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The Role of the Climate Technology Centre and Network as a Climate Technology and Innovation Matchmaker for Developing Countries

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Abstract: In this paper, the role of a matchmaker in transferring climate technologies to developing countries was explored from the perspective of open innovation. As the United Nations Framework Convention on Climate Change's Technology Mechanism, the Climate Technology Centre and Network (CTCN) has strong convening power amongst the stakeholders who are responsible for climate actions in their country. Our research identified that the CTCN has successfully provided "4 openness" models (open network, open request for Technical Assistance, open technology transfer and finance, and open knowledge for the public) to global partners through its technical assistance (TA) services. Then, on the basis of previous empirical Technical Assistance data and network management a new open innovation model was proposed by considering the CTCN matchmaking activities with key stakeholders (innovation networks) during the climate technology transfer processes. This model explains that the role of the CTCN and innovation networks such as academia/research institutions, governments, and the private sector can be interpreted as outside-in innovation at the first technology outsourcing stage, coupled innovation at the second technology research, development, and demonstration (RD&D) stage, and inside-out innovation at the third technology diffusion stage. Moreover, further matchmaker's approaches for supporting developing countries to establish a conducive and sustainable innovation system were suggested for the extension of our new model.

Keywords: climate technology; open innovation; technical assistance; matchmaker; innovation system

1. Introduction

Technology transfer to deal with climate change, including for both mitigation and adaptation solutions, was first addressed in the United Nations Framework Convention on Climate Change (UNFCCC) [1] and was one of the pillars in the 2007 Bali Action Plan [2]. A Technology Mechanism (TM) [3] was established in the Conference of the Parties (COP) at its 16th session in December 2010 Cancun Agreements with the objective of enhancing action on climate technology development and transfer. The mechanism has a Technology Executive Committee (TEC) as its policy arm, which does strategic planning, identify barriers, and facilitate collaboration. It also has a Climate Technology Centre and Network (CTCN) as its implementation arm, which facilitates transfer of climate solutions at the request of developing countries in collaboration with technology experts and providers (Figure 1).

The TEC and CTCN, as two components of the TM, have closely collaborated on areas of shared mandate and expertise since their inception, including climate technology research, development, and demonstration (RD&D) on matters relating to strengthened collaboration with the Financial Mechanism (FM); development of endogenous capacities and technologies; enhancing technical examination process on mitigation and adaptation; and communication and outreach. The technology

framework (TF) was established to provide overarching guidance to the TM in supporting the implementation of Paris Agreement on technology matters [4].



Figure 1. Two mechanisms for implementing Paris Agreement under UNFCCC.

There are five key themes reflecting focused areas of action to be undertaken by the TEC and CTCN: (1) Innovation, (2) Implementation, (3) Enabling environment and capacity building, (4) Collaboration and stakeholder engagement, and (5) Support. According to the TF, technology innovation can be fostered through: (1) the active engagement of the private sector and closer collaboration between the public and private sector, (2) new collaborative approaches to climate technology RD&D, and (3) the creation and promotion of relevant enabling policy to incentivize and nurture a supportive environment for innovation [4].

Technology innovation is critical for an effective, long-term global response to climate change and for promoting sustainable economic development. To achieve the purpose and goals of the Paris Agreement, there is a pressing need to accelerate and strengthen technological innovation so that it can deliver environmentally and socially sound, cost-effective, and better-performing climate technologies at a larger and more widespread scale. The CTCN has a mandate to provide technology innovation as a “matchmaker for climate technology transfer,” by both supporting developing countries’ climate change responses through innovative technologies, and building their national systems of innovation. This stimulates the local economy and social innovation ensuring inclusion.

The objective of this work is to shed light on the CTCN’s innovation policies in the past 6 years since its inception in 2013, by reviewing and analyzing how the CTCN enables innovative capabilities within its technical assistance (TA) processes, as a matchmaker with “4 openness”, models viz open network, open requesting, open technology transfer and finance, and open knowledge for public. Also, by analyzing the previous TA data with network engagement, a new open innovation model for climate technology transfer is proposed to address the roles of key stakeholders in innovation networks at the three stages of the CTCN TA services. Furthermore, from our new model, we suggest future strategies for the CTCN matchmaking during technology transfer, to establish stable innovation systems in developing countries.

2. Theoretical Backgrounds

2.1. Open Innovation

Innovation can be defined as the outcome of a set of activities that use knowledge such as ideas, skills, technologies, etc., to create new value benefiting from its use or rearrange the old in a new way [5]. In order to adapt to an ever-changing, complex, and uncertain environment, many organizations start to attain what they need by exploring, experimenting, and networking with people and entities inside and outside them in innovative ways never thought of before.

This collaborative approach is “open innovation,” which integrates both internal and external knowledge from a variety of sources. The central idea behind open innovation is that, in a world of widely distributed knowledge, companies cannot afford to rely entirely on their own research but should instead buy or license processes or inventions (i.e., patents) from other entities. Accordingly, Chesbrough [6], who pioneered the idea of open innovation, stated that even the most capable organizations must identify, connect to, and leverage external knowledge sources as a core process in innovation.

Historically, small companies have played an important role especially in technology innovation, often leading to the introduction of paradigm-shifting technologies and changes in the way we live [7–9]. However, they face many challenges in maturing to a point where they survive and have positive social, environmental, and economic impacts. Recently, there was an economic analysis on the impact of climate change on companies’ productivity and the knowledge spillovers, based on the empirical evidence [7]. In general, open innovation is a must for small organizations, which usually lack technologies, so always have an external focus to fully complete the innovation process. From a company size perspective, Lee et al. [8] explored the role of external actors in a small-sized company innovation process, and then identified the barriers to their innovations, based on an intermediary facilitating innovation model.

Furthermore, based on empirical database of 124 small companies, Gassmann and Enkel [9] proposed the three types of open innovation processes: (1) the outside-in process: Choosing to invest in co-operation with suppliers and customers, and to integrate the external knowledge gained, (2) the inside-out process: focusing on the external exploitation of company’s knowledge and ideas in order to bring them to market faster than internal development, and (3) the coupled process: Linking “outside-in” and “inside-out” by working in alliance with various actors in strategic networks. Here, considering that the CTCN is a small-sized, but externally networked organization, its innovation characteristic is worthy of being explored by observing the direction of ideas, knowledge, and technologies at different transfer stages.

2.2. Core Roles of an Innovation Matchmaker

The literature is in consensus on the role of academic/research institutions, the government, and the private sector—the three elements also referred as the “Triple Helix”—in stimulating innovative activities [10]. Some researchers have also included the fourth leaf to the clover (called the “four-leaf clover” model), the fourth element being the organizations acting as catalysts of innovative activities [11]. Especially, the desegregation of the open innovation process, requiring internal and external knowledge, has opened room for the innovative catalysts. These catalysts, which include such mechanisms as technology transfer organizations, research parks, innovation centers, etc., facilitate the speed and effectiveness of the transfer of knowledge and technology from academic/research institutions to the industry.

Howells [12] represented these catalytic entities (organizations and individuals) as “matchmakers”, previously called as “knowledge brokers” [13], which improve connectivity within and among innovation networks, and also play an active role in networking among dispersed but complementary organizations. Whatever their missions are, matchmakers facilitate the identification of external knowledge providers and make external knowledge accessible. Different roles of innovation

matchmakers have been analyzed and described in previous studies [14–16]. Three distinct roles of matchmakers are: (1) matchmakers for problem solving [14], (2) matchmakers for technology transfer [15], and (3) matchmakers as coordinators of networks in innovation systems [16]. Each role of the CTCN as matchmaker in some previous TAs is demonstrated in Table 1. Hence, it is noticeable to discuss the CTCN’s role as an innovation matchmaker in each stage of TA service processes, by considering innovative collaborations with academic/research institutions, governments, and private sectors within its innovation networks [4].

Table 1. Core roles of the CTCN as matchmaker during the technical assistance.

Matchmaker For	Technical Assistance (TA) Examples
(1) Problem Solving	Identification and prioritization of technologies to address water scarcity and climate change impacts in Namibia
(2) Technology Transfer	Development of a Mechanical-Biological Treatment (MBT) pilot project of the Waste NAMA in Cali
	Technology transfer and spread of gasifiers and biodigesters of residual biomass to minimize greenhouse gas emissions from municipal solid waste
	Substantial GHG emissions reduction in the cement industry by using waste heat recovery combined with mineral carbon capture and utilization
(3) Coordinator for Building National Innovation System (NIS)	Development of an institutional framework for the installment, use and management of solar PV systems in the Gambia

2.3. National Innovation System

As mentioned in the previous chapter, the third role of a matchmaker is to facilitate dynamic collaboration with various stakeholders as a coordinator in the innovation system. For this purpose, a matchmaker must initiate linkages and enhance accessibility to resources and knowledge on a larger scale and for longer time horizons. This implies building infrastructures, sustaining networks, and boosting exchange amongst a multitude of actors within different organizational and spatial levels from companies, sectors, regions, to nations. According to Camisón and Forés [17], this innovation system approach was initially developed at the national level [18] because it was established by policymakers to facilitate and regulate the technology transfer among the Triple Helix [10].

Regarding National Innovation System (NIS) for technology development and transfer, the TEC defined that the NIS is a network of actors (human capital), institutional contexts (structural capital), and linkages (relational capital) that underline national technological change: (1) **Actors:** Organizations that participate in technology development and transfer e.g., technology firms, universities, and financiers, (2) **Institutional contexts:** Norms, cultural practices and laws that shape actor efforts e.g., government policies that affect how the private sector invests in a particular sector, and (3) **Linkages:** Interactions and relations between the actors and the institutional context e.g., flows of information and knowledge, and collaboration between firms, academic and research institutions [19].

In order to support a country’s efforts to enhance action on climate change mitigation and adaptation, the CTCN’s function to connect people and organization may be sufficient for the singular mission-complete (“problem solved” or “technology transferred”) objectives in the first two matchmaker configurations. However, since the relevant stakeholders are not always clearly identified and successful matchmaking requires ongoing multilateral exchange within the network, the connection becomes more complicated. So, it is worthwhile to note that the CTCN’s role as a matchmaker extends to the establishment of NIS in developing countries by considering contribution of its three components: actors, institutional contexts, and linkages.

3. Innovation during Climate Technology Transfer: 4 Openness

The CTCN has three core services: (1) providing technical assistance (TA) at the request of developing countries, (2) creating access to information and knowledge on climate technologies, and (3) organizing outreach and networking activities among climate technology stakeholders [20]. Here, we focus on “openness” within the CTCN services to exemplify the aspect of open innovation model: (1) open network with various actors like academic/research institutions, governments, private sectors for agile use of external resources, (2) open requesting the climate issues from developing countries (country-driven request), (3) open technology transfer and finance, and (4) open knowledge for public.

3.1. Open Network: Innovative Triple Helix

A key component of the CTCN is its network. The network consists of a variety of climate technology experts/institutions that can engage in the CTCN’s activities to deliver climate solutions at the requests of developing countries, using their technical knowledge and expertise. As of March 2020, 554 organizations from 90 countries participate in the network, and among them private sector organizations are the most numerous (48%), followed by research and academic organizations (22%), non-governmental organizations (11%), not-for-profit organizations (7%), and public sector organizations (7%). Through our own category on their expertise, 99 organizations (about 20%) were selected as the innovative network members, which participated in Tas for innovative technology development and transfer as demonstrated in Table 2.

Table 2. Example of key activities of Tas for scaling up innovation.

Type of Service	TA Examples	Innovation Features
I. Technology Outsourcing	Harnessing wind energy in south Benin	New wind turbine system generating 7.7 GWh/y (200,000 people supply) and cutting 5 kilotons of CO ₂ e
	Photovoltaic solar cell design and manufacturing in Iran	Analysis on current local PV technology status and gap for market creation
	Benchmarking Energy & GHGs intensity in Metal Industry of Thailand	Technologies using low Nox regenerative combustion
II. Technology RD&D	Technology of Photovoltaic Solar Cell Design and Manufacturing	Innovative Solar PV R&D
	Scaling-up sustainable wood fuel systems in the Pwani, Lindi, and Mtwara regions of Tanzania	Charcoal production for cooking and heating, Improved Cook Stoves
III. Technology Diffusion	Incubating Climate Technologies in Small and Medium Enterprises in Chile	Engagement of 31 micro, small, and medium enterprises and Green Investment Banks for agricultural market creation
	Integrated Agroforestry policy in Belize	Identification of mechanisms with the private sector for promotion of agroforestry and mainstream women participation in agroforestry
	Development of a circular economy road maps in Latin America and the Caribbean	Country road map as a management tool for implementation with the private sector, in order to create new business models and job creation

The CTCN acts upon local and national ownership and country-driven needs, so the establishment of a National Designated Entity (NDE), a focal point of the CTCN under the TM, is an initial step for all stakeholders to engage into the network. The appropriate roles of NDEs in technology innovation include any actions that assist the stakeholders in meeting public good objectives that cannot be accomplished by the CTCN alone without government participation or leadership [21]. As of March 2020, 161 countries had nominated their NDEs to communicate with the CTCN. The CTCN activities promote innovation along the technology cycle, balancing NDEs' adaptation and mitigation priorities in line with the objectives of the Paris Agreement, by managing national requests for TA (for developing countries), facilitating engagement in the network, and coordinating regional and global peer learning, collaboration, reporting, and feedback.

Figure 2 shows the open network structure of the CTCN with its key stakeholders. The CTCN delivers TAs in response to the requests from the NDEs of developing countries, and many different actors are involved in the TA activities based on the interaction within the innovative Triple Helix [10], i.e., NDEs as governments, technology providers as academic/research institutions, and technology users as local proponents including private sectors.

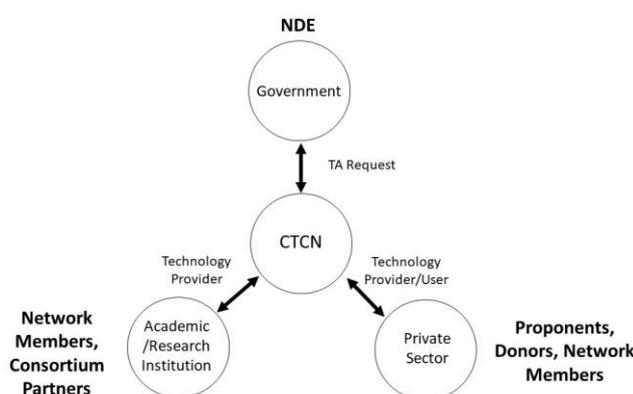


Figure 2. Open network structure of the Climate Technology Centre and Network (CTCN) with innovative Triple Helix.

3.2. Open Requesting from Developing Countries

Figure 3 depicts the full TA processes in the CTCN. As shown in the figure, first, one of the local proponents (academic institutions, public organizations, non-governmental organizations, and private entities) in a developing country, prepares a request in consultation with the NDE, based on the local political, regulatory, and business environmental contexts. Recognizing that the government i.e., NDE has a central role in developing its national climate action plans e.g., Nationally Designated Contributions (NDC), Technology Need Assessments (TNA), National Adaptation Plans (NAP) etc., it is quite important for the NDE to review the request to ensure that it is in line with national objectives and priorities, and submit it after formal approval during the TA process.

Then, the CTCN is required to evaluate and adopt the request-review by transparent and objective evaluation criteria that were approved by the advisory board meeting of the CTCN (The 2nd Advisory Board Meeting of the CTCN, held on 9–11 September 2013 in Bonn, Germany), as shown in Table 3. Then, the CTCN collaborates with an expert team to refine the requests and prepare a response plan within around 8 weeks, followed by selection of an implementor among consortium partners, network members, and external expert through open competition bidding process or a legal agreement.

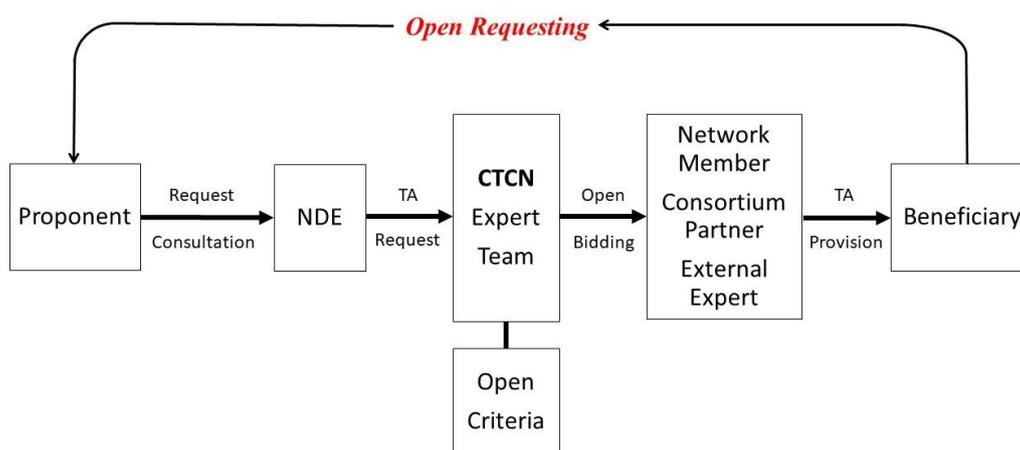


Figure 3. Full TA processes.

Table 3. The CTCN’s eligibility and prioritization screening criteria for requests.

Division	Criteria
Eligibility	<ol style="list-style-type: none"> 1. A clear and positive benefit to the requesting country in mitigating, or adapting to the negative effect of, climate change 2. In line with national strategies and plans (National Development Plans, Technology Needs Assessment (TNA), National Adaptation Plans, Nationally Appropriate Mitigation Actions etc.) 3. Strengthen endogenous capacities 4. Ensure project accountability via effective M&E(Monitoring and Evaluation) processes
Prioritization	<ol style="list-style-type: none"> 1. Demonstrate “project readiness” 2. Demonstrate potential for replication or scaling up nationally, regionally, and internationally 3. Leverage public and/or private financing 4. Promote endogenous and most appropriate technologies and processes 5. Promote and demonstrate multiple benefits, as well as social, economic, and environmental sustainability 6. Promote gender equality, and empowerment of vulnerable groups, including women and youth 7. Promote collaboration among stakeholders, including between countries, and having elements of South–South, bilateral, or multilateral cooperation 8. Promote multi-country approaches and the regional bundling of requests

3.3. Open Technology Transfer and Finance

In the context of climate change, the Intergovernmental Panel on Climate Change (IPCC) (The IPCC special report on Methodological and technological issues in technology transfer (IPCC 2000)) defines technology transfer “as a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, non-governmental organizations and research/education institutions.” In this regard, in order to be an effective and efficient innovation matchmaker for technology transfer, building trustful partnerships with many different stakeholders is both an essential and time-consuming issue. Climate technology is growing like other technologies from ideas to widespread use within its own technology transfer cycle: design, research, development, demonstration, deployment, and diffusion. During this cycle, it meets many stakeholders, especially providers and users of technology and funding in the public and private.

From the technology innovation point of view, climate technology transfer can take place when the innovative findings from research conducted by academic and research institutions (technology

providers) are transferred to local proponents within developing countries (technology users). Users are taking new technology from outside and implement it to adapt to the adverse effects of climate change or to improve their products, services, and processes. In this respect, this transfer process from providers to users can be considered as “open innovative” [22].

Furthermore, the CTCN employed an innovative strategy for financial allocation at different stages of technology transfer via the partnership with additional financial resources of the UNFCCC, i.e., the Financial Mechanism (FM) as illustrated in Figure 1. During the initial stage of technology transfer like concept development, most of the TA budget comes from the internal public fund for technology outsourcing, based on the technology-push innovation. Considering that climate technologies have long development timelines, risky, unattractive characteristics to market, public finance is essential to spur innovation and create the conditions that are attractive for private investment afterward. However, at the later stages for technology RD&D and technology diffusion, there is further focus on allocating external funding resources by learning from the feedback of customers and the broader society, e.g., economic sectors, municipalities and national governments, led by market-pull innovation.

Through the collaboration with the FM—the Global Environment Facility (GEF), Green Climate Fund (GCF), and Adaptation Fund, the output of CTCN’s TA support can be transformative by fostering further stages of technology transfer, i.e., R&D, piloting, and demonstration of technology, or market creation. For example, in 2020, the CTCN starts a five-year grant program of \$5 M, funded by the Adaptation Fund, with the aim to foster innovation of adaptation practices in vulnerable countries. Some countries are encouraged to contribute TA services through in-kind contributions or pro bono support, either partially or wholly providing their own technical expertise or finance to respond to TA requests from developing countries in collaboration with the CTCN. Public support to climate technology transfer is still essential, but more private finance is necessary for dominating market-induced innovation over technology-push. The collaboration with public funding and other funding resources, for example private funding, is known as innovation in a “blended finance” model [23]. Table 4 shows the blended finance model of the CTCN.

Table 4. The CTCN’s partnership with various external funding sources.

External Funding Sources		TA Examples
The partnership with FM	GEF-funded CTCN TA	Mali: renewable energy use for food processing (2016), Uganda: geothermal energy (2016), Vietnam: bio-waste valorization (2017), the Dominican Republic: energy-efficient lighting(2018), Chile: Replacement F-refrigerants (2018), ECOWAS: Mainstreaming gender for a climate-resilient energy system (2018), Zimbabwe: Industrial energy and water efficiency (2018), Paraguay: Environmental flows and river basin management (2019), Gambia: organic waste for energy (2019)
	GCF readiness proposal	Ghana: a national up-scaling of the EWS for droughts (2018), Myanmar: drought and flood management through science-based information (2019), Tonga: Energy Efficiency Master plan (2018)
	Adaptation Fund	A new five-year grant program starts in 2020 with the aim of fostering innovation of adaptation practices in vulnerable countries including SIDS and LDCs
In-kind Contribution	Pro bono	Incorporating innovative renewables and waste heat technologies in Serbia (Korea, 2016), Identification of energy efficient street lighting technologies for Thai municipalities (Japan, 2015)
	NDC Partnership	Enhance NDCs, including by raising ambition, as part of the Paris Agreement’s NDC update process and providing in-country technical expertise and capacity building (2020)

3.4. Open Knowledge for the Public: The On-Line Platform

Knowledge sharing is critical to diffuse successful output, outcomes, and impacts on technology transfer activities. The CTCN’s second core service is to foster access to information and knowledge on

climate technologies for public. Through its various communication tools and knowledge management system (KMS), the CTCN has successfully achieved its targets for outreach, networking, and stakeholder engagement, which are mainly dedicated to: (1) raising awareness and use of CTCN's services, (2) increasing membership of relevant organizations in the network, (3) encouraging external audiences to engage in an interactive communication with CTCN in order to improve execution of CTCN services, and (4) demonstrating value for money to current and potential donors. As of March 2020, there are 16,642 information resources available on the website, provided by a variety of stakeholders, including network members.

The third core service of the CTCN is to strengthen networking, partnerships, and capacity-building of CTCN's stakeholders. The CTCN has provided nearly 40 "open" webinars to more than 3000 participants and held over 60 regional forums and workshops, where about 2000 participants attended, including 161 NDE representatives. Through this service, the CTCN pursues two goals for enhancing innovation. The first objective is to train NDEs to ensure a sustained flow of high-quality requests from countries as well as to train a wider audience by sharing knowledge on climate technologies. The second objective is to link together a diverse global community of stakeholders for recruiting potential network partners, fostering discussion and collaboration within this community, and facilitating provision of innovative climate solutions.

4. New Innovation Model for Climate Technology Transfer

As a matchmaker bringing together proponents of technology transfer services, and implementers, the CTCN has a crucial role in providing an effective mechanism for fostering open innovation through the TA process. Since beginning its operations in 2013, the CTCN has engaged with 93 developing countries responding to 177 TA requests, including 11 multi-country TA requests. This has all been delivered for approximately \$60 million through a network of more than 500 expert implementing partners in 6 years.

Figure 4 illustrates distribution of TA service types, based on 177 previous TA requests during the past 6 years. Considering the entire technology transfer cycle, it is noticeable that the CTCN dominantly supports the earlier stage of technology transfer, i.e., "Decision-making tools and/or information provision" (28.2%), "Feasibility of technology options" (19.7%), "Technology identification and prioritization" (17.5%), and some strategies or policy recommendations, rather than the later stages of technology transfer cycle, such as "Piloting and deployment of technologies in local conditions" (6.8%), "Research and development of technologies" (3%), and "Private sector engagement and market creation" (1.7%). This dominancy originates from the country-driven requests, which are dependent on the social, economic, and environmental contexts of developing countries.

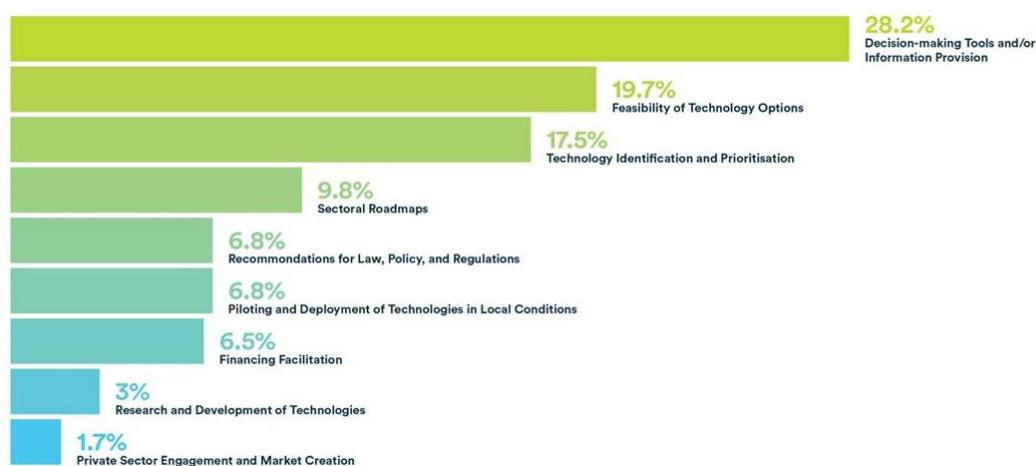


Figure 4. Distribution of the CTCN TA requests by type of assistance.

In order to elucidate the role of the CTCN as a matchmaker in climate technology transfer, first, we divided the whole TA services into three stages of: (1) the first technology outsourcing stage (*1st Stage*) including “Decision-making tools and/or information provision” (28.2%), “Feasibility of technology options” (19.7%), “Technology identification and prioritization” (17.5%), and other policy recommendations (16.6%); (2) the second; technology RD&D and finance stage (*2nd Stage*) of “Piloting and deployment of Technologies in local conditions” (6.8%), “Financing Facilitation” (6.5%), and “Research and Development of Technologies” (3%); and (3) the third technology diffusion stage (*3rd Stage*) of “Private sector engagement and market creation” (1.7%). We note that each percentage of the three service stages is 82%, 16.3%, and 1.7%, respectively, which means that the CTCN has mainly played its role as a “matchmaker for problem solving” [13] for climate issues at the *1st Stage* of technology outsourcing, rather than as a “matchmaker for technology transfer” [14] at the *2nd Stage* of technology RD&D and finance, or as a “matchmaker for NIS” [15] at the *3rd Stage* of technology diffusion.

In some literature [24,25], one can recognize that innovation performance of a country or an organization greatly depends on the relationship with key stakeholders, such as private enterprises, financiers, regulators, etc., within the innovation system. Hence, Söderholm et al. [25] elucidated how to manage the role of the actor networks in the innovation policy throughout the entire technological development processes. They established the analytical framework that addresses how effective innovation policy for technological development can be identified and pursued by the management of actor networks by employing the empirical case of advanced biorefinery technology development in Sweden.

With regard to this work, in this study, we analyzed the role of key stakeholders participating in the open innovation process during some empirical cases of innovative CTCN TA services (Table 2) by combining our 4 openness models, which originate from network management theory [25]. For this purpose, some representative TAs were reviewed in terms of management of actor networks, for example, (1) collaboration among Japanese government agency, Japan Iron & Steel Federation and Iron & Steel Institute of Thailand for CO₂ reduction & reuse technology [26]; (2) joint R&D activities among World Agroforestry Centre (ICRAF), Tanzania Renewable Energy Association (TAREA), and Tanzania regional governments for scaling up wood fuel [27] and incubating Chile’s SMEs for building new business model in agricultural sector [28]. These CTCN TA activities to facilitate and scale up innovation, which include (1) *1st Stage* of technology outsourcing, (2) *2nd Stage* of technology RD&D and finance, and (3) *3rd Stage* of technology diffusion.

Based on our empirical TA data within the innovation network, during some TAs for technology outsourcing, i.e., *1st Stage* of technology transfer, it was found that every request from technology users in developing countries (country-driven) involves open networking with external technology providers, which facilitates new technology from outside into the process. According to the previous open innovation process model [9], this is regarded as an “outside-in” open innovation process. Accordingly, we suggest that during the 1st Stage of technology outsourcing for the past 6 years, the CTCN played a major role as a matchmaker for problem solving, implying dominancy of “outside-in” open innovation approach.

After that, in the *2nd Stage* of technology RD&D and finance, we observed that a “coupled or inclusive” innovation approach dominates because the CTCN outsources new local innovative partners suitable for “inside-out” technology diffusion, such as “incubators or accelerators” and “private sectors” like SMEs, start-ups, etc. This can be done by various collaborations such as strategic alliances between public (NDEs, research institutions), private (business), and academic (university professionals) partnership. Only 1.7% of TAs were related to private sector engagement and market creation at the *3rd Stage* of technology diffusion. In order to fill the gap between unattractive climate technologies and market needs, private sector engagement and its collaboration with governments are very important. As explained by Gassmann and Enkel [9], this is an “inside-out” approach,

which externalizes and leverages the innovative technologies or knowledge in order to bring them to market faster than they can through internal development [29].

In summary, we propose a new open innovation model considering the CTCN's collaboration with key stakeholders at various stages during climate technology transfer process. The schematic of this model is depicted in Figure 5. Consequently, as a matchmaker to support more engagement of the stakeholders for open innovation, the CTCN should take more challenging innovation strategy from “outside-in” approach at the *1st Stage*, toward “coupled innovation” at the *2nd Stage*, and then “inside-out” approach at the *3rd Stage* during the TA processes.

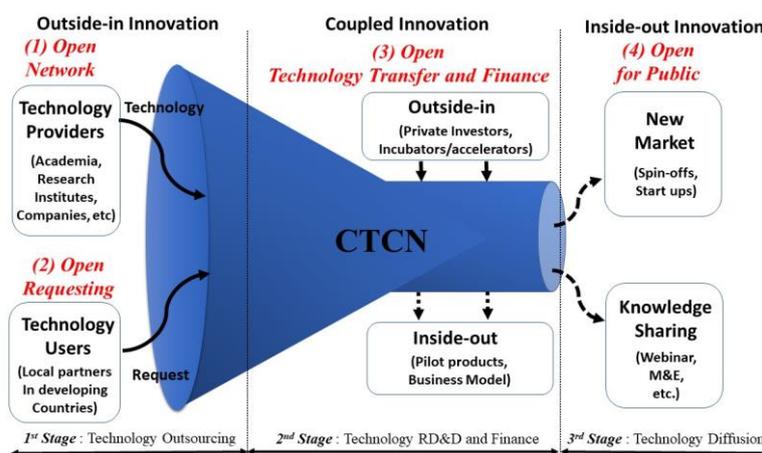


Figure 5. Open innovation model within innovation network during the CTCN's services.

5. Future Innovation for Climate Technology Transfer

Previously, we observed that the CTCN has successfully accomplished open innovation throughout its entire TA processes by collaborating with key stakeholders within innovation network at stages from technology outsourcing (*1st Stage*), technology RD&D and finance (*2nd Stage*), to technology diffusion (*3rd Stage*). However, in order to accelerate innovation as an effective and efficient matchmaker for climate technology transfer, there is a need to support developing countries to strengthen their NIS. This implies that the ultimate role of the CTCN should be emphasized as a “matchmaker for NIS” within innovation networks at the *3rd Stage* by engaging new innovation policies both at the *1st* and *2nd Stages*. Establishment of the NIS is essential for enhancing developing countries' capacity to develop, deploy, and diffuse climate technologies. Also, it is required to support continued technological improvement and adaptation to regional needs. As previously mentioned, in the NIS, technology innovation should be sustainable and diffusible and enable active linkage between the actors through effective matchmaking. Thus, based on our new open innovation model, we discuss futuristic roles of the CTCN in climate technology transfer as an innovative matchmaker within the context of the three components of the NIS establishment in developing countries: actors, institutional contexts, and linkages.

5.1. New Actor's Engagement

In order to boost the matchmaker roles for technology diffusion, the CTCN should employ more innovative features at the *1st Stage*, aiming to engage more governments through their NDEs and new academic/research institutions/private sectors within the TA services. As shown in Figure 6, for enhanced NDEs' participation, instead of filling in a template for TA requests, developing countries can submit their requests using a video file sharing their climate challenges and issues, which takes less time and effort than preparing TA requests. Regarding the requested climate TA, several candidates (service providers from the public and private sectors) compete with each other by presenting their proposals in an open competition event. Through this, fair and transparent competition under a

judging committee comprising various external stakeholders such as NDEs, FM entities, and the most innovative actors from the private sector with market-pull viewpoints, can be selected as TA service providers, “demonstrators or deployers” or “incubators or accelerators”.



Figure 6. New actor engagement at the *1st Stage* of technology outsourcing.

5.2. Institutional Context

In order to enhance coupled innovation during the *2nd Stage* of technology RD&D and finance, it is important for the CTCN to identify more national information of developing countries i.e., the national needs, priorities, and gaps related to the NIS, and to catalyze the enabling environment by considering their multiple barriers such as policy, legislation, regulations, economy, finance, market, technology, society, etc. From an institutional point of view, the CTCN has identified the multidimensional nature of the barriers for technology development and transfer, and also proposed policies, strategies, and initiatives to developing countries as an enabler to tackle them [30].

Thus, as an innovative matchmaker for technology transfer, the CTCN needs to support especially the learning processes to reduce risk and helping technology providers to transform inventions into technologies that meet economic or societal needs of developing countries by engaging new innovative actors at a developing country’s request on strengthening NIS. For this purpose, the CTCN is recommended to establish a new framework of technology RD&D, assigning participants as innovative actors such as “demonstrators or deployers” and “incubators or accelerators” at the *2nd Stage*. Firstly, the roles of the former innovative actors are to outsource the “innovative, but overlooked climate technology” from developed countries, and then widely demonstrate or deploy for modification to local contexts of developing countries under the less complicated regulation. This means that those technologies are to be easily “localized” in developing countries under the flexibility of local institutional regulatory frameworks.

Furthermore, a well-defined business model for those technologies in developing countries can be developed by the innovative actors of incubators and accelerators. Such models can be used to mobilize further funding from private investors like business angels, venture capitalists (VCs), and initial public offerings (IPOs). They are expected to participate in establishing stable business-friendly environment, for the NIS through “inside-out” innovation under external market-pull policy. Successful engagement of potential private investors in the framework of collaborative RD&D is another exogenous and effective “incentive” to accelerate growth and achieve market leadership, provided or organized by the innovation network. Figure 7 depicts the new collaborative RD&D process with institutional incentives for NIS.



Figure 7. New institutional framework at the *2nd Stage* of technology research, development, and demonstration (RD&D) and finance.

5.3. Linkages

As a final component for NIS, linkages mean more interactions and relations between new participants and the institutional context within NIS. Throughout the CTCN’s core mandate, they can

be done by preparing several initiatives on “coupled innovation” with local endogenous capacity engagement, building entrepreneurship, and incubation/acceleration at the 2nd Stage of technology RD&D and finance. Harmonized RD&D with the needs of the local partners is a key factor of the successful “coupled innovation” process for the ultimate establishment of NIS.

With the aim to strengthen the capacity of local industrial small- and medium-sized enterprises (SMEs) and create the industrial SME markets from climate technologies, the CTCN is running SME clinics in developing countries. Potential approaches are: (1) strengthening policy frameworks that support the scaling up of specific climate technologies in a country; (2) incubator program to support them with business plan development, strategic partnerships, or financing; (3) capacity building related to the operation of a specific technology; (4) development of a local service provider who can support the SME cluster with legal matters, communications, or storage facilities; (5) funding scheme development with local financial institutions for the take up of the selected climate technologies identified; and (6) demonstration project of selected climate technology. Two projects for industrial SME clusters in Kenya and Tanzania are actively on going by the support of the CTCN together with Kenya climate innovation center.

Kenya’s SME Clinic provides business development services for small entrepreneurs

Due to poor access to credit, small business owners in the country face challenges including low access to new markets, investment readiness and the lack of capacity and technical know-how on setting up systems necessary for growing their business. Data by the Central Bank of Kenya shows about 46 per cent of SMEs in Kenya close within a year of founding, and another 15 per cent in the year after that, unable to solve business-related challenges. SME Clinic, as one-stop shop, will be looking to tackle these challenges by putting together business development service providers in one space to not only reduce operational costs incurred by SMEs but create ease of doing business. Small business owners will benefit from access to 17 domain experts including Strategy, Finance, Legal, Human Resource Management, Process mapping, Marketing, Sales, Branding, Customer Service, Debt Collection, ICT, and Automation, all under one roof. They will also access training for their employees on soft and hard skills, access to a network of peers as well as exposure to other ecosystem actors including investors.

Moreover, for more outreach activities of innovation at the *3rd Stage* of technology diffusion for new market formation and knowledge sharing, it is worthwhile to note that climate technologies can be converged with so-called, emerging digital technologies, i.e., machine learning, cloud computing, Internet of Things (IoT), and blockchain technology. These emerging technologies can enhance information transparency, increase automation, and enable direct interactions between stakeholder groups by creating a trusted information layer by combining IoT sensors (data collection), machine learning (verification and analysis), and blockchain technology (distribution and execution).

Especially, blockchain acts as a decentralizing technology platform that creates innovative business and governance models [31,32]. These innovative models are particularly relevant for SME businesses in developing countries, which are disproportionately constrained by financial and informational barriers. By addressing these barriers, emerging technologies offer developing countries the opportunity to leapfrog into innovative systems to accelerate sustainable development and climate action. Previously, innovative early warning systems for enhancing climate resilience were developed in Thailand [33] by connecting various digital technologies with software (SW) modelling and associated climate data.

Also, these IT-incorporated TA results can be transformed to various types of outcomes on the CTCN’s website e.g., innovation reports, TA stories by social media, and SW products for on-line pay-as-you-go applications like waste-to-energy simulation tool, climate monitoring system, coastal hazard risk management system, etc. Therefore, with more IT connectivity to KMS, the CTCN can distribute more transparent and automated services by providing “one-stop technology transfer shop” on the website for developing countries seeking climate solutions through: (1) on-line requesting (from government, public), (2) auto reviewing and selecting best implementors for response plans/direct proposals by open competition events, (3) auto matchmaking based on artificial intelligence for analyzing or executing big data (about the requested climate issues, diverse local contexts, innovative

solutions by Network) gathered at virtual cloud server, from various local IoT sensors within blockchain security, and (4) growth in technology from laboratory to up-scaling for new businesses with linkage to further supports.

6. Conclusions

In this paper, the role of the CTCN as a powerful matchmaker for climate technology transfer to developing countries were investigated in view of open innovation. Based on the analysis of previous CTCN TA activities, firstly, we identified the CTCN has contributed to tackle the global climate action by using “4 openness models” (open network, open TA requests, open technology transfer and finance, and open knowledge for public). Then, a new open innovation model was proposed by considering the innovation networks at various stages of the CTCN TA service processes.

Empirical TA statistical data identified that the CTCN has mainly (over 80%) played its role as a matchmaker for problem solving during technology outsourcing at the *1st Stage* of technology transfer. We suggest that key stakeholders as members for open network and local partners for open requesting have dominant roles as technology outsourcing actors with the aspect of “outside-in” open innovation process. However, in the *2nd Stage* of technology transfer, the CTCN outsources new local innovative partners suitable for “inside-out” technology diffusion, such as “incubators or accelerators” and “private sector actors” like SMEs, start-ups, etc., indicating “coupled innovation” inside the CTCN. Then, in the *3rd Stage* of technology transfer, “inside-out” innovation prevailed for technology diffusion, such as market formation and knowledge sharing of innovation achievement, which gives the role as matchmaker for NIS.

Moreover, further matchmaking approaches for supporting developing countries to establish a conducive and sustainable innovation system were suggested based on a new model proposed during the CTCN TA. First, as an innovative matchmaker to support more engagement of new actors for building a conducive NIS, the CTCN should take a strategy for enabling the private sector’s market pull commercialization along with more engagement of NDEs and network members at the *1st Stage*. Then, the CTCN is recommended to establish a new framework of technology RD&D, assigning participants as innovative actors such as “technology demonstrators or deployers” and “business model incubators or accelerators” at the *2nd Stage*. Successful engagement of potential private investors in this RD&D model is an effective “incentive” to accelerate growth and achieve market leadership. Finally, at the *3rd Stage*, enhanced IT connectivity to the CTCN website is proposed as an efficient platform for further technology innovation diffusion.

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