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Article

Multi-Actor Systems in Water–Energy Nexus: Identifying Critical Stakeholders in Floatovoltaic (Floating Photovoltaic) Project

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Abstract: The intrinsic relation between water and energy has made the water–energy nexus a burgeoning issue in the discussion of sustainable development. Recently, research has begun to pay attention to stakeholders in the nexus. They, however, identified stakeholders as a given without employing methodically scientific processes with rigorous parameters. Filling in the gap, this study presents a heuristic approach to identifying critical stakeholders of multi-actor systems in the water–energy nexus. It involves three sources of influence (social roles, specific concerns, and key problems) along with four other boundary issues (motivation, control, knowledge, legitimacy), forming a matrix of the boundary categories of Critical Systems Heuristics (CSH). This study applied the heuristic analysis to the project of floating photovoltaics installed in a pond in Hyogo, Japan, as the case study. It is a unique case of the water–energy nexus since the location of the floatovoltaic installation is a privately owned pond that is also part of the public landscape and an irrigation source for the surrounding agricultural areas. The results identified two macrogroups of stakeholders (residents and project developers) driven by general interests in the project. They were derivable as overlapping micro-actors interested in more specific issues related to different facets of the project. Overall, conflicting interests in the multi-actor systems indicated deadlocked interactions due to a multidirectional tug-of-war between the microgroups of actors. Conceptually, this study significantly contributes to the literature on the water–energy nexus and stakeholder management. Practically, the approach used offers scientific processes to understand the multi-actor systems and conflicting interests involved in/affected by the nexus, paving the way for more comprehensive resolution processes of water–energy conflicts.

Keywords: Critical System Heuristics; stakeholder dynamics; pond management; communities; natural landscape; agricultural irrigation; renewable energy; heuristic analysis; systems thinking

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1. Introduction

Water and energy are two of the most essential elements for human societies [1]. Their availability is tremendously critical in determining the quality of life and economic developments all around the world. Water is indispensable for various human activities [2,3]—from basic things, such as drinking, to more complex uses in agriculture and industrial processes. Meanwhile, energy is necessary for numerous human activities on both the production and consumption sides [4], including transportation, heating and cooling, and powering machinery. Aside from the socioeconomic significance, water and energy have a substantial impact on the environment [5,6]. Their extraction, production, and consumption can cause environmental degradation and pollution, which, in turn, can have detrimental effects on the health and well-being of individuals and ecosystems. For instance, the depletion of natural water resources can result in the loss of habitat and the extinction of species.

Similarly, energy production and consumption can lead to greenhouse gas emissions, which contribute to global warming and climate change. Moreover, water and energy are closely interlinked [7,8], with energy production and distribution relying heavily on the availability and management of water resources, including in hydropower generation or simply to cool down electricity-generating equipment. In parallel, water resource management requires energy to operate every part of its activities, from powering water pumps to lighting and control systems. The management of water and energy resources, therefore, necessitates integrated thinking that considers their mutual dependence and their impact on the environment, human societies, and the economy [9].

In that sense, the intrinsic relationship between water and energy within human society is complex and interdependent, forming what is commonly referred to as the water–energy nexus [10,11]. This interlinkage, as aforementioned, refers to the interdependence between water and energy [12–14], where energy production/distribution depends on water availability and water management requires energy inputs. The interdependence of water and energy is progressively becoming more evident in numerous human populations all over the world [7,15–17], since consumable water resources are increasingly limited and energy availability remains crucial for water extraction and treatment. In many countries, water scarcity has become a major challenge for the energy sector [18], since water is required in energy supply and distribution—from cooling thermal power plants to extracting fossil fuels to generating hydroelectric power. The increasing demand for both water and energy, driven by population growth, technological progress, and economic development, has resulted in increased competition for these resources, leading to the need for more sustainable and integrated water–energy management practices [5,9,19,20]. The efficient use of water in the energy sector through the adoption of new technologies, e.g., advanced cooling systems [21] and the use of recycled and alternative water sources [22], can help reduce the demand for fresh water, eliminate energy poverty, and, eventually, achieve energy sustainability. On the water side, the development of energy-efficient systems to extract and treat water, including those utilizing cleaner and renewable energy sources [23] and the use of appropriate technologies [24], is necessary to improve water access for everyone, eradicate water poverty, and reduce ecological burdens.

However, most research on the water–energy nexus has focused on technical issues related to water provision for energy-related activities and vice versa. While past studies provided important insights into the interlinkages between water and energy, they largely neglected the role of human actors and the diverse stakeholder interests inherent in the water–energy nexus. Particularly, previous research on the water–energy nexus primarily considered the stakeholders involved as a given rather than conducting an independent scientific investigation to first identify and understand the multi-actor systems that exist in an observed water–energy nexus. This resulted in an inadequate understanding of the dynamic interactions among stakeholders (actors) and the interplay of their interests, values, and decision-making processes, which forms complex multi-actor systems. The absence of a systematic and systemic investigation into the stakeholders involved in the water–energy nexus has become a significant gap in the current literature, limiting our understanding of the multi-actor interactions within a water–energy nexus and the role of stakeholders in shaping its outcomes. Thus, this study aimed to achieve a more comprehensive understanding of a water–energy nexus by identifying its critical stakeholders, the stakes they hold, and how they think of others in the multi-actor systems, all within the nexus. This study would contribute to the preliminary process of multi-actor investigations, for which it would lay the foundation for more significant nexus interventions since multi-actor interactions and the interplay of their interests have been scientifically examined. Thus, this study attempted to answer the following research questions:

- **RQ1** Who are the critical actors in a water–energy nexus?
- **RQ2** What stakes do they hold in the nexus?
- **RQ3** How do the actors interact in the multi-actor systems?

2. Literature Review

2.1. Critical Multi-Actor Systems in the Water–Energy Nexus

A multi-actor system is a complex system that involves multiple actors, such as individuals, organizations, or institutions, which interact with each other and with the environment to achieve their goals [25]. These actors are often interdependent, meaning that the actions of one actor can affect the outcomes of others and that the actions of multiple actors can produce outcomes that are not possible for individual actors alone [26]. Understanding multi-actor systems is crucial when investigating social systems, as many social systems are inherently multi-actor systems. This is because social systems are composed of multiple actors with diverse interests, values, and decision-making processes, who interact with each other and with the environment to produce collective outcomes [27]. Understanding these complex interactions and interdependencies is essential for understanding the functioning of social systems and the impact of human actions on the outcomes of these systems [28,29]. Research on multi-actor systems has traditionally focused on mathematical and computational models that represent the interactions between actors and the environment. However, more recent research has also emphasized the importance of considering the social and institutional factors that shape the relationships between actors, as well as the cultural, political, and economic context in which these relationships take place [30–33].

In the case of water–energy nexus, multi-actor systems are essential in understanding stakeholder dynamics [10,34], as they provide a framework for analyzing the interactions and interdependencies between different actors and the environment in this context [35,36]. The water–energy nexus involves multiple actors, including governments, corporations, non-governmental organizations, and communities, who interact with each other and with the environment to produce outcomes related to the interlinked provision of water and energy [37,38]. In the water–energy nexus, different actors have different interests, values, and decision-making processes, and these differences can shape the relationships between actors and the outcomes of their interactions. For example, governments may prioritize the protection of water resources for public use [39], while corporations prioritize the production of energy to maximize profit [40]. These different priorities can create conflicts and trade-offs that affect the provision of both water and energy. Multi-actor systems analysis provides a useful framework for understanding the stakeholder dynamics in the water–energy nexus, by taking into account the interdependencies and interactions between actors and the environment. This analysis can reveal the factors that shape the relationships between actors, the trade-offs and conflicts that arise, and the potential outcomes of different policy and decision-making scenarios.

2.2. Multi-Actor Settings: The Involved and the Affected

In multi-actor systems, identifying immediate actors involved is crucial to discover the basic structure and interactions within the systems. In the case of the water–energy nexus, the direct actors involved can be broadly categorized into two groups [34,38,41,42]: supply-side and consumption-side actors. However, actors across the nexus are not limited to these direct actors. There are also indirect actors who are not directly involved in water or energy provision but whose presence have an impact on the nexus. These actors can include government agencies [33,43], NGOs [44,45], and the private sector [46,47]. For example, government agencies can regulate the water and energy sectors, while NGOs can advocate for environmental protection and sustainability. The private sector can also play a significant role in shaping market behavior, inventing new technologies, and influencing regulations. Therefore, to understand the water–energy nexus as multi-actor systems [48], it is important to identify not only the direct actors but also the indirect actors. This can provide comprehensive insight into the entire system's structure and the role that each actor plays in it. In turn, it can lead to a better grasp of stakeholder dynamics in the nexus and the systemic impact of these dynamics on the system and the actors within.

Distinguishing actors who are involved and actors who are affected in a multi-actor system is crucial when examining the water–energy nexus [34,38]. Actors who are involved in the water–energy nexus refer to those with active roles in water and/or energy provision. On the other hand, actors who are affected in the nexus refer to those who experience consequences of water/energy provision but do not have active roles in the provision process. Determining affected actors in the water–energy nexus is challenging, since the impact of the water/energy provision may extend far beyond those who are directly involved. Studies have employed various methods to identify actors who are affected in the water–energy nexus [34,49–51]. Some studies used surveys to gather information from individuals or communities, while other studies employed qualitative methods, including focus group discussions, to identify affected actors. Additionally, there have been studies that used remote sensing and spatial analysis to determine the extent to which the water–energy nexus affects specific geographical areas, including actors in the areas [52,53]. At the end, failing to consider affected actors can negatively impact their well-being and the environment and ultimately limit the sustainability of the water–energy nexus. It is therefore imperative to identify the affected actors and incorporate their perspectives in decision-making processes for the water–energy nexus.

2.3. Identifying Critical Actors: The Boundary Judgement

In multi-actor settings, understanding who the critical actors are requires observations and considerations over their roles and values in the systems of interest [38,54]. When the roles and values are unknown, or known to only a partial extent, to observers, the considerations and observations should establish the judgement over the criticality of the actors [55–58]. In other words, observers should make use of a boundary judgment as it determines which actors are relevant and which ones are excluded or deemed less important. This is particularly important when observers are distant from the observed system, by which there is no single "correct" way in ones' consciousness to identify critical actors precisely. In multi-actor settings, boundary judgments are even more crucial as the reference systems of the actors involved or affected, which refer to the frameworks of understanding and meaning that individuals and groups use to interpret the world, play a pivotal role in defining problems or assessing solutions [59–62]. Moreover, it is of utmost importance for observers to set aside their typical judgement over who the stakeholders "usually are", which makes the actors seem taken for granted from a helicopter's view. Critical examinations by challenging established "knowledge" and "rationality" would therefore allow for more inclusive and comprehensive problem-solving processes.

Being based on critical systems thinking, a boundary judgment should discover the sources of influence of potential actors within the observed systems. Multi-actor systems, technically, imply that the presence of an actor entails one's specific functions in the systems [63–65]. In other words, the social roles of actors in the systems reflect their positions as "stakeholders" of the systems in motion. In that sense, their social roles relate to specific concerns the "stakeholders" bring in and out of the systems [65–68]. Their specific concerns thus form the stakes that they hold within the systems of interest. Practically, there would be key problems the stakeholders would have to address to get their concerns addressed by the systems [68–70]. This indicates, as stakeholders, their act of holding stakeholder-specific stakes in the systems. Aside from the sources of influence, examining critical actors necessitates critical evaluations of other boundary issues, i.e., their sources of motivation, control, knowledge, and legitimacy [60,61,65]. In terms of actors directly involved in the systems of interest, which in this research, is the water–energy nexus, motivation, control, and knowledge reflect their critical functions in the systems. Meanwhile, critically evaluating indirect actors requires a legitimation of why they are affected by the water–energy nexus, or the worldviews brought by directly involved actors.

2.4. Theoretical Framework

In this study, making sense of multi-actor situations at the water–energy nexus is a necessary preliminary step for subsequent multi-actor investigations. The process of critically evaluating actors and hence stakeholders in the systems implies that the examination should aim at discovering the multi-actor nexus "as is" and not what it "should be". It necessitates a more realistic, descriptive analysis of who the actors "are" rather than an ideal, normative examination of who they "must be" in the made-up minds of observers. Considering multi-actor systems as organically formed, this study sees that it is important to apply a heuristic analysis. The theoretical framework (Figure 1) depicts the entire boundary judgment for the heuristics analysis as the product of intersections between the sources of influences (social roles, specific concerns, and key problems) and other boundary issues, which produce 12 boundary categories reflecting the total influences the actors wield toward the nexus. It produces a systematic way of mapping relationships between stakeholders, the issues with which they are independently concerned, and the key problems that they need to resolve. Applying a heuristic systems analysis based on the extensive boundary judgment allows for this study to identify key stakeholders and their relative positions, assess potential conflicts and synergies among them, and evaluate the distribution of power and influence in the systems.

Figure 1. Theoretical framework.

In a heuristics analysis over the water–energy nexus, understanding the motivation of the nexus gives insights into whose values are served in or by the nexus, implying who the beneficiaries are. Motivation also drives the purpose of the nexus as the stakes of the multi-actor systems. The key problems here thus reflect the measures of success in fulfilling the purpose. Meanwhile, understanding the control over the nexus provides insights into how an actor exercises its power and influences or becomes a decision maker over the outcome of the water–energy nexus. It also portrays resources, as the stakes, necessary to achieve the state of success for the nexus. The key problems for control thus relate to the indicators that are uncontrollable by the decision makers. Furthermore, recognizing knowledge driving the nexus gives insights into experts who can/are providing relevant knowledge/skills for the water–energy nexus, leading to the discovery of new knowledge and skills necessary to help the nexus achieve its purpose. The key problems here are thus the assurances, or in case of actors, a guarantor, which/who can ensure a well-run nexus. Then, affected actors represent the interests of being affected by the nexus but not actively involved in running the multi-actor systems, implying their role as the witnessing party. The stakes that they hold center on the chances to have expression and freedom, emancipating themselves against the nexus. Their key problems thus relate to spaces available for them to reconcile different worldviews of the nexus among those involved and affected.

3. Methodology

3.1. Research Design

The theoretical framework (Figure 1) implied the water–energy nexus as a complex and interrelated phenomenon that requires a nuanced approach to its analysis. A methodology that considers the interconnected nature of the boundary issues is thus critical to uncovering dynamics in the nexus. This is where Critical Systems Heuristics (CSH) [60] arise as a useful tool to identify multi-actor systems in the nexus. CSH is both an approach and a perspective that seeks to uncover the structures and processes that drive complex systems. It takes a critical perspective of the system and its components, exploring the assumptions, beliefs, and values that influence how the system operates [65]. In the context of the water–energy nexus, CSH allows us to grasp the relationships between the different stakeholders, the stakes they hold, and the ways in which they hold these stakes [57]. This approach of critical evaluation offers a holistic view of the system, as it considers the interrelationships between different elements and the system as a whole. It also allows for an exploration of the underlying cultural, social, and political factors [58] that shape the nexus. In short, CSH offers a thorough understanding of the water–energy nexus by uncovering inherent correlations among stakeholders, stakes, and their stakeholding.

Building on the prerequisites and components of CSH, this study was conducted based on the research design (Figure 2). Divided into three stages (Preliminary, Data Collection, and Analysis), this study began with a preliminary study to develop the theoretical framework (Figure 1). This research applied a case study method [71] over a real-life water–energy nexus to show the heuristics analysis in action over the phenomenon (water–energy nexus), the context (stakeholder mapping), and people (the actors). This study collected data through individual interviews with potential actors who might be/become involved in or affected by the nexus. The interviews asked open-ended questions based on the 12 boundary categories from the theoretical framework (Figure 1). Open-ended questions help interviewees express their minds with fewer technical constraints while also helping interviewers discover in-depth information [72]. During analysis (Figure 2), this study compared and contrasted interview data based on the 12 boundary categories to discover who the stakeholders were, their stakes and options, and the interactions among their options for action. From the analysis, this study expected to see how the matrix of stakes, stakeholders, and stakeholding against the other four boundary issues revealed the systematic and systemic structure of multi-actor systems in the observed water–energy nexus.

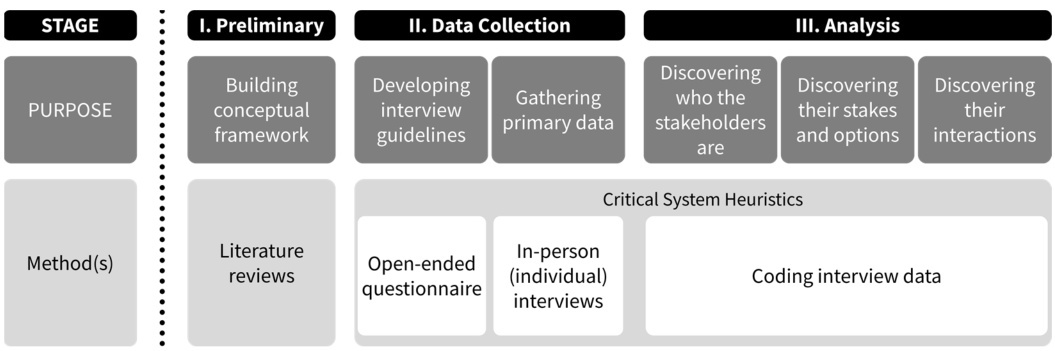

Figure 2. Research design.

3.2. Case Study

This work aimed to investigate multi-actor systems in the water–energy nexus, requiring a case study involving multi-actor interactions over inseparable water and energy issues. This study chose to focus on the floatovoltaics (floating photovoltaics) project in Inami Town, Hyogo Prefecture, Japan (Figure 3). Floatovoltaics is a form of the water–energy nexus due to the integration of both renewable energy generation and water management within it. Floatovoltaic systems consist of photovoltaic (PV) panels installed on floating platforms on water bodies [73]. By utilizing the large surface area of bodies of water, floatovoltaics generate a significant amount of renewable energy while also providing shading to reduce evaporation and preserve water quality [74,75]. The observed project was intended to install the floating PV on the Ohzawashinike pond in Inami, a small town in Kako District, the southern part of Hyogo prefecture. Hyogo covers about 20% of the total number of ponds in all of Japan [76], forming the largest network of freshwater bodies in Japan [77]. Covering 17% of the town's total area [78], ponds in Inami are parts of a wider agricultural irrigation network in Hyogo [76]. Many ponds, including Ohzawashinike, are owned by individuals or by groups of residents (cooperatives), yet they are also part of the natural landscape and an integral component of the surrounding ecological systems.

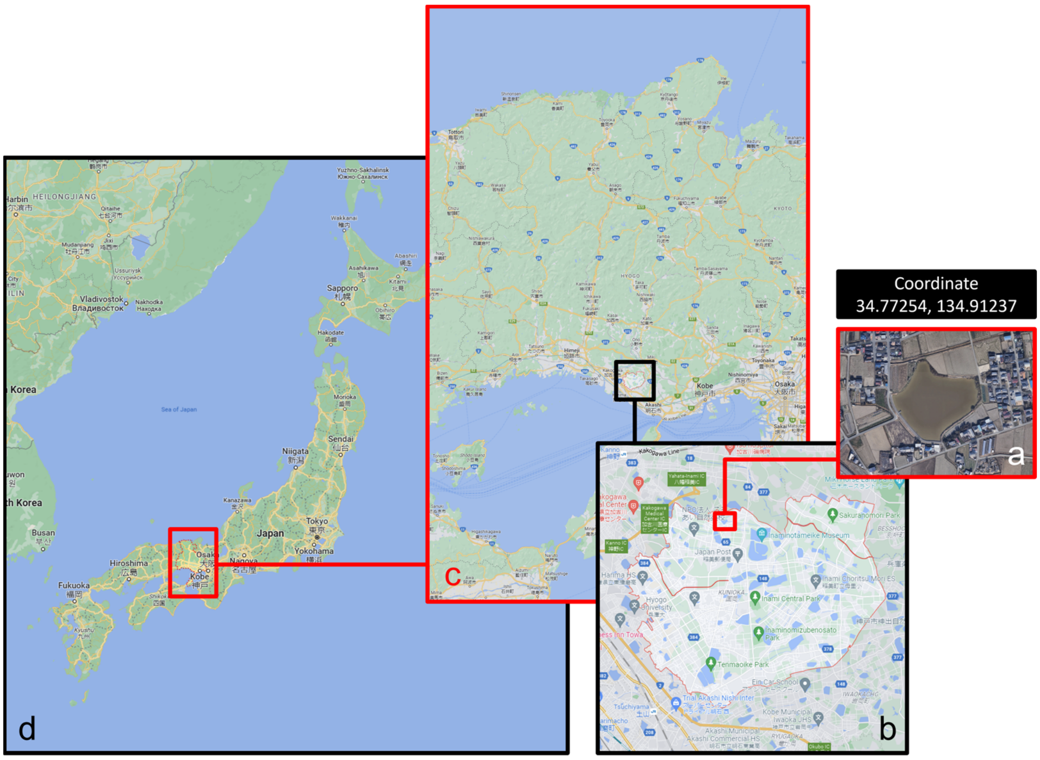

Figure 3. Location of the Ohzawashinike pond (**a**) in Inami Town (**b**), Hyogo (**c**), Japan (**d**).

The solar panels in the floatovoltaic system should cover the pond's surface by up to 9220 m^3 or approximately 38% of the pond's total surface (24,401 m^3). Technically, the floatovoltaic installation would be rated for 1148.00 kW of total capacity under ideal conditions (peak sun), generating an expected amount of electricity of 26,465,679 kWh for the next 20 years or about 1,323,284 kWh annually. Legally, the Ohzawashinike pond is owned by the Land Improvement District, an organization of local farmers founded under the Land Improvement Act no. 195/1949 [79]. In Kako, it manages and maintains irrigation-related facilities, including ponds and waterways [80]. Considering the rarity of settlements in the immediate proximity of the pond (Figure 3a), this study used purposive sampling [81,82] to choose potential interviewees. The sampling targeted three common parties in rural development [24,33,83,84], i.e., those with issue-specific expertise, community members, and the government. This study interviewed 16 people, each with decision-making influences in one of the common parties. The average interview length is about 1 hour per person. Eight of them were residents, with three of the residents held leadership positions in local communities. Another interviewee was an officer from the local government. Four other interviewees were members of the Land Improvement District of Kako (farmers), and the rest (three) were corporate officers of a construction company that won the tender for the Ohzawashinike floatovoltaic project. The background mix brought together potential actors with different perspectives and objectives on the project, forming multi-actor systems in the water–energy nexus. It would also give insights for other floating photovoltaic projects into scaling up or replicating the heuristics analysis.

4. Results

4.1. Macro and Microgroups of Stakeholders

In the water–energy nexus of the Ohzawashinike floatovoltaic project in Inami, Hyogo, Japan, there are two macrogroups of stakeholders, which include those who are involved or affected. The first macrogroup consists of residents living in areas surrounding the pond. As part of the local population, they have both physical and sociocultural relationships with the pond as an integral component of the natural landscape and the source of their irrigation water. From the perspective of the natural landscape, residents include those who reside within a certain radius of the project's boundary. The project boundary includes not only the physical boundary of the pond but also extended infrastructure built on the land to form the energy-generation site. Meanwhile, residents also include those living in nearby and farther locations but with specific interests in the pond as the source of their agricultural irrigation. Regardless of their physical proximity, those residents have an interest in maintaining the function of the pond to support the surrounding agricultural area, through which they can supply adequate agricultural products for other parts of the population. Apparently, this macrogroup of residents is derivable into at least two groups of microgroups. The first part includes those who oppose the floatovoltaic project (Figure 4, R_R). Basically, they oppose the project since they think that the floating PV installation and its on-land infrastructure would disrupt their natural landscape and the function of the pond to supply water for agricultural irrigation. Meanwhile, the second part of this macrogroup includes other residents in the water–energy nexus (Figure 4, R_N). To some extent, those in this microgroup can agree with opposition residents, while others may choose to be neutral between the opposition residents and the project. In that sense, this microgroup overlaps with the microgroup of opposition residents, making the microgroup of other residents a swing part of the local population.

On the other hand, the second macrogroup in the observed floating PV project consists of those involved as part of the project developers of the energy-generation project. Project developers are those with an interest in developing the project and ensuring successful implementation of the project. As developers, those included in the second macrogroup have knowledge of running the project from different techno-economic perspectives. The main motivation of those in this macrogroup is driven by economic interests, toward which all their efforts are directed. In the floatovoltaic project, economic interests refer to any profit-gaining in the project, whether it occurs during the development of the floating PV installation (for example, land leasing) or during the operational phase of the electricity generation from the installation (for example, electricity selling). Apparently, the macrogroup of project developers is also derivable into several microgroups. The first microgroup includes landowners (Figure 4, L). Since the pond and surrounding lands are privately owned, landowners include those owning parts of those lands and/or the pond itself. Although landowners are physically part of the local population, they are seen as structurally distant from the rest of the residents. Since their motivation, knowledge, and legitimacy are centered on the success of the project and driven by economic interests from the project, they are posited as part of the macrogroup of project developers. Meanwhile, the second microgroup consists of a construction contractor (Figure 4, C), who primarily acts as the constructor for the physical development of the entire floatovoltaics installation on the pond and the land. Then, the third microgroup includes the business operator (Figure 4, B), who, after commissioning the floatovoltaics installation, will run the operations of the electricity generation using the floating PV.

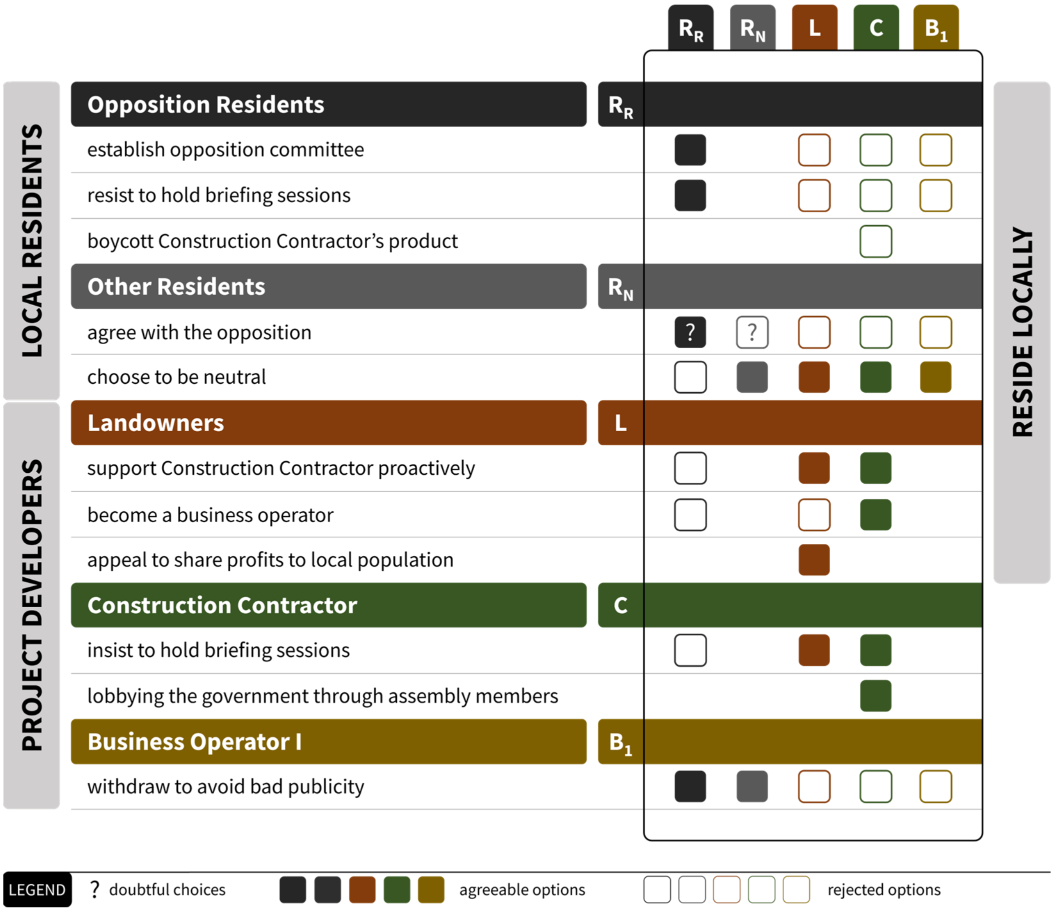

Figure 4. Actors, their options of actions, and their positioning over the options of other actors.

4.2. Their Stakes and Stakeholding Issues: Options of Actions

Looking at the explanations above, the specific actors involved/affected include opposition residents (R_R), other residents (R_N), landowners (L), the construction contractor (C), and the business operator (B). Their stakes are translatable into options for actions as their way of holding their own stakes (Figure 4, rows). In terms of the microgroup of other residents (R_N), they consider two options for actions that they might take within the water–energy nexus. The first choice is to agree with the opposition residents (R_R). As part of the local population with physical and sociocultural interests in the pond, which is part of their natural landscape and ecological systems, some members of the Other Residents (R_N) to some extent agree with the positioning of opposition residents. They thought that the floating PV project would disrupt the natural landscape. Some of them also think that the floatovoltaics installation might disrupt the supply of freshwater from the pond for their agricultural irrigation. However, some of the other residents consider the option to be neutral. They think that, despite their physical and sociocultural interests in the pond, the floating PV installation offers promising capability in the form of local electricity supply, which is expected to have a better selling price for residents living in certain proximity to the floatovoltaics installation. Still, they do not prefer to trigger any direct confrontation with opposition residents, who are also their neighbors. Some of them are even family relatives, and they probably live next to each other.

Furthermore, those in the microgroup of opposition residents (R_R) have three possible choices of actions. The first choice is their interest in establishing an opposition committee. Since they have a strong positioning to oppose the project, they intend to establish the committee as their concrete and formal action to direct their opposing standpoint against the project. The committee would be their medium to talk among the members of their own microgroup (opposition residents) and to talk to other microgroups with relevant connections to their opposing interests. In addition, the opposition residents also put up a strong positioning against holding briefing sessions with members of the project developer group. The strict choice of action seems to emerge from their thoughts that the briefing sessions are intentionally designed to convince them to shift their opposing standpoint into a more agreeable positioning. In that sense, they see that the briefing sessions avoid an active dialogue between their opposing interests and the interests of project developers. Then, the third option of action for the opposition residents is to boycott the product sold by the construction contractor (C). Since the construction contractor also sells their construction products to the general public, it appears that the opposition residents relate its product to its positioning as a proponent of the project. The counter-positioning leads to the choice of boycotting its products by the opposition residents as part of the negotiation technique considered by the opposition residents.

Next, the landowners group considers three options for action. Their first option is to support the construction contractor (C) proactively. Since landowners own the pond and/or parts of the land on which the floatovoltaics-based electricity generation will be installed, they work directly with the construction constructor to ensure that the floating PV project runs well. The pre-project economic interest of landowners in gaining profit from the land/pond lease eventually drives them to consider the option of supporting the construction contractor proactively. On the other hand, the landowners also have the option of becoming business operators of the floatovoltaics-based electricity generation. Since they legally own parts of the land and pond used by the energy-generation site, they have an extended interest in gaining profit by running the electricity-generation business after the construction has been completed. This remains optional since landowners need to negotiate with the entity currently holding the role of future operators of the energy-generation business. Then, landowners also consider the option of appealing to return the profit to the local population. This option relates to their physical presence in the local area, by which they intend to appeal to the energy-generation business to share the profits made from the floatovoltaics-based electricity generation with the local population. The forms of profit sharing remain unclear since these forms would be part of the negotiation process for the appeal. It also remains to be seen whether the landowners would become the business operator in the future, making the third option a viable action without less resistance from other members of the project developers.

For the construction contractor microgroup (C), their options of action primarily depend on their involvement in the project during the construction of the floating PV installation, including extended infrastructure on the land. In general, they can consider two options for actions. Since their primary task in the project is to build the physical site, they consider insisting on holding briefing sessions with the local population. Consequently, it does not go well with opposition residents, who resist holding the briefing sessions. Still, the construction contractor attempts to offer the briefing sessions to other parts of the local population that could be convinced. In the briefing sessions, they can offer benefits to the attendees to convince them to put forward their agreement with the project, by which they can build stronger support to accomplish the physical construction. On the other hand, the construction contractor can lobby assembly members to gain support from the government. Technically, the floatovoltaic project applies a business-to-business (B2B) scheme, in which, from the perspective of the construction contractor, the triggering interests for all actors involved are purely economic. This puts the government as an exogenous actor in the water–energy nexus, to which they remain passive and focus on their regulatory roles. Due to the strong opposing force from the opposition residents, who establish a formal opposition committee to strengthen their political bargain, the construction contractor considers lobbying the assembly members to, as part of regional governance, intervene in the conflicted situation, which, from the perspective of the construction contractor, is counterproductive to their construction process.

Then, the last microgroup (business operator, B) considers only one option of action. Since their active period in the water–energy nexus begins after the physical construction of the floating PV installation, they currently stay passive within the multi-actor systems. Their only concern centers on the preservation of their public image as a business-oriented entity, which means they cannot afford bad publicity. Due to the strong conflict between opposition residents and those in the project developer group, the business that currently holds the role of the future business operator considers withdrawing from the project to avoid any bad publicity. It is a shortcut for them, with the risk of losing profit from the project. If the conflict is prolonged, withdrawal may be an option with much lower risks for them. It could also allow landowners to take on an additional role as business operators. It remains to be seen whether the conflict is resolvable within an affordable time frame for the current business operator and how they calculate the risk and benefit of staying in or withdrawing from the project.

4.3. Positioning of Actors over the Options of Other Actors

The stakeholders in the multi-actor systems, along with their stakes and options of actions, interact with each other systematically and systemically. The interactions are apparent through their thinking about the options available for other actors, in which each group of stakeholders organically conducts compare-and-contrast processes between their own stakes and stakeholding to those of others (Figure 4, columns). For those in the microgroup of other residents (R_N), their swing positioning makes them place their agreement or rejection on a few options of others in the multi-actor systems. In principle, they do agree with two options while rejecting, albeit with some doubt, one option (Figure 4, R_N column). The two options that the other residents put forward for their agreement include the option for themselves to be neutral and the option for the business operator (B) to withdraw from the project. The agreement with the neutral option, in conjunction with the rejecting-leaning thinking over the agreement with the opposition residents, implies that the other residents put some distance between themselves and the opposition residents. They choose to wait and see over stakeholder dynamics within the water–energy nexus. On the one hand, some are hesitant to state a clear agreement with the opposition residents due to the strict positioning against the project and the project developers. On the other hand, the other residents are considering the benefits and losses that may arise from agreeing to support the floating PV construction. In other words, the microgroup is currently in full swing within the multi-actor systems.

For opposition residents (R_R), they agree with four options and reject four other options available in the multi-actor systems. The first two options with which they confirm their agreement are the establishment of an opposition committee and refusing to hold briefing sessions. These options, which are available for themselves, are strongly supported since they depict their core concern of opposing the floating PV project. The opposition committee is their formal way to direct their demands to the relevant actors, while their resistance to holding briefing sessions is their way of avoiding a single-sided conversation in the briefings. Consequently, they reject the insistence of the construction contractor to hold briefing sessions. To some extent, the resistance has a reciprocal influence on their option to establish an opposition committee, through which they act as a balancing force against the briefing sessions. Meanwhile, opposition residents do like the option of other residents standing together against the floatovoltaic project. However, some opposition residents are in doubt about whether the other residents will stay with them or eventually shift their choices due to the benefits offered by project developers. The fourth option agreed upon by the opposition residents is the withdrawal of the current business operator from the project. The opposition residents think that it will make their opposition effort easier if the future business operator withdraws, making the future of the electricity-generation business a bit unclear regarding whether it is going to be run professionally or not. On the other hand, the opposition residents reject the option of other residents being neutral in the nexus. They demand others put a clear standpoint in the nexus, by which the opposition residents can immediately see who supports or counters their opposition efforts. Opposition residents also reject the options for landowners to support the construction contractor and to become business operators. It is clear that these options stand in the way of opposing the project.

Regarding the landowners (L), they agree with four options and reject four other options available in the multi-actor systems. Basically, they agree with their own options to support the construction contractor proactively and to appeal to share profits from the electricity-generation business with the local population. However, interestingly, they do not prefer to take over the floatovoltaics-based energy generation business for themselves. They see that their knowledge and legitimacy are inadequate to run the business professionally. On the other hand, since economic motives drive the structural positioning of landowners within multi-actor systems, they reject the option for other residents (R_N) to be in agreement with opposition residents (R_R). They prefer other residents to remain neutral and stay aside from the current multi-actor conflict. In addition, landowners completely reject the options for opposition residents to establish an opposition committee. Apparently, the landowners support the option for the construction contractor to insist on holding briefing sessions for residents. It may relate to their positioning to support the construction contractor proactively. Consequently, landowners reject the option for opposition residents to resist the briefing sessions. In relation to the business operator (B), the landowners prefer that the current corporate entity that holds the role of future operator of the electricity-generation business remains in the multi-actor system. This directly relates to the non-preferable choice for landowners to take the operator role, considering their inadequate knowledge and legitimacy.

For the construction contractor (C), they agree with five options and reject five other options available in the multi-actor systems. This microgroup of stakeholders shows the strongest standpoint among others in the multi-actor systems, considering their decisive thinking over almost all options of actions available in the systems. Regarding their own options, the construction contractor remains insistent on holding briefing sessions, consequently rejecting the opposite option for opposition residents (R_R) to resist holding the briefings. Meanwhile, the construction contractor remains confident in resolving the deadlock occurring at the water–energy nexus by lobbying the assembly members. They attempt to align the interests of the government with their own, pushing opposition residents into a trickier position against the government as the regulatory, albeit exogenous, actor. Furthermore, the construction contractor accepts the proactive support from landowners (L) while also supporting the option if landowners eventually want to take over the role of business operator. Having a close relationship with an eventual business operator is good for their construction process, as it ensures that everything is well fitted to the needs of the user of the floating PV installation (i.e., the business operator). In parallel, the construction contractor rejects the possible withdrawal of the corporate entity that currently holds the role of future operator of the energy-generation business. For them, it is better to have everyone currently on their side stay in the multi-actor systems, maintaining the support of these fellow project developers while lobbying the government to intervene and attempting to convince the swing group of actors (other residents, R_N) to be decisive in their full support for the project. If it is difficult to convince the other residents (R_N) to support the project, the construction contractor prefers the swing group to remain neutral rather than supporting the opposition residents (R_R). Then, the construction contractor rejects all options for opposition residents since these options completely attempt to nullify their work in the physical construction of the floating PV installation.

The last microgroup (business operator, B) decisively agrees with one option and rejects the four other options available in the multi-actor systems. The only option with which the corporate entity agrees is the option for other residents (R_N) to be neutral between the proponents of the project (L, C, and B) and the opposite force (R_R). The business operator sees that it is the safest choice to avoid bad publicity from the other residents while also preventing worsening publicity in front of the opposition residents. Still, the business operator remains determined to reject the options for opposition residents to establish an opposition committee and to resist the briefing sessions held by the construction contractor.

The business operator also rejects the option for other residents to support the opposition force since it is against their economic motives to be involved in the project in the first place. Due to their strong economic interests, the current corporation that is designated to run the energy-generation business rejects the option of withdrawing from the project. They are still convinced that their current involvement in the project, albeit risky currently, will pay off in the future when they run the business and generate profits.

5. Discussion

In the study of the water–energy nexus, it is imperative to understand the multi-actor systems involved or affected [34,38], which should go beyond water- or energy-related technical issues. Taking the case of a floatovoltaic project in Inami, Hyogo, Japan, this study identified the critical actors involved/affected. There were striking evidence on the presence of two macrogroups of stakeholders in the project: residents living in the area and project developers. The residents, in turn, can be further divided into two microgroups: those who oppose the project (R_R) and those who are leaning to support the opposition or choose to stand neutral in the multi-actor systems (R_N). The multiple positioning of residents confirms the findings of similar studies in democratic regions [85–89]. Opposition residents argue that the floatovoltaic project will disrupt the natural landscape and the primary function of the pond, which is used to supply water for agricultural irrigation. The concerns raised by the residents are primarily rooted in their attachment to the local environment and their concern for the sustainability of agricultural activities in the area. On the other hand, project developers can be divided into three microgroups: landowners (L), the construction contractor (C), and business operators (B). The primary motivation of these groups is economic, such as land leasing and electricity selling. This corroborates the findings of other studies on infrastructure projects in rural areas [90–93].

Furthermore, this study found that each actor holds specific stakes in the water–energy nexus. Opposition residents hold the stake of protecting the natural landscape and the function of the pond as a source for agricultural irrigation. This goes in line with typical civil movement against seemingly exploitative corporate actions over natural resources [94,95]. For other residents, they hold the stake of balancing their attachment to the local environment with their economic interests. This confirms that common residents do not want to get too far involved in multi-actor conflicts [96–99]. Conversely, landowners hold the stake of maximizing their profits from the project, while the construction contractor holds the stake of ensuring the success of the project and their profits. Their options similarly conclude on typical behavior of the private sector that is aided by an influential subset of the local population [100–102]. Then, the business operator holds the stake of avoiding bad publicity, a behavior consistent with the findings of previous studies [103–105]. Looking at these results, the options for action available to each stakeholder are informed by their specific stakes and goals, supporting past research [106–108]. This provides insight into the complex interplay between stakeholders' stakes and stakeholding. These findings highlight the complexity of the water–energy nexus and the diverse interests and values held by the actors involved, providing a basis for their preferable actions.

As the follow-up, this study revealed further interactions between the stakeholders, in which each microgroup views the available options of actions for other microgroups. In general, opposition residents agree with options that support their attempt to stop the project and reject options that stand in their way of interrupting the project. This provides support for research on civil activism against large infrastructure projects that would disrupt the natural way of living [33,109,110]. Other residents seem to choose the safest bet by taking a wait-and-see stance against the ongoing multi-actor dynamics, confirming the risk-aversion behavior of indirect actors in societal affairs [111–113]. Landowners, construction contractors, and business operators, confirming typical economic-driven corporate behavior [114–116], largely maintain their position to keep the project going, agreeing with options that support the project and rejecting those that could jeopardize the project during both the construction and operation phases. The group of other residents, as seen in other multi-actor conflicts [117–119], remains a swing force that both sides of the conflict in the project are willing to devote efforts to influence. These results, in agreement with previous studies [49,120–122], highlight the dynamic and complex nature of the interactions between actors within the water–energy nexus and the importance of considering the interplay between different stakeholders and their motivations in the development of integrated and sustainable management strategies.

The heuristics-based identification of critical stakeholders in the water–energy nexus is a crucial step in understanding the complexity of multi-actor systems. The implications of the heuristics analysis presented in this study are far-reaching and can inform a range of decisions and policy developments in the future. In line with the findings of other research [123–125], identifying critical stakeholders can help observers better understand the relationships between stakeholders, their motivations, and the factors that shape their decisions. This can provide valuable insights into how to effectively engage with stakeholders and how to promote effective communication and collaboration between different groups. Furthermore, by understanding the critical stakeholders, one can better design projects and interventions that are appropriate for the needs of specific stakeholders and that take into account their motivations, capacities, and limitations. This reinforces the notion of inclusivity in development [123,126,127]. This can help to ensure that interventions are more likely to be effective and that they address the underlying causes of conflicts and problems. Then, identifying critical stakeholders can help observers understand the institutional and governance frameworks that support or constrain stakeholder engagement and collaboration in the water–energy nexus. This, consistent with past studies [128–130], can inform efforts to improve the governance of multi-actor systems and promote more equitable and sustainable outcomes.

6. Conclusions

Water and energy are two of the most essential resources for human societies and the economy, being critical for activities, such as drinking, agriculture, and industrial processes, as well as transportation, heating and cooling, and powering machinery. There is a close relationship between the two, where energy production and distribution are contingent upon water availability and water management necessitates energy inputs. This relationship is referred to as the water–energy nexus. As the demand for water and energy increases, competition for these resources also intensifies, leading to the necessity for more sustainable and integrated management practices. However, previous research on the water–energy nexus has largely focused on technical matters and overlooked the role of human actors and their varied interests. This study, to obtain a more comprehensive understanding of the water–energy nexus, sought to bridge the gap by heuristically examining the stakeholders involved, their interests, and how they interact with one another. This would establish the basis for more significant nexus interventions since multi-actor interactions and the interplay of their interests have been scientifically examined. This study took the case of a floating PV project in Inami, Hyogo, Japan, to give an example of how the heuristic analysis could discover critical actors in the water–energy nexus to pave the way for subsequent investigations in the future. Overall, deadlocked interactions emerged due to a multidirectional tug-of-war between the conflicting interests of multiple actors.

In the project, there are two macrogroups of stakeholders: residents living in the area and project developers. Residents can be divided into two microgroups: those who oppose the project and those who are neutral or in favor of it. Meanwhile, project developers can be divided into three microgroups: landowners, construction contractors, and business operators. Opposition residents argue that the project will disrupt the natural landscape and the function of the pond to supply water for agricultural irrigation. However, project developers are motivated by economic interests, such as land leasing and electricity selling. Answering the second research question, there are options for action for actors within the water–energy nexus. Opposition residents consider establishing an opposition committee, boycotting the product sold by the construction contractor, and avoiding briefing sessions with members of the project-developer group. In the meantime, landowners consider supporting the construction contractor proactively, becoming business operators of the floatovoltaics-based electricity generation, and appealing to return the profit to the local population. Furthermore, the construction contractor considers insisting on holding briefing sessions with the local population and lobbying assembly members to gain support from the government. In addition, other residents consider being neutral and not triggering any direct confrontation with opposition residents. Then, the business operator considers withdrawing from the project to avoid any bad publicity. Answering the third research question, each group of stakeholders has different options of actions with which they agree or disagree. Basically, the stakeholders have different motives that influence their decisions. Interestingly, the opposition residents are in doubt about whether the other residents will stay with them or eventually shift their choices due to the benefits offered by project developers. Then, the landowners prefer other residents to remain neutral and stay aside from the current multi-actor conflict.

Based on the findings, several recommendations can be made to enhance the sustainability and fairness of the water–energy nexus. First, policymakers should engage with a diverse range of stakeholders in the water–energy nexus, including residents and private sector entities. This engagement should aim to create a more inclusive and transparent decision-making process, allowing for the equitable distribution of benefits and the mitigation of potential adverse impacts. Second, it is crucial to prioritize the interests of residents and marginalized communities in water–energy projects. This can be achieved through targeted interventions, such as capacity building, education, and community engagement, which will empower these communities to actively participate in the management of water and energy resources. Third, it is recommended that the legitimacy of each stakeholder in the water–energy nexus be assessed, taking into account their motivations, capabilities, and the impact of their actions on other stakeholders. This will ensure that the interests of all stakeholders are considered in decision-making processes, leading to more sustainable and equitable outcomes. Finally, it is crucial to adopt a multi-disciplinary approach in addressing the water–energy nexus, considering the interdependent nature of water and energy systems. This requires collaboration between experts from various fields, including but not limited to water management, energy planning, and the social sciences, to develop integrated and sustainable solutions for the water–energy nexus.

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