AgriVoltaics World Conference 2022

Environmental, Legal and Socio-Economic Aspects

https://doi.org/10.52825/agripv.v1i.533

Published: 06 Feb. 2024

Agrivoltaics in Japan

A Legal Framework Analysis

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Abstract. A comprehensive and supportive legal framework is a key factor for the expansion of agrivoltaics. This study analyzed, therefore, the existing laws, regulations, and policies related to agrivoltaics in Japan and assessed its actual effects on relevant stakeholders. An increasing horizontal policy integration on the federal level was identified. However, the vertical policy integration is still insufficient with often skeptical municipalities and local agricultural councils. The key barriers are related to the land-use conversion process, financing of agrivoltaic projects, socio-political and market acceptance, and grid constraints in rural areas. There are, however, opportunities for addressing these challenges in recently established councils that include a variety of members from industry, academia, and government.

Keywords: Agrivoltaics, Japan, Legal Framework, Policy Integration, Policy Barriers

1. Introduction

The Japanese government released its Sixth Strategic Energy Plan in October 2021 aiming for a share of 36-38% renewable energy including 14-16% of solar photovoltaics by 2030 [1, 2]. With only 8.5% of solar PV in the Japanese energy mix at the time of the announcement, this equals to the need for almost doubling the capacity of solar energy in less than a decade [3]. Achieving this solar PV goal is challenging since only 34% of Japan's area is flatland and most of this land has already been developed during the solar boom after the introduction of the Feed-In Tariff in 2012 [4]. Photovoltaic projects on mountainsides and in forests face increasing opposition from local stakeholders due to concerns about deforestation and landslides [5]. Therefore, it is important to find alternative spaces to develop solar PV.

Agrivoltaics is a promising concept to reduce these land-use conflicts since it allows for dual use of land on agricultural land [6]. Moreover, it also has the potential to tackle other pressing challenges in Japan, such as the increasing areas of abandoned farmland. The extra income from the agrivoltaic system can be an incentive for the younger generation to continue the agricultural businesses of the aging farmers who currently struggle to find successors [7]. On a macro level, this can help to increase both the low food and energy self-sufficiency of Japan.

Even though Japan is a pioneer in agrivoltaics and recognizes its potential, agrivoltaics only has a share of under 1% of the non-residential photovoltaic systems in Japan [4]. It is important to analyze the socio-political context to understand why agrivoltaics is still a niche technology almost 20 years after its first introduction in Japan [8]. In this context, laws and regulations play a crucial role in the diffusion of new technologies such as agrivoltaics

since only a comprehensive legal framework including its uncomplicated implementation on the local level will enable a fast expansion. This study, therefore, analyzes the existing legal framework and identifies barriers and opportunities in the laws and regulations related to agrivoltaics in Japan.

2. Literature Review

Institutional barriers have been identified as a barrier to the diffusion of renewable energies in previous studies. Some common challenges are ambiguous energy policies, unsuitable legal frameworks, complicated bureaucracy in the approval process, conflicting interests among stakeholders, and the lack of research and institutions [9]. These factors can have negative effects on the willingness of stakeholders to invest in renewable energy technologies [10]. Well-designed laws and regulations are, therefore, crucial to establishing a predictable and secure environment that is also flexible for innovations in the sector [11].

The case of agrivoltaics is even more complicated than it is for other renewable energy technologies since it does not only directly affect the energy but also the agricultural sector. Moreover, the involvement of all levels of government is necessary to enable effective implementation. Thus, it creates the need for multi-sector and multi-level governance interactions [12]. Therefore, it is crucial to achieving policy integration that surpasses established policy sectors and enables the sharing of information, the establishment of transparency, and the aim of reinforcing policies based on the same goals [13]. The resulting joined-up policies can create win-win situations for all sectors and should be the aim for agrivoltaics. Policy integration can take place both in horizontal and vertical alignment. Horizontal alignment describes the interaction within the same level of government [14], whereas vertical alignment describes the interaction between the national, regional, and local levels of government. The municipalities play a key role in the adaption of policies and often decide its success or failure [15]. Therefore, capacity building and awareness-raising on the local level are crucial for successful implementation [16]. A comprehensive approach that includes both vertical and horizontal activities is important to establish a shared vision and foster an understanding of stakeholders from different sectors and governmental levels [17]. Japan is a unitary state with a strong central government. Research on climate change adaptation indicates that vertical integration in unitary countries is low and sub-national actors are hardly involved in the formulation of policies [16]. Moreover, Japan has traditionally had a strong departmentalization in which each ministry focuses on its own priorities and plans its policies accordingly with limited interdepartmental coordination or even in rivalry with ministries that have opposing interests [18]. However, there are also positive examples of horizontal policy integration in Japan [19].

3. Methods

A Legal Framework Analysis is applied to (1) identify the relevant components of Japan's legal framework for agrivoltaics, (2) analyze the law in action, and (3) assess the feasibility of revising the existing laws and regulations to remove policy constraints. We follow the concepts and guidelines for a Legal Framework Analysis for rural and agricultural projects by the Food and Agriculture Organization of the United Nations [11]. Legal Framework Analyses have been successfully employed in energy policy research [20, 21], including a recent study about the legal framework for agrivoltaics in the U.S. [12].

Regulatory and policy documents were used as a primary source to understand the existing laws and regulations, as well as to understand the dynamics of the different levels of the governments related to agrivoltaics. Moreover, a thorough review of the existing Japanese literature on agrivoltaics was conducted to identify challenges in the law-in-action and at the same time make Japanese research accessible to a wider international audience.

4. Results

4.1 Relevant Regulation and Policies

Regulations from both the agricultural as well as the energy sector are crucial for the implementation of agrivoltaics and will be discussed in the following section.

Unlike traditional ground-mounted PV systems, agrivoltaics are allowed on all categories of farmland in Japan since a directive by the Agricultural Promotion Bureau of the Ministry of Agriculture, Forestry and Fisheries (MAFF) was issued in March 2013 [22]. However, the area of the mounting frame of the agrivoltaics system must be approved for partial land-use conversion for non-agricultural use by the responsible local Agricultural Councils. Initially, a permit was permitted only for 3 years after which a re-permit had to be obtained. The requirements for approval are as followed: 1) the mounting structure is only temporary and easily removable, 2) the shading rate ensures enough sunlight for plant growth, 3) the minimum panel height is 2 meters, 4) the system should not hinder agricultural practices in surrounding areas nor negatively affect the implementation of the “Agricultural Promotion Plan” and 5) a yield reduction of under 20% compared to the average level of the surrounding farmland must be ensured which is monitored by annual reporting. The agrivoltaics systems must be removed in the case that agricultural production cannot be conducted accordingly. In the 2nd directive on agrivoltaics by the MAFF in May 2018, conditions to receive a 10-year permit were added if 1) a farmer can demonstrate competence in agricultural practices and management, or 2) the system is installed on “devastated farmland” or 3) the system is installed on “second class or third class farmland” [23]. The most recent 3rd directive by the MAFF in March 2021 allowed for exceptions to the established rules by 1) waiving the height requirement of 2 m for vertically mounted agrivoltaic systems and 2) abolishing the need for temporary land conversion and yield requirements for agrivoltaics on devastated land [24].

An Environmental Impact Assessment (EIA) is necessary for solar PV projects, including agrivoltaics, with a capacity of over 30-40 MW since an amendment of the EIA Act in April 2020 [25]. Currently, the agrivoltaic systems in Japan do not reach this large-scale size, but stricter regulations that include also smaller projects can be enforced by ordinances on a local level. Agrivoltaics that fulfill the requirements for temporary land-use conversion are not considered as “buildings” and therefore do not fall under the Building Standard Act according to the Ministry of Land, Infrastructure, Transport and Tourism notification No. 3762 [26].

The Act on Special Measures Concerning Procurement of Electricity from Renewable Energy Sources by Electricity Utilities, also known as the Feed-In-Tariff (FIT) Act, was first introduced in 2012 under the jurisdiction of the Ministry of Economy, Trade and Industry (METI). It plays a key role in the sale of electricity from the agrivoltaic system by providing a stable and predictable income for 20 years. The second amendment of the FIT Act was enforced in April 2022 and for the first time, provides preferential treatment for small-scale agrivoltaic systems, which is the most common form of agrivoltaics in Japan. The amendment requires photovoltaic projects with a capacity between 10-50 kW to allocate 30% of their electricity to regional use. However, this clause is waived for agrivoltaics if it already received a ten-year land-use conversion permit and can provide electricity for regional use during times of disasters [27].

Major national policies in recent years also recognized the importance of agrivoltaics for both the energy transition and a sustainable agricultural sector. In 2019 and 2020, the nationwide expansion of agrivoltaics was mentioned in the *Follow-up on the Growth Strategy*, which is a yearly governmental report that is approved by the Cabinet Office after the draft is being discussed with ministries and agencies [28, 29]. The content has a strong influence on future legislation and policies. For the energy sector, the *Basic Energy Plan* is a key policy document by METI. The sixth and newest plan from October 2021 states that “the expansion of the introduction of farm-based solar power generation, where both the power generation

and farming are possible, should be promoted" [2]. For the agricultural sector, MAFF recommended using agrivoltaics in their *Basic Plan for Food, Agriculture and Rural Areas*, which stipulates governmental goals for the medium to long-term. Moreover, the *Green Growth Strategy for 2050 Carbon Neutral* which is a strategy document to "enable sustainable growth and innovation by mobilizing all policies" drafted by all relevant ministries in 2021 also mentions agrivoltaics as a solution to decarbonize the rural areas [30]. These major policies in recent years by all relevant ministries and legal authorities indicate an increasing horizontal policy integration on the federal level with an aligned goal to strengthen and promote agrivoltaics to achieve carbon neutrality in 2050.

Horizontal policy integration on the highest level of government is important, especially in a unitary country like Japan. Nevertheless, vertical policy integration with supportive measures on a prefectural and local level is also crucial for the actual implementation and expansion of agrivoltaics. So far, there are only a few examples of supportive measures explicitly for agrivoltaics, such as subsidies for the necessary equipment [31].

4.2 Law in action

After clarifying that agrivoltaics is legally possible on all categories of farmland if the requirements are fulfilled and that there is generally the goal of promoting agrivoltaics by the government, it is important to assess the actual effect of the laws and policies on the ground. The analysis of the Japanese academic literature on agrivoltaics shows four main barriers to agrivoltaics in Japan (*Table 1*):

Table 1. Barriers to a successful implementation of agrivoltaics in Japan.

Category	Barriers	References
Land-use conversion	a. Yield requirement not based on scientific evidence b. Arbitrary approval process by local Agricultural Councils c. Approval process is too complicated/time-consuming d. Re-permit at least once necessary	[4, 7, 32-40]
Financing of projects	a. Difficulty to receive loans b. Declining FIT that does not take higher cost of agrivoltaics into account	[4, 33, 36, 37, 39, 41]
Social Acceptance (Socio-political and market)	a. Municipalities and farmers lack awareness and knowledge about agrivoltaics b. Concerns about the impact of agrivoltaics on agricultural production, landscape, living and natural environment and resulting conflicts with residents/neighbors c. Increasing bad-practice examples and good-practice examples are not shared d. Old farmers without successors cannot commit to 20 years of continuous farming	[7, 32-34, 36-40, 42, 43]
General problems	a. Grid constraints b. High costs of grid connection	[38, 43]

The land-use conversion to non-agricultural land was identified as one of the major barriers to the implementation of agrivoltaics [4, 7, 31-39]. Especially problematic is the aspect that the yield requirement is not based on scientific evidence since there is a lack of academic research regarding the growth of crops under shading in the Japanese environment. Farmers need to know which crops can be successful in an agrivoltaics setting to be able to make an informed decision on such a high-cost investment. A failure to meet the yield requirements would result in the removal of the installation and a severe financial loss.

The yearly yield can also be affected by various factors (e.g., weather, diseases, or pest) that are not related to the installation of agrivoltaic systems. Moreover, it is difficult to

access the yield of certain crops that need years until their first harvest, such as cleyera japonica (Sakaki).

The arbitrary approval process by local Agricultural Councils which often lack sufficient knowledge and have a negative attitude towards agrivoltaics is also seen as problematic, especially in areas with low numbers of installed agrivoltaic projects. The time needed for the approval process varies widely between the different municipalities within a range of approximately three months to two years. 60% of 1174 members of local Agricultural Councils who were asked about agrivoltaics in 2018 answered that they do not believe that sufficient agricultural production can be conducted under solar panels [35]. The decisions after a generally complicated and time-consuming application for a land-use conversion permit are, therefore, unpredictable and lead to high uncertainty for farmers.

Even if the decision is made to invest in agrivoltaics, it is difficult to secure the financing for the project [4, 32, 35, 36, 38, 40]. Especially, the need for a re-permit during the project duration is seen critically by financial institutions which are reluctant to take this risk and provide loans. Moreover, the declining FIT rates for solar PV that do not take the higher prices of agrivoltaics into account are challenging [7, 39].

The lack of social acceptance [44] of agrivoltaics is another barrier to the implementation of agrivoltaics [7, 31-33, 35-39, 41, 42]. The socio-political acceptance is hindered by the skepticism of municipalities about the impact of agrivoltaics. The potential of agricultural promotion is only recognized by a few local government and concerns about the negative impact on the living and natural environment, landscape, and agricultural sustainability prevails. Possible conflicts with residents are feared in this context by municipalities. The occurrence of bad practices and the lacking awareness of good practice examples that demonstrate the wide range of positive effects of agrivoltaics strengthens these beliefs. Most municipalities are unwilling to enact supportive policies in this context. The market acceptance is also still low. Many farmers have little knowledge and awareness about agrivoltaics. There are concerns about soil run-off, agricultural sustainability, and difficult consensus-building processes with neighbors. Some farmers had bad experiences with PV companies in the past and are hesitant to allow other businesses than agriculture on their land. Moreover, the long commitment of 20 years of continuous farming is seen as a burden by older farmers who have no successors. These factors indicate a low willingness to implement agrivoltaics for many farmers. Community acceptance also is a concern of municipalities and farmers but has no empirical backing so far and further research is necessary.

In addition to these specific challenges, there are still general problems with the energy transition in Japan that also affect agrivoltaics. First and foremost, the grid constraints and high grid connection costs, especially in rural areas [38, 43].

4.3 Feasibility of addressing legal constraints

The Taskforce for Review of Regulations on Renewable Energy was established in December 2020 with the aim to review and reduce legal barriers in a joint approach of relevant ministries and agencies. The regulations of agrivoltaics are also being reviewed and already led to the 3rd directive by MAFF that exempts the yield requirements for devasted farmland [45]. In February 2022, the MAFF initiated the *Advisory Council to Study the Desirable Future of Agrivoltaics* with experts from industry, academia, and government to promote agrivoltaics that are compatible with the maintenance of prime farmland and in harmony with the local community [46]. Both efforts present opportunities to address the legal constraints and further improve policy integration.

The land-use conversion, especially the uncertainty about the yield requirement, was identified as a major barrier. Yield requirement is a useful measure to avoid bad practices that prioritize electricity generation over agricultural production. More research on agricultural

productivity, crop choice, and agricultural-friendly equipment design can help to reduce the uncertainty for all stakeholders without the need for a legal change. Moreover, the research can provide the basis for standardization of the land-use conversion process that reduces the burden on local governments and agricultural councils.

5. Conclusion

The legal framework analysis identified the directives of the MAFF that set the requirements for the land-use conversion and the FIT Act for the sale of electricity as the key regulations for agrivoltaics. Recent policies from various relevant ministries show an alignment of the goal to promote agrivoltaics and indicate an increased policy integration on the federal level. However, vertical policy integration is still insufficient with municipalities and local agricultural councils that often lack understanding and do not share a common vision for agrivoltaics. Awareness raising and the sharing of good-practice examples are necessary since the local governments play a key role in the actual implementation of agrivoltaic projects. 702 local governments already announced their commitment to net-zero carbon emission by 2050 [47] and can become important facilitators if they realize the potential of agrivoltaics for their communities and their decarbonization ambitions.

More research on agrivoltaics in the Japanese context is necessary to reduce the remaining uncertainties for all relevant stakeholders. This would help to increase the social acceptance of farmers, municipalities, and agricultural councils. It would also provide financial institutions with better information for their decision on financing agrivoltaic projects. Moreover, suitable crops can be identified that guarantee high agricultural production under the shade of the agrivoltaics systems.

Overall, there are still many challenges to accelerating agrivoltaics from a niche to a well-established technology in Japan. A comprehensive legal framework based on horizontal and vertical policy integration can provide a robust basis for a successful expansion.

Author contributions

Christian Doedt: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Writing – original draft, Writing – review & editing **Makoto Tajima**: Guidance, Analytical Framework **Tetsunari Iida**: Supervision, Funding acquisition

Competing interests

The authors declare no competing interests.

Funding

This work was supported by the Japan Fund for Global Environment.

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