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Identifying and Prioritizing Barriers to Climate Technology International Cooperation from the Perspective of Korea

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Abstract: Climate technology development and transfer have gained significant attention as a means to combat climate change and promote sustainable development. However, there is a lack of studies that systematically identify, categorize, and prioritize the barriers to technology transfer, especially within international cooperation projects. This paper addresses this literature gap by conducting an in-depth analysis of closure reports from Climate Technology Centre and Network (CTCN) technical assistance projects and incorporating the perspectives of Korea which has the largest number of CTCN members. The 204 barriers identified from the 77 reports were grouped into 10 categories, and the *information and awareness* category had the largest number of barriers, followed by the *institutional and organizational capacity* and the *technical* categories. When prioritizing the 32 survey responses, the top three difficulties were *economic and financial*, *legal and regulatory*; category-level difficulties included 'technical barriers,' and sub-category-level difficulties included 'COVID-19 restrictions', 'challenges in gathering good data', and 'limited budget.' These findings will enhance the understanding of policymakers and practitioners on the significance of resource allocation, capacity-building efforts, and risk management strategies to improve the effectiveness of climate technology international cooperation projects.

Keywords: barriers; climate technology; technology development and transfer; climate technology international cooperation

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1. Introduction

The concentration of carbon dioxide in the atmosphere is reported to have reached 421 parts per million (ppm) in May 2022 at Mauna Loa Atmospheric Baseline Observatory [1]. Compared to 280 ppm during the pre-industrial society, the record has increased by almost 50%, accelerating global warming [2]. The rise of 2 °C above pre-industrial levels is known as a tipping point to bring irreversible impacts on humans and ecosystems. Accordingly, the international community has set a goal to limit the temperature increase below 1.5 °C [3]. However, the Intergovernmental Panel on Climate Change (IPCC) [4] has reported that "there is at least a greater than 50% likelihood that global warming will reach or exceed 1.5 °C in the near-term, even for the very low greenhouse gas emissions scenario," which calls for taking urgent and collective action against the climate crisis.

While the globe struggles with the negative aftermath of climate change, developing countries are disproportionately affected by it, and they lack the necessary capacity and infrastructure to respond to detrimental consequences [5–7]. Yet, they are not free from international efforts to combat climate change. Article 3 of the United Nations Framework Convention on Climate Change (UNFCCC) codified the principle of 'common but differentiated responsibilities (CBDR).' CBDR not only recognizes that all countries have responsibilities towards the global environmental problem but also that states have different levels of contributions to it. As a response to CBDR, developed countries have tried to take a greater share of responsibility by providing climate finance or technical know-how to developing countries; however, it has been challenging to meet the actual needs and specific circumstances. Especially, this paper will focus on climate technology development and transfer and the factors that hinder it.

UNFCCC's Technology Mechanism was established as a channel to facilitate technology development and transfer to developing countries. Climate technology is known as "any equipment, technique, practical knowledge or skill needed to reduce greenhouse gas emissions or adapt to climate change [8]," and it has been highlighted as a solution to respond to climate crisis and promote sustainable development [9–11]). Climate technology development and transfer is crucial for developing countries since their lack of climate-related technologies and skills has prevented efficient recovery from the negative effects of climate change.

The Climate Technology Centre and Network (CTCN) is an implementation arm of the Technology Mechanism that works on "providing technical assistance at the request of developing countries to accelerate the transfer of climate technologies; creating access to information and knowledge on climate technologies; and fostering collaboration among climate technology stakeholders via the Centre's network of regional and sectoral experts from academia, the private sector, and public and research institutions [12]." The rise in the cumulative technical assistance (TA) requests from developing countries to the CTCN Secretariat—from 4 in the first quarter of 2014 to 385 in the fourth quarter of 2022 [13]—demonstrates the increasing demand for climate technology international cooperation.

Additionally, National Designated Entities (NDEs) serve as national focal points for the Technology Mechanism [14], and in the case of Republic of Korea (hereafter, Korea), the Ministry of Science and ICT (MSIT) is the NDE playing an important role in communicating with and contributing to the CTCN. Korea has the largest number of CTCN members, is one of the active countries to implement pro bono technical assistance (TA) projects through the CTCN, and hosted the world's first CTCN Partnership and Liaison Office in Incheon [15–18]. In addition, the Korean government offers different kinds of programs or funds to foster climate technology development and transfer [19,20].

Despite the growing number of climate technology projects being implemented, practitioners often face challenges in developing exemplary cases and scaling up interventions. Moreover, there are not many studies that policymakers and implementers can refer to when carrying out climate-related interventions in developing countries. Especially, there is a gap in research that specifically focuses on the barriers within climate technology international cooperation projects and systematically identifies, categorizes, and prioritizes these barriers. Moreover, there are few studies on the barriers incorporating Korea's viewpoint despite its significant role in technology transfer under the CTCN.

This paper aims to address this literature gap by investigating the barriers to climate technology development and transfer through an in-depth literature review and an expert survey. In particular, CTCN TA projects are examined as representative of climate technology international cooperation, and the results of a survey targeting Korean experts who make up a significant proportion of CTCN members are examined. Research questions are as follows: First, what barriers hinder the successful implementation of climate technology cooperation projects in developing countries? Second, which barriers do Korean practitioners perceive as the most challenging in pursing effective climate technology cooperation?

By answering these questions, the paper will expand the scope of literature on examining barriers to climate technology development and transfer. This paper is the first in examining the challenges from all the available CTCN TA closure reports and incorporating the perspectives of Korean experts who have engaged in international cooperation on climate technology. To ensure accuracy and relevance, most recent data were collected and a carefully designed expert survey was conducted. Practically, the findings will provide valuable insights for policymakers in formulating and refining policy options to promote international cooperation in climate technology. Additionally, practitioners will benefit by gaining an understanding of potential obstacles and alternative approaches when planning and executing climate technology projects.

The remainder of this paper is structured as follows. In Section 2, the literature on barriers to climate technology international cooperation is reviewed. The research design of the study is described in Section 3. In Section 4, the identified barriers from project documents and the ranking of the barriers based on expert surveys are delineated. Section 5 includes a conclusion, policy recommendation, and research limitations.

2. Literature Review on Barriers to Climate Technology International Cooperation

Existing studies have investigated various factors that have challenged effective climate technology international cooperation. Barriers identified in the process of technology development and transfer are not only related to technical issues but also interrelated with a broad range of topics including institutions for the selected technology, stakeholders' awareness and acceptability, and market conditions [21].

Wilkins [22], focusing on renewable energy technology, defined barriers as "any technical, economic, institutional, legal, political, social or environmental factor impeding the deployment of renewable energy technologies," and described them as interrelated. The author outlined the types of main barriers as five groups, i.e., political, institutional, and legislative; local capacity, infrastructure, and knowledge; economic/financial; social/environmental; and technical, and explained each category with sub-types and case studies. Nygaard and Hansen [23] revealed that barriers were the "reason why a target is adversely affected, including any failed or missing countermeasures that could or should have prevented the undesired effect (s)." They also analyzed general methods for identifying and analyzing barriers (i.e., organizing the process, identification of barriers, screening barriers, and decomposition), examined barriers for market or non-market goods, and illustrated how to overcome barriers.

Understanding barriers to climate technology international cooperation is essential in designing and applying more efficient and effective measures ([24,25]). By recognizing the importance of studying barriers, the CTCN considers how to overcome barriers and foster an enabling environment for climate technology development and transfer [12]. It is necessary to address barriers to improve the quality and quantity of climate technology development and transfer.

Usually, barriers to technology transfer have been examined within a certain technology (e.g., biogas energy [26], offshore wind energy [27], solar energy [28], or renewable energy [29]) or a certain area (e.g., India [30], Pakistan [31], Zambia [32], or Asia [33]). Painuly's work [29] is one of the early studies examining barriers to climate technology development and transfer, and it focused on the renewable energy sector. The author listed 41 major barriers and classified them into seven types: market failure/imperfection; market distortions; economic and financial; institutional; technical; social, cultural, and behavioral; and other barriers. Suzuki [34] investigated barriers related to clean energy technology innovation and diffusion, and summarized the identified challenges under three categories: technological, financial, or institutional barriers. Some of the recent studies are summarized in Table 1.

Pathak et al. [35] identified and prioritized barriers to the development of renewable energy technologies in India by surveying the literature, interviewing experts, and conducting modified Delphi and AHP. The authors selected twenty barriers and categorized them into five: social and economic barriers; policy and political barriers; technical barriers; administrative and market barriers; and geographical and environmental barriers. Policy and political barriers, including lack of transparent decision processes, lack of renewable energy policy, corruption and nepotism, and political instability, were found as the most significant hindrance. Oryani et al. [25] focused on obstacles to adopting renewable energy, particularly solar photovoltaic, wind turbines, and biomass in Iran. From the literature review and experts' opinions, thirteen barriers were classified into five groups. The greatest deterrent effect on renewable energy development based on AHP results was economic and financial barriers, consisting of high initial investment and high costs of renewable technologies, lack of access to credit and long payback period, and the absence of private and state sectors' investors. Ghimire and Kim [36] also examined barriers to renewable energy. In the context of Nepal, twenty-two barriers were listed from previous studies and interactions with stakeholders, were grouped into six, and were ranked using AHP. Among the six, the two most important categories were economic barriers (i.e., high capital cost, lack of credit access, lack of sufficient market size, lack of end use, and lack of subsidies/funds), and policy and political barriers (i.e., lack of transparency in the decision process, political instability, absence of coherent renewable energy policy, and corruption and nepotism).

When it comes to Korea, there are a few studies examining barriers to technology transfer. Kim et al. [37] operationalized barriers as the difficulties that prevent small and medium enterprises (SMEs) from successfully entering overseas markets, and conducted a survey targeting Korean green and climate technology SMEs to investigate satisfaction level and obstacles to overseas business development. In the overseas expansion obstacle analysis model that they developed, professional staffing, human resource development, production funds, labor costs, market information, market development, technology and product development, and standard certification were included as obstacles. In the paper by Jo and Eom [38], facilitating and challenging factors in technology transfer of the Clean Development Mechanism (CDM) were analyzed, and for deterrence factors, five main categories were listed: low commercial viability, lack of information, lack of access to capital, weak institutional framework, and low technology capability.

This study generally adopted methodologies, such as reviewing literature or project reports, and barrier categories, including technical or economic, used by many previous researchers. In addition, this research took a novel approach in specifically investigating barriers or challenges from completed CTCN TA projects and prioritizing the identified barriers from the perspective of Korean experts. The present paper targeted climate technology institutions in Korea as in Kim et al. [37]'s paper; however, this study tried to analyze climate technology international cooperation focused on concessional or grant projects implemented in developing countries. Additionally, this paper analyzed climate technology interventions under the Technology Mechanism, especially CTCN TA projects, which have not been addressed as far as we understand in the literature on barriers to climate technology international cooperation conducted from Korean perspective. Further explanation is provided in the next chapter.

Table 1. Barriers or challenges to climate technology development and transfer in previous studies.

Source	Region or Country	Sector	Method	Barriers or Challenges		
				No. of Identified Barriers	**No. of Categories**	**Categories**
[25]	Iran	Renewable energy	Literature review, AHP	13	5	Economic and financial; social, cultural, and behavioral; political and regulatory; technical; institutional
[26]	32 countries	Biogas	Literature review	33	6	Technical; economic; market; institutional; socio-cultural; environmental
[27]	India	Offshore wind energy	Fuzzy AHP	46	7	Technical; financial; regulatory and political; social; supply chain; institutional; geographical
[39]	Africa	Low-carbon development	Interview data analysis, secondary data analysis	551	6	Limited institutional capacity; lack of finance; technology limitations; lack of awareness; weak physical infrastructure; unfavorable politics
[36]	Nepal	Renewable energy	Literature, site visits, interactions with stakeholders, analytical hierarchical process (AHP)	22	6	Social; policy and political; technical; economic; administrative; geographic
[40]	Pakistan	Renewable energy	Literature, modified Delphi, fuzzy AHP	21	5	Political and regulatory; market competitiveness; institutional; technical; social
[41]	Denmark	Transport	Literature review, fuzzy Delphi, AHP	30	5	Horizontal transport collaboration organization; information quality; behaviors and attitudes; collaborative decision support systems; market and business
[42]	India	Wastewater treatment and reuse	Literature review, case studies, Delphi	22	8	Governance; other; regulations and legislation, policies and government support; institutional arrangements; financing/cost recovery; technology options; resource context
[35]	India	Renewable energy	Literature review, modified Delphi, AHP	20	5	Social and economic; policy and political; technical; administrative and market; geographical and environmental

3. Research Design

This study has three main phases as demonstrated in Figure 1. First, this paper examined project documents to identify barriers to climate technology international cooperation. Then, the listed impediments were categorized into groups. Third, a survey questionnaire was developed based on the barriers identified and categorized in the previous steps, and it was distributed to Korean institutions that have expertise in cooperative climate technology development and transfer. The main research methodologies were an in-depth literature review and an expert survey, which are delineated below.

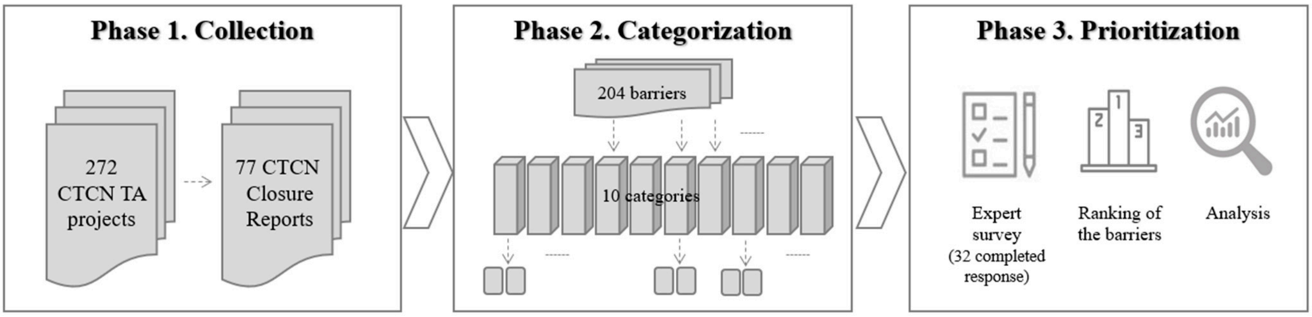

Figure 1. Schematic diagram of research flow.

3.1. Collection of Data

In order to compile a comprehensive list of barriers to international cooperation in climate technology, this paper extracted barriers or challenges from the CTCN TA Closure Reports publicly accessible on the CTCN website. Among the 272 CTCN TA projects listed on the CTCN website (as of 5 July 2022), 142 projects were reported as completed. Closure Reports were available for 77 out of the 142 cases (54.23%). All the barriers mentioned in these 77 reports were collected, and if barriers were not specified in a report, needs or challenges were gathered instead. As a result, a total of 204 barriers were identified in the data collection phase.

3.2. Categorization

The 204 barriers identified from the analysis of 77 CTCN TA Closure Reports were classified according to the ten categories initially developed by Nygaard and Hansen [23]. This categorization framework has been used in previous studies to examine barriers to climate technology development and transfer within the Technology Mechanism, such as [10,43,44]. Each category is explained in Table 2, and outcomes of the categorization process are described in the next chapter.

3.3. Prioritization

The survey for prioritization was designed to figure out the barriers faced by Korean institutions, which take the largest portion among the total number of CTCN members. It was conducted online for 20 days (from 7 September 2022 to 26 September 2022) and distributed to 205 people from 158 climate technology-related institutions in Korea that have implemented or planned to carry out climate technology international cooperation projects in developing countries. Reaching the right target respondents was important for this survey; thus, the institutions registered as CTCN members and on the CTis (Climate Technology Information System) platform were intentionally selected as a survey target audience. A response from the person in charge of climate technology international cooperation in an organization was allowed; thus, each response represents each organization. Fifty people accessed the survey; however, after sorting out incomplete answers, the number of complete responses was narrowed down to 32. The response rate was approximately 20.25% (32 out of 158 institutions).

Table 2. Ten categories of barriers to climate technology development and transfer.

Category	Explanation
Economic and financial	High cost of capital, investment in technology considered risky (e.g., due to few prior local reference examples), low expected rate on return
Market conditions	Few local suppliers of auxiliary goods and services, uneven playing field (e.g., due to subsidies on competing technologies), market control by industry incumbents
Legal and regulatory	Technology opposing incumbent actors (such as utilities), insufficient legal framework, highly controlled sector, conflicts of interest, political instability, bureaucracy, rent-seeking behavior
Network	Weak connectivity between actors, incumbent networks being favored, limited distribution networks
Institutional and organizational capacity	Few professional institutions, limited institutional capacity, limited management and organizational skills
Human skills	Unskilled technical personnel and inadequate training
Social, cultural, and behavioral	Consumer preferences and social biases, traditions, dispersed settlements
Information and awareness	Inadequate information, missing feedback, lack of awareness
Technical	Poor technology quality/performance, few local reference examples
Other	Environmental impacts, physical infrastructure conditions

Source: Nygaard and Hansen [23].

The survey consisted of 45 questions in three sections: general information on respondents, barriers faced in the process of implementing projects using climate technology, and needs for government support programs to facilitate climate technology international cooperation. Questions in the general information section included the information of the person in charge, such as the number of years of experience in international cooperation tasks, and the information of the institute, such as the type and expertise of the institution, which are analyzed in Section 4.3.1. General information on survey respondents. The second section asked whether and how the institution implemented climate technology international cooperation projects and to what extent the 20 sub-barriers and the ten categories of barriers prevent the successful delivery of climate-related interventions, which are a main topic in Section 4.3.2. Prioritization of barriers from the survey results. Questionnaires were reviewed by five experts in relevant fields, and both multiple choices and short-answer questions were included to better understand respondents' concerns and experiences. Informed consent for research was obtained from all respondents.

4. Findings and Discussions

4.1. Identified Barriers from Literature

Each of all the available CTCN TA Closure Reports were reviewed, and barriers or challenges specified in the reports were collected with basic information on projects. As of 5 July 2022, a total of 77 project reports were accessible and examined to identify barriers to climate technology development and transfer. The studied projects were implemented between June 2015 and April 2021. A total of 29 out of the 77 projects focused on adaptation, 32 targeted mitigation, and 16 were carried out for adaptation and mitigation objectives. By regions, 28 were implemented in Africa, followed by 20 in Asia, 15 in North America, 7 in South America, 3 in Oceania, 2 in Europe, and 2 in Eurasia. Concerning sectors, the number of cross-sectoral projects was the highest with 13, the second was energy efficiency with 10, and the third was agriculture and forestry with 9. In terms of the type of assistance, decision–making tools and/or information provision projects were 24, followed by technology identification and prioritization with 13, and feasibility of technology options with 11. For each project, one to seven barriers were identified, resulting in a total of 204 barriers.

Figure 2 shows the comparison between the number of projects and that of identified barriers in terms of project objectives and sectors. In general, the number of projects and the number of barriers have a similar trend, but some sectors such as water demonstrate a relatively higher number of identified barriers compared to the overall trend.

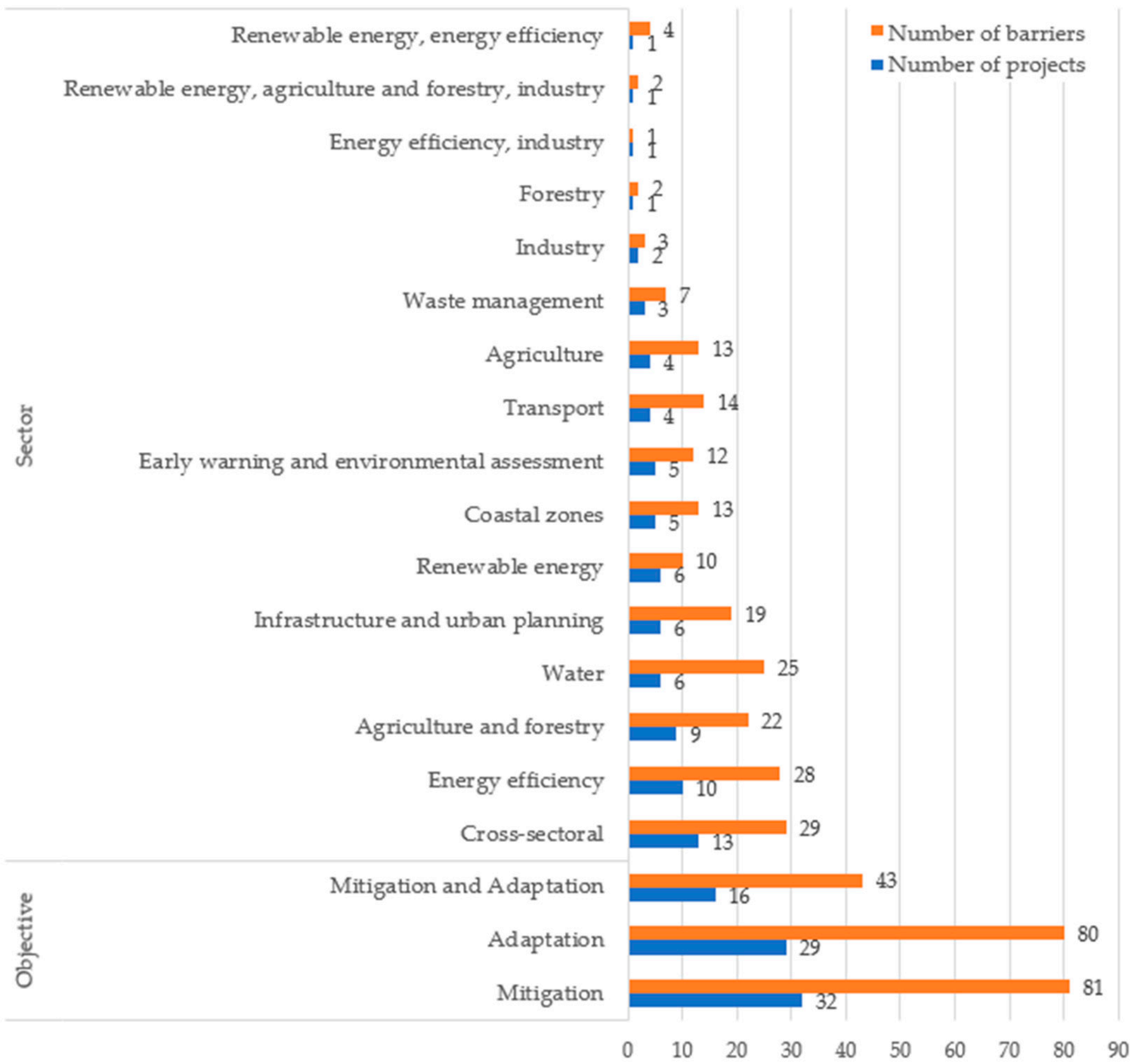

Figure 2. The number of reviewed CTCN technical assistance projects and identified barriers.

4.2. Categorized Barriers in Ten Groups

The identified 204 barriers were classified based on the ten categories of Nygaard and Hansen [23] described in Table 2, and the result of the categorization phase is demonstrated in Figure 3. The category of *information and awareness* was found as the most frequently mentioned barrier with 36 (17.65%), followed by the *institutional and organizational capacity* with 31 (15.20%), and the *technical* with 29 (14.22%). These three categories account for approximately 47.06% of the total identified barriers. The least was the *social, cultural, and behavioral* with seven sub-barriers (3.43%).

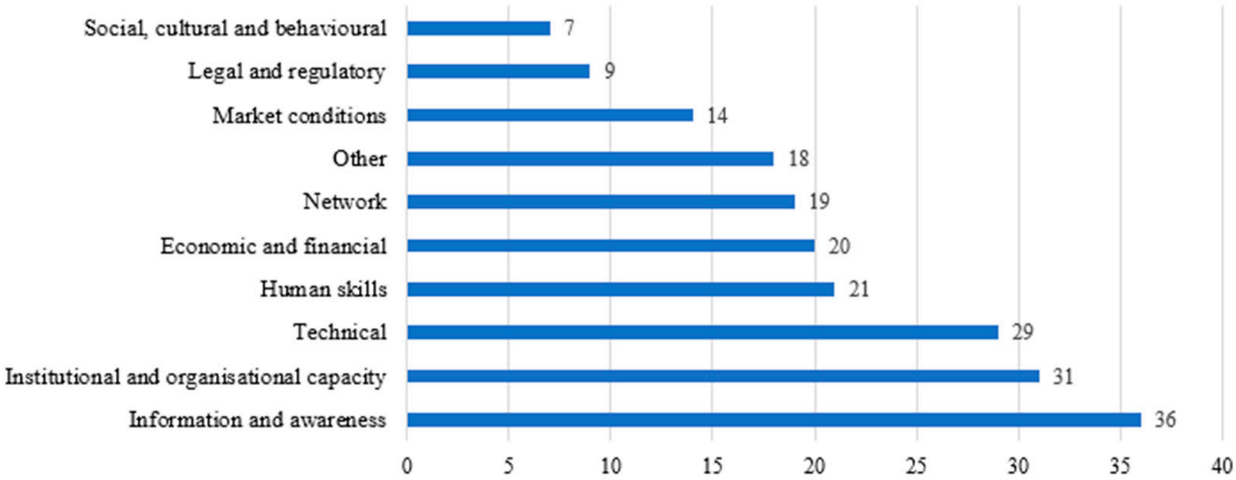

Figure 3. The number of barriers in climate technology development and transfer by ten categories.

The category of *information and awareness* includes stakeholders' lack of awareness on issues related to a project, difficulties in accessing or gathering relevant data, and lack of information on technologies or markets. Lack of understanding of the scope of work was one of the frequently mentioned obstacles in this category. For example, project proponents expected a full feasibility study, whereas implementers planned to undertake only a pre-feasibility study. Limited availability and accessibility of information or data was the second important challenge in delivering successful projects. For instance, additional resources were required to collect necessary data, and accurate assessment was difficult due to a lack of time-series data or precise data.

In the *institutional and organizational capacity category*, lack of coordination among ministries or limited capacity of institutions in processes and systems were major obstacles. This may lead to inefficient resource allocation during projects by duplicating efforts or preventing consistent policies and regulations. Concerning the *technical* category, there were challenges in the selection and utilization of the most appropriate technologies and difficulties in technical planning. This might require additional time and resources to adapt the selected technology to the local conditions and demonstrate its performance. For the *human skills* category, the capacity, knowledge, or experience of involved staff were found insufficient for the effective implementation of projects, which hinders sustainability of projects and impacts.

The *economic and financial* category includes a lack of funding to start pilot projects, operating and maintenance costs, and project budget. Limited involvement or participation of key stakeholders and a lack of communication among stakeholders are the main contents in the *network* category. COVID-19 restrictions were frequently mentioned as a serious challenge in the *other* category, as well as an increase in conflicts due to climate change and environmental conditions.

Regarding *market conditions*, the market of the targeted technology was dominated by a few providers, and they were reluctant to share information, or their capacity was quite limited. In terms of the *legal and regulatory* category, there were no or lacking policy, regulation, or incentives, and the frequent changes in local government officials and relevant policies were barriers as well. The *social, cultural, and behavioral* category includes low social acceptance of new technology or cultural barriers.

In addition, barriers were analyzed by geographical classification and income level to take some characteristics of countries into account. By regional group based on the criteria of CTCN, 67 barriers were identified from the completed projects in Africa, 54 from Asia, 42 from North America, 24 from South America, 8 from Oceania, 5 from Eurasia, and 4 from Europe. This shows similar trends in the number of the projects implemented in each region. In Africa, barriers related to *technical* (17.91%), *institutional and organizational capacity* (16.42%), and *network* (14.93%) were most frequently mentioned. The *information* *and awareness* category was the top challenge in both Asia (25.93%) and North America (19.05%). For South America, *institutional and organizational capacity* was found to be the main difficulty, taking up 37.50%.

When it comes to the income group according to World Bank classification, lower-middle-income and upper-middle-income groups formed the majority by accounting for 34.31% and 32.84%, respectively, among the total 204 barriers. The least were from low-income countries, with 13 barriers (6.37%). This is partly because only five projects were implemented in low-income countries and a serious lack of infrastructure and financial means might prevent the design and execution of projects there. For the projects in low-income countries, the *institutional and organizational capacity*, *network*, and *technical* categories were the most frequent barriers, comprising 23.08% each. The *information and awareness* category was the most repeated barrier for the lower-middle-income (24.29%) and upper-middle-income (17.91%) countries. As for high-income countries, the *institutional and organizational capacity* and *market conditions* barrier categories comprised 25.00% each.

4.3. Prioritized Barriers Based on Expert Survey

4.3.1. General Information on Survey Respondents

Regarding the type of institutions, half of the responses (50.00%) were from private sectors as shown in Table 3, and the second largest group was public institutions with 11 responses (34.38%), followed by universities with four answers (12.50%). For the number of employees, most organizations reported that they had one to five personnel involved in climate technology international cooperation (81.25%). However, when comparing the numbers with the total number of employees, it seemed that a higher number of staff members in total did not necessarily mean more staff engaged in climate technology international cooperation tasks. For example, all three institutions with one to nine total employees designated one to five people for climate technology international cooperation tasks, whereas six out of seven institutions with over 1000 employees only had one to five staff for the tasks. Regarding demographic information of the person in charge of climate technology international cooperation, most staff were in their forties (50.00%) and the years that they had worked were mostly ten to fifteen years (31.25%). Compared to their work experience, the years of their experience in the international cooperation field were mostly less than two years (31.25%). Specifically, three respondents had worked for over ten years, but they had been involved in international cooperation for less than two years.

Table 3. Characteristics of survey respondents.

Characteristics		Response	Percentage
Type of institution	Public institutions	11	34.38%
	Private institutions	16	50.00%
	Universities	4	12.50%
	Others	1	3.13%
Number of total employees	1–9	3	9.38%
	10–99	12	37.50%
	100–999	10	31.25%
	Over 1000	7	21.88%
Number of employees in charge of climate technology international cooperation	0	2	6.25%
	1–5	26	81.25%
	6–10	4	12.50%

Table 3. *Cont.*

Characteristics		Response	Percentage
Age	20–29	2	6.25%
	30–39	7	21.88%
	40–49	16	50.00%
	50–59	7	21.88%
Experience	Less than 2 years	4	12.50%
	2 years—less than 5 years	4	12.50%
	5 years—less than 10 years	7	21.88%
	10 years—less than 15 years	10	31.25%
	Over 15 years	7	21.88%
Experience in international cooperation projects	Less than 2 years	10	31.25%
	2 years—less than 5 years	9	28.13%
	5 years—less than 10 years	8	25.00%
	10 years—less than 15 years	3	9.38%
	Over 15 years	2	6.25%

Respondents were also asked about their institutions' sector expertise in climate technology (multiple answers were allowed). As Figure 4 shows, many institutions have expertise in renewable energy (15 responses) among eight options in mitigation, and water (9 responses) among seven items in adaptation. Additionally, more answers were found in mitigation-related technologies (59 responses) compared to adaptation technologies (29 responses). Responses showed that the targeted institutions have strength in the mitigation sector, especially energy-related technologies.

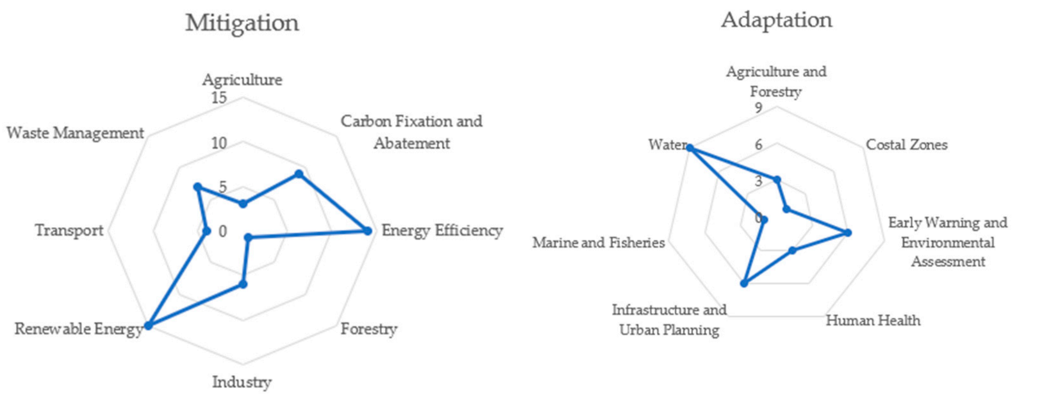

Figure 4. The expertise of respondents' institutions in climate technology.

The types of services that they can provide during the implementation of CTCN TA projects (multiple replies were allowed) are exhibited in Figure 5. The majority of respondents (20 out of 32) answered that they can deliver projects on research and development of technologies, followed by the feasibility of technology options (14 responses), piloting and deployment of technologies in local conditions (10), and technology identification and prioritization (10). For climate technology international cooperation (multiple replies were allowed), which is presented in Figure 6, it is found that most institutions aimed to win contracts for international projects (16) and to conduct research and development of technologies (15). Carbon credit acquisition (8) and global technology demonstration (7) were also pursued as important objectives. Thus, respondents are capable of providing climate technology-related services and are willing to conduct research, development, and demonstration internationally with their climate technology expertise. This implies that they have interests or strategies in climate technology international cooperation, and they are appropriate representatives to prioritize the barriers identified in CTCN TA projects.

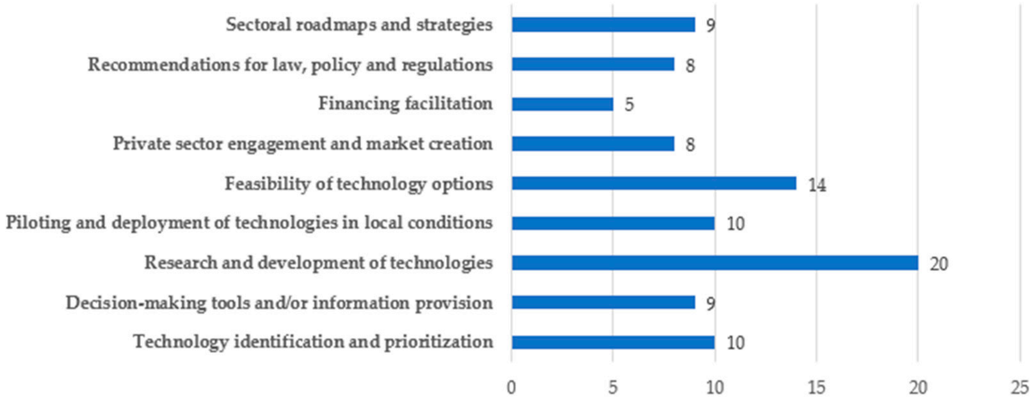

Figure 5. Types of services that respondents or respondents' institutions can deliver through CTCN TA projects (multiple replies allowed).

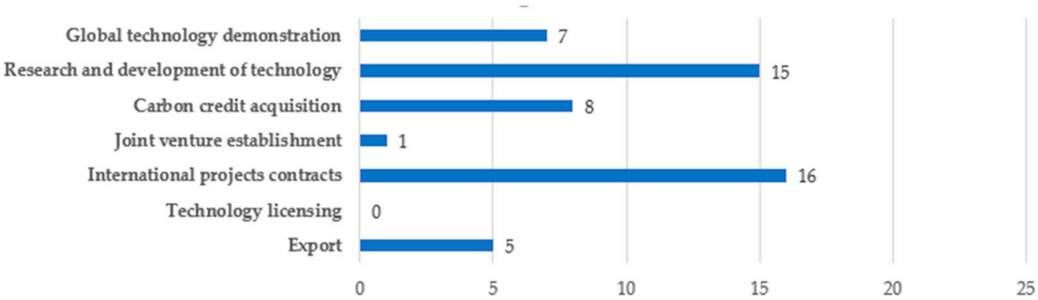

Figure 6. Institutions' purpose of climate technology international cooperation (multiple replies allowed).

4.3.2. Prioritization of Barriers from the Survey Results

Respondents were asked to prioritize the twenty barriers in ten categories using a five-point Likert scale. The '1' on the scale indicates the barrier had the least impact on preventing the successful delivery of projects on climate technology, and the '5' on the scale signifies it had a significantly negative impact on fulfilling the project objectives. The results are summarized in Table 4, calculated by IBM SPSS Statistics 25.

Among the twenty barriers, 'COVID-19 restrictions' from the *other* category were perceived as the most significant impediments with a mean value of 3.69, followed by 'challenges in gathering good data' from the *information and awareness* category with 3.63 and 'limited budget' from the *economic and financial* category with 3.53. Many respondents answered that due to COVID-19, they were not able to visit the site or meet stakeholders in person, which prevented effective communication or progress checks and delayed the project schedule.

Three barriers that had the lowest mean value were 'challenges in the selection and utilization of the most appropriate technology' (3.03) and 'difficulties in technical planning' (3.03) from the *technical* category, and 'language barrier' (3.06) from the *social, cultural, and behavioral* category. *Technical* barriers received relatively low points, which might be because respondents have expertise and experience in climate technology development and transfer.

To further examine the survey data, the responses were clustered using the two important survey questionnaires: Has your institution implemented climate technology international cooperation projects since the year 2018? and has your institution received policy support programs when implementing climate technology international cooperation projects since the year 2018?

Table 4. Assessment of twenty barriers by survey respondents.

Category	Sub-Category	Average	Std. Dev.
Technical	Challenges in selection and utilization of the most appropriate technology	3.03	0.90
	Difficulties in technical planning	3.03	0.97
Economic and financial	Limited budget	3.53	0.98
	High cost to procure technology	3.31	1.03
Market conditions	Market monopoly or oligopoly	3.28	1.02
	Limited capacity of local suppliers	3.44	1.01
Legal and regulatory	Limited local policy, regulatory, and support	3.22	0.94
	Changes in local government officials and relevant policies	3.31	1.00
Institutional and organizational capacity	Limited coordination between ministries and institutions	3.34	0.97
	Limited ministerial and institutional capacity in process and system	3.34	1.04
Information and awareness	Limited understanding of the scope of work	3.31	0.97
	Challenges in gathering good data	3.63	1.07
Network	Limited involvement of local stakeholders	3.16	1.14
	Limited communication among stakeholders	3.16	1.02
Human skills	Limited capacity of local staff	3.34	1.00
	Limited opportunities to build capacity of local staff	3.19	1.00
Social, cultural, and behavioral	Work culture differences	3.16	0.92
	Language barrier	3.06	0.88
Other	COVID-19 restrictions (difficulties in site visit, in-person discussions, etc.)	3.69	1.00
	Local constraints (exacerbated conflicts due to extreme climate, lengthened voting period, etc.)	3.19	1.18

Regarding the first set of responses, 21 institutions that have implemented projects in the last five years were classified as Group A, and the others (11 institutions) were Group B. Both Group A and B answered 'challenges in gathering good data' under the *information and awareness* category as the greatest difficulties. When comparing the responses on barriers between Group A and B, the institutions that implemented projects in the last five years (Group A) found the following barriers more critical than Group B: 'limited budget' (Group A: 3.62, Group B: 3.36) and 'high cost to procure technology' (Group A: 3.36, Group B: 3.18) from the *economic and financial* category; 'limited capacity of local staff' (Group A: 3.38, Group B: 3.27) and 'limited opportunities to build the capacity of local staff' (Group A: 3.19, Group B: 3.18) from the *human skills* category; 'language barrier' (Group A: 3.14, Group B: 2.91) from the *social, cultural, and behavioral* category; and 'COVID-19 restrictions' (Group A: 3.81, Group B: 3.45) and 'local constraints' (Group A: 3.19, Group B: 3.18) from the *other* category.

With the second question, 20 respondents answered that since the year 2018, they have implemented more than one climate technology international cooperation project using funds from the government (Group C), and the others (12 respondents) were notated as Group D. The institutions that recently received government funding when implementing projects (Group C) showed a higher value than Group D in only two barriers in two categories: 'high cost to procure technology' (Group C: 3.40, Group D: 3.17) in the *economic and financial* category and 'challenges in gathering good data' (Group C: 3.65, Group D: 3.58) in the *information and awareness* category.

There were also survey questionnaires asking to rank the ten categories based on the level of difficulties in implementing climate technology international cooperation projects. Respondents chose from the first, meaning the most severe barrier, to the tenth, the least influential one. The results showed that the *economic and financial* category has affected climate technology international cooperation the most, followed by the *legal and regulatory* and the *technical* categories. Throughout all the groups except Group B, 'limited budget' classified under the *economic and financial* category was consistently mentioned as one of the top three greatest impediments. Institutions that recently implemented climate technology international cooperation projects recognized budget limitation as a more significant factor than those that did not carry out the projects in the past five years. However, the groups that received government funding felt fewer difficulties in their budget constraints compared to those that did not benefit from government support programs, which calls for increased support.

4.4. Discussion

The analysis showed the factors related to *information and awareness* (17.65%), *institutional and organizational capacity* (15.20%), and *technical* (14.22%) categories were the most frequently mentioned barriers in the 77 CTCN TA Closure Reports. From the expert survey with 32 completed responses, the top three impediments were 'COVID-19 restrictions,' 'challenges in gathering good data,' and 'limited budget' among the 20 barriers within ten categories, and *economic and financial*, *legal and regulatory*, and *technical* categories were the most frequently mentioned among the ten categories of barriers.

When analyzing the survey results by different sub-groups, it is evident that the ranking of the barriers varied; however, the obstacle of 'limited budget' consistently emerged as one of the top three major hindrances. Financing has been recognized as one of the most challenging barriers in previous studies [45,46]. This implies that bolstering financial support for an implementer to carry out a project would be one of the significant policy recommendations. Given that the budget range for CTCN TA is up to 250,000 USD [47], facilitating follow-up projects subsequent to the CTCN TA projects would serve as valuable support measures. An ongoing example of this is the "Climate Technology Deployment Roadmap for E-mobility Ecosystem in Cambodia," which is a Green Climate Fund readiness project. This builds on the outcomes of CTCN TA support provided to Cambodia in 2019, which aimed to develop an action plan on sustainable and low-emission policies and a proposal for relevant funds. This case demonstrates the potential for further climate technology development and transfer based on CTCN TA projects.

Moreover, most respondents reported 'COVID-19 restrictions' as the greatest obstacle, which shows the importance of effective risk management. When designing projects, assumptions were underlain to deliver activities successfully; thus, unexpected events like pandemics affected the project substantially. To minimize the negative effects of various risks, it would be beneficial to provide risk management guidelines or request to fill out a risk management template from the planning stage of projects. CTCN [48] published a report to expedite climate-resilient recovery after COVID-19, and TEC [49] recognized COVID-19 as a key challenge to international cooperation on climate technology. Nevertheless, more concrete actions will be necessary to effectively address this challenge.

In addition, technical issues have been frequently mentioned as impediments to technology development and transfer. When analyzing the barriers by geographical classification and income level, technical barriers accounted for a considerable portion of the total barriers identified in the projects implemented in Africa and low-income countries.

This is in line with previous studies such as [21] which found technical issues as the top difficulties and highlighted the importance of addressing technical barriers. For the long-term success and sustainability of technology transfer, capacity building needs to be included as well [50]. These results reinforce the importance of the means of implementation of the Paris Agreement, which are climate finance, technology transfer, and capacity building.

5. Conclusions

Climate technology has been highlighted as a solution to respond to the climate crisis and promote sustainable development. Accordingly, the need for climate technology development and transfer has been emphasized significantly. For both policymakers and practitioners, understanding barriers to climate technology development and transfer is important to successfully implement climate technology international cooperation projects.

This study investigated barriers to climate technology development and transfer focusing on CTCN TA projects. The barriers were identified from all the available CTCN TA Closure Reports and prioritized based on the results of expert surveys targeting climate technology-related institutions in Korea, which make up a sizable portion of CTCN members. As a result, 204 elements were found as impediments, and the identified challenges were classified into ten categories initially developed by Nygaard and Hansen [23]. When it comes to the number of barriers, the largest number of obstacles were categorized under *information and awareness*, followed by *institutional and organizational capacity*, *technical*, *human skills*, and *economic and financial*. To investigate which barriers were particularly influential to Korean practitioners, the two most frequently mentioned items were singled out from each category, comprising twenty barriers out of ten categories. From the survey, 'COVID-19 restrictions,' 'challenges in gathering good data,' and 'limited budget' were the top three difficulties that the respondents faced during the implementation of climate technology international cooperation projects.

The findings shed new light on the barriers to climate technology development and transfer in international cooperation projects by focusing on a certain type of climate technology intervention, i.e., CTCN TA projects, rather than investigating one specific type of climate technology or only one country where projects were implemented like in previous studies. This enables to bring a more comprehensive picture of the barriers that can possibly occur during the provision of technical assistance. Lack of understanding of the barriers may result in developing inappropriate policies or inadequate strategies [25], which highlights the necessity and significance of this research. Additionally, incorporating the perspective of Korean experts added further depth to the study by capturing specific challenges and needs experienced by practitioners engaged in this field.

Overall, the implications from this study can influence policymaking processes, shape effective strategies, and guide practitioners in successfully addressing the barriers and challenges in climate technology development and transfer. For policymakers, analyzing prioritized barriers would provide insights into the areas that require attention in formulating policies and strategies on climate technology international cooperation. Considering the survey result that COVID-19 was one of the most challenging risks, policymakers will be able to develop risk management guidelines or provide trainings for practitioners to handle unforeseen events like global outbreaks. In light of the frequently mentioned barrier of financial issues, increasing financial support for project implementation and subsequent project design will be one of the feasible policy options. In the case of the Korean government, the findings will serve as useful references in developing future strategies on climate technology international cooperation and in planning pro bono CTCN TA projects.

Practitioners can draw practical implications from this research. As unprecedented or unexpected challenges like COVID-19 might hinder the successful delivery of climate-related interventions, incorporating contingency measures could be one of the lessons from this study. As economic and financial factors and limited budget were often mentioned as major barriers, implementers can put more efforts into devising efficient and flexible budget plans considering local conditions. In addition, improving data collection and management processes to ensure data quality and quantity will be one of the useful further actions to take since 'challenges in gathering good data' were recognized as the greatest difficulties for both Group A and B, as classified in 4.3.2.

This study is not free from limitations. The target population was intentionally limited to the person in charge of international cooperation in climate technology-related institutions in Korea to increase the credibility of the responses. This resulted in the lack of the number of responses; thus, not many statistical methods were applicable. Future research would be able to collect more answers and conduct additional analysis with other statistical tools. Qualitative studies including in-depth interviews or case studies would be useful to figure out underlying mechanisms for promoting climate technology development and transfer. Furthermore, this paper prioritized the barriers from the perspective of a donor country. Therefore, including perspectives from other donor countries or comparing the priorities between donor and partner countries might give insights or enhance mutual understanding on climate technology international cooperation.

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