Fragmentation of International Low-Carbon Technology Governance: An Assessment in terms of Barriers to Technology Development

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Abstract

The purpose of this paper is to understand the degree of fragmentation of low-carbon technology institutions by examining different functions of existing institutions to remove barriers to technology development. In order to understand the functions of existing institutions, we first identify barriers of technology development for making low-carbon society in the world, with particular consideration to Asia. We do this by extensive literature review on low-carbon technology, technology innovation as well as insights from the result of case studies. After identifying barriers, we then analyze institutional characteristics of the existing institutions working on low-carbon technology, by looking into their main purposes and actor configurations and by investigating whether and how each institution is working to overcome identified barriers to technology development. Through this analysis, we identify the directions we should follow in order to make more cooperative fragmentation regime in low-carbon technology. We argue that low-carbon technology governance may be best served through a fragmentation of governance architecture, but coordinated by a hub that is capable of quickly accessing usable information and transmitting it to the appropriate institutional nodes in the network.

Key words: beyond 2012, governance architecture, institutional fragmentation, low-carbon technology

1. Introduction

In recent years, a growing number of international fora have been addressing post-2012 institutional architecture relating to climate change. To name a few, they include different kinds of ad-hoc working groups (AWG) under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol (KP), the Major Economies Meeting on Energy Security and Climate Change (MEM), and the Asia Pacific Partnership on Clean Development and Climate (APP). There are also political fora that address climate change as part of the issues they have frequently discussed. They include Group of Eight Summit (G8) and Group of Twenty (G20), the Asia Pacific Economic Cooperation (APEC) and ASEAN. International organizations such as the Organization for Economic Cooperation and Development (OECD), International Energy Agency (IEA) and Food and Agriculture Organization (FAO), as well as the World Bank and other regional banks also discuss and conduct research on issues related to climate change, or are working on climate issues as part of their operations. Since 2009, the International Renewable Energy Agency (IRENA) has been added to the list. Looking beyond inter-governmental organizations, there are even more fora and initiatives. To point to a few, the Renewable Energy and Energy Efficiency Partnership (REEEP), Global Sustainable Electricity Partnership, Carbon Sequestration Leadership Forum, Global Bioenergy Partnership, and so on, are all related to the issue of climate change.

The profusion of diffuse institutions that deal with climate change and low-carbon issues has been examined by a growing number of global governance studies. Recently it has been termed in different ways such as polycentricity, fragmentation of regimes, or a regime complex (Ostrom, 2010; Brafman & Beckstrom, 2006; Folke *et al.*, 2005; Biermann *et al.*, 2009; Keohane & Victor, 2010; Abbott, 2011). However it may be termed, the important point here is that no nation-state-based international institution centered on a single international regime, such as the UNFCCC, has been able to solve the

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complex issue of climate change on its own. For various reasons, there have emerged many institutions that deal with climate change in one way or another. Many, and sometimes inter-related, issues have resulted in this phenomenon. A frequently mentioned reason is the lack of the US engagement in the Kyoto framework. Even though the US agreed on the deal made at the Kyoto Conference in 1997, it refused to ratify the protocol. Refusal to ratify the protocol on the side of the largest emitter in the industrialized world resulted in emergence of different approaches to engage them in a different manner.

Other reasons include the malign nature of the climate change issue (Miles *et al*., 2001), changes in political dynamics in the 21st century (such as the growing political and economic power of emerging economies) on energy and climate issues (Biermann *et al*., 2012a, 2012b; Kanie, 2010), or the emerging political influence exerted by various kinds of non-state actors (Kanie & Haas, 2004).

Diffusion of international institutions is also being applied to the area of low-carbon technology. To put it differently, many of the emerging initiatives, as described above, deal with technology in one way or another. These initiatives have been established on an ad-hoc and rather fragmented basis.

Biermann *et al*. (2009) categorized types of fragmentation as synergistic, cooperative, and conflictive fragmentation in relative terms. Synergistic fragmentation involves a core institution that includes (almost) all countries, and provides effective and detailed norms throughout different yet substantially integrated institutions. Cooperative fragmentation involves a core institution that does not comprise all key countries in the given issue area, but exists with other institutions that are loosely integrated. Its core norms and principles are ambiguous, but not conflicting. Conflictive fragmentation involves different and largely unrelated institutions with different sets of decision-making procedures and memberships, and diverse norms and principles in conflict with each other. Biemann *et al*. (2009) concluded that "conflictive fragmentation of global governance architectures appears to bring more harm than positive effects, and can generally be seen as a burden on the overall performance of the system".

At first glance, low-carbon technology initiatives, so far, seem to have come under conflictive fragmentation in this typology. Although the UNFCCC and the KP are unifying initiatives, technology has not been their central concern, and not only are their ad-hoc initiatives hardly connected with each other, their decision-making procedures also differ from each other. They have independent sets of principles and norms that are not coordinated. Their memberships and the actors involved in their respective activities are different. Therefore, efforts are needed to transform their institutional fragmentation away from conflictive to a more cooperative and ideally synergistic one.

Two approaches may be envisaged for complying with this purpose. The first approach would be to start with an analysis of the existing institutions to identify what elements of the different institutions, be it norms, principles, or decision-making procedures, could be linked. Another approach would be to start with technologies and an examination of elements that are required by low-carbon technology institutions. After identifying the elements, they can be compared with the existing institutions and an effort made to figure out what is missing and what the required changes should be.

We take the latter approach here. The modest purpose of this paper is to understand the degree of fragmentation of low-carbon technology institutions by examining different functions of existing institutions to remove barriers to technology development. We first identify barriers to technology development for making low-carbon societies around the world, with particular consideration of Asia. This inevitably requires consideration into international cooperation and transfer of technology. We do this by an extensive review of literature on low-carbon technology, technology innovation and insights from the results of case studies. After identifying barriers, we then analyze the institutional characteristics of the existing institutions working on low-carbon technology, by looking into their main purposes and involved actors briefly and by investigating whether and how each institution is working to overcome the identified barriers to technology development. We chose the institutions that are included in the database developed by Abbot (2011). Through this analysis, we identify the directions that should be followed in order to make a more cooperative fragmentation regime in low-carbon technology.

2. Identifying Barriers to Technology Development

The purpose of this section is to identify barriers to technology development. The first part of this section reviews the results of several key research initiatives on barriers. The results indicate that there are a variety of barriers in technology development including economic, technological, regulatory, social and others. In the second part, we attempt to pinpoint some of these barriers at different stages of technology development. In the early stage of technology development, technological barriers are dominant, but as the stages of technology development progress, financial as well as institutional barriers are identified as major barriers to diffusing technologies. In the third part, we demonstrate the results of several studies examining barriers on a case study basis. In our view, the case study approach is useful and effective in identifying technology-specific as well as country- or region-specific barriers, especially since these barriers are often overlooked by other studies looking at developing countries or renewable energy as a whole.

2.1 Review of literature on barriers to technology development

Several different research initiatives have identified a variety of barriers to innovation and transfer of low-carbon technologies in developing countries (Painuly, 2001; OECD/IEA, 2001; Painuly & Fenhann, 2002; Raddy & Painuly, 2004; Doukas *et al*., 2009; Balachandra *et al*., 2010).

The OECD/IEA conducted a comprehensive study and identified major barriers to technology development in general (OECD/IEA, 2001). They identified nine broad categories of barriers. The first barrier is institutional. This includes inappropriate frameworks of laws and regulations, and insufficient levels of assessment of technology needs and implementation. Political barriers follow, which include political instability and corruption. Then come technological barriers, including inappropriate infrastructure and lack of technology standards, supporting frameworks, capacity and knowledge. The fourth barrier is economic. Economic instability, inappropriate subsidies, a poor macro-economic situation, and un-transparent market are included here. The fifth barrier regards information, and includes inappropriate access to information on technology and finance, as well as insufficient information for technology users. Finance is another barrier. In addition to a lack of funding, a tendency to prioritize large-scale projects is considered a barrier, and this is especially the case for low-carbon technology. Another problem identified is high risks for foreign investors. There are also cultural barriers. Cultural influences on consumer preferences and social biases regarding imported goods and technologies are considered one of the barriers to technology transfer. Laws and regulations also constitute part of the barriers. Uncertain property rights or lack thereof coupled with uncertain arbitration schemes hinder technology transfer. Finally, a lack of participation by local people and of understanding of local needs are also considered barriers.

Other literature also points to similar barriers to technology development. Doukas *et al*. (2009) address economic, technological, regulatory and social barriers. Other studies describing similar barriers include UNFCCC (2003), Worrell *et al*. (2001), Kathurina (2002), Luken and Rompaey (2008), Schneider *et al*. (2008), Thorne (2008), Fedrizzi *et al*. (2009), Ölz and Beerepoot (2010) and IEA (2011b).

While OECD/IEA's study indicates economic barriers at the macro level, according to these studies, there are even more micro- or project-level economic barriers, including relatively expensive implementation and energy costs, and limited access to local and regional financial sources. These barriers can be translated as "lack of potential for commercial validity" (Schneider *et al*., 2008; Karakosta *et al*., 2010; Ravindranath & Balachandra, 2009; Guerin, 2001). Transferred technologies are efficient, but generally more expensive, and require higher initial costs. In addition, they involve higher risk.

Similar to OECD/IEA's study, there are studies that recognize un-transparent investment environments, and lack of knowledge on technology management, implementation, spare parts and maintenance as technological barriers. Using unfamiliar chemical products and/or resources as well as new process technology may be added here (Luken & Rompaey, 2008). When it comes to renewables, grid integration may become a technological problem as well (IEA, 2011a). As for regulatory barriers, the studies indicate barriers associated with domestic regulatory frameworks, especially fossil fuel subsidies, strong bureaucracies (including embedded interests in the existing energy resources), existence of a large national company, and preferences for cheap but relatively environmentally harmful technology (Ravindranath & Balachandra, 2009; Kathuria, 2002).

There are additional barriers that OECD/IEA did not indicate but have been discussed among other studies. A government's lack of areas of specific focus is sometimes considered part of an institutional barrier (Guerin, 2001; Reddy & Painuly, 2004; Painuly, 2001; Kathurina, 2002). Others point to a high number of bureaucratic stakeholders involved in the sustainable energy sector as part of the problem (Flamos *et al.,* 2008). This can apply not only to the horizontal level of the government (such as national level government), but also to vertical levels (such as national, provincial, prefectural and local levels). The implication of this is a delay in investment, as receiving permission requires a long period of time (such as 2 to 7 years before starting a project). Another barrier to renewable energy is that it is often not included in urban planning in developing countries (Ölz & Beerepoot, 2010). In addition, a negative impact of transferred technology on the existing social structure of the community is considered a social barrier.

2.2 Barriers in different stages of technology development

Innovation of a new technology and transference of an existing technology from developed countries to developing countries have usually been discussed in a separate policy forum. Since technology innovation and transfer were not central issues in (UNFCCC) negotiations for a long time, there was a lack of communication between experts working on future innovative low-carbon technologies, such as clean coal, carbon capture and storage (CCS) and solar thermal, and experts working on transferable technologies such as wind power, solar photovoltaic (PV) and mini-hydro. Recently, however, innovation and transfer of technologies are being discussed as part of the same flow of technology development under the framework of the UNFCCC. The UNFCCC has published a paper in which it addresses its "integrated strategy" to cope with technology transfer and innovation at the same time (UNFCCC, 2009a). The mandate of the Climate Technology Center (CTC) proposed under the UNFCCC covers both elements (Expert Group on Technology Transfer, 2010). In addition, there have been discussions on how to provide financing effectively in both innovation and transfer of technologies (Camody, 2007; Doornbosch & Knight, 2008; World Economic Forum, 2010). According to the IEA (2012), an additional US$36 trillion in clean energy investments will be required from now until 2050 in order to limit the long-term global temperature increase to 2 degrees Celsius. In this context, not only does the role of the Green Climate Fund (CGF) under the UNFCCC hold significant importance but so do those of other institutions that mobilize private finance for mitigation and adaptation projects.

The reports submitted to the UNFCCC use the RDD&D chain (research, development, demonstration, deployment & diffusion, and commercial maturity) to indicate the flow from innovation to transfer of technologies (UNFCCC, 2009a; UNFCCC, 2009b; UNFCCC, 2009c). The chain consists of several stages of technology development. Figure 1 shows the stages of technology development with several examples of technologies at each stage.[*1]

According to the definition by the UNFCCC, the demonstration stage involves full-scale implementation of a limited number of installations by a small number of companies or research facilities (UNFCCC, 2009b). Prior to the demonstration stage, there is the research and development stage where the basic science is clarified and the technology is at the stage of conceptual design or testing at the laboratory or bench scale (UNFCCC, 2009b). In our view, the technologies both in the R&D and demonstration stages can be seen as at the innovation stage since there is no prospect for the private sector to be engaged on a business basis at either stage. Therefore, we combined these two stages together as the demonstration stage.

The stage of deployment is where technologies are available for selected commercial applications but are more costly than the established technology (UNFCCC, 2009b). As discussed later, there must be strong initiative and support from the public side to advance the technologies forward to the next stage. The diffusion stage is where technologies are available more widely but there are many generic as well as country- or technology-specific barriers to diffusion. The next section illustrates these barriers in detail. The commercial stage is where technologies are available even without any funding support or economic incentives from the public side (UNFCCC, 2009b).

In the very early stages of technology development, technological barriers typically dominate until the technologies are proven to be feasible. At this stage, public national institutions and funding sources mainly provide financial resources for the R&D, since for the private sector, the future prospects of the technologies are too uncertain to invest in (UNFCCC, 2009b). Railway transport, nuclear power plants, the Internet and GPS were all developed by research projects funded by governments (IEA, 2011b). However, funding for clean energy technology innovation and countermeasures to the risks associated with investment into clean energy technology are not reflected in priority areas of overseas development agencies (Ölz & Beerepoot, 2010). Another incentive is anticipation by entrepreneurs and investors for markets, technology and policies. Prospects for market behavior are now considered one of the largest incentives for innovation of a new technology, and more importantly, it has become key information on the direction of technology development (Philibert, 2011). It is often shared, explicitly or implicitly, by different companies in the same sector (Foxon & Pearson, 2008). In the later stages of technology development, financial barriers emerge as a major obstacle, since public funding becomes less available than at the earlier stages (Bloomberg New Energy Finance, 2010; Clean Energy Group, 2010; UNFCCC, 2009b). In reality, however, private funding is still difficult to bring in at this stage due to the high risks perceived or involved in such investments. This stage of technology development is known as the "valley of death," as a metaphor for the gap in financial resources available at this stage of technology development (see, for example, UNFCCC, 2009b.)

In the later stages of technology development, together with financial barriers, institutional barriers are identified as major obstacles to diffusing technologies (UNFCCC, 2009b). Institutional barriers include a lack of regulatory support or incentive programs for investment into clean energy technologies. When the return on investment into a clean energy project is lower than that of other investment opportunities, regulatory support such as feed-in-tariff programs is crucial in improving such investment conditions (DB Climate Change Advisor, 2011; ECOFYS, 2009). Institutional barriers also include a lack of information on appropriate technologies as well

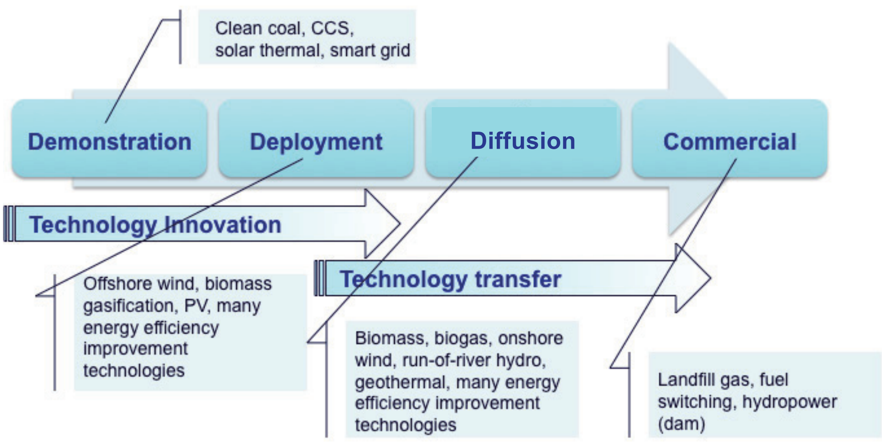

Fig. 1 Stages of technology development and examples of technologies at each stage.

as a lack of knowledge and expertise on imported technologies, and a lack of skills and know-how for operations and maintenance. These barriers are often observed even after technologies are widely available and the return on investment in the technologies seems promising for the private sector.

2.3 Barriers identified through a case study approach

This part of the section addresses barriers through a case study approach. As noted earlier, the case study approach is useful and effective in identifying technology-specific as well as country- or region-specific barriers that are often overlooked when considering developing countries or renewable energy as a whole. There is also an accumulation of knowledge in the lessons drawn by various case studies (Dalhammar *et al*., 2009; Gerstetter & Marcellino, 2009; Haselip *et al*., 2011; Ockwell *et al*., 2007; 2009). The results of these case studies indicate lack of information and local knowledge as one of the major institutional barriers to introducing technologies at the diffusion and even at the commercial stage of technology development.

A collaborator to the current project conducted a case study on large-size biogas plants in India, and the team identified the following twenty-one barriers (Schmidt & Dabur, 2011): 1) lack of market openness, 2) lack of awareness among market participants (customers, financers, etc.), 3) limited access to technology, 4) favors (such as subsidies) to conventional energy and non- consideration of externalities, 5) lack of access to capital and high capital cost, 6) capital-expenditure intensity of renewables 7) high hidden costs, such as operation and management costs, and costs associated with gathering and analyzing information, 8) problematic buyer-supplier relationship, 9) lack of trusted institutions for disseminating information, 10) lack of long-term legal regulatory frameworks, 11) lack of policy instruments for commercialization, 12) lack of involvement of stakeholders in decision making, 13) high level of bureaucracy, 14) difficulty in mainstreaming environment into development plans, 15) lack of standards, codes and verification, which negatively affects product quality and product acceptability, 16) lack of technical knowledge in India, 17) lack of reliable technology, 18) lack of coordination among research groups, academic institutions and private industry, 19) lack of complimentary infrastructure, 20) lack of consumer acceptance of the product and high risk perception, and 21) improper profitability indicators.

A case study on biogas power generation projects in Thailand conducted by our project confirmed many of the aforementioned points. The case also demonstrated that limited access to information and expertise is a major barrier in implementing projects (Jain *et al*., 2011; Suzuki *et al*., 2010). In Thailand, many biogas projects have experienced failures to secure sufficient amounts of biogas for power generation. The study revealed that the problems were largely due to a lack of know-how in maintenance and training of local employees for operating the plants. The result of the study in Thailand, together with the case studies illustrated above, suggests a strong need for institutional support for accessing information and enhancing local capacity to handle technologies at the diffusion stage of technology development.

The barriers identified here are summarized in Table 1.

Table 1 Barriers to technology development.

Code	Description of barriers
Institutional Barriers	
I-1	Lack of regulatory support /incentives for investment into clean energy technology
	Lack of long-term legal regulatory frameworks
	Lack of policy instruments for commercialization
I-2	Lack of government interest and capability to promote renewable energy technology
	Not reflected in priority areas of overseas development agencies
	High number of bureaucratic stakeholder involvements in sustainable energy sector
	Political instability and corruption
I-3	Uncertainty or lack of property rights
I-4	Limited access to information and expertise
	Lack of trusted institutions for disseminating information
I-5	Lack of consumer acceptance of the product and high risk perception
I-6	Lack of social interest in the project
I-7	Lack of involvement of stakeholders in decision-making
	Lack of participation by local people
I-8	Preference for conventional energy and non-consideration of externalities
	Fossil fuel subsidies
I-9	Lack of infrastructure
Financial/Economic Barriers	
F-1	Lack of financial resources and high production costs
F-2	Lack of awareness and interest among financial institutions in the projects
	High risks for investors
F-3	Lack of commercial viability
	Technology imported from industrialized countries more efficient but also more expensive
F-4	Lack of financial institutions to support renewable energy technologies, lack of instruments
F-5	Inappropriate access to information on finances
F-6	Limited size of markets
F-7	Lack of market liberalization and transparency
F-8	Prioritization of large-scale projects
Technological/ Technical Barriers	
T-1	Limited access to technology
T-2	Lack of capacity and knowledge
	Lack of knowledge and expertise on imported technologies
	Lack of skills and know-how for operations, spare parts and maintenance
	Inappropriate access to information on technology
	Insufficient information for technology users
	Unfamiliarity with products and/or resources
	Unfamiliarity with process technology
	Lack of technical knowledge on the target country
T-3	Lack of coordination among research groups, academic institutions and private industry
	Lack of standards, codes and verification, which negatively affects product quality and product acceptability
	Lack of consistency in quality of the product
T-4	Lack of ownership

3. Existing Institutions in Low-Carbon Technology

This section reviews the existing institutions dealing with low-carbon technology, and identifies which of the barriers respective institutions are addressing. We look at the purposes, principles, activities and participants of the institutions, but pay closest attention to their (planned) activities, as purposes and principles sometimes fail to result in actual activities and behaviors. The institutions we are taking up here are 17 technology institutions that are included in the "Governance Triangle" presented by Abbott (2011). The Governance Triangle is a mapping of the emerging system of transnational climate change governance produced by focusing on organizations as the unit of analysis. Organizations are categorized according to the identity of their constituent actors that are centered on state, civil society organizations (CSOs) and business firms. Various types of public and private combinations are configured somewhere in the triangle. By focusing on actors, the Governance Triangle has been able to capture many emerging initiatives, even though their function is just information sharing.

The 17 institutions are, the APP (Asia-Pacific Partnership on Clean Development and Climate), Carbon Sequestration Leadership Forum, GEN IV Nuclear Energy Systems, GBEP (Global Bioenergy Partnership), The Global Gas Flaring Reduction Partnership (GGFR), GMI (Global Methane Initiative), Collaborative Labeling and Appliance Standards Program (CLASP), Climate Works Foundation Best Practices Networks, Global Sustainable Electricity Partnership, IEA, International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE), ISES (International Solar Energy Society), REEEP, REN21 (Renewable Energy Policy Network for the 21st Century), The Roundtable on Sustainable Biofuels (RSB), The Climate Group, and European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP) (Table 2).

We analyzed which of the barriers are addressed by each institution (Table 3). This coding is rather indicative, and not definitive, as some activities fall between two different categories and are hard to classify. We need further in-depth research to identify a linear relationship between the code and activities. Still, these initial results can serve as a first step toward identifying different activities, in terms of barriers, included in each institution in a comparative manner.[*2]

Only a handful of institutions are related to funding, and some of them do not fund on their own but facilitate funding from other sources. None of them explicitly targets removal of risks for investors. Although some include development agencies and multilateral development banks, they do not have the influence to change priority areas of those institutions .

Regulatory support is provided by many of the institu-

Table 2 Seventeen institutions to be addressed in this paper.

Name	Purposes and Targeted Sectors	Actors
APP	Technology cooperation and development over aluminum, buildings and appliances, cement, cleaner fossil energy, coal mining, power generation and transmission, renewable energy and distributed generation, and steel	7 countries and relevant private sectors
Carbon Sequestration Leadership Forum	Technology cooperation and development over carbon capture and storage	Ministers from 21 countries and the European Commission and United Arab Emirates
GEN IV Nuclear Energy Systems	Technology cooperation and development over next-generation nuclear energy system	12 countries and the European Union
GBEP	Cooperation to promote bioenergy	23 countries and 13 international organizations and institutions
GGFR	Technology cooperation to reduce gas flaring	18 countries, 20 oil companies from the developed and developing countries, and 6 organizations including the European Union
GMI	Cooperation to reduce global methane emissions and promote the use of methane as a clean energy source	40 countries and the European Commission, and members from private sectors, universities and non-governmental organizations
CLASP	Cooperation to provide technical and policy support to governments on energy efficiency standards and labeling for appliances, lightning and equipment	(non-profit organization)
Climate Works Foundation Best Practices Networks	Cooperation to reduce greenhouse gas emissions associated with building energy use, through technology cooperation, providing information to governments and the private sector, and advancing policies and programs	(non-profit organization)
Global Sustainable Electricity Partnership	Reflecting global electricity issues within the international framework and promote sustainable energy developments	Comprising electric utility companies from all major regions
IEA	Ensuring reliable, affordable and clean energy	28 member countries
IPHE	Technology cooperation, development and commercialization of hydrogen and fuel cell technologies	17 countries and the European Commission
ISES	Promoting the development and utilization of renewable energy	(non-profit organization)
REEEP	Accelerating markets for renewable energy and energy efficiency, such as by scaling up clean energy business models, particularly in emerging economies and developing countries.	Non-governmental organization funded by 11 countries and the European Commission
REN21	Providing a forum for sharing knowledge and facilitating renewable energy technologies	Non-profit association comprising governments, international organizations, industry associations and civil society
RSB	Cooperation to ensure the sustainability of biofuels production and processing	International initiative coordinated by the Energy Center at EPFL in Lausanne that brings together farmers, companies, non-governmental organizations, experts, governments, and inter-governmental agencies
The Climate Group	Inspiring and catalyzing leadership to reduce greenhouse gas emissions.	(non-profit organization)
ZEP	Promoting, developing, commercializing, and diffusing carbon capture and storage (CCS). ZEP serves as an advisor to the European Commission on the research, demonstration and deployment of CCS.	European utilities, petroleum companies, equipment suppliers, scientists, academics and environmental NGOs

Table 3 Technology institutions and barriers within their scope.

Institutions	Institutional Barriers	Financial/Economic Barriers	Technological/Technical Barriers
APP	I-1, I-2, I-3, I-4	F-1, F-2, F-6	T-1, T-2, T-3
Carbon Sequestration Leadership Forum	I-1, I-3, I-5	n/a	T-3
Council on Global Financial Regulations	n/a	F-4	n/a
GBEP	I-2, I-4, I-8	F-1, F3	T-3
GEN IV Nuclear Energy Systems	n/a	F-1	T-3
GMI	I-2, I-4	n/a	T-3
CLASP	I-2, I-4, I-5, I-7	n/a	T-2, T-3
Climate Works Foundation Best Practice Networks	I-4	n/a	T-3
Global Sustainability Electricity Partnership	I-1, I-2, I-4, I-7	F-2, F-5	T-2, T-3
IEA	I-1, I-4	F-7	T-3
IPHE	I-1, I-6, I-9	n/a	T-3
ISES	I-2, I-4	n/a	T-2, T-3
REEEP	I-1	F-1, F-2, F-6	n/a
REN21	I-1, I-4, I-6, I-7	F-1	n/a
RSB	I-1, I-4	n/a	T-3
ZEP	I-4	F-3	T-2, T-3
The Climate Group	n/a	n/a	T-3

tions in a different way, mainly by providing information related to changing the regulatory framework. Many provide information on best practices or such topics as benefits of FIT in a different manner. Most of the institutions aim to remove capacity and knowledge barriers. Information sharing and knowledge dissemination on emerging low-carbon technology are the major issues that they are working on. International institutions, however, neglect removal of bureaucratic barriers, political instability and corruption, IPR issues and elimination of uncertainties.

As the number of partnerships grows, more and more business actors have been involved in institutions, and growing attention has been paid to market barriers. Here, some institutions explicitly target markets. For instance, the GBEP aims for the commercialization of renewable energy as does the ZEP for commercialization of carbon capture and storage. The REEP supports creation of new forms of business models to make small-sized renewable energy economically attractive. The IEA initiates and monitors key policy issues such as regulatory reform and market liberalisation.

Cooperation on technology innovation is considered part of lowering costs in the long run, and we also counted it as such. However, in reality there are many uncertainties as to whether technology cooperation can lead to lower technology prices in the future. More policy-oriented activities would be needed. The activities of many institutions working on markets are related to raising awareness among market participants.

Regarding technology, some work on standardization, while most others work on capacity and knowledge development, as well as information sharing. Coordination among research groups, academic institutions and industry actors is another major activity.

Overall, these institutions are highly independent, and except for a few cases such as the GMI, there is no conscious linkage or nesting effort with the UNFCCC regime. Their decision-making procedures differ, and their memberships are totally different – some include nation states, while others do not, and some others include NGOs while still others include businesses. Their principles overlap, and they are not explicitly conflictive. Therefore, we conclude that low- carbon technology is in a situation of conflictive fragmentation, but has a potential to be cooperative.

The next question is to what direction we should be proceding from here.

4. Conclusion: the Direction Ahead

We now know that different institutions address different barriers to technology development, and some of their areas overlap, while some others do not. According to recent organizational literature, decentralized and information-rich systems are the best institutional architecture for addressing highly complex and tightly interwoven problems such as climate change (Aggarwal, 1998; Ansell & Weber, 1999; Ostrom, 2001; and Haas *et al*., 2004). Thus, low-carbon technology governance may be best served through fragmentation of governance architecture, but coordinated by a hub that is capable of quickly accessing usable information and transmitting it to the appropriate institutional nodes in the network. We should also be reminded that redundancy can become strengths in such decentralized systems, as redundancy amplifies the political influence of policy networks involved in governance, and also assures that the governance system persists even if one part of the system collapses (Kanie, 2007). As for the networked institutions, such as the 17 institutions identified here, some may need to be integrated and reshuffled to have a stronger institutional backbone. Unnecessary integration is harmful, but communicating with each other to explore mutual benefit is helpful. This insight would gain particular importance with the adoption of the Cancun and Durban agreements at the UNCCC, where countries have agreed to enhance international technology governance further via the Climate Technology Center Network (CTCN).

That said, we still need to understand which functions would be best played by international institutions regarding low-carbon technology that would help facilitate a low-carbon transition on the ground. As we saw above, some of the barriers may be better addressed at the local or national level. Only after understanding this should we consider the configuration and architecture of the institutions.

Suggestions for understanding different functions may be drawn from the existing literature. In the early stages of technology development, the empowerment of a network of local research groups is needed in order to encourage technologies, especially with stronger initiative from the public side (Benioff *et al.*, 2010; Morey *et al.*, 2011; UNFCCC, 2009b). International institutions can play an important role in part by facilitating networking among international and local actors (Benioff *et al.*, 2010; Morey *et al.*, 2011; UNFCCC, 2009b). At the bilateral level, in fact, there have already been several initiatives to build a network among research institutions. For example, there are research agreements between the EU and China as well as between the US and India in the area of clean coal and CCS. At the multilateral level, while there have been no remarkable efforts on the public side, there have been several industry-based programs for several years, including APP as well as specific industry-based programs for technology innovation, such as the Technology Breakthrough Program in the steel sector.

As for financial mechanisms, technology-funding mechanisms for developing country participants, especially in R&D activities, are necessary in the early stages of technology development. In addition, financial mechanisms to provide strong incentives for clean energy incubators, venture capitalists and entrepreneurs are needed to mitigate their business risks and encourage their participation at the deployment stage. However, as stated above, private funding is still difficult to bring in at the deployment stage due to the high risk involved in investment, as illustrated in the "valley of death." The roles of public national institutions in providing financial resources for the R&D are still essential at this stage of technology development.

At the later stages of technology development, providing economic incentives is recognized as an important measure for improving investment conditions and encouraging the participation of the private sector. Clean energy finance and carbon finance vehicles, some of which have already been established by multilateral financial institutions, are effective at introducing technologies at the diffusion stage. For example, economic policy instruments such as CDMs may play an instrumental role at this stage of technology development, while it is not realistic to regard them as a universal policy instrument for diffusing technologies across all stages of technology development. If they are designed well, bilateral carbon crediting mechanisms as well as expansion of project-based CDMs into sectoral or program-based mechanisms can be also a good policy candidate for technology transfer in the post-Kyoto regime.

Figure 2 illustrates several examples of policy options (highlighted in green) and financial mechanisms for the later stages of technology development (highlighted in orange):

By mapping existing institutions combined with functions of international institutions for low-carbon technology and associated with removal of barriers, we may gain a clearer idea of low-carbon technology governance architecture towards cooperative fragmentation.

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Notes

*1 The original version of this figure is contained in UNFCCC (2009b). The authors modified the figure by simplifying the stages of technological development from six stages to four and adding several examples of technologies along the chain. This figure should be treated only as a conceptual flow of technological development. The actual mapping of the technologies depends upon various conditions of a country or region. It is also noted that the stages are not as clearly separated in reality as shown in the figure.

*2 As our primary concern regards developing countries, a project primarily focusing on a developed country was excluded from the assessment. This applies, for example, to some projects under a task force (*i.e.*, coal) of the APP.

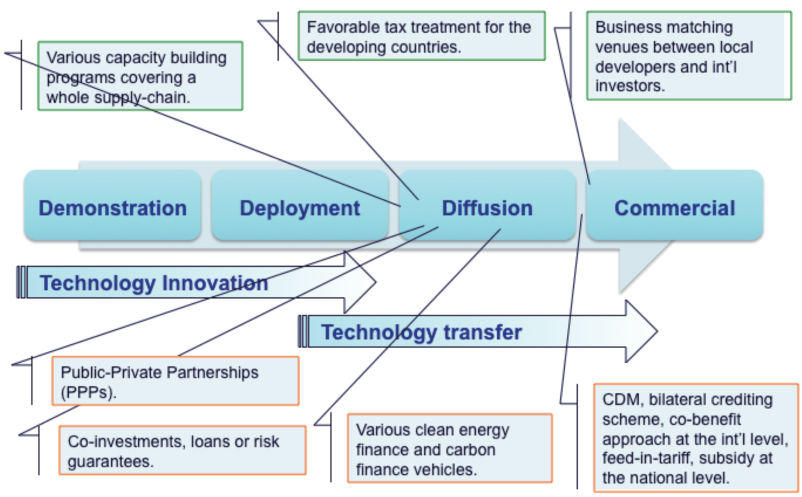

Fig. 2 Policy options and financial mechanisms for the later stages of technology development.

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