Technologies for Adaptation to Climate Change: a Stepchild of International Climate Negotiations

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Contents

1 Introduction

This paper starts from the assumption that the adaptation side of climate-related technologies has so far been underspecified both in scholarly and policy debates. Research gaps include, *inter alia*, the lack of insights into the institutional architecture on adaptation technologies and into context-specific conditions for their diffusion and adoption. The policy gaps, as I discuss in this paper, materialize in a predominant focus of technology debates on mitigation and a lack of detailed guidelines on adaptation.

This neglect may severely undermine adaptation processes across political levels, as technologies may play a crucial role in every step of such processes: from awareness-building and planning to implementation and evaluation. In light of these detrimental consequences, this paper seeks 1. to take stock of the current understanding and treatment of adaptation technologies in international relations, 2. to identify major shortcomings of these approaches, and 3. to discuss suggestions for a more appropriate incorporation of adaptation concerns into technology-related discussions.

The paper's concentration on the international level can explore but one part of the debate. Adaptation is a multi-level process that, ultimately, involves implementation and evaluation at the local level. But the selected focus on international negotiations should be a helpful starting point to approach the issue of adaptation technologies: major programmatic and funding decisions are taken at the international level – and the ongoing negotiation process for a post-2012 climate regime makes it all the more urgent to gain a systematic perspective on core requirements for future adaptation governance.

The paper starts with an introduction of key concepts, i.e. adaptation and adaptation technologies (section 2). It shows that there are no consensus definitions on these issues and makes the case for broad understandings of both terms. It further presents and critically discusses typologies of adaptation technologies which inform current negotiations on a future technology framework. Section 3 continues the conceptual introduction, briefly focusing on synergies, tensions and major differences between mitigation and adaptation technologies. I hold that these differences can be held accountable for the different levels of attention these technologies meet in international negotiations. I scrutinize these negotiations in the two ensuing sections: section 4 attends to existing international institutions on climate-related technologies, while section 5 discusses proposals for a future architecture. Both sections find that adaptation technologies are side-lined and not appropriately incorporated into agendas within and outside the UN climate regime. I therefore argue in favor of elaborate guidelines across arenas which do justice to the peculiarities of adaptation technologies and facilitate a better institutional division of labor. The last section summarizes major findings and concludes with brief considerations on enhancing the role of adaptation technologies in German development assistance.

2 Key Concepts

2.1 Adaptation to Climate Change

Given the plethora of definitions by both scholars and practitioners,[1] there is no consensus understanding of adaptation – indicating that the concept necessarily remains a moving target: a. since it is subject to continuous change, keeping pace with the broadening agenda of climate negotiations, scientific progress and development practice (Horstmann 2008: 3-4); b. since, as I further discuss in this section, a clear-cut distinction of adaptation activities from (sustainable) development is only feasible for a minority of cases.

In an attempt to capture the scope of concepts underlying adaptation projects, McGray et al. (2007: 23) developed a continuum stretching from a science-based concentration on impacts to a social science-based focus on development and vulnerability (see Figure 1). The impacts-oriented end of the continuum reflects a traditional understanding that was predominant, for instance, in 1994 guidelines of the Intergovernmental Panel on Climate Change (IPCC). This category comprises the few stand-alone climate-related activities that can be distinguished from other development strategies. "Adaptation was discussed as a kind of 'retrofitting' of development planning to expected future climate change impacts, and it focused on technological solutions such as irrigation schemes or construction of higher dams" (Horstmann 2008: 29).

This paper takes a broader, development-oriented view which covers the whole spectrum displayed in the Figure 1. There are various reasons for adopting this perspective. First, the impacts-based approach has drawn criticism due to the uncertainty and lack of knowledge about regional or local impacts of climate change. Given this uncertainty, artificially separating adaptation from other strands of development activities would provide but little incentives for developing countries to dedicate financial resources to address these impacts (Horstmann 2008: 29-30). Second, the vulnerability-based approach reflects the reality of the bulk of adaptation projects today. Most of them are cross-cutting and cannot be attributed to just one of the four types in Figure 1. They hence hardly differ from development projects:

[1] For an overview of these different understandings, see Horstmann (2008: 7-27).

"the majority of cases utilize methods and approaches that come straight out of the development toolbox" (McGray et al. 2007: 14). Third, a wider concept captures a broader scope of technologies and thus allows for a more comprehensive analysis of relevant policy discourses.

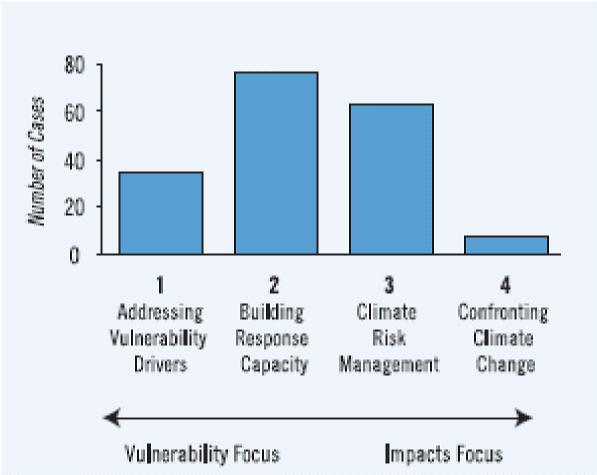


Figure 1: Characterization of Projects by Adaptation Type (Mc Gray et al. 2007: 23).

While the impacts-based approach views vulnerability as the end point of the analysis, the vulnerability-based perspective takes it as a starting point and assumes the complementarity or interplay of climate variability and non-climatic stressors (Horstmann 2008: 29-30). Taking vulnerability as a starting point entails a different type of adaptation objectives, namely "to reduce the vulnerability of individuals and communities by building on and strengthening their coping mechanisms with specific measures and by integrating vulnerability reduction into wider policies" (CIDSE & Caritas 2009: 9). Depending on the proportion by which climate variability is considered, entry points of adaptation projects may vary (see types 1-3 in Figure 1): they either focus on livelihoods (trying to tackle climatic and non-climatic vulnerability drivers), on building local response capacities, sensitivity and local empowerment, or on risk management and early warning (Eriksen & Naess 2003: 13).

The different understandings of adaptation entail different degrees of integration of adaptation activities into development action – and, importantly for the purpose of this paper, different priorities for relevant technologies. An impacts-based perception is likened to a 'mainstreaming minimum' approach with a strong focus on climate-proofing technological and infrastructural investments. The paramount objective "is to ensure that climate risks […] are incorporated into sectoral planning and decision-making. This means that there are ambitious information requirements for these tools to work effectively" (Scholz & Klein

2008: 7). The associated technological needs comprise information technologies to define the impacts of global warming and technological alternatives to do justice to changed natural conditions.

On the other hand, a vulnerability-oriented understanding forms the basis for a comprehensive 'mainstreaming plus' approach which goes beyond climate-proofing (Scholz & Klein 2008: 7). It opens a much broader scope of relevant technologies, staying abreast of the uncertainties climate impact projections. Klein & Persson (2008: 3) identify three elements of this extended scope. First, technological adaptation measures also need to address non-climatic factors that contribute to vulnerability to climate change, e.g. ensuring access to and equitable distribution of benefits yielded by a certain technology. Second, these measures need to be suited to local conditions, e.g. taking into account conditions for their acceptance in an affected community. Third, they need to recognize relevant social and environmental processes to avoid maladaptation, for instance, to avoid that irrigation measures lead to groundwater salinization and wetland degradation.

In short: adaptation technologies largely coincide with technologies designed for other development objectives; the discussion about their research, development or transfer should hence not succumb to the pitfall of unrealistic additionality debates, but rather target effective coordination and mainstreaming of adaptation technology policies into overall technological strategies. By the same token, it would be more adequate to speak of 'technologies for adaptation to climate change' instead of 'adaptation technologies'. Yet for simplicity's sake, I use both terms interchangeably in this paper. The 'mainstreaming plus' approach can facilitate a reduced vulnerability of populations with regard to impacts of climate change, a more effective and efficient use of available resources, including technologies, and, last but not least, less negative effects of development on adaptation, and vice versa (BMZ 2009: 6).

The last point stresses that both types of activities are not necessarily mutually supportive. Maladaptation can cut both ways. Projects to reduce poverty may increase vulnerability, e.g. infrastructure investment in disaster-prone areas. Likewise, adaptation measures can have adverse impacts on development, e.g. when shifting to climatically well-adapted crops that yield lower prices in the market (Horstmann 2008: 32-33; cf. Adger et al. 2003; Eriksen & Kelly 2007).

By adhering to a vulnerability-based approach, this section has stressed that adaptation is ultimately a local process, since it should account for the social, environmental and economic conditions of areas where climate impacts are felt. Vulnerability assessment, hence, starts

with the analysis of key vulnerabilities of regions and communities, of the consequences of climate change for these communities and, subsequently of their technological needs.
This notwithstanding, decisions on adaptation technologies are not only taken at the local level.

> "Effective adaptation […] requires simultaneous actions from all levels – individuals, communities, development agencies, private companies and, importantly, government and public bodies at all levels. Local adaptation efforts should be provided with support and guidance from national policies and programmes, and national efforts should be supported by cooperation at the international level" (CIDSE & Caritas 2009:9).

Based on this rationale, the following sections put specific emphasis on conceptual discussions and policy options at the international level.

2.2 Adaptation Technologies

In this section, I discuss distinctive criteria for illustrating the scope of adaptation technologies**,** depending on their material character (soft, hard), their role in different stages of the adaptation process and their suitability for certain sectors. In the last sub-section on sectors, I list examples for such technologies.[2]

2.2.1 Soft and Hard Technologies

This paper also adheres to a broad definition of the second key term, i.e. 'technology', in line with scholarly consensus expressed by the IPCC. In 2000, in its special report on technology transfer, the panel defined technology as "a piece of equipment, technique, practical knowledge or skills for performing a particular activity".[3] Elaborating on this definition, the Fourth Assessment Report (AR4) stressed the soft-hard duality: exceeding or complementing a traditional understanding of technology as tangible hardware, the term also comprises know-how and organization (i.e. management approaches that link hardware and know-how (Meyer-Stamer 1996:6-7). Accordingly, technology is defined as "[t]he practical application of knowledge to achieve particular tasks that employs both technical artefacts (hardware, equipment) and (social) information ('software', know-how for production and use of artefacts)" (IPCC 2007: 821).
Examples for hard adaptation technologies include drought-resistant seeds, seawalls and irrigation equipment while soft technologies are, for instance, insurance schemes (inasmuch as they incorporate elements of awareness building and information dissemination) and crop

[2] A further classification not presented here refers to the spatial scope of technologies, distinguishing between regional, national and local levels (UNFCCC 2007: 12-14).
[3] Quoted in UNFCCC (2006: 11).

rotation patterns. "A successful adaptation strategy would typically combine both hard and soft technologies. For example, an early warning system would rely on hard technologies such as measuring devices and information technology, but also on knowledge and skills to strengthen awareness and promote appropriate action when a warning is given" (UNFCCC 2006: 18).

2.2.2 Traditional, Modern, High and Future Technologies

As a second typological approach, the Climate Change Secretariat mapped adaptation technologies according to four not mutually exclusive categories (UNFCCC 2006: 18):

- *Traditional technologies* are approaches "that have been developed and applied to adapt to weather hazards in traditional societies." Examples include the use of herbal medicine or the design of buildings to ensure cool or warm interiors. These locally confined technologies are not carved in stone, but are subject to constant change, adapting to new conditions over decades or centuries (e.g. new varieties of natural treatments).
- *Modern technologies* "have been newly created since the industrial revolution […] have been commercialized and are widely, though not universally, available." Examples include synthetic materials (e.g. plastics, fabrics), chemicals, crop varieties (e.g. hybrid corn) and water use technologies (e.g. drip irrigation).
- *High technologies* "are some of the more recently developed technologies that derive from scientific advances in recent decades". They include, for example, information and communication technology, earth observation systems and genetically modified organisms.
- *Future technologies* "are those that are yet to be invented or developed", e.g. a malaria vaccine or crops that need little or no water.

Each of these technologies can exert an important function in a particular adaptation activity. The exact role depends on the actual impact of climate change and the social, economic and environmental conditions in a given context. A major challenge is to combine these different elements, especially to integrate traditional knowledge and insight from affected communities into modern technically based systems (CIDSE & Caritas 2009: 11).

When approaching this UNFCCC typology with a critical lens, one may question the linear understanding of technological development that is implied here. In practice, one rather finds mixes of these types, for instance, traditional technologies that have come to include modern or high-tech elements. This UNFCCC Secretariat's teleological view on this matter contradicts a more elaborate paradigm of development which has moved away from treating industrialized countries as undisputed role models for catch-up development – the more so when it comes to anthropogenic climate change (Bauer and Richerzhagen 2007). In fact, this perspective might constitute a barrier to technology adoption in its own right, since its evolutionist bias ignores the context conditions in a particular country or community which significantly shape such adoption processes (Meyer-Stamer 1996: 152).

2.2.3 Stages: Technological Maturity and Role in the Adaptation Process

One may also distinguish technologies according to their stage of maturity, i.e. their position on the progressive line between the research and development stage and extensive availability. With a view to the complexity of the innovation process, the idea of such a linear succession of technological stages is certainly an oversimplification – yet nonetheless one of heuristic value when trying to compare different adaptation technologies.

The UNFCCC (2009: 16) differentiates between five major stages of technological maturity and respective barriers:

- *Research and development:* "the technology is at the stage of conceptual design or testing at the laboratory or at the bench scale"; possible barriers may concern the proof of concept and to technical challenges;
- *Demonstration:* "involves full-scale implementation of a limited number of installations by a small number of companies or research facilities"; this process shall provide information on costs and performance of a technology;
- *Deployment:* a technology at this stage "is available for selected commercial applications but is more costly than the established technology"; hence, buyers and owners must be given additional incentives, e.g. financial governmental support;
- *Diffusion / transfer:* a technology at this stage is fully "competitive with the established technology", if equivalent policy is taken into account; barriers might still exist however, e.g. regarding the economic environment or social and cultural acceptance;
- *Commercially mature stage:* a technology is fully competitive with an established technology in terms of costs and performance; no public support (e.g. feed-in tariffs) is needed; as for barriers, it might have to overcome market failures and specific transaction costs.

This mapping of five stages was developed for mitigation technologies. The stages hence only apply to adaptation technologies to a certain extent. For instance, competitiveness with established technologies might play a minor role, at least in poorer societies where technological alternatives for an identical purpose are not available. Moreover, the research and development stage is hardly relevant for traditional technologies which have developed over a long period of time, and clearly outside any research laboratory. In the same vein, many adaptation technologies are already known, inexpensive and available (CIDSE & Caritas 2009: 4). "[E]xamples abound within developing countries of successful implementation and operation" (UNFCCC 2006: 21), with technologies being tailored to the local environment and socio-economic circumstances where they have been developed.

However, while adaptation technologies are rich in variety, people are not making satisfactory use of it. Unlike for mitigation technologies, stronger emphasis should be put on adoption processes "to expand the range of adaptation possibilities by expanding opportunities or reducing costs" (Smith et al. 2009: 58). Technology adoption however is a multi-conditional process that, *inter alia*, implies complex and protracted forms of learning, e.g. through enhanced understanding, application and interaction among users (Meyer-Stamer 1996: 145). Strategies for the adoption of adaptation technologies need to facilitate these learning processes and identify potential barriers which prevent such internalization, e.g. trajectories or mind-sets or the aforementioned neglect of context conditions in given countries, regions or sectors (ibid.: 146, 152).

In light of these considerations, it is more suitable to apply a different typology of stages, not so much regarding the maturity of technologies, but their roles in the adaptation process. Successfully identifying this role "may well include actions that are directed at improving prevailing social, economic and environmental conditions and management practices in a system or sector" (UNFCCC 2006: 6). Altogether, technologies can perform functions in a four-stage process (ibid.: 19):

- *Information development and awareness:* "technologies for data collection and information development are prerequisites for adaptation, particularly to identify adaptation needs and priorities";
- *Planning and design:* technologies can be helpful for selecting the right adaptation strategy; or they can be subject to the selection process, based on criteria like cost-effectiveness, environmental sustainability, cultural compatibility and social acceptability of a strategy and the associated technologies;
- *Implementation and adoption:* any mix or hybrid of technologies listed in the previous section (traditional, modern, high, future) can be part of an adaptation strategy in its implementation and adoption stage; one of the critical requirements for the success of

this stage "is the presence of appropriate and effective institutions" which facilitate the learning and application processes; these institutions as well as other adoption-conducive contexts may vary widely across scales and sectors;

- *Monitoring and evaluation:* the performance of technologies should be periodically or continuously evaluated; on the other hand, certain technologies are instrumental for carrying out such evaluation processes.

2.2.4 Sectors: Coastal Zones, Water Resources, Agriculture, Public Health and Infrastructure

The broad understanding introduced above covers a wide array of technologies, often not distinguishable from technologies employed to enhance sustainable development. Given this breadth, the following overview of sectors and examples necessarily falls short of an exhaustive account, but can serve as an illustration of the scope of adaptation technologies for different sectors[4]. The five sectors presented here are based on a differentiation underlying a comparative study commissioned by the UNFCCC (2006: 6-8; cf. CIDSE & Caritas 2009: 13-19). They are not meant to be mutually exclusive. For example, infrastructure measures also apply to the other four sectors.

With regard to **coastal zones**, an effective reduction of vulnerability to weather-related hazards – such as storm surges, cyclones, flooding and coastal erosion – can to a great deal rely on existing management practices, inasmuch as these are adjusted to local needs. But to this end, existing (as well as new) technologies need to address or control non-climatic stresses when seeking to reduce vulnerability. Different equipments and forms of knowledge are required depending on the adaptation strategies communities choose to pursue: "to retreat (planning for relocation and emergency management), to accommodate (improving existing infrastructure) and to protect (planning and regulation to protect vulnerable zones)" (CIDSE & Caritas 2009: 13):

Since the impacts of climate change in coastal zones largely affect collective goods and systems under governmental jurisdiction, the public sector plays a key role in the implementation of these strategies. It usually prioritizes hard technologies for the implementation process. Yet in addition, soft skills as developed by affected communities can play a crucial and complementary role. Aside from modern technologies, traditional ones such as afforestation can help enhance resilience (CIDSE & Caritas 2009: 13-15).

[4] The following listings by the UNFCCC (2006a) partly blur the frontiers between adaptation technologies and options. For a more consistent overview focusing particularly on technologies, see Appendix I, featuring a list collated by the UNFCCC Expert Group on Technology Transfer.

Protect	Retreat	Accommodate
• *Hard structures* – dykes, sea-walls, tidal barriers, detached breakwaters • *Soft structures* – dune or wetland restoration or creation, beach nourishment • Indigenous options walls of wood, stone or coconut leaf, afforestation	• Establishing set-back zones • Relocating threatened buildings • Phasing out development in exposed areas • Creating upland buffers • Rolling easements	• Early warning and evacuation systems • Hazard insurance • New agricultural practices, such as using salt-resistant crops • New building codes • Improved drainage • Desalination systems

Table 1: Examples of Adaptation Technologies for Coastal Zones (UNFCCC 2006a: 13)

Regarding **water resources**, climate change can have an impact both on water supply (e.g. through changes of precipitation patterns which in turn affect flood protection, food production, etc.) and water demand (e.g. through increases in average temperatures which induce growing demand for potable water) (see Table 2). Adaptation technologies can help "not only to allow access to water for poor communities but also to ensure sustainable and integrated watershed management" (CIDSE & Caritas 2009: 15). Hard technologies are needed, for example, to build new infrastructure such as reservoirs, whereas soft ones include, *inter alia*, the introduction of new pricing forms to incentivize behavioral changes (CIDSE & Caritas 2009: 16).

Use category		Supply side	Demand side
Municipal or domestic		• Increase reservoir capacity • Desalinate • Make inter-basin transfers	• Use "grey" water • Reduce leakage • Use non-water-based sanitation • Enforce water standards
Industrial cooling		• Use lower-grade water	• Increase efficiency and recycling
Hydropower		• Increase reservoir capacity	• Increase turbine efficiency
Navigation		• Build weirs and locks	• Alter ship size and frequency of sailings
Pollution control		• Enhance treatment works • Reuse and reclaim materials	• Reduce effluent volumes • Promote alternatives to chemicals
Flood management		• Build reservoirs and levees • Protect and restore wetlands	• Improve flood warnings • Curb floodplain development
Agriculture	Rain-fed	• Improve soil conservation	• Use drought-tolerant crops
	Irrigated	• Change tilling practices • Harvest rainwater	• Increase irrigation efficiency • Change irrigation water pricing

Table 2: Examples of Adaptation Technologies for Water Supplies (UNFCCC 2006a: 18)

The challenge is to combine these efforts in a meaningful and effective way to facilitate the mainstreaming of adaptation strategies into sustainable development efforts. For instance, building communities of practice around integrated water resources management can promote the diffusion and use of "information technologies (remote sensing, forecasting) […] and tools that support decision-making (e.g. scenario-driven processes and multicriteria assessment technologies)" (UNFCCC 2006: 7).

As for **agriculture**, the mix of technologies equally depends on the selected response strategy (see Table 3). Hard technologies may be employed, for example, for flood control, drainage, irrigation, and the introduction of diversified crop varieties with greater tolerance to drought or salty condition. Soft technologies, on the other hand, "include capacity building and training in extension services, farmer education on applied scientific research and new agricultural practices" (CIDSE & Caritas 2009: 16). These approaches need to be cost-effective in order to surmount barriers to technology transfer such as the lack of financial and human capital (UNFCCC 2006: 7). Traditional technologies play a crucial role in this sector. They include soft skills such as community experiences of dealing with droughts, floods and salinity, e.g. floating agriculture and diversification of cropping patterns. Supporting such technologies may "contribute to the empowerment of rural communities by respecting traditional knowledge and local innovation" (CIDSE & Caritas 2009: 16).

Response strategy	Some adaptation options
• Use different crops	• Carry out research on new varieties
• Change land topography to improve water uptake and reduce wind erosion	• Subdivide large fields • Maintain grass waterways • Roughen the land surface • Build windbreaks
• Improve water use and availability and control erosion	• Line canals with plastic films • Where possible, use brackish water • Concentrate irrigation in periods of peak growth • Use drip irrigation
• Change farming practices to conserve soil moisture and nutrients, reduce run-off and control soil erosion	• Mulch stubble and straw • Rotate crops • Avoid monocropping • Use lower planting densities
• Change the timing of farm operations	• Advance sowing dates to offset moisture stress during warm periods

Table 3: Examples of Adaptation Options for Agriculture (UNFCCC 2006a: 23)

Impacts of climate change on **public health** are highly complex, due to a variety of causal factors. They call for a comprehensive and coordinated set of adaptation strategies across all political levels (from community to international level) and social functions and fields (legislative, technical, educational and cultural options) (see Table 4).

These strategies have to aim for a strengthening of public health systems – both through hard technologies (e.g. for urban planning, sewage and solid waste management as well as improving water treatment and sanitation systems) and soft ones (e.g. diverse hygiene measures, health education programs, disaster preparedness plans). Early warning systems – often a combination of soft technologies (e.g. knowledge and skills to strengthen awareness) and hard technologies (e.g. measuring devices) – can be instrumental in preventing the spread of diseases, depending on the effectiveness of diseases surveillance and control programs (CIDSE & Caritas 2009: 18; UNFCCC 2006: 7).

Health issues	Legislative options	Technical options	Educational and advisory	Cultural and behavioural
• Extreme weather events including thermal stress	• New planning laws • New building guidelines	• Urban planning to reduce heat island effects • Air conditioning	• Early warning systems	• Using appropriate clothing • Taking siestas in warm climates • Using storm shelters
• Air quality	• Emission controls • Traffic restrictions	• Improved public transport • Catalytic converters • Tall chimneys	• Pollution warnings	• Carpooling
• Vector-borne diseases		• Vector control • Vaccination, impregnated bednets	• Health education	• Greater care with water storage
• Waterborne diseases	• Watershed protection laws • Water quality regulation	• Genetic/ molecular screening of pathogens • Improved water treatment and sanitation	• Boil water alerts	• Washing hands and other hygiene behaviour • Using pit latrines

Table 4: Examples of Adaptation Options for Health (UNFCCC 2006a: 29-30)

Finally, with respect to **infrastructure**, a variety of technologies are needed, depending on the size of affected settlements (from small villages to mega-cities) and the type of infrastructures (e.g. power supply, transportation systems, waste disposal, etc.). Hard technologies contribute to improving energy efficiency and public transport systems, while soft ones may include "land-use planning, environmental assessment, education, awareness raising, poverty alleviation and administrative reforms" (CIDSE & Caritas 2009: 19). An integrated governance structure is vital to ensure success of adaptation in infrastructure and urban environments, based on improved awareness-building and involvement throughout government as well as private and community groups (UNEP 2006: 7-8).

Hard technologies	Soft technologies
Building sector	
• Lay out cities to improve the efficiency of combined heat and power systems and optimize the use of solar energy • Minimize paved surfaces and plant trees to moderate the urban heat island effects and reduce the energy required for air conditioning	• Limit developments on flood plains or potential mud-slide zones • Establish appropriate building codes and standards • Provide low-income groups with access to property
Transportation sector	
• Cluster homes, jobs and stores • Control vehicle ownership through fiscal measures such as import duties and road taxes as well as through quotas for vehicles and electronic road pricing • Develop urban rail systems	• Promote mass public transportation • Use a comprehensive and integrated system of planning • Link urban transport to land-use patterns
Industrial sector	
• Use physical barriers to protect industrial installations from flooding	• Reduce industrial dependence on scarce resources • Site industrial systems away from vulnerable areas

Table 5: Examples of Infrastructure Technologies for Adaptation (UNFCCC 2006a: 35)

As to the **current use** of the aforementioned technologies, a 2007 report by the Climate Change Secretariat indicates a dominance of the agriculture and water resources sectors. The report summarizes submissions by 13 Annex I parties and nine non-Annex I parties. It further shows that parties provided roughly equal reporting on hard and soft technologies (Figure 2). However, one should treat the findings with caution in a development context, given the low number of data from non-Annex I parties.

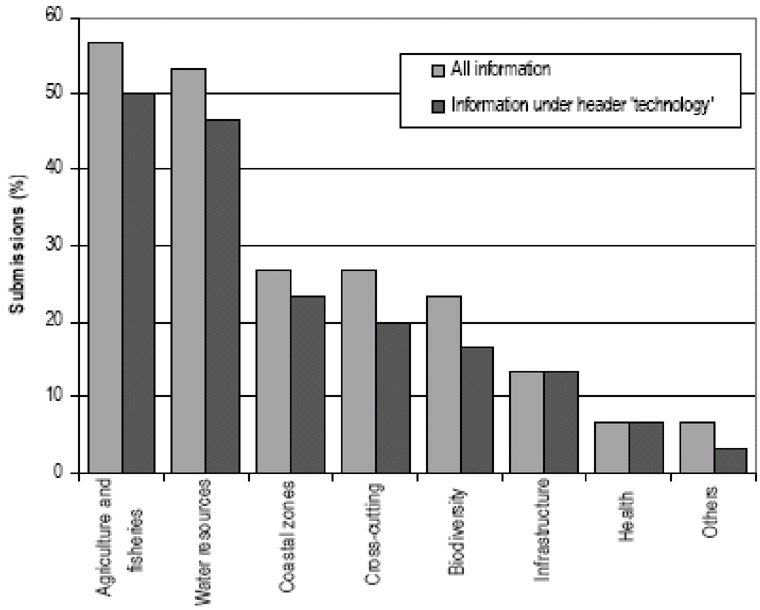


Figure 2: Commonly Reported Sectors for Technologies for Adaptation
(UNFCCC 2007: 7)

2.2.5 Summary: Principles and Requirements

Based on the previous conceptualization and overview, I conclude this section by summarizing core qualities of adaptation technologies as stressed by the UNFCCC (2006: 21, 2007: 15-17) and the report by CIDSE & Caritas (2009: 19):

- Sectors that need technology for adaptation are ubiquitous.
- Most technologies for adaptation are already available in developing countries. Strategies should hence promote the adoption of these technologies, by facilitating information exchange and learning processes.
- This focus on adoption notwithstanding, technology transfer is also important for adaptation efforts, e.g. for water management desert greening, etc.
- There is still inadequate allocation of resources for implementation of adaptation technologies. These resources should target capacity-building, technical assistance as well as information and awareness-raising to tackle the predominant concerns and barriers for technology deployment.
- Adaptation technologies should do justice to the environmental, ethical, cultural, social and economical aspects of communities and their wider development needs, and where possible, empower the most vulnerable communities (e.g. traditional technologies based on indigenous cultural knowledge). The stakeholders involved will differ significantly across sectors and communities.
- Technologies should avoid maladaptation. They should allow access to information on potential impacts of climate change and reduce vulnerability and strengthen people's resilience to extreme weather events.
- Most needed technologies for adaptation are not likely to be as capital-intensive as those for mitigation, since they tend to be more amenable to small-scale intervention.
- Technologies should provide synergy with mitigation (see next section).

3 Adaptation and Mitigation Technologies: Synergies and Tensions

Aside from the relationship between adaptation and development (see section 2.1), a second pairing of concepts should be taken into account: "In order to ensure sustainable development, the synergies between adaptation and mitigation technologies should be strengthened" (CIDSE & Caritas 2009: 12). There is large potential for synergies, e.g. in the agriculture and forest sectors. Organic farming and the conservation of agricultural and forest biodiversity not only contribute to food security, but also assist in reducing greenhouse gas emissions through traditional knowledge and local innovation (cf. Neubert & Speranza 2009); for instance: incentivizing the introduction of fuel-efficient stoves in conjunction with reforestation (thereby promoting indigenous species and integrating reforestation within an agricultural system) (CIDSE & Caritas 2009: 12-13).

On the other hand, similar to the relation between adaptation and development, tensions may occur. A prominent example is the construction of hydropower dams. While reducing greenhouse gas emissions (by substituting carbon-intensive electricity sources), dams might induce maladaptation (e.g. by threatening livelihoods and exerting detrimental effects on ecosystems, such as loss of biodiversity, forests, wetlands and wildlife habitats as well as causing salt water intrusion into estuaries) (WCD 2000: 81).

Beyond these synergies and tensions, encompassing strategies need to take into account core differences between both types of technologies. This starts with their different quality in terms of private or public goods. Most mitigation technologies, inasmuch as they were developed by companies, are private goods, i.e. they are characterized by rivalry in consumption and excludable benefits (Samuelson 1954).[5] On the other hand, adaptation technologies tend to be public goods, in particular soft and traditional technologies whose benefits are shared by entire communities. This aspect is connected to the aforementioned observation that most adaptation technologies, rather than mitigation technologies, are already available – their core challenge being less one of innovation (e.g. by private companies) than one of proper distribution, choice and application.

These different qualities of technologies have implications for their financial support and their legal status. With respect to mitigation technologies, most of the financing resources (probably over 60 per cent) for development and transfer are provided by businesses. About 90 per cent of technology development is concentrated in the US, the EU, Japan and China (UNFCCC 2009: 6). The bulk of financing for adaptation technologies, on the other hand, will come from public sources and is likely to be included in adaptation project spending.

This constellation entails different incentive structures and, supposedly, a concentration of efforts on mitigation technologies in specific countries. Industrialized countries and leading developing countries (such as Brazil, China, India, and South Africa) share an interest in low-carbon development and associated investment opportunities. For private companies that develop respective technologies, the growth rates, mitigation potentials and enabling environments of newly industrialized countries promise considerable investment returns. On

[5] The concept of public goods has been further developed, e.g. by Kaul et al. (2003: 24) who introduced a "triangle of publicness", distinguishes goods according to their publicness in consumption, publicness in decision-making and publicness in the distribution of net benefits.

the other hand, the necessary funding processes for adaptation technologies, would largely be similar to those of financial aid, especially when targeting least developed countries. They would not yield investment returns and thus call for a much stronger effort from public donors.[6]

Moreover, the prominent role of companies and private ownership induced a debate on intellectual property rights (IPR) of mitigation technologies. Both in the World Trade Organization (WTO) and in the United Nations climate regime, developing countries[7] called for a relaxation of IPR systems, arguing that such systems render the acquisition of technologies more costly. However, concerned about potential losses for their patent-holding companies, industrialized countries rejected such an idea. They argued that IPR systems are beneficial for all sides, as they protect innovators, prevent industry piracy, and may therefore induce technological research development (cf. Fritz Carrapatoso 2009: 5; Meyer-Ohlendorf & Gerstetter 2009: 23ff.; Santarius 2009: 27). Altogether, experts still disagree whether, on balance, an easing of IPR systems might help or hinder the transfer of climate-friendly technologies (Barton 2007; Littleton 2008: 7-19; Shrivastava & Goel 2010[fc.]; Mani 2009: 37-38). Unlike mitigation technologies, the debate has concerned adaptation technologies to a lesser extent so far. Exceptions mostly relate to the agricultural sector, since the WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) explicitly protects private breeders' patent rights over plant genetic resources – including, for instance, drought-resistant crops (Goodman 2009: 8-16).

Finally, a major difference between both types of technologies regards estimates of their financial needs. As for adaptation technologies: given the diverse understandings of adaptation, the overlap between adaptation and development activities, and the high uncertainty over concrete impacts of climate change in a given area, estimates are highly imprecise. The UNFCCC (2009: 6) vaguely speaks of "between tens and hundreds of billions of USD per year." On the other hand, projected future spending needs for the development, deployment and diffusion of mitigation technologies are more exact – although still spanning considerable range: they stretch from 262 and 670 billion USD per year (UNFCCC 2009a: 24).

In light of the discussed synergies, tensions and differences, the challenge for policy-makers is to facilitate a path towards both low-carbon and climate-resilient development. At the

[6] See next section on the state of international negotiations on adaptation technologies.

[7] India and Pakistan led these debates for the G-77, whereas some developing countries, in particular China and other Asian rapidly industrializing countries, have a slightly more moderate position on this matter (ICTSD 2008: 6).

international level, such a broad approach calls for better coordination of programmatic and financing efforts on mitigation and adaptation technologies. At the domestic level, it would imply dovetailing implementation and assessment of mitigation and adaptation activities – for instance, by building sustainability criteria into innovations systems (cf. Stamm et al. 2009: 30-36). The next section discusses to what extent such an integrated approach has already emerged in international climate governance – i.e. an architecture suitable to promote environmentally sound technologies, not only low-carbon technologies (UNFCCC 2006: 11),

4 Current Governance Architecture on Adaptation Technologies

In this section, I show that the international architecture addressing adaptation technologies is highly fragmented. Such a patchwork is unavoidable since technologies may touch upon different sectors and respective policy fields, e.g. industries, research, education, agriculture or trade (Meyer-Stamer 1996: 9-10). Yet even when taking this cross-cutting character into account, the institutional patchwork and its lack of coherence is striking – both within and outside of the UN climate regime.

4.1 Negotiations under the UN Climate Regime

> "The UNFCCC has so far failed to adequately address adaptation technologies. There is a risk that unless adaptation technologies feature more prominently in negotiations, the technology needs of the poorest and most vulnerable will be overlooked, further undermining their livelihoods." (CIDSE & Caritas 2009: 22)

There is no single setting in climate negotiations that dedicates specific attention to adaptation technologies. Instead, the topic is discussed in both the negotiating track on technology and the one on adaptation, in a variety of contact groups and bodies.

The agendas of technology-related debates feature a prevalence of mitigation issues, especially the promotion of research and development in leading developing countries. These debates take place, in the convention's two subsidiary bodies, in particular in the Expert Group on Technology Transfer (EGTT) under the Subsidiary Body for Scientific and Technological Advice (SBSTA). In 2001, the Conference of the Parties (COP) of the UNFCCC adopted a technology transfer framework (Decision 4/CP.7). The framework focuses on a set of activities under key thematic areas; these include: technology needs assessments (TNAs), technology information (to be fed into the clearing house TT:CLEAR), enabling environments, capacity-building and transfer mechanisms. Building on this framework, the EGTT drafted a strategy paper and a report for COP 15 in December 2009.

Both documents include recommendations on enhancing the development, deployment, diffusion and transfer of technologies (UNFCCC 2009a, 2009b). While distinguishing between mitigation and adaptation technologies and providing a list of the latter, the bulk of the two documents concentrates on low-carbon development. Still, the reports' explicit passages on adaptation technologies signal that a shift of attention has taken place in recent years. The increasing focus on adaptation technologies is also visible in the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA). Pursuant to the Bali Action Plan, the working group's agenda items also include financing and enhanced action on adaptation technologies (UNFCCC 2009c).

In the adaptation track, the 'Nairobi Work Programme on impacts, vulnerability and adaptation to climate change' lists adaptation technologies as one of its nine work areas. The program shall assist parties in improving their understanding and assessment of adaptation needs. However, it does not provide major funding for the implementation of respective strategies. The program's mandate refers to both hard and soft technologies, one of its goals being: "promoting research on adaptation options and the development and diffusion of technologies, know-how, and practices for adaptation" (COP Decision 2/CP.11). Based on this mandate, the SBSTA invited parties and relevant organizations to provide structured submissions which were summarized in a synthesis report on technologies for adaptation (UNFCCC 2007).[8]

Yet apart from the mandate of the Nairobi Work Programme, negotiators in the UN climate regime have put strong emphasis on hard technologies whereas insufficient attention is given to soft technologies (CIDSE & Caritas 2009: 23). This skewed focus is reflected in two types of country reporting documents. In national adaptation programs of Action (NAPAs), least developed countries may identify priority activities to respond to their urgent and immediate adaptation needs. In their TNAs, developing country parties are encouraged to undertake analyses of context-specific technology needs.[9] In both types of reports submitted to the UNFCCC Secretariat to date, parties mostly concentrate on hard technologies. What is more intriguing, the information provided in both types of reports is not coherent, as parties refer to very different sets of adaptation technologies: "only 15 of 165 technologies for adaptation were identified by both NAPAs and TNAs" (UNFCCC 2009: 7).

[8] I have referred to the findings of this report in chapter 2.

[9] TNAs also form part of the Strategic Programme on Technology Transfer, launched at COP 14 in Poznań, which seeks to promote the piloting of technology projects and the dissemination of successfully demonstrated technologies.

All in all, the lack of a comprehensive approach under the UNFCCC umbrella has prevented parties from identifying and addressing coherent strategies towards adaptation technologies. Negotiators have not sufficiently attended to issues like financing, capacity-building, intellectual property rights or awareness-building with a view to the development and adoption of these technologies.[10]

4.2 Multilateral Technology Cooperation Outside of the UN Climate Regime

In addition to the UN climate regime, a number of climate-related multilateral governance arrangements have evolved in recent years. Most notably, the previous US administration under George W. Bush launched several agreements on sectoral technology cooperation. These initiatives often involve companies as direct or associate members, thereby constituting public-private partnerships. Chief examples are the Asia-Pacific Partnership on Clean Development and Climate (APP), the Carbon Sequestration Leadership Forum (CSLF), the International Partnership for a Hydrogen Economy (IPHE), and the Methane to Markets Partnership (MMP) (McGee and Taplin 2009: 220ff.; Ott 2007: 18; cf. van Asselt and Karlsson-Vinkhuyzen 2009). Moreover, the Bush government initiated the Major Economies Process on Energy Security and Climate Change, which held its first meeting in Washington, DC in September 2007 (White House 2007).[11] These various partnerships are merely loosely connected to the UN regime, often consciously avoiding closer ties. Some scholars therefore argue that they are partly designed to be alternatives to the UN climate regime (van Asselt 2007; Biermann et al. 2009[fc.]; McGee and Taplin 2006, 2009: 221-228).

Another forum is the Informal Trade Ministers' Dialogue on Climate Change. It was initiated by the Indonesian government during COP 13-CMP 3 in Bali in December 2007, marking the first time that trade ministers attended climate regime negotiations. Yet the dialogue only involved trade representatives and missed the opportunity for a broader, cross-ministerial session with environment or development communities. Similarly to the aforementioned initiatives, most representatives came from developed and leading developing countries.

[10] In addition, there are general deficits of existing technology-related mechanisms under the UN climate regime which concern mitigation technologies as well as adaptation technologies. They give limited support for technologies in demonstration and deployment phases (the so-called 'valley of death' stages) and do not explicitly provide resources for technology transfer. Moreover, they only support about half of the technologies that developing countries need (UNFCCC 2009: 8).

[11] In April 2009, the process was continued by the new US administration under President Obama as 'Major Economies Forum on Energy and Climate'. It is too early to ascertain whether and how the change in US government will affect the design and goals of this forum (http://www.globalclimatelaw.com/2009/04/articles/ environmental/ major-economies-forum-on-energy-and-climate-to-address-emissions-targets-clean-energy-tech-more/; accessed 12 August 2009).

Participants explored, *inter alia*, the removal of trade barriers for varied climate-friendly goods and services, including mitigation technologies (ICTSD 2007).

All in all, the last years have been witnessing an emerging 'club culture' targeting enhanced North-South trade flows of hard mitigation technologies (Brewer 2009: 65-66). These clubs feature compositions similar to the G8+5: they include major industrialized countries plus a smaller group of selected newly industrialized countries (NICs) such as China, India or Brazil. As a result, specific concerns of poorer countries are side-lined and do not show in the agendas of these forums. This particularly regards the question of suitable strategies for adaptation to climate change, including the development, transfer or adoption of respective technologies.[12]

4.3 The Funding Architecture Within and Outside of the UN Climate Regime

There is no major fund dedicated to technologies under the UN climate regime. The instrument that comes closest to this purpose is the Clean Development Mechanism (CDM), which aims at providing low-cost emissions reductions to Annex I countries through activities in developing countries (Stripple & Falaleeva 2008: 3). However, in its current shape, the mechanism incentivizes mitigation efforts that yield emissions credits in isolated projects at a low price – while guidelines regarding adaptation have not been specified. The assessment of a project's impact on local environmental and social conditions is entirely at the discretion of host governments. The CDM process does not formally support these governments in the formulation, monitoring or enforcement of sustainable development criteria (Sterk & Wittneben 2006: 276-277).

In turn, none of the four adaptation funding mechanisms of the UN climate regime features an elaborate thematic focus on technologies. These funds are "technically inadequate when it comes to responding to developing countries' needs", owing both "to the complex design of the funds" and to "poor implementation of the guidance" (Möhner & Klein 2007: 16).

Under its focal area of climate change, the Global Environment Facility (GEF) Trust Fund pursues a three-stage approach on adaptation: planning (Stage I), capacity-building (Stage II) and implementation (Stage III). While the COP never provided explicit guidance for Stage III

[12] The same goes for recent G8+5 meetings. While giving the UN process some new impulse, they have done so in an asymmetric manner, by putting the emphasis on mitigation issues while adaptation was given relatively little attention. For instance, in the 2007 summit declaration, 3 out of 14 items on climate change (§ 58-60) dealt with "adapting to climate change"; however, two of these items did not tackle core issues of adaptation (i.e. enhancing resilience, assessing vulnerability, response measures), but instead addressed ozone layer depletion and simply referred to a future report.

funding, it identified fourteen adaptation-related activities to be supported by the fund in Decision 5/CP.7, including enhancing technical training and promoting the transfer of adaptation technologies (Möhner & Klein 2007: 7). But so far, the GEF only responded to this request by establishing the Strategic Priority on Adaptation (SPA), which operated between 2004 and 2007 to support pilot Stage III activities (GEF 2005).

The Special Climate Change Fund (SCCF) finances programs and measures that are complementary to those funded by the Trust Fund, with adaptation and technology transfer as two of its four priority areas. Yet these two focal areas have not been combined into an explicit agenda on adaptation technologies. COP Decision 5/CP.12 on SCCF guidelines mostly refers to "less-greenhouse-gas emitting advanced fossil-fuel technologies". Adaptation technologies are only mentioned indirectly in the wording "climate-friendly agricultural technologies and practices".

The Least-Developed Countries Fund (LDCF) supports the preparation and implementation of NAPAs and other components of the convention's least-developed countries work program. COP guidelines for this fund, provided in Decisions 6/CP.9, 3/CP.11 and 5./CP.14, do not mention technologies at all. Only few of the adaptation projects proposed in NAPAs have been funded so far. This lack of implementation is "largely driven by the conflicts in funding procedures" (McGray et al. 2007: 34).

Unlike the aforementioned funds under the convention, the Adaptation Fund (AF) was established under the Kyoto Protocol. In December 2007, delegates at COP 13 in Bali agreed that a special AF Board, representing developing and developed countries, would supervise and manage the fund.[13] The AF will not apply the incremental cost principle that informs GEF activities (i.e. only funding measures in response to anthropogenic climate change), but instead supports adaptation on a full-cost basis (Horstmann 2008: 20). However, similar to the SCCF and LDCF, the AF guidelines, as defined in Decision 5/CMP2, do not specifically refer to adaptation technologies.

These various funds fall significantly short of what is needed for adaptation technologies, i.e. the aforementioned vague cost estimates of tens or hundreds of billions US$.[14] By the same token, they do not match more concrete projected global costs for adaptation efforts in general. While the World Bank Development Committee (2006) expects US$ 9-41 billion per

[13] Especially developing countries opposed a stronger role of the facility in the AF. They had grown suspicious of the GEF's increasing scope of activities and were unwilling to distribute monies among too many focal areas (DeSombre 2006: 160).

[14] In fact, the financing resources for technologies for both mitigation and adaptation make up only a small share "(probably less than 3.5 per cent) of the resources devoted globally to all technology development and transfer" (UNFCC 2009a: 55).

year, the UNFCCC (2008) assumes annual costs between US$ 28 and 67 billion in 2030.[15] As of May 2009, 11 out of 13 contributing participants had paid their pledged contributions to the SCCF, amounting to US$ 101 million, while 17 of 19 countries had fully contributed to the LDCF, totaling US$ 143 million (pledged: US$ 176 million). The Adaptation Fund will be filled by means of a 2% levy on CDM projects; it is worth about € 37 million at the time of writing, with a total of € 80-300 million expected by 2012 (UNFCCC 2007a: 3).

A look beyond the UN climate regime – at other multilateral as well as bilateral mechanisms – reveals further elements of a fragmented climate funding architecture, which fails to adequately address adaptation technologies (see Figure 3 for an overview). In July 2008, industrialized countries decided to establish two climate investment funds under the World Bank. By April 2009, a total of US$ 6.1 billion had been pledged for the Strategic Climate Fund (SCF) and the Clean Technology Fund (CTF).[16] The CTF solely supports mitigation technologies, seeking to promote environmental and social co-benefits. Hence, adaptation technologies may rather be financed by the SCF, which will serve as an overarching fund for various programs. However, the only direct reference to adaptation is the SCF's objective to "promote incentives for scaled-up action and transformational action (both mitigation and adaptation) and for solutions to the climate change challenge and poverty reduction in developing countries".[17]

In addition to these funds, the World Bank and the International Monetary Fund may promote adaptation-related activities through the implementation of poverty-reduction strategies. These strategies are incorporated into national Poverty-Reduction Strategy Papers (PRSPs). However, PRSPs are prepared by ministries of finance or planning, which "are often entirely disconnected from the environment ministries most closely associated with the NAPA process [...]. Efforts to mainstream adaptation into development agendas have so far largely failed to penetrate the world of PRSPs" (McGray et al. 2007: 34).

Figure 3 also displays a set of bilateral funding initiatives which are emerging. Aside from these few approaches however, bilateral funding for adaptation and the respective technologies still takes place in the context of traditional official development assistance (ODA). As McGray et al. (2007: 34-35) observe, there is a conflict in priorities between ODA and climate funding mechanisms. While the former predominantly address drivers of

[15] Oxfam (2007: 3) estimates global adaptation costs of US$ 50 billion per year by 2050, while the UNDP (2007: 26) even expects US$ 86 billion per year in 2015. Taking these figures into account, a July 2009 proposal for a new adaptation fund by UK Prime Minister Gordon Brown included a working figure of around $100 billion per annum by 2020 (http://climatesecurity.blogspot.com/2009/07/gordon-browns-adaptation-fund-proposal.html; accessed 14 August 2009).

[16] http://www.climatefundsupdate.org/listing/architecture (accessed 13 August 2009).

[17] http://www.climatefundsupdate.org/listing/strategic-climate-fund (accessed 13 August 2009).

vulnerability, the latter are driven by the imperative for increased funding in response to climate change. Nonetheless, many activities important for adaptation, including capacity-building and risk management displayed in Figure 1 above, "fall in the 'messy middle'" (McGray et al. 2007: 36). Thus, many soft adaptation technologies, which are instrumental in building response capacities, are neglected in the current mix of bilateral and multilateral mechanisms.

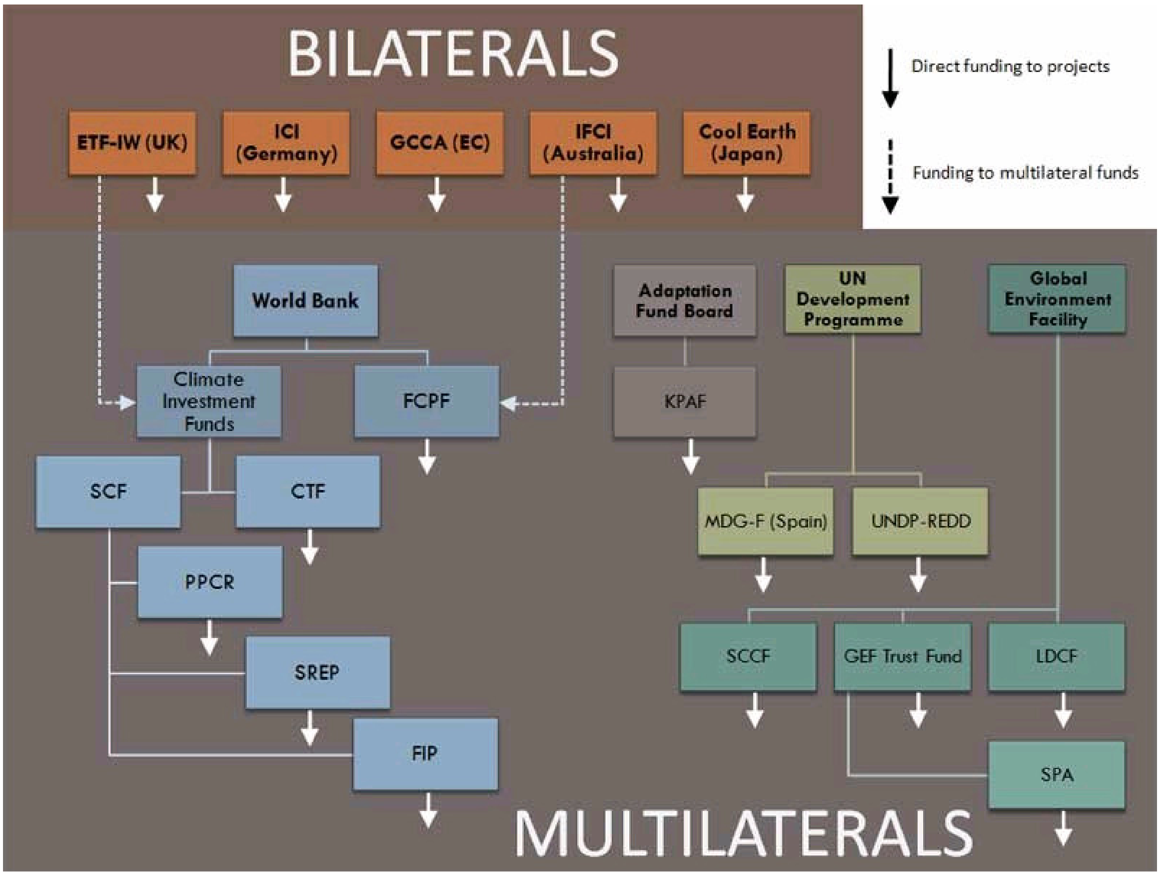


Figure 3: Climate Funds Architecture (Source: Climate Funds Update[18])

(ETF-IW = Environmental Transformation Fund - International Window; FCPF= Forest Carbon Partnership Facility; FIP = Forest Investment Program; GCCA = Global Climate Change Alliance; ICI = International Climate Initiative; IFCI = International Forest Carbon Initiative; KPAF = Kyoto Protocol Adaptation Fund; MDG-F = Millennium Development Goals Achievement Fund – Environment and Climate Change thematic window; PPCF = Pilot Program for Climate Resilience; SREP = Scaling-Up Renewable Energy Program for Low Income Countries; UNDP-REDD = UN Collaborative Programme on Reduced Emissions from Deforestation and Degradation in Developing Countries, administered by UNDP)

4.4 Summary: Fragmented Adaptation Governance and Neglect of Adaptation Technologies

The brief overview of the global governance architecture on adaptation has shown that adaptation technologies are a stepchild both of multilateral negotiations and ODA. Apart from

[18] http://www.climatefundsupdate.org/listing/architecture (accessed 13 August 2009).

the Nairobi Work Programme, none of the debates attends to this issue in a more specific and elaborate manner. Guidelines across funding mechanisms are vague and not sufficiently dovetailed, especially regarding the relationship between adaptation and mitigation as well as between adaptation and sustainable development. Altogether, the bulk of efforts concentrate on low-carbon development and mitigation technologies while adaptation technologies often appear tagged onto the respective agendas.

Although further research is necessary to pinpoint the exact drivers behind this underspecified treatment, the observed neglect confirms the duality among adaptation and mitigation presented in section 3: given the nature of adaptation technologies as (providers of) public goods and the uncertainty over financial needs, the willingness of public and especially private actors to address the matter is considerably lower than for mitigation technologies. Thus, the emerging arenas of cooperation on low-carbon development among industrialized and leading developing countries reflect the constellation of chief interests in international climate politics – to the disadvantage of least developed countries and their adaptation needs (Biermann et al. 2009[fc.]).

Moreover, the lack of a more tailored approach towards adaptation technologies mirrors the general negotiation dynamics on adaptation to climate change with its “huge diversity of interests” (Horstmann 2008: 9). This does not only concern (possible) donors, i.e. industrialized countries, but also the block of G-77 & China whose members “where struggling with various, also conflicting, interests and national circumstances that represented an obstacle for the evolution of an adaptation framework” (ibid.). For instance, much of the early debate on adaptation was shaped by oil-exporting countries who drew attention to adverse impacts of climate change and response measures on their economies, leaving “the [adaptation] fund or other issues to be held hostage until this issue is resolved” (Dessai 2004: 23)

Any attempts to tackle the identified shortcomings at the international level need to take these potential drivers and barriers into account. This implies, in particular, a stronger role of public actors – as agenda-setters, facilitators and funding sources – to make up for the low profile that private actors keep on adaptation technologies. Still, where possible, public actors should facilitate the early involvement of the private sector (UNFCCC 2007: 16). All in all, what is needed is a more coordinated approach that does justice to the various overlaps with mitigation technologies and development policies – bridging the gap between the “two parallel flows” (Scholz & Klein 2008: 12) of traditional ODA and response-oriented climate funding mechanisms. This raises questions about the policy implications of an enhanced focus on adaptation technologies, e.g. regarding new institutional arrangements, additional criteria and guidelines, and their interaction with existing mechanisms (UNFCCC 2006: 8). The next section discusses some of the main proposals advanced so far.

5 Policy Options at the International Level

5.1 Under the UN Climate Regime

With a view to the various bargaining arenas which touch upon adaptation technologies, the obvious general recommendation is to take a joined-up approach:

> "In the adaptation negotiation track the role of technology should be recognised, and in the technology negotiating track the use of technology for adaptation should be recognised." (CIDSE & Caritas 2009: 23).

To this end, the CIDSE & Caritas report suggests enhanced information exchange across both tracks, building on institutional proposals by the G-77 & China for an Adaptation Executive Board and a Technology Executive Board. Staff of these two boards should partly overlap to identify common topics and need for coordination. Moreover, the two boards could produce regular reports to the COP on adaptation technologies, based on information gathered from the various negotiation tracks – and from further submissions by parties, under the Nairobi Work Programme and the convention's technology transfer network. By summarizing adaptation technology-related activities, discussions and proposals, these reports could provide a consolidated basis of information – and a starting point for negotiators and experts to develop integrated response strategies. The reports could also incorporate evidence gathered through mechanisms outside of the UN climate regime, e.g. from regional centers or sectoral agreements (ibid.). Likewise, the IPCC could provide further input, e.g. in a special report on adaptation technologies or in respective sub-chapters of the Fifth Assessment Report.

Aside from building such a knowledge base, parties could agree on an "international technology mechanism" (CIDSE & Caritas 2009: 24) or a robust institutional arrangement on technology (UNFCCC 2009b: 3). The EGTT envisions such a program by 2030, seeking 1. to expand public and private research, development and demonstration programs, 2. to enhance deployment and diffusion programs, and 3. to strengthen enabling environments as well as technological and institutional capacity (ibid.). Figure 4 summarizes the elements of a possible operational framework to pursue these objectives as suggested by the EGTT.[19] It is a hybrid structure where programs are coordinated through an institutional core under the UNFCCC, which bases its decisions on input from country plans as well as NGO programs. Implementation is either conducted centrally or in a distributed fashion – depending on the most suitable and available agents. Sectoral approaches would concentrate on a particular economic sector at global, regional or national levels whereas regional approaches would implement a cross-cutting portfolio of program elements in a specific region (ibid.: 5-6).

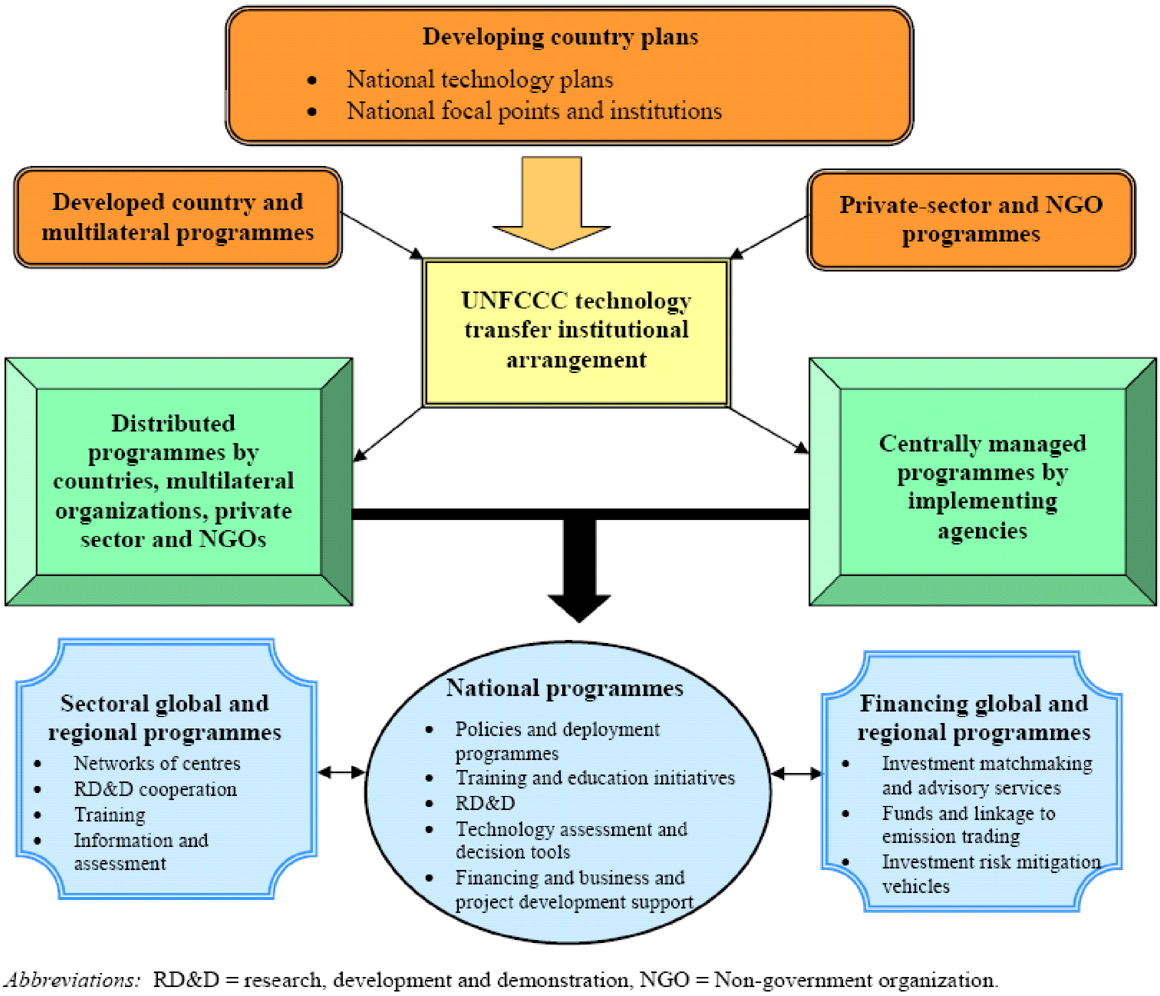


Figure 4: Example of Operational Technology Framework under the UNFCCC

(UNFCCC 2009b: 6)

While such a blueprint of an institutional division of labor might leave little to be desired at first glance, a closer look unveils some open questions. How realistic is such a framework in light of current coordination problems and their underlying drivers? And how does it combine

[19] The EGTT report discusses various approaches from centralized to strongly decentralized arrangements (UNFCCC 2009c: 38-52). Of these, the hybrid model discussed in the following appears most realistic, as it comes closest to the current governance architecture.

aspects of adaptation and mitigation in a meaningful way? The first question addresses the incentive structure in current negotiations. I come back to this point in the section on funding proposals below.

As for the second question, the framework needs to give adaptation technologies a more prominent role. This starts with streamlined debates on aforementioned barriers to the diffusion of such technologies – not only financial obstacles, but also legal and economic ones, e.g. IPRs in the agricultural sector (UNFCCC 2009d: 21). Furthermore, particular bodies operating in the framework, e.g. working groups, could focus on research, development and demonstration of new adaptation technologies. They could further provide technical expertise and assistance to developing countries (CIDSE & Caritas 2009: 24). Most importantly, the framework has to be informed by a coherent set of guidelines which addresses the adaptation effect of mitigation technologies and vice versa – as well as the impact of adaptation technologies on other sustainable development goals.

At the implementation level, strategies should direct more attention to processes of technology adoption and the facilitation of learning processes. The EGTT proposal largely omits this important aspect, since it concentrates on the *transfer* of technologies. In the same vein, the structure of the report partly follows the maturity stages for mitigation technologies (see section 2.2.3 above) (UNFCCC 2009d: 11-24). As discussed earlier, such a focus does not do justice to the peculiarities of adaptation technologies, which often are already available, but need to be adopted and applied to specific contexts. The EGTT proposal is not silent on these matters: one core programmatic element is the enhancement of enabling environments and capacity building, e.g. through global and regional technology standards, various training and workforce development measures, national education and awareness programs and integrated sectoral planning (UNFCCC 2009d: 29-36). However, programs should put more emphasis on learning processes, by promoting the exchange of information and experiences between producers / providers and users of adaptation technologies across communities. Lessons from these adoption processes and their transferability across communities could then be made available to all parties.

Such lessons could also inform integrated "Adaptation Technology Action Plans (ATAPs) that will identify policies, actions and funding requirements for a specific set of adaptation technologies" (CIDSE & Caritas 2009: 24). These national plans could embody and advance the suggested guidelines on mitigation, adaptation and wider sustainable development objectives at the international level. The guidelines could provide the various ministries (and other institutions involved in the drafting of these plans) with overarching criteria and parameters for needs assessments. Based on such common guidelines – and the subsequent provision of technical expertise and assistance – developing countries could dovetail their NAPAs and TNAs – and might also have stronger incentives to "apply a climate lens" to non-UNFCCC planning devices such as PRSPs (OECD 2009: 77). Thereby, they could identify more consistent priority actions for the development and adoption of technologies (McGray et al. 2007: 34; OECD 2009: 73-81).

5.2 Outside of the UN Climate Regime

Building on ideas presented in the previous section, guidelines on adaptation could also be built into emerging regional and sectoral partnerships on low-carbon development technologies, such as the APP and the CSLF. These could materialize as criteria or standards for the approval and evaluation of projects funded under these partnerships. Role models for such a step are the increasing number of regional trade agreements where parties incorporated environmental or climate-related standards (Kim 2009: 60-62). Such a guidelines-based approach is most likely to achieve for partnerships which are linked to the UN process, e.g. the MMP which is registered with the Commission on Sustainable Development. Where possible, the agenda of these partnerships might even be broadened to include specific guidelines on adaptation technologies. Aside from facilitating an integrated approach on mitigation and adaptation, this move could leverage a stronger adaptation-related engagement of businesses – namely those who are members of existing sectoral partnerships.

Likewise, Regional Centers of Excellence could be instrumental in the promotion of adaptation technologies (see Figure 4 above). These centers have been proposed by the G-77 & China in current climate negotiations. In fact, while rather envisioned for mitigation technologies, they would be particularly suitable for adaptation objectives, since they aim at enhancing learning processes on site through knowledge exchange and transfer – thereby emphasizing processes of regional diffusion and adoption. The regional centers could draw on experiences of disaster risk reduction frameworks and other information-knowledge sharing platforms that are linked to civil society experiences (CIDSE & Caritas 2009: 24). In leading developing countries, the centers could as well build on experiences with sustainability-oriented innovation systems (cf. Stamm et al. 2009: 33-35).

On a more ambitious note, countries might also initiate novel regional agreements specifically geared towards adaptation technologies. Several scholars argue in favor of similar arrangements, e.g. a climate-wise development treaty (Sugiyama & Sinton 2005) or a regional, ethics-based initiative (Grasso 2006). The rationale behind these proposals is:

- Smaller groups of neighboring countries are more likely to share environmental goals and threats (including possible climate impacts), which could lead to increased legitimacy and accountability of such agreements.
- The UN process may be too slow – whereas adaptation is mainly about a timely transfer of relevant knowledge, which might be quicker to achieve in regional agreements with fewer members (Biermann et al. 2009[fc.]).
- The agreements may make use of existing geopolitical ties between countries.

However, these advantages have to be weighed against possible pitfalls, most importantly:

- Regional adaptation agreements might be unrealistic, given low incentives for industrialized countries to join responsibility-driven initiatives.
- They might further advance the undesirable separation of adaptation and mitigation technologies.

With respect to the first concern, the regional setting of the agreements could actually provide an incentive which is lacking in the global climate regime. There might be higher political pressure on possible donor countries to join and actively promote the diffusion and adoption of adaptation technologies in neighboring countries – in order to prevent some of the immediate consequences they might face, e.g. climate-induced migration from these countries. With its regional perspective, such an agreement could also be in a better position to promote context-specific projects, e.g. for an exchange of know-how and experiences (for instance, by establishing the aforementioned regional centers), or for sustainable community and infrastructure planning (UNFCCC 2009d: 19-21).

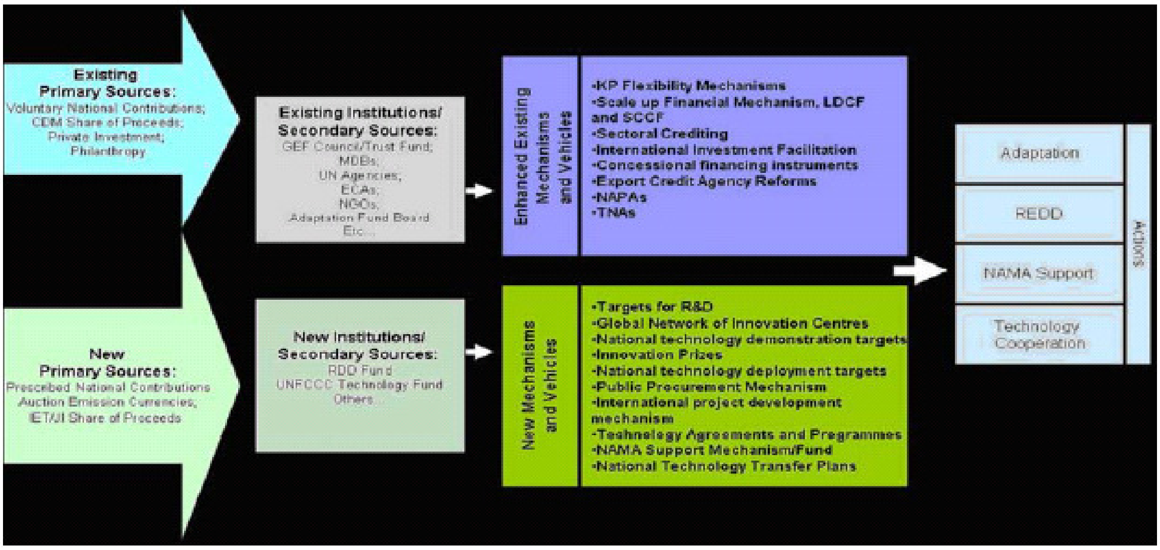
Regarding the second caveat, such initiatives should only be complementary to the aforementioned idea of feeding adaptation guidelines into existing agreements. Moreover, they should be closely connected to the UN process – as shown in Figure 4 above – preferably directly to the UNFCCC (explicitly linked to the Nairobi Work Programme and technology-related programs). This could ensure regular evaluation of these agreements on their substance and contribution to the objectives of the UN climate regime. Altogether, regional agreements might not be a perfect solution, but, as a stop-gap or learning experience, they could well speed up action in the face of a relatively slow progress at the UN level (Zelli & van Asselt 2008: 160-163).

5.3 Funding Architecture

Given the considerable gap between currently available multilateral and bilateral funding and projected financial needs, adaptation technologies should not be simply added to these agendas of the numerous financing efforts. To overcome financial barriers to the various stages from research to adoption of these technologies, new funding is necessary, which is additional to existing multilateral and ODA targets (CIDSE & Caritas 2009: 23). This entails scaling up existing funds and / or establishing further mechanisms.

The overall challenge of a new financial architecture for both mitigation and adaptation technologies

> "is to stimulate the development of a continuously changing set of technologies […] that are at different stages of technological maturity and have different requirements for further developments. Those technologies need to be adapted for, and transferred to, about 150 developing countries, each with its own needs for specific technologies and enabling environments to support those technologies (UNFCCC 2009: 8).



Abbreviations: CDM = clean development mechanism, ECA = export credit agency, GEF = Global Environment Facility, IET = international emissions trading, JI = joint implementation, KP = Kyoto Protocol, LDCF = Least Developed Countries Fund, MDB = multilateral development bank, NAMA = nationally appropriate mitigation action, NAPA = national programme of action, NGO = non-governmental organization, R&D = research and development, RD&D = research, development and deployment, REDD = reduced deforestation and forest degradation in developing countries, SCCF = Special Climate Change Fund, TNA = technology needs assessment.

Figure 5: Proposals on Technology Funding (UNFCCC 2009a: 55)

Funding vehicles can hence differ significantly across different contexts. Accordingly, parties have so far submitted a large number of diverse proposals for technology mechanisms which either seek to scale up existing sources or to create new sources (see Figure 5, collated by the EGTT).

Curiously, the EGTT structured these proposals according to stages of maturity typical for mitigation technologies – which, once again, reveals a certain bias in negotiations to the disadvantage of adaptation technologies (UNFCCC 2009a: 61-63). Proposals on the RD&D stage include national targets, a convention fund, and the earlier mentioned global network of innovation centers. Regarding the deployment stage, suggestions involve a public procurement mechanism, an international project-development mechanism and, most importantly, a UNFCCC technology fund. This fund could comprise more specific financial instruments, e.g. to support renewable energy technologies, international public venture and public equity or a credit line for subordinate debt (ibid.: 49). Finally, country proposals on technology diffusion include a reform of flexibility mechanisms (e.g. an expansion of domestic emissions trading schemes, project-based or sectoral Clean Development Mechanism [CDM]) as well as sectoral technology agreements and programs. Further proposals for this stage are concessional financing, an international investment facilitation and national renewable energy and energy efficiency targets (ibid.: 42-43; cf. Project Catalyst 2009: 20).

Based on this overview, the EGTT coined three indicative options for a new international funding architecture. The first two options mirror the more extreme choices of either an enhanced existing architecture, preferred by developed countries, or a comprehensive new technology financing scheme, favored by developing countries. Given the standoff between both country camps, a third option appears more realistic: a combination of new and enhanced old elements.[20] This option would match the hybrid scenario for an overall technology framework presented in section 5.1 above. While having more operational responsibilities than the current financing scheme – after significantly scaling up current funding – the new scheme under the convention could mostly focus on a facilitative role, i.e. coordinating the various mechanisms within the climate regime and outside of it (UNFCCC 2009: 10).

Within the regime, the new technology financing arrangement could support developing country participation at different technology stages. It could further assist in integrating strategies on mitigation and adaptation technologies: by supporting the preparation, implementation and coordination of NAPAs and TNAs – as well as plans for nationally appropriate mitigation actions (NAMAs) by developing countries, which are currently discussed in climate negotiations (UNFCCC 2009a: 71).

Outside of the climate regime, such a hybrid financing scheme could enhance the division of labor with sectoral initiatives like the APP as well as private-public partnerships. It could also feature an expansion of other multilateral financing initiatives such as the World Bank's climate investment funds. To this end, as mentioned in section 5.1 on institutional integration,

[20] For similar hybrid proposals, see Project Catalyst 2009: 7, 20; 2009a: 17.

the EGTT suggests a “new coordination mechanism” associated with the financing scheme, in order to streamline international cooperation efforts and to identify best practices for national policy and regulation (ibid.: 72). This mechanism would need to set strong standards under the UNFCCC to ensure that the various funds operate on similar rules (Project Catalyst 2009: 7). For instance, at the project level, an ideal division of labor would imply close coordination among the new framework, the GEF, multilateral development banks, enhanced capital allowances, investment facilitation mechanisms, institutional investors, venture capital and private equity funds (UNFCCC 2009a: 68).[21]

On the upside, the EGTT’s detailed suggestions target the important issue of coordination and also allow for context-based approaches, by involving tailored sectoral and regional approaches outside of the UN climate regime. However, with a view to adaptation technologies, the options largely focus on the peculiarities of low-carbon development: as mentioned before, they are framed according to maturity stages of mitigation technologies; moreover, the discussed guidelines mostly regard emission reductions and overall coordination, but do not attend to adaptation in similar detail.

Thus, in order to complement the idea of a hybrid financial architecture on technology, specific qualities of adaptation technologies should be accentuated in the overarching guidelines. While the EGTT lists such aspects in its report, it fails to integrate them more explicitly into the options it advances. In general, the expert group recognizes that

> “the financing needs for technologies for adaptation differ from those for mitigation. Development and transfer of technologies for adaptation is expected to occur mainly in conjunction with the implementation of adaptation projects and programmes. In these cases, R&D largely consists of adjusting existing technologies to the local circumstances. The main vehicles for financing […] are therefore expected to be the funds that implement adaptation projects and programmes, such as the Adaptation Fund” (UNFCCC 2009a: 57).

More concretely, the EGTT stresses that for adaptation technologies

- risk management is important for those technologies that may not have an established market;
- strengthening of endogenous research and development capacity is particularly important;
- financing should be provided in a way that allows technology to be tailored to the specific site and application (UNFCCC 2009a: 57-59).

However, instead of singling out individual aspects for each maturity phase – and merely adding them to a portfolio dominated by mitigation strategies – a more pronounced funding

[21] It would go beyond the scope of this paper to present these options more explicitly. For a detailed account, see UNFCCC (2009a: 65-73).

approach towards adaptation technologies should be based on major key adaptation priorities, as suggested in section 2.1 above. These priorities could include: investing in knowledge to reduce uncertainty, increasing climate resilience to reduce vulnerability and planning for extreme events (Project Catalyst 2009a: 5). The various elements of a hybrid technology architecture (public budget, public-private partnerships, private funds [including insurance schemes], mitigation budget, development budget) could then structure and coordinate their adaptation-related activities according to such priorities. For instance, for the goal of increasing climate resilience, public sources could grant subsidies, loans and tax reliefs for technology adoption and invest in equity of technology companies, while development budgets may "leverage development investments to finance adaptation levers that also serve development purposes" (ibid.: 9). Moreover, key design parameters need to be agreed, not only regarding the principle of additionality, but also questions of accountability and conditionality, funding terms (grants or loans) and, last but not least), governance (i.e. the specific ties of the funding initiatives to the UNFCCC framework) (ibid.: 19).

Altogether, these open questions show that there is still a long way to go from the current financing patchwork to a meaningful division of labor which directs adequate attention to the peculiarities of adaptation technologies. Apart from feeding these guidelines and criteria into such an architecture, the core challenge remains the incentive structure: to what extent are countries and private companies willing to move away from their currently skewed concentration on low-carbon development? In any case, the discussed proposals go into the right directions, since a sensible approach has to combine international efforts on both types of technologies, treating them in a common technology mechanism: 1. to tackle overlaps and avoid a trade-off between mitigation and adaptation objectives, 2. to provide sufficient incentives for parties to address adaptation technologies, by linking them to the mitigation debate and integrating them into a possible technology package deal, instead of neglecting them as a side-issue.

6 Conclusions

The paper proceeded in two steps: first, it introduced the issue of adaptation technologies, presenting key concepts and typologies; second, it focused on the international debate, regarding current efforts and major proposals for a future institutional and funding architecture. The intention was not to give an exhaustive account of the political implications of adaptation technologies at different levels; this would have involved explicating international proposals in much more detail and, most importantly, exploring the implementation and context-dependency of approaches at the country or community level. Instead, I focused on the international level, where overarching programmatic are taken. I showed that while concepts on adaptation technologies are relatively advanced, current efforts and proposals within and outside of the UN climate regime fail to incorporate many of these conceptual aspects.

Conceptual advantages, as discussed in section 2, include, *inter alia*, directing attention towards soft technologies, i.e. know-how to produce and use equipment for adaptation, and traditional technologies, which are instrumental for context-specific adaptation efforts. Moreover, expert groups collated extensive lists of adaptation technologies according to major sectors. They also identified peculiarities of these technologies, for instance, that policies should be dovetailed with technology-related strategies for mitigation and development in general. These benefits notwithstanding, some concepts still apply a mitigation or evolutionist lens to adaptation technologies: they artificially separate traditional and modern technologies, distinguish among maturity stages typical for mitigation equipment, and concentrate on development and transfer phases. Instead, they should put more emphasis on the question of (barriers to) technology adoption, since many adaptation technologies are already available in developing countries, while learning processes need to be facilitated to ensure their effective and context-specific use.

A separate conceptual section (3) focused on the relationship between adaptation and mitigation technologies, addressing potential synergies but also risks of maladaptation. It further stressed major differences like the private goods character of mitigation technologies and, consequently, their high share of private funding. I argued that this discrepancy, among other reasons, entails different approaches – and in particular degrees of attention – to both types of technologies in international negotiations.

Section 4 indeed showed that adaptation technologies are largely side-lined in these discussions. In a generally fragmented climate governance architecture, they play a marginal role, whereas technology debates are characterized by an emerging consensus among industrialized and leading developing countries on low-carbon development. If considered, adaptation technologies often appear as add-ons to the agendas of these debates, framed as underspecified objectives or criteria. Moreover, as for the adaptation issue in general, technological priorities of multilateral efforts and bilateral ODA differ significantly, with the latter rather focusing on drivers of vulnerability.

In light of these shortcomings, core features of an enhanced technology-related architecture should be a stronger and more tailored focus on adaptation technologies and a better coordination across arenas. As discussed in section 5, some proposals currently discussed in post-2012 climate negotiations seek to advance these two aspects. Still, these suggestions repeat some of the weaknesses which characterize the current patchwork of efforts, especially a bias towards mitigation technologies. To overcome this bias, overarching and more elaborate guidelines need to be established across institutions inside and outside of the UN system. These guidelines should address synergies and tensions between adaptation and mitigation technologies and embody some of the specific qualities of adaptation technologies identified in section 2. They should target core adaptation priorities like reducing uncertainty, increasing resilience and planning for extreme events. Ideally, such common guidelines should inform a more coordinated set of institutions, built around an institutional core under the UN climate regime – including both a coordinating mechanism and a financing scheme – and more closely involving external sectoral and regional agreements to ensure context-specific implementation. All in all, a future architecture should not single out adaptation technologies, by establishing new institutions on this matter. This would only widen the existing coordination gap. Instead, these technologies should be integrated in a more visible way into an emerging hybrid framework on low-carbon and climate-resilient development.

While such a suggestion certainly makes a noble take-home message, severe barriers to such a meaningful division of labor might remain. Aside from the considerable gap between currently pledged contributions and projected financial needs, the incentive structure for the various agents to take action on adaptation technologies is the key obstacle. Governments and businesses may well continue their reluctance to combine efforts on mitigation and adaptation technologies. In addition, one should not underestimate turf wars among institutions who are not eager to give away some of their competences, especially not where large amounts of funding are involved. In the same vein, donor countries are more willing to disburse monies through institutions where they have favorable voting structures like the World Bank, rather than the UN climate regime.

To a certain extent, the idea of a hybrid structure of might accommodate these caveats. But follow-up work on this topic needs to further scrutinize the underlying drivers of the current lack of political will. Moreover, going beyond the focus of this paper, they could shed more light on the role of ODA and on the implementation at the country and community levels, e.g. on specific technical challenges of dovetailing NAPAs, TNAs and other planning documents. Furthermore, studies could address the crucial phase of technology adoption and adjustment as well as concrete tools to facilitate learning processes in a given context. Likewise, they could devise or evaluate strategies to improve national and local capacities and enhance enabling environments (UNFCCC 2009c: 6). Altogether, given the considerable research gap on adaptation technologies, there is a whole array of topics to be covered in order to inform the policy process.

With respect to German ODA, the Federal Ministry for Economic Cooperation and Development (BMZ) could further integrate adaptation issues into its technology-related programs (e.g. the BMZ sector strategy on ‘sustainable energy for development’), trying to match the attention currently given to technologies for low-carbon development. As suggested by Scholz and Klein (2008: 10-11), this step should build on dialogue activities with partner countries to identify priority areas. The authors further insinuate training of BMZ staff “with regard to impacts of climate change, adaptation strategies, options and activities” (ibid.: 11). Adaptation technologies and context-specific barriers to their implementation could be part of the training agenda.

A major challenge will be the coordination among implementing agencies, ministries and non-governmental actors. Implementing agencies could mainly contribute to broadening the knowledge base, capacity development and the integration of adaptation into development planning (ibid.: 9-10). Within this context, they could especially attend to questions of technology adoption, by organizing workshops and information exchange within and across communities, and through training measures and other awareness-building measures (cf. UNFCCC 2009d: 13).

Moreover, German ministries on research, environment and development (BMBF, BMU and BMZ) could develop a joint strategy on supporting research, development, diffusion and adoption of adaptation technologies in developing countries – dovetailing such efforts with their current approaches on mitigation technologies. This strategy should seek to broaden the knowledge base on the use of technologies and the respective climate impact to which they are related (Scholz & Klein 2008: 9-10, 13). Given the role of both ministries in international climate and development negotiations, they could table proposals to coordinate current bilateral and multilateral funding efforts and to enhance investment on adaptation through multilateral development banks. Likewise, both BMZ and BMU could advance the establishment of a coordination mechanism and common guidelines on adaptation technologies as suggested in section 5.

Regarding non-governmental actors, a key task will be to leverage more business funding for the development and transfer of adaptation technologies. This might be feasible on the implementation side, through joint strategies for mitigation and adaptation equipment and know-how, inasmuch as the same companies provide elements of these different technologies. Yet on the programmatic level, public actors will remain the key players, since it will be much more difficult to incentivize private funding for adaptation efforts.

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Appendix: Technologies for Adaptation to Climate Change

(Source: UNFCCC 2009a)

(a) Coastal zones

Technology	**Technology type**	**NAPAs**	**TNA**
Restoration of coastal forests and coral reefs	**Traditional/indigenous**	Yes	No
Monitoring coastal and coral erosion		Yes	No
Sand dune restoration and construction		Yes	No
Dykes, dams, levees, nets and dredging		Yes	No
Community-based conservation programmes and aquaculture		Yes	No
Sea walls, revetments and bulkheads		No	Yes
Dykes and gryones		No	Yes
Saltwater intrusion barriers		No	Yes
Tidal barriers		No	Yes
Reef protection		No	Yes
Beach nourishment and dune restoration		No	Yes
Protection and restoration of wetlands		No	Yes
Littoral drift replenishment		No	Yes
Afforestation		No	Yes
Creation of drainage areas		No	Yes
Monitoring coastal and coral erosion	**Modern technology**	Yes	No
Dykes, dams, levees, nets and dredging		Yes	No
Detached breakwaters		No	Yes
Dykes and gryones		No	Yes
Saltwater intrusion barriers		No	Yes
Tidal barriers		No	Yes
Reef protection		No	Yes
Monitoring coastal and coral erosion	**High technology**	Yes	No
Sea level and tide monitoring		No	Yes
Coastal zone monitoring		No	Yes
Impact assessment studies		No	Yes
LiDAR (Light Detection and Ranging)		No	Yes

(b) Energy

Technology	**Technology type**	**NAPAs**	**TNA**
Use of biomass for small-scale energy production	**Traditional/indigenous**	Yes	No
Use of solar energy for small-scale indigenous industrial processes		Yes	No
Unspecified use of renewables		Yes	No
Use of jatropha oil		Yes	No
Use of hydropower	**Modern technology**	Yes	No
Unspecified use of renewables		Yes	No

(c) **Health**

Technology	Technology type	NAPAs	TNA
Malaria protection and prevention	**Traditional/indigenous**	Yes	No
Promoting a communications system to inform people of disease		Yes	No
Improved water storage and transportation		No	Yes
Health education		No	Yes
Malaria protection and prevention	**Modern technology**	Yes	No
Monitoring and improving sanitation and water control		Yes	Yes
Improving heath treatment infrastructure		Yes	No
Promoting a communications system to inform people of disease		Yes	No
Database and information centre for climate-related diseases epidemics		Yes	No
Unspecified vector disease control		Yes	Yes
Improved water storage and transportation		No	Yes
Production of biopesticides	**High technology**	Yes	No
Spatial information system for disease monitoring		Yes	No
Improve health treatment infrastructure		Yes	No
Unspecified vector disease control		Yes	Yes
Early warning systems		No	Yes
Medical research		No	Yes
Improvement of collector and drain array and prophylactics		No	Yes

(d) **Early warning and forecasting**

Technology	Technology type	NAPAs	TNA
Agriculture and food security management system	**Modern technology**	Yes	No
Natural disaster response systems		Yes	No
Improved weather forecasting	**High technology**	Yes	Yes
Early warning system for floods and droughts		Yes	No
Unspecified early warning systems		Yes	No
Unspecified monitoring systems		Yes	No
Improved data gathering		No	Yes
Improved hydrometeorological networks		No	Yes
Improved communications systems		No	Yes
Improved weather prediction tailored to the needs of health systems with regard to heat waves		No	Yes
Early warning system for desertification		No	Yes
Early warning system for famine		No	Yes
Unspecified remote sensing and geographic information system (GIS) use		No	Yes

(e) Infrastructure

Technology	Technology type	NAPAs	TNA
Improved technical design and construction	**Traditional/indigenous**	No	Yes
Changes in roofing material		No	Yes
Improved levee construction		Yes	Yes
Establishment of building codes		No	Yes
Windmills		No	Yes
Burying electric cables		No	Yes
Improved planning		No	Yes
Use of local non-metallic construction material		Yes	No
Unspecified coastal infrastructure improvement		Yes	No
Unspecified urban infrastructure improvement		Yes	No
Improved technical design and construction	**Modern technology**	No	Yes
Changes in roofing materiel		No	Yes
Improved levee construction		Yes	Yes
Establishment of building codes		No	Yes
Windmills		No	Yes
Rehabilitation and construction of dams and dykes		Yes	No
Rehabilitation of waterways		Yes	No
Construction of water gates		Yes	No
Unspecified coastal infrastructure improvement		Yes	No
Unspecified urban infrastructure improvement		Yes	No
Rehabilitation of multiple use reservoirs		Yes	No
Implementation of communications infrastructure	**High technology**	Yes	No
Rehabilitation and reconstruction of meteorological/climate stations		Yes	No

(f) Terrestrial ecosystems

Technology	Technology type	NAPAs	TNA
Afforestation, replanting and improved silviculture	**Traditional/indigenous**	Yes	No
Watershed restoration and management (unspecified)		Yes	No
Flood zone restoration and creation		Yes	No
Protection and rehabilitation of degraded soil and lands (unspecified)		Yes	No
Forest and brush fire prevention methods		Yes	No
Promotion of agro-farming and forestry in semi-arid landscapes		Yes	No
Lake training	**Modern technology**	Yes	No
Eradication of invasive flora species		Yes	No

(g) Water resources

Technology	Technology type	NAPAs	TNA
Water harvesting	**Traditional/indigenous**	Yes	Yes
Spate irrigation		Yes	No
Control of sand encroachment		Yes	No
Unspecified small-scale irrigation and harvesting for arid areas		Yes	No
Gravity irrigation systems		Yes	No

Technology	Technology type	NAPAs	TNA
Maintenance and construction of reservoirs and wells		Yes	No
Creation of safety zones and backup devices to control pollution		Yes	No
Capture of water run-off		Yes	Yes
Drip irrigation	**Modern technology**	Yes	No
Installation and maintenance of water pumps		Yes	Yes
Groundwater recharge of wells		Yes	No
Maintenance and construction of reservoirs and wells		Yes	No
Wastewater treatment		Yes	Yes
Establishment, maintenance and improvement of water supply infrastructure		Yes	No
Solar power drilling systems		Yes	No
River training		Yes	No
Registry containing information on protected areas		No	Yes
Additional pumps		Yes	Yes
Sustainable urban drainage systems		No	Yes
Water transfer		No	Yes
Water quality monitoring		Yes	No
Desalinization	**High technology**	No	Yes
Early warning flood systems		No	Yes
Reverse osmosis		No	Yes
Leakage detection systems		No	Yes
Computer simulation of floods		No	Yes
Online, searchable flood risk maps		No	Yes
Diversify and improve aquaculture		Yes	No

(h) Agriculture, livestock and fisheries

Technology	Technology type	NAPAs	TNA
Investigation of new techniques for live bait management	**Traditional/indigenous**	Yes	No
Erosion control		Yes	Yes
Development, use and treatment of fodder crops		Yes	No
Implementation of irrigated crops and cropping techniques		Yes	No
Zero-grazing techniques		Yes	No
Improving grazing and pasturing of livestock		Yes	No
Development of swamps for rice production		Yes	No
Integrated farming practices		Yes	No
Improvement of pluvial zone agriculture (unspecified)		Yes	No
Soil conservation and land improvement		Yes	
Coastal zone protection		Yes	No
Changing cultivars and crop varieties		No	Yes
Improved water distribution networks		No	Yes
Improving cultivation practices		No	Yes
Crop rotation		No	Yes
Bench terracing and contour cropping		No	Yes
Construction of windbreaks		No	Yes
Integrated pest management		No	Yes

Technology	Technology type	NAPAs	TNA
Dry farming		No	Yes
Diversify and improve aquaculture		Yes	No
Investigation of new techniques for live bait management	Modern technology	Yes	No
Food processing and preservation		Yes	No
Development, use and promotion of drought- and heat-resistant crops		Yes	Yes
Implementation of irrigated crops and cropping techniques		Yes	No
Genetic improvement of local bovine species		Yes	No
Unspecified livestock improvement to deal with climate stress		Yes	Yes
Unspecified modernization and diversification of agricultural production		Yes	No
Changing cultivars and crop varieties		No	Yes
Drip irrigation systems		No	Yes
Improved water distribution networks		No	Yes
Pest-resistant crops		No	Yes
Sub-surface dams to use underground water		No	Yes
Research and promotion of saline resistant crops		Yes	No
Improve quality of fishery-related data	High technology	Yes	No
Installation of Device for Fish Concentration (DFC) on coastal zones		Yes	No
New navigation technologies for fishing		Yes	No
Development, use and promotion of drought- and heat-resistant crops		Yes	Yes
Changing cultivars and crop varieties		No	Yes
Pest-resistant crops		No	Yes
Networks of early warning systems		No	Yes
Promotion of new rice varieties		No	Yes
Agricultural forecast modelling		No	Yes

Note: This table indicates whether a technology is mentioned or included in national adaptation plans of action (NAPAs) or technology needs assessments (TNAs).