 1482 (Fukuoka D. Ct. June 2, 1954), aff'd 113 Hanrei jiho 10 (Fukuoka High Ct. Nov. 8, 1956), aff'd, 157 Hanrei jiho 14 (Sup. Ct. July 1, 1958).

[25] Goto v. Horikawa, 5 Kamin 985 (Oita D. Ct. June 28, 1954); Inoue v. Hadano, 7 Kamin 2151 (Oita D. Ct. Aug. 9, 1956).

Typically, courts treated the customary hot springs right as a "property right" (they called it a "customary bukken"). Accordingly, the holder held both (a) a right to specific performance as appropriate, and (b) a right that he could enforce against a good-faith purchaser of the land from which the hot water flowed. The plaintiff in one 1968 case had contracted for hot springs water from a landowner. The local real estate registry did not formally record such contracts, but the plaintiff did report his arrangement to the prefectural health agency, and the pipes were easily visible on the land. When the defendant bought the source land and refused to deliver the hot water, the plaintiff sued. The court ordered specific performance.[26]

IV. Geothermal Promotional Policy

A. Early development:

Japanese utilities began developing commercial scale geothermal generators in the 1960s. In northeastern Iwate prefecture, Tohoku Natural Energy placed the 25 MW Matsukawa dry steam generator in service in 1966 (see Tables 1, 2). In southern Oita prefecture, Kyushu Electric placed the 12.5 MW Otake flash generator in service in 1967. Development continued, and by the end of the century Japanese utilities ran geothermal plants with a combined capacity of 530 MW.

And there in 1996 it stopped. Geothermal plants were expensive, and produced only trivial amounts of electricity. Together, all geothermal plants in the country produced 530 MW. By contrast, the nuclear reactors at Fukushima alone produced 9,200 MW.

B. Post Fukushima:

The 2011 meltdown changed all this, of course. The Japanese government now returned almost immediately to the geothermal project. To promote the technology, it faced several straightforward problems. First, over 80 percent of Japanese geothermal potential lay in national, quasi-national, or prefectural parks (Nihon onsen N.D) -- and geothermal plants are massive eye-sores. The Hacchobara complex in Oita covers 20 million square meters. The plants present an unsightly maze of pipes, tubes, cooling towers. They emit constant flumes of steam.

Notwithstanding what might otherwise seem environmental obstacles, the Japanese government moved quickly. In 2012, the Environmental Ministry liberalized the standards for approving projects. These new liberalized rules applied specifically to national parks.[27]

Second, geothermal plants are expensive. To encourage their development, the government announced a portfolio of subsidies. The amounts vary by the size of the plant, and so forth. In general, however, the government will pay 2/3 of the cost of surveying an area, and up to 3/4 of the cost of any exploratory drilling. It will subsidize the cost of negotiating with local residents.[28] It will provide equity investment and guarantee debt (Yamazaki 2019). In the case of the 46 MW Wasabisawa plant, the loan guarantees reached 21 billion yen (about $210 million; Keizai 2020).

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[26] Kokka komuin kyuzai kumiai rnegokai v. Hayama onsen kanko K.K., 543 Hanrei jiho 70 (Yamagata D. Ct. Nov. 25, 1968).

[27] Kankyo sho (2012). Onsen shigen no hogo ni kansuru gaido rain (jinetsu hatsuden kankei) [Guidelines Regarding the Protection of Hot Springs Resources (Regarding Geothermal Electrical Generation)]. Available at:. http://www.env.go.jp/nature/onsen/docs/chinetu_guideline.pdf. (Shin 2016; Kawanami 2013, 50; Yamazaki 2019; Kankyo 2017, 3.4.1; Kondo 2015, 8

[28] Yamazaki (2019); Kappatsuka (2019); Keizai (2020).

Third, energy prices fluctuate wildly. To placate potential investors, government instituted a "feed-in tariff" (FIT) program to provide high fixed electricity prices. Under FIT, it required utilities to buy specified amounts of electricity from approved renewable suppliers at specified prices. In effect, it guaranteed geothermal producers steady demand at high prices.

Under the post-Fukushima FIT program, the government guaranteed geothermal prices of 26 yen/kWh for plants with capacity of 15 MW or more, and 40 yen for smaller plants (Table 3).[29] The FIT supports applied to other renewable energy sources as well. Of the FIT-approved capacity in 2017, 78.5 percent went to solar energy (Kankyo 2017, 1.3).

[Insert Table 3 about here.]

For locations that accepted nuclear power plants, the government had provided elaborate subsidies directly to the communities themselves (rather than the developers; Ramseyer 2012). The same programs apply to communities that accept geothermal plants. Because the programs key the amount of the subsidies to the power capacity of the plants, however, to communities accepting geothermal plants the government pays only trivial amounts.

C. Minor and Well-less Plants:

Since 2011, entrepreneurs have mostly built geothermal plants that are small or which require no new wells. Between 2011 and September 2017, Japanese developers built 33 binary plants (see Table 5). Most were extremely small. A 100 kW plant produces electricity for about 125 households (Ishida 2015; Nihon 2019). Of the 33 plants, 24 are smaller than 100 kW. Only 3 are larger than 1 MW, and one of those was an in-house generator for a large medical facility.

Many of the plants did not involve new wells. Recall that binary plants can use cooler water than that required for the large flash plants. With binary technology, an entrepreneur can even use water below 100 C to power a turbine. It will use that water to heat a liquid with a lower boiling temperature, and power a generator with the gas from that second liquid.

With binary technology, the hot springs hotels could use their own water to power the hotel. If their water were 90 C, for example, they would need to cool that water to 50 C anyway before piping it into their baths. With a binary generator, they could use the energy released in the cooling to power a turbine generator.

Even some of the larger binaries did not involve new wells. Take the 5.05 MW Takigami plant (see Table 4). As Table 2 shows, Takigami already had 27.5 MW flash capacity. The water emitted from this plant was still hot, even if not hot enough to power a flash generator. With the addition of a binary generator in 2017, the firm was able to use the water from the flash plant to generate still more electricity (Kamitake 2017, 2).

[Insert Table 4 about here.]

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[29] Kappatsuka (2019); Kondo (2015, 4); Denki jigyosha ni yoru shin enerugii to noriyo ni kansuru tokubetsu sochi ho [Special Measures Act Regarding the Use of New Energies, Etc. by Electrical Industry Firms], Law No.. 62 of 2002. This set up the Renewable Portfolio Standard (RPS), and would later be amended to cover geothermal plants. The Denki jigyo sha ni yoru saisei kano enerugii denkino chotatsu ni kansuru tokubetsu sochi ho [Special Measures Act Regadrding the Raising of Renewable Energy Electricity by Electrical Industry Firms], Law No. 108 of 2011, creates the FIT scheme.

Similarly, the Yamakawa flash plant in Kagoshima prefecture has a 26 MW capacity (Table 2). Like Takigami, it emitted hot water. In 2017, it installed a binary plant. With the water left from the flash plant, it powered the new binary turbine and generated another 5.0 MW (Shin 2018).

D. The Overbuilt Hot Springs Industry:

Unfortunately for the government's geothermal drive, by 2010 hot springs hotels realized that their industry was badly over-built. Over the course of the second half of the 20th century, hotel owners had sunk massive numbers of wells. They had turned small rural villages into tourist retreats, and small retreats into massive entertainment centers.

From 1973 to 1998, hot springs developers had doubled productive capacity: from 1,258,000 liters/minute, to 2,639,000 (Table 5). Then, around 2007 output began to fall: from 2,799,000 l/min (2007) to 2,772,000 (2008), to 2,643,000 (2013) to 2,547,000 (2018). The decline hit the biggest resort communities hardest. The northern island of Hokkaido promised visitors both hot springs and lavish skiing. From 1998 to 2018, total hot springs output in the prefecture fell 35 percent. The central Japanese mountain ranges in Nagano (home to the 1998 winter Olympics) promised hot springs and fresh powder too: from 2003 to 2018, hot springs output fell 16 percent. Output in the deep northern prefectures of Aomori and Iwate fell 15 percent (2008-2018) and 29 percent (1998-2018). Output in Kagoshima, home to the spectacular Mt. Kirishima volcano, fell 20 percent (2003-2018).

[Insert Table 5 about here.]

In the wake of the Fukushima meltdown, the Japanese government proposed to drill massively for geothermal. It did this just as firms in the hot springs industry were coming to realize how far they had already passed the level of energy they could safely extract from the ground. They had created a massive industry: 13,800 hot spring inns in 2011, and 1.4 million workers. And that industry was now in peril.

V. Contracting for Geothermal

A. Introduction:

1. The Problem. -- By 1996, Japanese utility companies had built a solid start in geothermal. A 10 MW capacity plant provides electricity for about 12,500 households (Nihon 2019; Ishida 2015). By 1996, the utilities had placed 12 10+ MW plants in service. And then, they stopped.

After the 2011 meltdown, the Japanese government tried to restart the geothermal project. It eased the regulatory restrictions in the national parks. It subsidized development. It guaranteed high prices. It successfully convinced hot springs hotel owners to install small binary generators. And in May of 2019, Mitsubishi Materials, Mitsubishi Gas Chemicals, and a privatized government agency together opened a 46 MW plant in northern Akita prefecture. The new Wasabisawa plant was the first 10+ MW plant since the 27.5 MW Takigami plant opened in southern Oita prefecture in 1996 (Kappatsuka 2019; Yamazaki 2019).

Nine years after the meltdown, the utilities had finally built a large geothermal plant. The question is why it took so long.

2. The solvable hurdle. -- The 1948 Hot Springs Act is an obvious problem. The Act requires a geothermal developer to obtain clearance from the prefectural governor before he drills.

The governor must consult his hot springs committee before issuing that clearance. And by most accounts, incumbent hot springs hotels and inns dominate the committees. As political scientist Jacques E.C. Hymans (2020) put it, the "Hot Springs Law hands a virtual veto to local onsen [hot springs] businesses to block any unwanted drilling in their vicinity."

This may be a problem, but it is a legally solvable problem. Should the government want to do so, it could amend the statute to lower the influence of industry incumbents. It could even repeal it.

More fundamentally, if the geothermal plant were indeed social-welfare-increasing (as posited in this article, see Sec. II.A.6.), a geothermal developer should be able to buy the approval of any local hot springs committee. The developer earns a return from his investment, but imposes a risk of loss on the hotel owners on the committee. It follows from the definition of welfare maximization that the developer's return should exceed the risk-adjusted loss to the committee members. Necessarily, he should be able to purchase their approval.

B. <u>The Reciprocal Contracting Problems:</u>

1. <u>Ex post -- the developer's promissory credibility</u>. -- The private-law obstacles to geothermal development are less obvious but potentially cut more deeply. The problems are two-fold. First, the geothermal developers cannot credibly promise to compensate a hot springs hotel for any harm ex post. No rational hotel or inn keeper would fight a geothermal project if the developer coupled substantial compensation ex ante with a credible promise to pay damages for harm ex post.

Yet although a developer can promise those damages, he will find credibility elusive. Obviously, he can promise a hot springs hotel not to lower the volume of steam or hot water. He can promise to compensate the hotel if he does. But given that hot springs routinely go dry for no apparent reason, he will rarely find it profitable to compensate the hotels for all wells that go dry. The hotel owner himself knows hot springs randomly go dry. He also knows that for decades now, the hotels and inns have been extracting steam and hot water at rates the local sources cannot sustain. And he knows that many geologists and most government officials insist (and would testify in court) that 1- to 3-km-deep geothermal wells would never affect the amount or temperature of the water in the separate hot springs cavities 100 to 300 meters below the surface.

As a result, each hot springs hotel owner knows that even if a geothermal plant were to cause its spring to go dry, he would find judicial recovery problematic. The owners reason, writers one observer, that "you can't see underground" (Uechi 2016, 51). "Even if a geothermal plant exhausted" their hot water source, "we'd never be able to prove causation." Complained the village council chair in one hot springs community (Jinetsu 2011), even if a geothermal plant were to damage their source, "it'd be nearly impossible for us to prove in court that the plant had caused the harm."

2. <u>Ex ante -- the hotel owner's promissory credibility.</u> -- Second, no individual hotel owner can credibly promise ex ante that all of his competitors will negotiate in good faith. By Japanese common law (see Sec. III.C.), hot springs users in many of the most popular resort areas have a customary property right to the continued use of the steam and hot water that they currently use. That right includes the right to enforce their continued use against good-faith third party transferees. And it includes the right to enforce the continued use through injunctions.

By common law, in other words, many Japanese hot springs hotel owners may have a right to hold up an electrical plant. Absent an injunctive right, if electrical generation constituted a more efficient use of the underground steam and water than the local hot springs hotels, the utility could simply ignore the hotels. It would build the generating plant. Maybe it would harm the local hotels, and maybe not. But if it did, the utility would let the hotels sue. After all, it could make them whole through expectation damages and still make a profit.

With the injunctive right, however, the hotel owner (in many resort communities) may have a right to shut down the plant. He does not necessarily have that right. The geothermal plant will not necessarily affect hot springs water flow. Even if it did, the hotel owner would find it hard to prove his claim in court. But potentially he has that right.

Should the plant and the hotels try to negotiate a solution to this problem ex ante, they face a collective action problem. If a geothermal plant is indeed welfare enhancing, it would benefit the developer and incumbent hotel owners both: it would pay the developer returns high enough to more-than-compensate each hotel owner for the risk of harm. Should the developer try to negotiate such an arrangement ex ante, however, he must negotiate with each hotel seriatim -- yet no hotel owner can credibly promise him that each succeeding owner will agree to terms that will leave him a market return on his investment.

The government would find it problematic even to solve this problem by statute. It could indeed repeal the Hot Springs Act; after all, the Act merely specifies administrative procedure. The customary right to continued use, however, is a property right, and the Japanese Constitution (Art. 29) declares the right "to own or to hold property" to be "inviolable." The Japanese government may "take" this property, but a utility cannot. Even the government can "take" it only if it pays "just compensation." The common law of hot springs property presents, in short, a problem without a straightforward statutory solution.

C. Successful New Plants:

Hence the twin reciprocal problems: the developer cannot credibly promise local hotel owners that they can successfully sue him ex post for any damages he might cause; in turn, should a developer try to negotiate a deal -- any deal -- with all hotel owners ex ante, he faces a sequence of bilateral monopoly negotiations that could potentially leave him no return on his investments.

Geothermal developers and hot springs hotels cannot necessarily solve these problems. But some do. And among the geothermal plants that one observes, the instances where the parties did solve these problems obviously predominate.

1. Credible Promises. -- The most successful of the geothermal plants solved their inability credibly to promise not to harm hotel owners by piping steam and hot water to them directly. Recall the problem: a geothermal plant would like to promise hot springs hotels that if it caused their wells to go dry, it would pay them expectation damages in the courts; yet the plant and the hotels both know that the hotels would find causation hard to prove. By providing the hotels with the steam and hot water directly, the most successful geothermal plants eliminate the entire question about whether a hot springs hotel will ever find itself without water.

The first plant to pipe water directly to nearby hotels was the very first modern geothermal plant of them all: the Matsukawa plant in Iwate prefecture. Matsukawa opened in 1966 with a 23.5 MW capacity. From the beginning, it piped hot water, free, to all 38 local hotels and inns.[30]

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[30] Onsenchi (2011); Jinetsu (2011); MOE (2015). Nihon (2010, 42-3) writes that Matsukawa charges for the water.

Kyushu Electric followed the same practice at Hacchobara, the largest geothermal operation in the country. The plant covers 20 million square meters in the Oita mountains of central Kyushu -- within the Aso kuju National Park, no less. The complex includes three geothermal plants: a 55 MW double flash plant from 1977, a second 55 MW double flash plant from 1990, and a 2 MW binary plant from 2006. The first two plants rely on 30 wells (as of 2008); the binary plant uses the emissions from the two flash plants.[31]

Like Matsukawa, the Hacchobara plant pipes steam and hot water, free, to all local hotels and inns. When the plant opened in 1977, seven hotels and inns operated in the area. Attracted by the prospect of free hot water from Hacchobara, the local village now houses 29 hotels and inns (Kirishima 2015). Given that the plant pipes distilled hot water, the hotels and inns add minerals as necessary to replicate the water they would obtain directly from the ground (Kirishima 2015).

Geothermal developers have continued to pipe hot water to local hotels and inns in a variety of projects. They cannot do it always. Only if their wells yield a sufficient volume can they safely commit to supplying hot water to the hotels, and many wells do not yield that volume. Some hotels and inns would probably find it unsatisfactory anyway. Although many do use pumped hot water, others rely on naturally percolating hot springs. For them, water piped from a utility may lack the "natural" cache their customers demand.

Other geothermal plants piping steam and hot water to local hotels and inns include:[32]
Otake, Oita prefecture, 12.5 MW flash unit placed in service 1967.
Onuma, Akita prefecture, flash, 9.5 MW flash unit placed in service 1974.
Yanaizu Nishiyama, Fukushima prefecture, 65 MW flash placed in service 1995.
Waita, Kumamoto prefecture, 2 MW flash unit placed in service 2014.
Sugawara, Oita prefecture, 4.4MW binary unit placed in service, 2015.
Tsuchiyu, Fukushima prefecture, 440 kW binary unit placed in service 2016.

2. <u>Local initiative.</u> -- Turn to the second problem: unless the hot springs hotels and inns agree to waive their hold-up rights simultaneously, the geothermal plant faces a sequential set of contractual negotiations, each of them a bilateral monopoly. Although all hotels and inns would do better if they all agreed ex ante to limit their demands, no hotel can legally speak for any other hotel. Unable collectively to limit the demands they each will make, they leave the developer at risk of not earning a positive return.

Disproportionately, the plants we observe are plants where the hotels and inns seem to have solved this collective action problem before negotiating with the geothermal developer. A plant might -- conceivably -- make a conditional offer: we will pay x to each hotel if they all agree to waive later claims. Instead, disproportionately the plants we observe seem to have solved the collective action problem by informally enforcing the group decision on everyone in the industry. "Seem to have," because the apparent enforcement is informal and not visible-- the hotels and inns organized themselves into an association that negotiated on their behalf, or they negotiated through their industry association or town government. Rural Japanese communities have long enforced collective norms on each other through ostracism, and perhaps they do so here. The ostracism can bite: a hotel in a hot springs village that found itself banned from any local commerce would find it hard to stay in business.

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[31] Jinetsu (2011); Abe (2012); Kirishima (2015).

[32] Abe (2012); Ministry of Environment (2015a); Yamazaki (2019); Risoteki (2018); Onsen (2014, 65); Ministry of Environment (2015).

Should the bulk of the local hotels decide to do business with a geothermal developer, in other words, they can sometimes enforce their decision on the more reluctant hotels. Note that there need not be anything "fair" about an arrangement like this. Influential village leaders can and sometimes do capture local organizations. They can negotiate deals that exclude disfavored local firms. They then can prevent the disfavored firms from complaining by ostracizing or threatening to ostracize their owners and families. Ostracize effectively (as Ramseyer & Rasmusen 2020 show), and a Japanese village can run a disgruntled resident out of business.

The Tsuchiyu hamlet in suburban Fukushima had once thrived. Throughout the 1980s, it had served as a popular hot springs destination for tourists, but then had fallen on hard times. After the 2011 nuclear meltdown, tourism plummeted still further. To earn local revenue, several residents urged the community to accept a geothermal plant. They (and the local cooperative) formed the K.K. Genki Appu Tsuchiya (Invigorate Tsuchiya!) firm, and opted for a 440 kW binary plant -- enough for 720 households. They built it on land provided by the city, and used a well provided by the hot springs association.[33]

The small hamlet of Waita in Kumamoto had faced a geothermal developer in 1996. The developer had presented a plan, but the proposal had split the community, and the opposition killed the proposal. Like many rural Japanese villages, however, the hamlet continued to lose population. The average age of those who remained steadily climbed.

In 2011, several of the more entrepreneurial Waita citizens revisited the idea of a geothermal plant. They organized residents into LLC. They obtained government subsidies for the development. They negotiated a contract with an electrical firm to build and operate the plant. The modest 2 MW flash plant opened for business in 2015 (electricity sufficient for 3,900 households).[34]

Several years ago, geothermal developers decided to expand the 26 MW Yamakawa plant. To facilitate the expansion, the city government negotiated with the developer itself. The city rented a 3500 square meter piece of land to supply to the plant. From the plant, it contracted to buy 30 ton/hour of pressurized water at least 120 C (Ibusuki 2019; Sasaki 2019).

In Yuzawa village of Akita prefecture (not the Niigata Yuzawa mentioned in the introduction), the developer for the Wasabizawa plant gave the town several 1000-meter-class wells. In turn, the town pipes hot water from the wells to local inns. Not only did this eliminate opposition to the Wasabizawa plant, it actually brought new hot springs inns to the community (Akitaken N.D.).

To build the Sugawara binary plant in Kokonoe village, the geothermal developer similarly negotiated with the village. It rents the requisite well from the village (METI 2020; Ministry of Environment 2015a).

VI. Conclusions

Japan has no oil, no coal, and an understandably vehement public opposition to nuclear power. It does have the third largest deposit of geothermal energy in the world. Yet its total installed geothermal generating capacity remains a paltry 533 MW, tenth in international rankings.

In part, contractual problems of promissory credibility have apparently stymied the geothermal development. The problem does not just lie in the administrative law apparatus of the Hot Springs Act. Instead, by the common law of property, hot springs hotels in many communities

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[33] Onsen (2018); Ito (N.D.); Moriya (N.D.); Ishida (2015); METI (2020); Kagoshimaken (2019).

[34] Ishida (2015); Shizen (2017); Waita (N.D.); Nihon (2019).

can potentially (not probably, but at least potentially) shut down geothermal plants. Geothermal developers could promise to compensate the hotels for any damages they cause, but cannot make that assurance credible. The hot springs industry is badly over-developed in Japan, and existing wells randomly go dry on a regular basis. Whatever a developer may say, owners know that if a geothermal plant were to damage a well, they would find it hard to prove causation in court.

What is more, by the basic logic of collective action, hot springs hotels in many communities cannot credibly promise to negotiate in good faith. Because each hot springs owner in these areas has a right to the continued use of steam and hot water enforceable through injunctions, each can potentially (not certainly, but at least potentially) hold up the entire geothermal project. The developer faces sequential negotiations, each of them a bilateral monopoly, and no one owner can credibly promise the developer that all subsequent owners will negotiate in good faith.

The few geothermal plants that one observes are disproportionately those where the hot springs owners and geothermal developer did solve these contractual problems. The geothermal developer made credible its promise not to damage hotels by piping hot water to the hotels directly from its geothermal plant. The hotels solved their collective action problem by negotiating through their trade association or town government, and (apparently) controlling would-be deviants through threats of social ostracism.

Figure 1: Japan

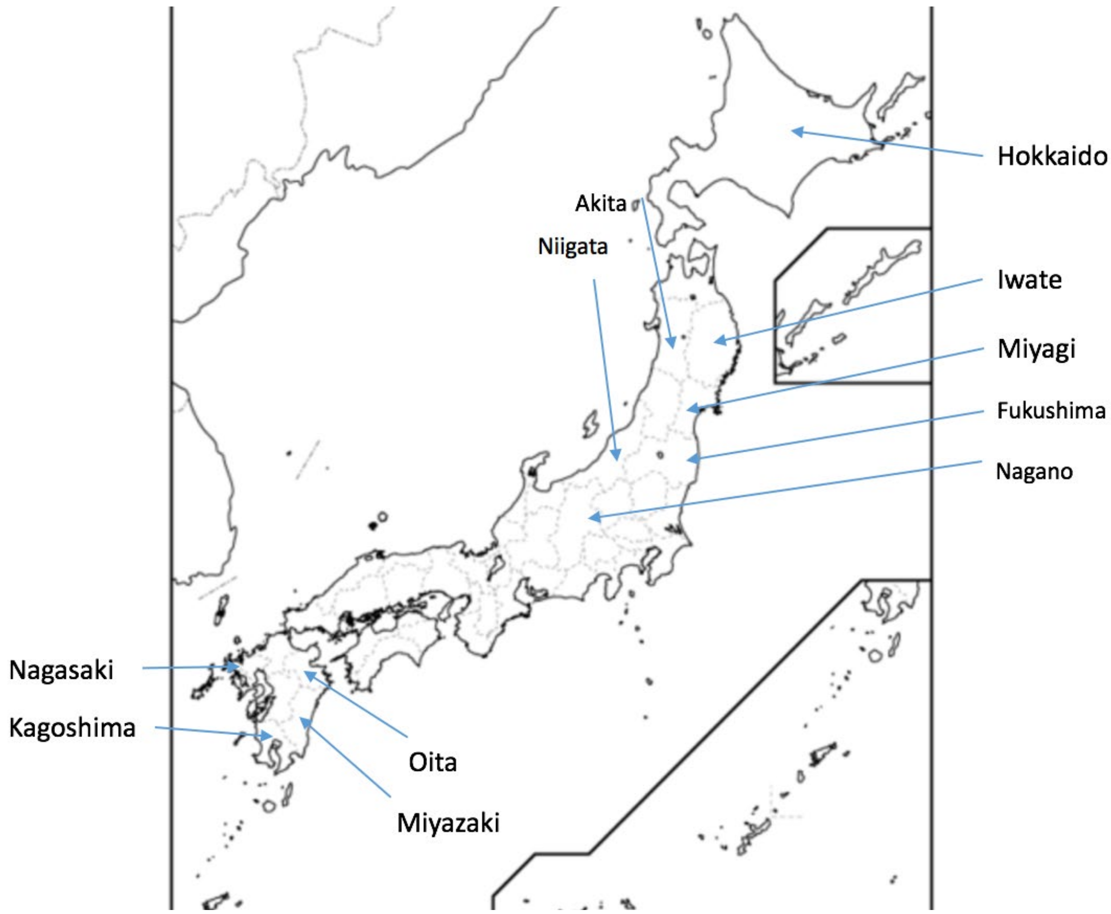

Table 1: Geothermal Production

A. Geothermal Installed Capacity and Aggregate Production:

	MW	GWh
1975	52	379
1980	161	1,091
1985	214	1,493
1990	270	1,724
1995	504	3109
2000	533	3,349
2005	534	3,228
2010	540	2,652
2011	540	2,689
2012	515	2,609
2013	515	2,570
2014	520	2,591
2015	525	2,567
2016	530	2,250

B. All Renewable Energy:

	2010	2011	2012	2013	2014	2015	2016	
Solar		0.4%	0.5%	0.7%	1.4%	2.1%	3.3%	4.8%
Wind	0.4	0.4	0.4	0.5	0.5	0.5	0.6	
Geothermal		0.2	0.2	0.2	0.2	0.2	0.2	0.2
Biomass	1.0	1.1	1.1	1.1	1.5	1.6	1.7	
Hydro (sm-scale)	1.5	1.6	1.6	1.6	1.7	1.7	1.7	
Hydro (large-sc)	6.3	6.7	6.0	6.2	6.5	7.1	5.8	
All renewable	9.8	10.5	10.1	11.0	12.5	14.5	14.8	
Nuclear	24.8	9.1	1.5	0.9	0.0	0.9	1.7	
Total electricity (indexed at 2010)	100	96	95	95	92	89	90	

Sources: ISEP, Shizen enerugii hakusho [Natural Energy Whitepaper] Sec. 4.5 (2017), available at: https://www.isep.or.jp/jsr/2017report/chapter4/4-5.

Table 2: Geothermal Electrical Generating Plants with Capacity > 10 MW

Plant	Prefec.	PIS	Installed capacity MW	2010/ 1997 pdtn	2010-1997 temp ch C	Park
Matsukawa	Iwate	1966	23.5	57.6%	+49	Yes
Otake	Oita	1967	12.5	82.0	-56	Yes
Onikobe	Miyagi	1975	15	77.7	-25	Yes
Hacchobara	Oita	1977	112	85.9	-5	Yes
Kakkonda	Iwate	1978	80	54.0	-1	Yes
Mori	Hokkaido	1982	25	59.6	-3.6	No
Uenotai	Akita	1994	28.8	20.4	-11.7	Yes
Sumikawa	Akita	1995	50	77.2	-7	Yes
Yanaizu NY	Fukushima	1995	65	48.7	-1.1	Yes
Yamakawa	Kagoshima	1995	26	62.5	-7.8	No
Ogiri	Kagoshima	1996	30	99.9	-4.1	Yes
Takigami	Oita	1996	27.5	100.5	-3.2	No
Wasabisawa	Akita	2019	46	--	--	No

Notes: Park -- whether the plant is located in a national, quasi-national, or prefectural park.

Sources: Kaori Kondo, Jinetsu hatsuden no genjo to kadai [The Current State of and Issues Relating to Geothermal Electrical Generation], [National Diet Library] Issue Brief, 837: 5-6 (2015); Masao Oyama, Jinetsu hatsuden to onsen no kyozon no mondai [Problems in the Coexistence of Geothermal Electrical Generation and Hot Springs], Onsen kagaku, 63: 341-52 (2014); NEDO, Saisei kano enerugii gijutsu hakusho [Renewable Energy Technology White Paper] 2d ed. (N.D.).

Table 3: FIT Guaranteed Prices, 2017

Solar		
	x < 10 kW	28 yen
	10kW < x 2MW	21
	x > 2MW	Auction
Wind (land)		
	x < 20 kW	55
	x > 20kW	21
Wind (sea)		
		36
Geothermal		
	x < 15 MW	40
	x > 15 MW	26
Small-scale hydroelectric		
	5 MW < x < 30MW	20
	1 MW < x < 5 MW	27
	200 kW < x < 1MW	29
	x < 200 kW	34

Notes: Separate prices given for replacement facilities in some cases.

Sources: ISEP, Shizen enerugii hakusho [Natural Energy Whitepaper] Sec. 2.6 (2017), available at: https://www.isep.or.jp/jsr/2017report.

Table 4: Binary Plants
With Capacity > 100kW, Placed in Service 2011-2017

Name	Location	Installed Capacity	PIS
Takigami	Oita pref, Kokonoe	5,050 kW	2017
Sugawara	Oita pref, Kokonoe	4,400 kW	2015
Medipolis	Kagoshima pref, Ibusuki	1,410 kW	2015
Tsuchiyu onsen	Fukushima pref, Fukushima	440 kW	2016
Cosmo Tech	Oita pref, Beppu	400 kW	2014
Okujiri	Hokkaido pref, Okujiri	250 kW	2017
Beppu Supa Service	Oita pref, Beppu	125 kW	2016
Obama onsen	Nagasaki pref, Unzen	115 kW	2016
Setouchi Nat Energy	Oita pref, Beppu	110 kW	2015

Sources: Tadahiko Okamura, Zenkoku no nessui katsuyo oyobi bainarii hatsuden no jirei [The Hot Water and Binary Generators in the Country], Sept. 27, 2017; Kankyo enerugii seisaku kenkyu jo, Shizen enerugii hakusho [Natural Energy White Paper] 4.1, 4.5 (2017), available at https://www.isep.or.jp/jsr/2017report.

Table 4: Hot Springs Production (liter/minute),

A. Major Producer Prefectures:

Total	1998	2003	2008	2013	2018 .
Hokkaido	305,381	261,822	267,397	243,192	198,022
Aomori	162,812	149,080	171,961	140,537	147,259
Iwate	159,338	113,174	113,224	107,977	113,077
Nagano	128,391	134,622	121,734	118,858	113,400
Shizuoka	127,581	119,810	119,672	123,009	116,004
Kumamoto	119,822	149,595	132,084	135,730	133,158
Oita	261,804	267,434	295,740	285,553	279,253
Kagoshima	196,777	200,804	200,694	186,824	160,132

B. Change Over Time:

1963	930,110
1968	1,258,138
1973	1,348,554
1978	1,557,303
1983	1,846,090
1988	2,037,301
1993	2,375,503
1998	2,638,980
2003	2,681,178
2007	2,799,418*
2008	2,772,022
2013	2,642,705
2018	2,546,813

Note: * -- peak.

Source: Ministry of Environment, Onsen riyo jokyo [Hot Springs Usage] (2010), available at: https://www.env.go.jp/nature/onsen/data/index.html

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