TECHNOLOGY TO UNDERSTAND AND MANAGE CLIMATE RISKS

Background Paper for the UNFCCC Seminar on the Development and Transfer of Environmentally Sound Technologies for Adaptation to Climate Change, Tobago, 14–16 June 2005

Richard J.T. Klein[1,2,*], William W. Dougherty[3], Mozaharul Alam[4] and Atiq Rahman[4]

[1] Potsdam Institute for Climate Impact Research, P.O. Box 601203, 14412 Potsdam, Germany
[2] Stockholm Environment Institute–Oxford, 10B Littlegate Street, Oxford OX1 1QT, UK
[3] Stockholm Environment Institute–Boston, 11 Arlington Street, Boston, MA 02116, USA
[4] Bangladesh Centre for Advanced Studies, House No. 10, Road No. 16A, Gulshan 1, Dhaka 1212, Bangladesh

[*] Corresponding author: tel.: +49 331 2882651; fax: +49 331 2882642; e-mail: richard.klein@pik-potsdam.de

D R A F T

Prepared for the UNFCCC Secretariat and the Expert Group on Technology Transfer

10 June 2005, Version 1.0

Technology is dominated by two types of people:
those who understand what they do not manage,
and those who manage what they do not understand.

— Archibald Putt, 1976

TECHNOLOGY TO UNDERSTAND AND MANAGE CLIMATE RISKS

Background Paper for the UNFCCC Seminar on the Development and Transfer of Environmentally Sound Technologies for Adaptation to Climate Change, Tobago, 14–16 June 2005

SUMMARY

Many different technologies exist to adapt to natural weather-related hazards. These technologies can also play an important part in reducing vulnerability to climate change. Technologies are available to develop information and raise awareness, to plan and design adaptation strategies, to select adaptation technologies and implement them, and to monitor and evaluate their performance. This background paper briefly describes these four steps and provides important examples of technologies that can be employed to accomplish them, as well as examples of successful case studies. It identifies three trends in adaptation and associated technology use: (*i*) a growing recognition of the benefits of "soft" technologies, (*ii*) an increasing reliance on technologies to develop and manage information, and (*iii*) an enhanced awareness of the need for adaptation to be appropriate for local natural and socio-economic conditions. In addition, the paper address a number of critical features associated with the process of technology transfer for adaptation technologies, namely the relevant framework, key dimensions and the integration of adaptation and development priorities in technology transfer.

DISCLAIMER

TABLE OF CONTENTS

Page

1. INTRODUCTION

1. This background paper aims to provide the Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC) and the Expert Group on Technology Transfer (EGTT) with a summary overview of (*i*) the current knowledge and understanding of adaptation to climate change, (*ii*) a framework for assessing technologies for adaptation to climate change, (*iii*) the process of technology development and transfer as relevant to adaptation to climate change, and *(iv)* examples of important technologies for adaptation, together with case studies. It may serve as a starting point for a more comprehensive technical paper on the development and transfer of environmentally sound technologies for adaptation to climate change.

2. The paper should be seen as part of the process to implement Article 4.5 of the UNFCCC, which states that the developed country Parties and other developed Parties included in Annex II shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention. This commitment is echoed in similar provisions under the Kyoto Protocol (Article 10c).

1.1. Context and Scope of this Paper

3. This is not the first paper on technologies for adaptation that has been produced within the UNFCCC process. An initial report, providing an inventory and assessment of technologies to mitigate and adapt to climate change, was prepared by the UNFCCC Secretariat in 1996 (FCCC/SBSTA/1996/4). It identified what type of information on technologies and know-how would be most useful to the Parties to the UNFCCC. The emphasis of the initial report was on mitigation, reflecting the predominant political interest and the state of knowledge at the time.

4. Participants in an expert meeting convened by the UNFCCC Secretariat in Amsterdam in 1997 recommended the Secretariat to develop a work programme to prepare to the following papers (FCCC/SB/1997/3):

   - An overview paper on adaptation;
   - Focused papers, initially on technologies related to human health, agriculture, coastal zones, urban areas and freshwater resources;
   - A long-term "vision paper" to set out technological goals in different sectors.

5. The overview paper was produced as a technical paper in 1997 (FCCC/TP/1997/3). It was followed by one focused paper two years later: a technical paper on coastal adaptation technologies (FCCC/TP/1999/1). In the meantime, the results of a survey of technology and technology information needs of developing countries had become available (FCCC/SBSTA/1998/INF.5).

6. In response to a request by the Subsidiary Body for Scientific and Technological Advice (FCCC/SBSTA/1995/3), the Intergovernmental Panel on Climate Change (IPCC) prepared a Special Report on Methodological and Technological Issues in Technology Transfer (SRTT), which was published in 2000 (Metz *et al.*, 2000). The SRTT contained two chapters devoted explicitly to adaptation (Human Health and Coastal Adaptation), and other chapters that discussed both mitigation and adaptation (*e.g.*, Agriculture).

7. At COP-7 in 2001, an Expert Group on Technology Transfer (EGTT) was established, with the objective of enhancing the implementation of Article 4.5 of the UNFCCC, including, *inter alia*, by analysing and identifying ways to facilitate and advance technology transfer activities and making recommendations to the Subsidiary Body for Scientific and Technological Advice (SBSTA). The EGTT comprises 20 experts, including three members from each of the developing country regions (Africa, Asia and the Pacific, and Latin America and the Caribbean), one from the small island developing states, seven from Annex I Parties and three from relevant international organisations. The progress of work and the terms of reference of the EGTT will be reviewed at COP-12 in 2006.

8. In 2003 two technical papers were produced, which addressed issues relevant to technology transfer for both mitigation and adaptation. FCCC/TP/2003/1 discussed issues pertaining to capacity-building in the development and transfer of technologies, whilst FCCC/TP/2003/2 analysed enabling environments for technology transfer. In addition, the compilation and synthesis of Annex II National Communications included information with specific reference to technologies for adaptation. In 2004 the UNFCCC Secretariat made available a Compendium on methods and tools to evaluate impacts of, vulnerability and adaptation to climate change.

9. The EGTT's programme of work for 2004, endorsed at SBSTA-19 in 2003, includes cross-cutting activities, including a proposed action aimed at encouraging the development of environmentally sound technologies, in particular adaptation technologies. As part of the work programme, a draft scoping paper has been prepared by the chairman of the EGTT, outlining the basic concepts of adaptation-relevant technologies. The scoping paper complements Secretariat working paper no. 10 (2003): "Review of Adaptation Activities under the Convention".

10. Most recently at COP-10 in 2004, Parties decided to initiate a programme of work on adaptation to climate change (Decision 1/CP.10). The decision emphasises technology transfer for adaptation on an urgent basis in priority sectors. Moreover, it instructs SBSTA to develop a structured five-year programme of work encompassing a range of technology transfer issues.

11. As a next step, this background paper is meant to help to stimulate discussion at the UNFCCC Seminar on the Development and Transfer of Environmentally Sound Technologies for Adaptation to Climate Change, which will take place in Tobago from 14 to 16 June 2005. In addition, it is expected that the background paper may serve as a starting point for a more comprehensive technical paper on the development and transfer of environmentally sound technologies for adaptation to climate change.

1.2. Relevant UNFCCC Articles, Decisions and Definitions

12. This subsection reviews the UNFCCC Articles pertinent to the development and transfer of environmentally sound technologies for adaptation to climate change, and lists a number of key decisions made by the Conference of the Parties. In addition, it presents definitions for several of the terms and concepts that are used throughout this background paper.

13. Articles 3 and 4 of the UNFCCC make various references to adaptation—what it is and how it should be considered—that can be summarised as follows:

- Article 3.3 states that where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost. To achieve this, such policies and measures should take into account different socio-economic contexts, be comprehensive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation, and comprise all economic sectors.
- Article 4.1, paragraph (b) states that all Parties shall formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing measures to mitigate climate change by addressing anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, and measures to facilitate adequate adaptation to climate change. Paragraph (e) states that all Parties shall co-operate in preparing for adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone management, water resources and agriculture, and for the protection and rehabilitation of areas, particularly in Africa, affected by drought and desertification, as well as floods.
- Article 4.1(f) states that all Parties shall take climate change considerations into account, to the extent feasible, in their relevant social, economic and environmental policies and actions, and employ appropriate methods, for example impact assessments, formulated and

determined nationally, with a view to minimising adverse effects on the economy, on public health and on the quality of the environment, of projects or measures undertaken by them to mitigate or adapt to climate change.

- Article 4.5 states that the developed country Parties and other developed Parties included in Annex II shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention. In this process, the developed country Parties shall support the development and enhancement of endogenous capacities and technologies of developing country Parties. Other Parties and organisations in a position to do so may also assist in facilitating the transfer of such technologies.
- Article 4.8 states that the Parties shall give full consideration to what actions are necessary under the Convention, including actions related to funding, insurance and the transfer of technology, to meet the specific needs and concerns of developing country Parties arising from the adverse effects of climate change and/or the impact of the implementation of response measures.
- Finally, Article 4.9 states that the Parties shall take full account of the specific needs and special situations of the least developed countries in their actions with regard to funding and transfer of technology.

14. Regarding Articles 4.8 and 4.9 of the Convention, there have been several key decisions related to Development and Transfer of Technologies and Implementation. These are summarised in Annex 1.

15. There are several key concepts that are used throughout this background paper. Brief definitions are summarised in the paragraphs below. The definitions of the first three concepts are taken from the IPCC Third Assessment Report (TAR; McCarthy *et al.*, 2001). The latter three definitions are taken from the IPCC SRTT (Metz *et al.*, 2000).

16. ***Adaptation:*** Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.

17. ***Adaptive capacity:*** The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities or to cope with the consequences.

18. ***Vulnerability:*** The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity.

19. ***Technology:*** A piece of equipment, technique, practical knowledge or skills for performing a particular activity.

20. ***Environmentally Sound Technologies:*** Technologies which protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, and handle residual wastes in a more acceptable manner than the technologies for which they were substitutes and are compatible with nationally determined socio-economic, cultural and environmental priorities. The term includes hard and soft technologies.

21. ***Technology Transfer:*** The broad set of processes covering the exchange of knowledge, money and goods amongst different stakeholders that lead to the spreading of technology for adapting to or mitigating climate change. The word “transfer” encompasses both diffusion of technologies and co-operation across and within countries.

2. BACKGROUND

22. Human-induced climate change is caused by the emission of greenhouse gases, which trap long-wave radiation in the upper atmosphere and thus raise atmospheric temperatures, as well as produce other changes in the climate system. Carbon dioxide is the most important of these gases and its atmospheric concentration has increased exponentially since the beginning of the industrial revolution as a result of fossil fuel combustion and land-use change. In 1800, the atmospheric concentration of carbon dioxide was about 280 parts per million (ppm); today it is about 350 ppm and rising. Similar increases have been observed for other greenhouse gases such as methane and nitrous oxide.

23. Projections of future climate change are based on global scenarios of future emissions of greenhouse gases. These emission scenarios are subject to great uncertainty, as they reflect patterns of economic development, population growth, consumption and other factors that are not easy to predict over a 100-year period. A large number of emission scenarios are used to account for this high degree of uncertainty. The most recent emission scenarios, which formed the basis of the climate projections of the IPCC TAR, were published in the IPCC Special Report on Emission Scenarios (SRES; Nakićenović *et al.*, 2000) and are known as the SRES scenarios.

24. By 2100, carbon cycle models project atmospheric carbon dioxide concentrations of 540 to 970 ppm for the illustrative SRES scenarios, with a range of uncertainty of 490 to 1260 ppm (Houghton *et al.*, 2001). Based on these projections and those of other greenhouse gases and sulphate aerosols, the IPCC TAR projects an increase in globally averaged surface temperature of 1.4 to 5.8°C over the period 1990 to 2100, and a global mean sea-level rise of 9 to 88 cm over the same period. These results are for the full range of 35 SRES scenarios, based on a number of state-of-the-art global climate models. The IPCC TAR further states that it is very likely that nearly all land areas will warm more rapidly than the global average, particularly those at northern high latitudes in the cold season (Houghton *et al.*, 2001).

25. Both natural and human systems are vulnerable to the impacts of climate change and some of these systems may be irreversibly damaged. Impacts will depend on the region with some areas experience more extreme heat, whilst others may cool slightly. Flooding, drought, and intense summer heat would result, as well as more violent storms and more frequent extreme weather events due to the increased energy stored in the warming atmosphere. Box 1 provides a sampling of the types of impacts that could be expected in agriculture, water resources, forestry, coastal zones, human health and sensitive ecosystems.

Box 1: Potential Impacts of Climate Change

Agriculture: Growth duration and biological yields of certain crop types would decrease both under rain fed and irrigated conditions. Subsistence farmers are significantly at risk.

Water: In many countries, significantly less runoff is being predicted, relative to observed data, due to the expected increase in temperature, which in turn would lead to increased evapotranspiration.

Forestry: Profound shifts in bio-climatic zones are expected in some countries. Some areas in semi-arid countries are expected to be overcome by tropical desert scrub (bush lands / scrublands).

Coastal zones: Much infrastructure and economic activity is located in coastal zones, which would be vulnerable to sea level rise and more frequent weather events (*e.g.*, cyclones, storm surges). Temperature increases could also adversely affect local flora and fauna of coastal areas, as well as the biological equilibrium of marine life.

Human Health: Anopheles vectors would increase and with it the incidence and prevalence of malaria in many countries. The appearance of malaria at altitudes close to 2,000 meters is a new phenomenon, but with increasing temperatures, the malaria altitude belt is expected to widen. This could be compounded by the already high incidence and prevalence of diarrhoea, upper respiratory infection and malnutrition.

Sensitive Ecosystems: Global climate models predict extreme warming in many ecosystems if greenhouse gas emissions continue to rise. Climate change could endanger the provision of goods and services provided by such ecosystems as forests and woodlands, rangelands, mountainous areas, inland wetlands, and arctic regions.

26. The IPCC TAR noted that the impacts of climate change are likely to be experienced disproportionately by the poorest groups – those with the least resources available for adaptation. These groups may include specific populations (*e.g.*, ethnic tribes or nomadic groups) or certain livelihoods (*e.g.*, fisherfolk, smallholders or livestock herders). The extent to which these groups can adapt to the impacts of climate change will depend on their adaptive capacity. Human and natural systems will to some degree adapt autonomously, although planned adaptation, which includes the development and transfer of technologies for adaptation, will be important for the facilitation of this process.

27. The magnitude of the impacts of climate change will depend on a variety of factors, including the magnitude of climate change and the interaction of climate change with other stresses. These other stresses include demographic pressures (*i.e.*, population growth, rural-urban migration patterns) and socio-economic pressures (GDP per capita changes, global energy prices). The development of adaptation policy priorities relative to climate change impacts risks are best assessed in the light of the combination of stresses. Measures designed to reduce vulnerability to drought, or to other direct and indirect climate risks (*e.g.*, floods, pest invasions, diseases, unseasonable frosts), will be less effective and can be counterproductive unless they are considered within this broader context.

28. In Article 4.1(b), the UNFCCC refers to two options to address climate change: *mitigation* of climate change by reducing greenhouse gas emissions and enhancing sinks, and *adaptation* to the impacts of climate change. Most industrialised countries have committed themselves, as signatories to the UNFCCC and the Kyoto Protocol, to stabilising greenhouse gas emissions at 1990 levels by the year 2000 and to reducing their overall greenhouse gas emissions by at least 5% compared to 1990 by the period 2008–2012. However, the lag times in the global climate system mean that no mitigation effort, however rigorous, is going to prevent climate change from happening in the next few decades (Wigley, 1998; Pittock and Jones, 2000; Dessai and Hulme, 2001). The warming now being experienced is the result of emissions that took place decades ago. Indeed, the first impacts of climate change are already being observed in natural systems (*e.g.*, Parmesan and Yohe, 2003; Root *et al.*, 2003).

29. Adaptation is therefore a necessity (Parry *et al.*, 1998). On the other hand, relying on adaptation alone without taking steps to mitigate climate change could well lead to a magnitude of climate change to which effective adaptation is no longer possible, or only at very high social and economic costs. In other words, adaptation to climate change is not an alternative to mitigation. Both are required to reduce the risks of climate change (Burton and Van Aalst, 2004).

3. ADAPTATION TO CLIMATE CHANGE

30. In spite of the fact that the UNFCCC refers to both mitigation and adaptation, until recently national and international climate policy focused mainly on mitigation. On the one hand this reflected the concern of some that a stronger focus on adaptation would weaken society's willingness to mitigate climate change, on the other hand it signified the belief of others that the "invisible hand" of natural selection and market forces will bring about adaptation without the need for policy intervention (Kates, 1997). Since the IPCC TAR established that humans are—at least in part—responsible for climate change and that some impacts can no longer be avoided, academic and policy attention for adaptation has increased sharply (Burton *et al.*, 2002).

3.1. Types of Adaptation

31. There are various ways to classify or distinguish between adaptation options. First, depending on the timing, goal and motive of its implementation, adaptation can be either reactive or anticipatory. Reactive adaptation occurs after the initial impacts of climate change have become manifest, whilst anticipatory (or proactive) adaptation takes place before impacts are apparent.

A second distinction can be based on the system in which the adaptation takes place: the natural system (in which adaptation is by definition reactive) or the human system (in which both reactive and anticipatory adaptation are observed). Within the human system a third distinction can be based on whether the adaptation decision is motivated by private or public interests. Private decision-makers include both individual households and commercial companies, whilst public interests are served by governments at all levels. Figure 1 shows examples of adaptation activities for each of the five types of adaptation that have thus been defined.

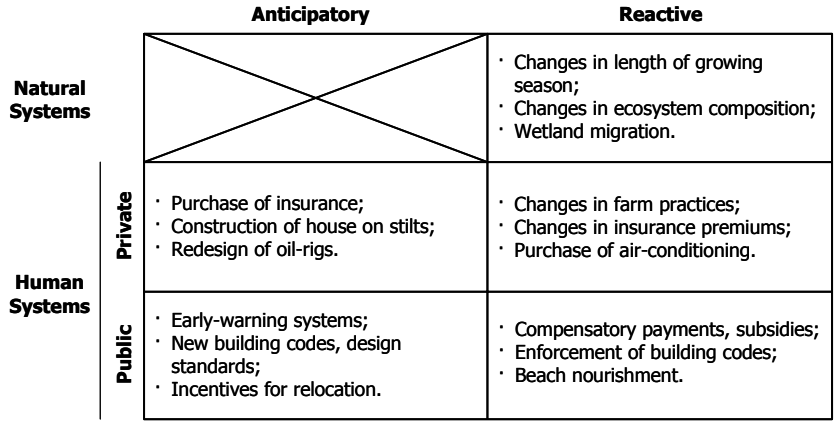

Figure 1: Matrix showing the five prevalent types of adaptation to climate change, including examples (Klein, 1998; Smit *et al.*, 2001).

32. An additional distinction that is often made is the one between planned and autonomous adaptation (Carter *et al.*, 1994). Planned adaptation describes the result of decisions that are based on an awareness that conditions have changed or are about to change, and that some type of action is required to achieve, maintain or return to a desired state. This could, for example, mean building sea walls in anticipation of a rise in sea level, or investing in irrigation in anticipation of dryer conditions.

33. In contrast, autonomous adaptation refers to the changes that natural and (most) human systems undergo in response to changing conditions in their immediate environment, irrespective of any broader plan or policy-based decisions. Such changes, for example, can be triggered by observed changes in weather patterns that result in shifting market signals or welfare changes (such as the price of crops and the occurrence of diseases). Examples of autonomous adaptations might include changes in farming practices, the purchase of air-conditioning devices, insurance policies taken out by individuals and private companies, and changes in recreational and tourist behaviour. Autonomous adaptation in human systems would therefore be in the actor's rational self-interest, whilst the focus of planned adaptation is on collective needs (Leary, 1999). Thus defined, autonomous and planned adaptation can correspond with private and public adaptation, respectively (see Figure 1).

34. Many of the actions taken by individuals, communities and companies as they adapt to climate change are likely to be autonomous (*i.e.*, not requiring external intervention), particularly as such autonomous action has, in the past, been taken in response to variations in climate that have been natural, rather than human-induced. There is currently much interest in whether society can rely on autonomous adaptation to reduce the potential impacts of climate change to an acceptable level, particularly since such initiatives would not require government intervention. In many parts of the world, however, the future impacts of climate change are likely to be significantly greater than those that have been experienced in the past as a result of natural climate variability alone. Such impacts may be more than many of those affected are able to handle effectively with autonomous adaptation, particularly given additional constraints such as limited information, inadequate knowledge, and insufficient access to resources.

35. As a result, it is now widely acknowledged that there is a need to implement policies for planned adaptation aimed at preparing for the impacts of climate change, and at facilitating and

complementing autonomous adaptation initiatives. Article 3.3 of the UNFCCC suggests that anticipatory planned adaptation, as well as mitigation, deserves particular attention. Some of the forms that such planned adaptation could take are (Klein and Tol, 1997):

- *Increasing the ability of physical infrastructure to withstand the impacts of climate change*. One approach, for example, would be to extend the temperature or rainfall range that a system can withstand; another would be to modify a system's tolerance to loss or failure;
- *Increasing the flexibility of potentially vulnerable systems that are managed by humans*. This could include allowing for mid-term adjustments in management practices, including changes in use or location;
- *Enhancing the adaptability of vulnerable natural systems*. This could involve reducing stresses due to non-climatic effects, or removing barriers to the migration of plants or animals;
- *Reversing trends that increase vulnerability*. This could range from reducing human activity in vulnerable areas to preserving natural systems that protect against hazards;
- *Improving public awareness and preparedness*. This could include informing the public about the risks and possible consequences of climate change, as well as setting up early-warning systems for extreme weather events.

3.2. The Process of Adapting to Climate Change

36. Planned adaptation is best seen as a process entailing more than merely the implementation of a policy or technology. The process of planned adaptation has been described as a multi-stage and reiterative process, involving four basic steps (Klein *et al.*, 1999; Risbey *et al.*, 1999):

- Information development and awareness raising;
- Planning and design;
- Implementation;
- Monitoring and evaluation.

37. This process of adaptation can be conceptualised as depicted in Figure 2. Climate variability and/or climate change—together with other stresses on the environment brought about by existing management practices—produce actual or potential impacts. These impacts trigger efforts of mitigation to remove the cause of the impacts, or adaptation to modify the impacts. The process of adaptation is conditioned by policy criteria and development objectives, and interacts with existing management practices. It is important to note that Figure 2 represents a simplified decision framework, which does not capture the multitude of actors involved in decision-making, the uncertainty with which these actors are faced, the other interests they have, or the institutional and political environments in which they operate.

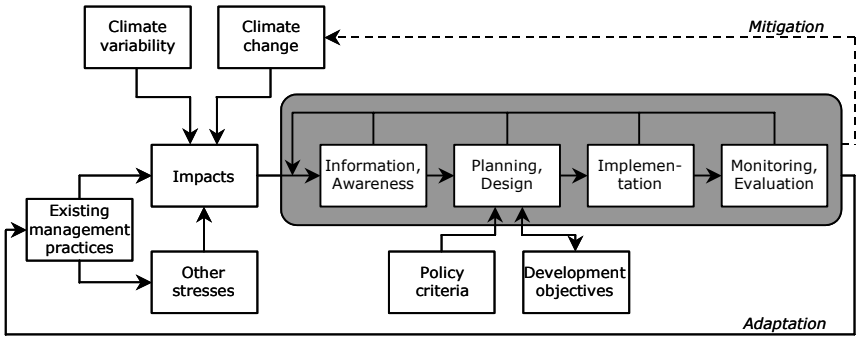

Figure 2: Conceptual framework showing in the shaded area the reiterative steps involved in planned adaptation to climate variability and change.

38. It should be noted that adaptation in Figure 2 refers to planned adaptation, aimed at changing existing management practices. Autonomous adaptation is implied in Figure 2 as it determines the manifestation of impacts (Klein *et al.*, 1999).

39. Another decision framework that has particular relevance to adaptation to climate change is the Technology Needs Assessment (TNA). A TNA handbook has been developed by the United Nations Development Programme (UNDP) (Gross *et al.*, 2004) that provides an overview of the process of technology identification/selection as it applies to mitigation and adaptation. From an adaptation perspective, technology needs assessment is intended to help to prioritise technologies, practices and policy reforms that can be implemented in different sectors of a country to adapt to climate change. Technology needs assessment—with its emphasis on identification and selection of technology—is fundamental to the process of technology transfer and can be seen as part of an overall integrated framework to promote technology transfer.

40. Carrying out a technology needs assessment takes into consideration six essential activities:

- Preparation of an initial list of options;
- Development of criteria for assessment;
- Prioritisation of key sectors;
- Identification of barriers;
- Selection of options;
- Preparation of a synthesis report.

41. Within this broad framework, there are some additional steps that are specific to the nature of the adaptation process itself. These include the identification of vulnerable sectors and groups, the development of criteria for prioritisation of vulnerable sectors and groups, characterisation of prioritised sectors and groups, assessment of local capacity to use technologies for adaptation, and selection of options. There are two issues—stakeholder engagement and barriers analysis—that cut across all these activities and are integral to the successful implementation of a technology needs assessment.

42. The technology needs assessment process overlaps the simplified decision framework shown in Figure 2 in two critical ways. First, the six essential activities of a TNA fit squarely within the information awareness and planning/design phases of the simplified framework. This means that any effort to modify the impacts of climate change through technology transfer would involve initial activities that are defined in large part by the process of undertaking a TNA. Secondly, the policy criteria and development objectives inputs to the planning/design activities in the simplified framework can be largely obtained from carrying out the additional TNA steps specific to the adaptation process. This means that specific TNA activities involving the development of criteria for prioritisation of vulnerable sectors/groups, characterisation of prioritised sectors/groups, and assessment of local capacity for the use technologies for adaptation can help meet broad planning and design objectives.

43. As an example showing the intersection between TNA the proposed simplified framework, Box 2 provides a sampling of the types of technologies for adaptation in agriculture, water resources, and coastal zones that emerged from a TNA for adaptation conducted in the country of Mauritius (TT:CLEAR). The Box illustrates the range of potential technologies that can emerge from the TNA process. The research, stakeholder discussions, and the resulting consensus that emerged around the specific technologies highlight the important role of TNA in promoting awareness building, as well as merging technology identification and selection with planning and design objectives.

Box 3: Mauritius' TNA for adaptation results	
Agric	Extension of irrigation facilities
	Introduction of hydroponics culture
	Cultivation in greenhouses and under cover
Water Resources	Increasing Surface Storage Capacity
	Reduce Loss of Surface Runoff to the sea
	Desalination (conversion of seawater into potable water)
	Efficient water pricing
	Recycling Waste Water
	Increase Use of Gray Water for secondary household purposes
	Increase Irrigation Use Efficiency by shifting centre pivot and drip techniques
	Reduce Leakage by rehabilitating distribution systems
	Increase Drought Toleration through drought tolerant cultivars
Coastal Zones	Replacement Casements
	Setback Building Distance
	Inland flood defences
	Flood warning systems
	Better management of rain / waste water
	Building with 'nature' techniques
	Stimulate growth of coral reefs naturally or artificially
	Hand-placed rock sea walls
	Gabion walls
	Groynes
	Revetments
	Bulkheads and seawalls
	Breakwaters
	Storm surge barriers
	Flooding and storm drains
	Beach nourishment

44. A key point about Figure 2 is that it shows that adaptation involves more than merely the implementation of a particular technology. Adaptation to climate change is an ongoing and reiterative process that includes information development, awareness raising, planning, design, implementation and monitoring. Reducing vulnerability requires having mechanisms in place and technologies, expertise and other resources available to complete each part of this process. The mere existence of adaptation technologies does not mean that every vulnerable community, sector or country has access to these options or is in a position to implement them.

45. As mentioned earlier, the IPCC TAR defined adaptive capacity as the "ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities or to cope with the consequences". Factors that determine a country's or community's adaptive capacity to climate change include its economic wealth, its technology and infrastructure, the information, knowledge and skills that it possesses, the nature of its institutions, its commitment to equity and its social capital (Smit *et al.*, 2001). It is therefore not surprising that most industrialised countries have higher adaptive capacities than developing countries. For example, Bangladesh and The Netherlands share a similar physical susceptibility to sea-level rise, but Bangladesh lacks the economic resources, technology and infrastructure that The Netherlands can call on to respond to the potential impacts (Huq and Klein, 2003).

46. On the other hand, having adaptive capacity is no guarantee that it is used successfully. In this respect, the development and use of new and existing information are especially important. For example, significant coastal development and urbanisation occurred on the east coast of the United States from 1966 to 1989, increasing exposure during a period when hurricane activity was well below average. New inhabitants were often ignorant of the hurricane risk, which became manifest with the more frequent and stronger hurricanes that began with Hurricane Hugo in 1989 (Pielke and Landsea, 1998).

47. The notion of adaptive capacity has brought to light the importance of considering the linkages between adaptation and development. It is recognised that climate change poses a threat to important development issues such as water supply, food security, human health, natural resources and protection against natural hazards. This recognition has moved adaptation from being the "handmaiden to impacts research in the mitigation context" (Burton *et al.*, 2002) to an activity that is considered crucial within the broader context of sustainable development. The link between adaptation and sustainable development is particularly relevant when seeking to enhance the capacity of countries and communities to adapt to climate change, which is often limited by lack of resources, poor institutions and inadequate infrastructure, amongst other things (Smith *et al.*, 2003). In addition, the notion of adaptive capacity has helped to demonstrate that adaptation is not a new activity only relevant when addressing climate change, but instead an ongoing process to reduce vulnerability both to today's and tomorrow's climate. When considered in this way, technology for adaptation to climate change can be assessed relative to vulnerability- and poverty-driven considerations in which the adaptation process itself becomes country-driven and based upon local needs and national development priorities.

4. TECHNOLOGIES FOR ADAPTATION TO CLIMATE CHANGE

48. This section provides important examples of technologies that can be employed to accomplish each of the four steps shown in the dark-shaded box in Figure 2, and provides some contextual information on their application. In the technical paper that is to follow this background paper, technologies will be presented and discussed in detail for a range of important sectors and systems, including agriculture, water supply, human health, and infrastructure and settlements. The reader is referred to FCCC/TP/1997/3 and to the draft scoping paper by the chairman of the EGTT for summary overviews of technologies for adaptation in various sectors. As an illustration of the more comprehensive approach proposed for the technical paper, this section focuses on technologies for adaptation to sea-level rise and related hazards in coastal zones. It draws strongly on the chapter "Coastal Adaptation" of the IPCC SRTT (Klein *et al.*, 2000). It should be noted that it is impossible to provide all-inclusive lists of technologies. Rather, the technologies and references listed in this section are meant to be illustrative and to encourage the reader to consider as wide a spectrum of adaptation technologies as possible.

49. Technologies for adaptation can comprise "hard" technologies, such as water treatment and supply technology, drought-resistant seeds or a seawall to protect against sea level rise, and "soft" technologies, such as materials and knowledge for awareness raising and capacity building, insurance mechanisms, methods for hazard and impact assessment, and general sustainability practices. Typically a successful adaptation strategy would combine 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. Box 3 summarises a case study on climate information and flood forecasting in Bangladesh.

4.1. The Role of Technology in Adaptation

50. In many places technology has been instrumental in reducing society's vulnerability to ever-present weather-related hazards. Extensive research has shown that today's hazard potential for many sectors and communities will increase because of climate change. However, in many cases the nature of the hazard will not change. Many existing technologies that have proven to be effective in reducing vulnerability to weather-related hazards will therefore also be important as technologies for adaptation to climate change. Technologies may have to be adjusted to meet local needs, and technological development and innovation will continue to increase the effectiveness and efficiency of existing technologies, but given current projections of climate change, successful adaptation does not have to rely on the development of new technologies specifically for adaptation.

51. In addition to the increased hazard potential referred to above, climate change will also pose new challenges to communities and sectors. Adaptation to climate change therefore also

involves preparing for situations previously unknown to sectors and communities. Such new situations may arise when trends in temperature, precipitation, sea level and other climate variables exceed critical limits. In these cases technology development and transfer may be particularly important.

Box 3: Early Warning Systems as Adaptation: The Case of Community-based Flood Information Systems in Bangladesh.

Every year millions of people in Bangladesh are exposed to catastrophic flooding. When they occur, floods can result in thousands of deaths and can lead to epidemics, as well as seriously habitats, agricultural production, fisheries, and pastoral systems. In rural areas of Bangladesh, disaster preparedness and early warning systems are almost non-existent. Moreover, millions of people living in coastal communities have little possibility for evacuation from flood prone areas and are highly vulnerable to flood related diseases.

The Reducing Risk and Vulnerability to Floods through Community-based Flood Information System (CFIS) Project is an initiative to enhance the adaptive capacity of local Bangladeshi communities regarding the risks of floods and cyclones. The project account for experience throughout the world that has shown that it is local people who are best placed to prepare for and respond to disasters, including floods. The CFIS Project worked in several flood prone coastal districts through partnerships with local organisations and communities. Its goal was the building of an interactive process of monsoon flood information collection and effective dissemination to community stakeholders, thereby increasing the capacity of local communities to adapt to adverse climate phenomena.

Prior to the project, most people in the project region would obtain flood-forecast information from a combination of sources - word-of-mouth (*i.e.*, neighbours, relatives, friends), traditional knowledge (*i.e.*, wind, cloud, rain patterns), and local media (*i.e.*, radio, TV, newspapers). The former two information sources are notoriously "hit-or-miss" and have been prone to inefficiencies in communication. Information from local media is ineffective as most people are unable to easily understand media reports and as a result cannot take full advantage of any warnings provided.

The CFIS project generated useful flood information during the devastating flood of 2004. The timely and widespread delivery of a flood warning in the project region was widely acknowledged to be helpful in the community response for taking steps to protect crops, habitats, livestock and other support systems. Initial findings of the project were shared in a national workshop just after the flood in September 2004. The Honourable Prime Minister of Bangladesh appreciated the experience of the CFIS project and recommended the concerned agencies including the Disaster Management Bureau to replicate the model in other flood prone areas of the country.

52. Vulnerability to climate change is not only determined by the degree of climate change, but also by the prevailing social, economic and environmental conditions in a community and the existing management practices in a system or sector (see Figure 2). Therefore, successful adaptation to climate change (*i.e.*, actions that reduce vulnerability to the impacts of climate change) may well include actions that are directed at improving such conditions and management practices.

4.2. Information Development and Awareness Raising

53. Data collection and information development are essential prerequisites for adaptation, particularly to identify adaptation needs and priorities. The more relevant, accurate and up-to-date the data and information available to the decision-maker, the more targeted and effective adaptation strategies can be. Coastal adaptation requires data and information on coastal characteristics and dynamics, patterns of human behaviour as well as an understanding of the potential consequences of climate change. In addition, it is essential that there is a general awareness amongst the public of these consequences and of the need to take appropriate action.

54. Large-scale global and regional data repositories have been established for a great number of climatic and socio-economic variables relevant to coastal zones. These sources of data may be accessed, displayed and downloaded from the Internet. Sea-level data, for example, may be obtained from the Permanent Service for Mean Sea Level (http://www.nbi.ac.uk/psmsl/index.html), the Global Sea Level Observing System (http://www.pol.ac.uk/psmsl/programmes/gloss.info.html) and the University of Hawai'i Sea Level Center (http://uhslc.soest.hawaii.edu/). Additional global data sets can be accessed via the IRI/LDEO Climate Data Library (http://ingrid.ldeo.columbia.edu/), the ICSU World Data Center (http://www.wdc.rl.ac.uk/wdcmain/), IGBP/IHDP-LOICZ (http://www.loicz.org/), the Center for International Earth Science Information Network (http://www.ciesin.org/) and the IPCC Data Distribution Centre (http://ipcc-ddc.cru.uea.ac.uk/). The latter centre also provides climate and socio-economic scenarios.

55. The Global Earth Observation System of Systems (GEOSS), adopted in 2004, complements these data repositories. It represents an international co-operative to enhance preparedness for environmental disasters, bringing together existing and new hardware and software. In addition, the World Meteorological Organization (WMO) has ongoing weather-watch programmes for short-range weather prediction and emergency response.

56. Useful as they may be, coastal adaptation to climate change will often require additional, more detailed information than these global data sets and initiatives can provide. Table 1 lists a number of technologies that can serve to increase the understanding of the coastal system (which involves data collection and analysis), to conduct climate impact assessment in coastal zones (so that potential impacts can be quantified for given scenarios) and to raise public awareness (that some form of adaptation is necessary). It is important to note that many technologies listed in Table 1 represent "soft" options that are vital to building capacity to cope with climatic hazards. Where appropriate, reference is made to publications that either describe the technology in detail or provide examples of its application. Further information on a broad range of technologies for coastal system description can be found in Morang *et al.* (1997a), Larson *et al.* (1997), Morang *et al.* (1997b) and Gorman *et al.* (1998). Capobianco (1999) discussed technologies in relation to integrated coastal zone management.

57. Some of the technologies listed in Table 1 make use of Geographical Information Systems (GIS). GIS combines computer mapping and visualisation techniques with spatial databases and statistical, modelling and analytical tools. It offers powerful methods to collect, manage, retrieve, integrate, manipulate, combine, visualise and analyse spatial data and to derive information from these data. GIS is an example of a technology that is crosscutting, in the sense that it contributes not only to information development and awareness raising but also to the other three steps shown in Figure 2. Collected data can be stored in a GIS, combined to develop new insights and information, and visualised for interpretation and educational purposes. In combination with scenarios of relevant developments and models to assess and evaluate changes in important natural and socio-economic variables (including climate), GIS can assist planners in identifying appropriate adaptation technologies and their optimal locations for implementation, depending on the criteria of the decision-maker. One simple, first-order application of GIS in coastal adaptation would be overlaying scenarios of sea-level rise with elevation and coastal development data to define impact zones. More sophisticated applications may include the modelling of morphodynamic and ecological responses to climate change. In addition, GIS allows for the non-invasive, reversible and refinable testing of specific technologies for adaptation before these are implemented in the real world. After implementation, newly acquired data can be analysed to evaluate technology performance. Once created, a GIS database will have further utility in other aspects of management and policy.

58. The modelling of potential futures based on plausible scenarios is particularly pertinent for the planning and design of adaptation technologies, when relevant impacts are quantified, alternative adaptation options are evaluated and one course of action is selected. Climate impact assessment requires models of relevant changes in morphological, ecological and human factors, as well as their interaction over appropriate time scales (*i.e.*, a decade or longer). The necessary modelling capabilities are increasing rapidly and current developments in information technology are facilitating the transfer and application of these tools as they are developed. However, the limitations inherent in all models (*i.e.*, they are representations of a part of reality for a specific purpose) must not be overlooked. Human expertise and interpretation remain essential for the intelligent use of any model.

4.3. Planning and Design

59. When the available data and information point towards a potential problem that would justify taking action, the next stage is to decide which action could best be taken and where and when this could best be implemented. The answers to these questions depend on the prevailing criteria that guide local, national or regional policy preparation, as well as on existing development and management plans that form the broader context for any adaptation initiative. Important policy criteria that could influence adaptation decisions include cost-effectiveness,

environmental sustainability, cultural compatibility and social acceptability. In addition, countries may choose to take a precautionary approach when postponing action would involve substantial risks, even though uncertainty may still be considerable.

60. Planners will always face a certain degree of uncertainty, not only because the future is by definition uncertain, but also because knowledge of natural and socio-economic processes is and always will remain incomplete. This uncertainty requires planners to assess the environmental and societal risks of climate change with and without adaptation (Carter *et al.*, 1994). The information thus obtained can help to determine the optimal adaptation strategy and timing of implementation. There are a number of decision tools available to assist in this process. Examples of these tools include cost-benefit analysis, cost-effectiveness analysis, risk-effectiveness analysis and multi-criteria analysis. The latter technique is particularly relevant when great significance is attached to values that cannot be easily expressed in monetary terms.

61. One recent type of decision-making framework that has relevance to the planning and design of adaptation technologies is the UNDP's Adaptation Policy Framework (APF; Lim and Spanger-Siegfried, 2005). The APF is intended to be a complement to existing policy making related to climate change in developing countries, including processes of assessment, project development and monitoring. It is structured around the following four major principles:

- Adaptation to short-term climate variability and extreme events is explicitly included as a step towards reducing vulnerability to longer-term climate change;
- Adaptation policy and measures should be assessed within a developmental context;
- Adaptation occurs at different levels in society, including the local level;
- Both the strategy and process by which adaptation activities are implemented are equally important.

Table 1: Examples of important technologies to collect data, provide information and increase awareness for coastal adaptation to climate change. Note that this table is not intended to provide an exhaustive list of applications and technologies (Klein *et al.*, 2000).

Application	Technology	Additional Information
Coastal System Description		
• Coastal topography & bathymetry	- Mapping and surveying	- Birkemeier *et al.* (1985, 1999); Stauble and Grosskopf (1993)
	- Videography	- Debusschere *et al.* (1991); Holman *et al.* (1994); Plant and Holman (1997)
	- Airborne laserscanning (lidar)	- Lillycrop and Estep (1995); Sallenger *et al.* (1999)
	- Satellite remote sensing	- Leu *et al.* (1999)
• Wind and wave regime	- Waverider buoys	- Morang *et al.* (1997a)
	- Satellite remote sensing	- Martinez-Diaz-de-Leon *et al.* (1999)
• Tidal and surge regime	- Tide gauges	- Pugh (1987); Zhang *et al.* (1997)
• Relative sea level	- Tide gauges	- Emery and Aubrey (1991); Woodworth (1991); Gröger and Plag (1993); Nicholls and Leatherman (1996); NOAA (1998)
	- Historical and geological methods	- Van de Plassche (1986)
• Absolute sea level	- Satellite remote sensing	- Nerem (1995); Fu *et al.* (1996); Nerem *et al.* (1997); Cazenave *et al.* (1998)
	- Tide gauges, satellite altimetry, global positioning systems	- Douglas (1991); Baker (1993); Miller *et al.* (1993); Zerbini *et al.* (1996); Neilan *et al.* (1997)
• Past shoreline positions	- Historical and geological methods	- Crowell *et al.* (1991); Beets *et al.* (1992); Crowell *et al.* (1993); Moore (2000)
• Land use	- Airborne and satellite remote sensing	- Redfern and Williams (1996); Clark *et al.* (1997); Henderson *et al.* (1999)
• Natural values	- Resource surveys	- Lipton and Wellman (1995); Turner and Adger (1996)
• Socio-economic aspects	- Mapping and surveying	- Penning-Rowsell *et al.* (1992)
• Legal & institutional arrangements	- Interviews, questionnaires	- English Nature (1992)
• Socio-cultural factors	- Interviews, questionnaires	- Tunstall and Penning-Rowsell (1998); Tunstall (2000)
Climate Impact Assessment		
• Index-based methods	- Coastal vulnerability index	- Hughes and Brundrit (1992); Gornitz *et al.* (1994); Shaw *et al.* (1998)
	- Sustainable capacity index	- Kay and Hay (1993); Yamada *et al.* (1995); Nunn *et al.* (1994a,b)
• (Semi-) quantitative methods	- IPCC common methodology	- IPCC CZMS (1992); Bijlsma *et al.* (1996)
	- Aerial-videotape assisted vulnerability assessment	- Leatherman *et al.* (1995); Nicholls and Leatherman (1995)
	- UNEP impact and adaptation assessment	- Klein and Nicholls (1998, 1999)
• Integrated assessment	- Coupled models	- Engelen *et al.* (1993); Ruth and Pieper (1994); West and Dowlatabadi (1999)
Awareness Raising		
• Printed information	- Brochures, leaflets, newsletters	
• Audio-visual media	- Newspapers, radio, television, cinema	
• Interactive tools	- Board-games	
	- Internet	
	- Computerised simulation models	

62. The APF framework is comprised of five basic steps, each of which is linked to two important cross-cutting issues, as shown in Figure 3.

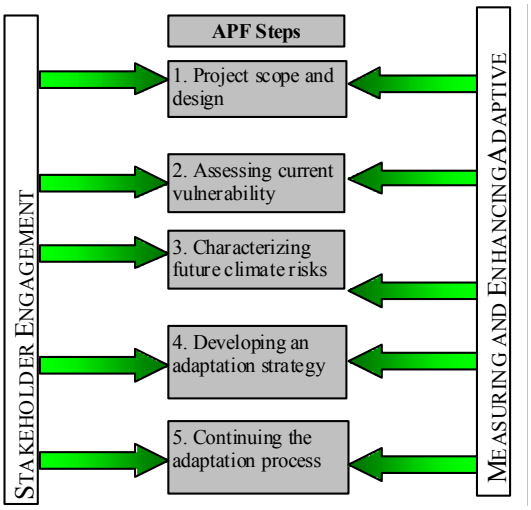

Figure 3: Outline of the APF process.

63. Since specific adaptation measures are usually implemented at the local level, the APF is also intended to be accessible to the private sector, the general public and other stakeholders. The APF is capable of yielding a variety of outputs, depending on how it is applied. Whilst specific outputs depend on particular needs and goals, in general, a completed APF process leads to a clarification of adaptation strategies, policies and/or technology measures that a country could implement. These strategies, policies and measures can be aimed at different levels of society, as well as at different spatial and temporal scales. Their general purpose will be to reduce the potential negative impacts and exploit the opportunities of climate variability and change, and to enhance the capacity to adapt.

64. Another recent type of decision-making framework that has relevance to the planning and design of adaptation technologies is the National Adaptation Programme of Action (NAPA) process, which emerged from COP-7 in 2001. The NAPA process is being implemented in the least-developed countries. It is intended to yield a concise document that specifies a list of priority activities that communicate the immediate and urgent needs of vulnerable communities, resources, or systems, considering their low adaptive capacity to climate change. The NAPA process seeks to ensure adequate stakeholder representation, identify a set of climate change adaptation initiatives, establish country-driven criteria by which to evaluate and prioritise adaptation initiatives, make consensus-based recommendations for adaptation activities, and as needed, recommend capacity building, and policy, programme and institutional integration, as part of adaptation priority activities.

65. One key feature of the NAPA process is the role of stakeholder consultations for establishing priority vulnerabilities and potential adaptation technologies. Together with an assessment of national development plans, the stakeholder consultation process is intended to link experts and local groups for weighting and ranking of potential adaptation projects and technologies. Once prioritised, specific information such as geographical location, institutional weaknesses and strengths, should be identified as such characteristics are important in order to further define resilient features, competing interests and uses, overlap with other sectors and synergy opportunities (*i.e.*, adaptation measures taken in one sector can have indirect benefits in another related sector).

66. The quality and effectiveness of the planning and design process is affected by the context in which the decision is made. For example, coastal management in many countries used to be top-down by nature, but as public interest and involvement in coastal issues have grown, so has resistance to top-down decision-making (*e.g.*, Taiepa *et al.*, 1997). The successful

implementation of many coastal policies, including adaptation to climate change, is now increasingly dependent on public acceptance at the community level. Hence, in addition to informing the public so as to raise their awareness of the issues at stake (see Section 4.2), it is also important to involve them throughout the planning process. Gaining public acceptance is an important prerequisite for identifying and transferring appropriate adaptation technologies. Further, local expertise will be required for successful technology implementation, application, maintenance and enforcement.

67. In some settings, however, public involvement can be difficult to accomplish. In situations where there is little truly private land, coastal inhabitants may have little long-term stake and therefore interest in the land they occupy (*e.g.*, in parts of Tonga; Nunn and Waddell, 1992). Further, governments may have neither the resources to address countrywide coastal or other forms of natural resource management nor, compared to long-resident inhabitants, the local knowledge or experience that are essential for effective management (*e.g.*, in parts of Fiji; Nunn *et al.*, 1994a). In other settings, the combination of local stakeholder involvement, perceived vulnerability, and prudent planning and design can lead to adaptation solutions that meet strategic near- and long-term climate-related challenges (see Box 4).

Box 4: Factoring future climate change in today's decisions: The case of Boston Harbor

Some planning agencies are beginning to incorporate future climate change in current decision-making. An interesting example comes from Massachusetts in the USA, where the Massachusetts Water Resource Authority (MWRA) has installed a sewage treatment plant for the greater Boston metropolitan area with climate change – and in particular accelerated sea-level rise - in mind.

Even before the arrival of English and European settlers, the Boston Harbor was an important natural resource with local Native Americans fishing and planting crops along the coasts of the 30 or so Islands that dot the Harbor. In the early 1600's the Massachusetts Bay Company landed and began settling the area, clearing land for livestock and firewood. Boston Harbor quickly became a busy trading port and by 1660 almost all English imports to New England came through these waters. As Boston grew and flourished over the next 300 years, however, the city's waste began to exert a toll on the Harbor. Those treatment plants that were installed only performed primary sewage treatment, not secondary treatment, and the facilities were often overloaded. By the early 1980's the media was calling Boston Harbor the filthiest harbor in the nation.

As a result of litigation initiated by a private citizen, the courts ordered the city of Boston to build a new secondary treatment plant, and carry out a subsequent cleanup of the harbor. Deer Island, located within the Harbor was selected as the site for the sewage treatment plant. The design called for raw sewage collected from communities on shore to be pumped under Boston Harbor and then up to the Deer Island treatment plant. After waste treatment, the effluent would be discharged into the harbor through a downhill pipe. In order to reduce the costs of pumping untreated sewage from the shore up to the Deer Island treatment plant, the MWRA originally planned to lower the level of the Deer Island plant about half a meter to be closer to sea level. However, design engineers were concerned that sea-level rise would necessitate construction of a wall around the treatment plant to keep the sea out. The effluent would then need to be pumped up over the wall and into the harbor. Such a pump would cost several hundred million dollars. To avoid such a cost, even though it might be decades before it would need to be installed, the designers decided to leave the island at a higher elevation. In 1998 the Deer Island treatment plant was completed.

Three points deserve special mention concerning the proactive adaptation planning by the MWRA. First, the decision by the MWRA to account for climate change will also enhance the resilience of the Harbor treatment system under current climate variability from storm surges (Weiner (1993) found the 10-year surge elevation in Boston Harbor to be 2.8 meters, the 100-year surge elevation to be 3.16 meters and the 500-year surge elevation to be 3.41 meters). Second, while the planning involved was proactive and innovative, the pump technology involved was conventional and readily accessible. Finally, the Boston Harbor has become progressively cleaner with native fish species like smelt, herring, striped bass, and bluefish returning to the Harbor, as well as porpoises and harbor seals.

4.4. Implementation

68. Once all options for coastal adaptation have been considered and the most appropriate strategy has been selected and designed, implementation is the next stage. An adaptation strategy to sea-level rise can comprise one or more options that fall under the three broad categories protect, retreat and accommodate (IPCC CZMS, 1992). Table 2 provides an overview of these options and the technologies that make them possible (see also NRC, 1987; IPCC CZMS, 1990; Bijlsma

et al., 1996). It should be noted that, in addition to the subdivision between protect, retreat and accommodate, there are various other ways to classify or distinguish between different adaptation strategies, both in generic terms (*e.g.*, Smit *et al.*, 2000) and for coastal zones (*e.g.*, Kay *et al.*, 1996; Pope, 1997).

69. Klein and Nicholls (1998) concluded that most of the options listed in Table 2 require strategic planning, whereas few would occur autonomously. In addition, options to protect against sea-level rise can be implemented both reactively and proactively, whilst most retreat and accommodation options are best implemented in an anticipatory manner. To date, the assessment of possible adaptation strategies in coastal zones has focused mainly on protection. Bijlsma *et al.* (1996) noted the need to identify and evaluate the full range of options listed in Table 2. The range of appropriate options will vary amongst and within countries, and different socio-economic sectors may prefer competing adaptation options for the same area. The existence of such a broad range of options is one of the reasons why adaptation to climate change is recommended to take place within the framework of integrated coastal zone management (see also Section 5.3).

70. Table 2 combines hard technologies, such as dikes, levees and floodwalls, and soft technologies, such as evacuation systems. Note that there are also a range of applications that require only limited technology, such as increasing or establishing set-back zones and creating upland buffers.

Table 2: Examples of important technologies to protect to, retreat from or accommodate sea-level rise. This table is not intended to provide an exhaustive list of applications and technologies (Klein *et al.*, 2000).

Application	Technology	Additional Information
Protect		
• Hard structural options	- Dikes, levees, floodwalls	
	- Seawalls, revetments, bulkheads	- Pilarczyk (1990); Silvester and Hsu (1993)
	- Groynes	
	- Detached breakwaters	
	- Floodgates, tidal barriers	- Gilbert and Horner (1984); Kelly (1991); Penning-Rowsell *et al.* (1998)
	- Saltwater intrusion barriers	- Sorensen *et al.* (1984)
• Soft structural options	- Periodic beach nourishment	- Delft Hydraulics and Rijkswaterstaat (1987); Davison *et al.* (1992); Stauble and Kraus (1993); Hamm *et al.* (1999)
	- Dune restoration and creation	- Doody (1985); Vellinga (1986); Nordstrom and Arens (1998); Nordstrom *et al.* (1998)
	- Wetland restoration and creation	- NRC (1992, 1994); Boesch *et al.* (1994); Tri *et al.* (1998)
• Indigenous options	- Afforestation	
	- Coconut leaf walls	
	- Coconut fibre stone units	- McLean *et al.* (1998); Mimura and Nunn (1998)
	- Wooden walls	
	- Stone walls	
(Managed) Retreat		
• Increasing or establishing set-back zones	- Limited technology required	- NRC (1990); Kay (1990); Owens and Cope (1992); Caton and Eliot (1993); OTA (1993)
• Relocating threatened buildings	- Various technologies	- Rogers (1993)
• Phased-out or no development in exposed areas	- Limited technology required	- OTA (1993); DETR (2000)
• Presumed mobility, rolling easements	- Limited technology required	- Titus (1991, 1998)
• Managed realignment	- Various technologies, depending on location	- Burd (1995); English Nature (1997); French (1997, 1999)
• Creating upland buffers	- Limited technology required	- Kaly and Jones (1998)
Accommodate		
• Emergency planning	- Early-warning systems	- Penning-Rowsell and Fordham (1994); Haque (1995, 1997); Handmer (1997); Rosenthal and 't Hart (1998); Elliot and Stewart (2000)
	- Evacuation systems	- Parker and Handmer (1997); Rosenthal and 't Hart (1998)
• Hazard insurance	- Limited technology required	- Davison (1993); OTA (1993); Crichton and Mounsey (1997); Clark (1998); Arnell (2000)
• Modification of land use and agricultural practices	- Various technologies (*e.g.*, aquaculture, saline-resistant crops), depending on location and purpose	
• Modification of building styles and codes	- Various technologies	- FEMA (1986, 1994, 1997)
• Strict regulation of hazard zones	- Limited technology required	- May *et al.* (1996)
• Improved drainage	- Increased diameter of pipes	- Titus *et al.* (1987)
	- Increased pump capacity	- Titus *et al.* (1987)
• Desalination	- Desalination plants	- Ribeiro (1996)

71. In the process of implementing technologies for adaptation to climate change, one of the critical components is the presence of appropriate and effective institutions. Institutions vary widely across scales (small to large, local to national), sectors (such as agriculture, water, forestry, transport) and from formal (*e.g.*, Ministry or Department of Environment, NAPA Secretariat) to informal (*e.g.*, a local village community). Whilst formal institutions can respond to adaptation needs and challenges within its regulations, institutional guidelines and allocated resources, informal institutions often respond to specific adaptation challenges such as drought, flood or a cyclone as self-organised and self-motivated systems. In between these two extremes there is a range of institutional arrangements and different degrees of formalisation. For example, small to large level of NGOs can play important roles in advancing adaptation technology.

72. In most countries and ecosystems, indigenous knowledge of communities has been accumulated into experiences of responses to different climate-related challenges. Flood- or drought-affected areas have often evolved local-level adaptation technologies that can be of great value to areas likely to be affected by similar events. Hence there is a need to assess these indigenous technologies and community-level response strategies. Successful and appropriate technologies may be replicated and adopted in the areas likely to be affected by climate change.

73. The relevant institutions need to have their mandates ascertained so that they can respond to the needs of advancing technologies for adaptation. Further, skilled manpower, well-developed and tested tools and methodologies need to be established and resourced. For institutions to succeed in assisting adaptation, they themselves must be responsible and flexible. These institutions should be able to interact, involve and be guided by stakeholders such as communities, farmers, fisherfolks, local NGOs, local-level government agencies, amongst others. There is a need for adequate and continuous funding so that key institutions are well established and prepared to advance adaptation technologies and need of the different stakeholders.

74. Finally, it is important to note that the issue of climate change insurance is receiving increasing attention. Insurance is particularly important when facing the risk of catastrophic losses. Insurance companies have the responsibility of dealing with many of the consequences of climate change and are aggressively mobilising to understand the new risks that flow from climate change, and to help customers to manage these risks though the enhancement of adaptive capacity. Insurers can uniquely contribute to the climate change debate through their understanding of risk and the needs of homeowners and businesses (Dlugolecki, 2004).

75. In countries with climate-related insurance markets, insurance can have a positive or a negative role in promoting adaptation to climate change and any associated technology transfer. This may happen directly via contacts with customers or indirectly as the insurance industry lobbies institutions. Technology underpins this interaction as improving data management and modelling capability give the insurance industry more detailed information of both the risks and opportunities that climate variability and change present. However, more knowledge may benefit the insurance industry, but it does not necessarily lead to overall social benefits. Clark (1998) argued that partnerships between governments and the insurance industry can benefit both the industry and wider society in terms of reduced exposure and maintain the long-term viability of the insurance industry.

4.5. Monitoring and Evaluation

76. It is recommended practice in any field of policy that the performance of implemented measures is periodically or continuously evaluated against the original objectives. Such evaluation can yield new insights and information, which could give rise to adjust the strategy as appropriate. This process is illustrated in Figure 2 by the feedback loop from evaluation within the shaded box. This post-implementation evaluation must be distinguished from the evaluation exercise that is done to identify the most appropriate technology. The latter can be considered pre-implementation evaluation and is part of the planning and design phase (Section 4.3).

77. Effective evaluation requires a reliable set of data or indicators, to be collected at some regular interval by means of an appropriate monitoring system. Indicators are a tool for reporting and

communicating with decision-makers and the general public. They should fulfil a range of properties, including (*i*) a relationship to functional concepts, (*ii*) be representative and responsive to relevant changes in conditions, and (*iii*) be easily integrated within a broader evaluation framework. Evaluation is an ongoing process and the monitoring should be planned accordingly. There is limited experience of such long-term monitoring, so in many situations it is unclear which are the most appropriate data or indicators (Basher, 1999).

78. For coastal physical systems, experience can be drawn from countries where the coast has been monitored for long periods. In The Netherlands, for instance, the position of high water has been collected annually for nearly a century and cross-shore profiles have been measured annually since 1963 (Verhagen, 1989; Wijnberg and Terwindt, 1995). Observations of the "natural" evolution of the coast allow trends to be reliably estimated and hence the impact of human interventions on the coast (breakwaters, nourishment, *etc.*) to be evaluated.

79. In general, the technologies to be used for monitoring are the same as those used for initial description of the coastal system. They are therefore listed in the upper part of Table 1 and discussed by Morang *et al.* (1997a), Larson *et al.* (1997), Morang *et al.* (1997b) and Gorman *et al.* (1998).

5. TECHNOLOGY DEVELOPMENT AND TRANSFER

80. To enhance the development and transfer of environmentally sound technologies to address climate change requires an understanding of whether mitigation or adaptation objectives are being sought. The particular processes to assess technology needs in these two areas—whilst fundamentally consistent and overlapping in some key areas—are operationally distinct in others. The assessment and transfer of environmentally sound technologies for mitigating climate change is fairly straightforward, in the sense that such technologies have a clear objective: to reduce or avoid greenhouse gas emissions. They tend to target specific, well-known emitting sectors such as power generation, transportation and industrial operations. Moreover, there is a large literature of mitigation technology applications from which lessons can be learnt and taken into account when assessing such technologies in various local contexts.

81. On the other hand, the assessment and transfer of environmentally sound technologies for adaptation to climate change pose a more complex challenge, at two distinct levels. First, there is inherently more uncertainty regarding vulnerability and subsequently, adaptation to the impacts of climate change. This uncertainty is manifested most acutely at the local level and carries over to the identification of appropriate adaptation measures, options and technologies, as well as to the stakeholders that are affected. Therefore, hard technologies may not be appropriate and hence the relevance and importance of soft technologies as discussed earlier. This is particularly true since there are potential synergies between mitigation and adaptation with may have either positive or negative effects. Secondly, adaptation concerns have only recently moved onto centre stage of the climate change negotiations. Unlike the mitigation area, which can claim a formal protocol as a framework for North-South co-operation on reducing greenhouse gases (*i.e.*, the Kyoto Protocol), there is no comparable approach for focused international co-operation in the adaptation area. As a result, there are limited examples of real-world successes from which to draw lessons.

82. Technology transfer is a complex process that involves multiple stakeholders, a variety of perspectives, and is highly interdisciplinary. It encompasses diffusion of technologies and co-operation across and within countries. It covers technology transfer processes between developed countries and developing countries, amongst developed countries, amongst developing countries and amongst countries with economies in transition. Finally, technology transfer comprises the process of learning to understand, utilise and replicate the technology, including the capacity to choose it and adapt it to local conditions and integrate it with indigenous technologies.

83. Although there have been numerous frameworks and models put forth to cover different aspects of technology transfer, there are no corresponding overarching theories (IPCC, 2000). In this

section, the emphasis is on exploiting opportunities for transferring technologies for adaptation as represented in various multilateral and bilateral frameworks, understanding the various dimensions for promoting the transfer of adaptation technologies, and making the overall process more integrated in national development processes.

5.1. Frameworks for Facilitating Adaptation Technology Transfer

84. Frameworks for adaptation technology transfer exist in the form of multilateral environmental agreements (MEAs), which are linked with multilateral agencies that have clear development goals such as the United Nations Development Programme, the World Bank, and regional development banks. These organisations support technology transfer as a way of achieving country-driven goals in implementing the various MEAs. In addition, there are numerous bilateral assistance frameworks that donor countries have established to encourage technology transfer via development assistance. These frameworks can support a range of development and political goals, often including the expansion of foreign markets for exports and the expertise of national firms.

85. In addition to the UNFCCC, there are several other multilateral environment and development frameworks that are either relevant to or conducive to the transfer of adaptation technology. These frameworks are represented—legally as well as operationally—by two major international environmental agreements (MEAs): the Convention on Biological Diversity (CBD) and the United Nations Convention to Combat Desertification (UNCCD). Several other MEAs have potential as frameworks within which adaptation technologies are implied. The implementation of each of these MEAs has evolved along quite distinct paths over the years in signatory countries, with different communication products, institutional leads, and schedules for implementation.

86. In the course of preparing this background paper, a sampling of several country-specific action plans (*i.e.*, Eritrea, Ethiopia, Yemen, and Sudan) emerging from MEA implementation have been considered in order better to assess a range of activities where potential synergies may exist. The reviewed action plans contain a variety of measures, initiatives and technologies that contribute directly to the goals of the particular MEA. It is important to note that many of these same measures, initiatives and technologies also contribute implicitly to meeting adaptation goals through their enhancement of local capacity to cope with climate hazards. In other words, there are opportunities for actions taken under the various MEAs to complement actions taken to promote the transfer of soft and hard climate change adaptation technologies.

87. Table 3 illustrates this point, summarising the various sectors that would benefit from implementation of National Action Plans for the MEAs. Clearly, these sectors have strong overlap with the sectors that are likely to experience significant climate impacts discussed earlier (see Box 1). The overlap suggests that the overall process of technology transfer will likely include specific initiatives that could be credited as meeting climate change adaptation goals. Considering adaptation technology transfer within the broader MEA framework will enhance the opportunities for exploiting the range of positive synergies across the initiatives and help to build local adaptive capacity.

Multilateral Environmental Agreement	Sectors affected
Convention on Biological Diversity	Forestry, coastal zones
Convention to Combat Desertification	Agriculture, forestry
Cartagena Protocol on Biosafety	Agriculture, human health
Convention on International Trade in Endangered Species (CITES)	Agriculture, coastal zones, forestry, water resources
Convention on the International Maritime Organization	Coastal zones
World Heritage Convention	Coastal zones, forestry

Table 3: MEAs potentially relevant to the transfer of climate change–related adaptation technologies.

88. Adaptation to climate change is, of course, explicitly considered in the UNFCCC. Articles 3 and 4 of the Convention make various references to adaptation, including language regarding policies

and measures, different socio-economic contexts, and the range of economic sectors (see Section 1.2).

89. Another important framework for technology transfer for adaptation exists in the form of bilateral development assistance. Particularly for the poorest developing countries, which happen to be the most vulnerable to climate change, development assistance remains a main conduit for government supported technology transfer efforts (IPCC, 2000). Such assistance needs to be developmental and concessional meaning that aid flows in the form of grants and/or low-interest loans. Whilst there are 21 OECD member governments (out of 26) that have development assistance programmes, there are three—Canada, Germany and the Netherlands—that have programmes specifically targeted to climate change adaptation, as described below.

90. In 2000, Canada established a fund dedicated to helping developing countries achieve their commitments as stated in Article 4 of the United Nations Framework Convention on Climate Change. Through the Canada Climate Change Development Fund (CCCDF), Canada helps people in developing countries address climate change in four key ways: introducing policies and technologies that will reduce harmful greenhouse emissions; b) promoting forestry and agriculture practices that will protect and enhance carbon sinks; c) reducing the vulnerability of people in developing countries to climate change and helping them adapt to its negative effects; d) raising awareness and helping to develop tools and technologies to combat climate change. The CCCDF is a five-year, $100 million initiative and is administered by CIDA.

91. Germany's Climate Protection Programme for Developing Countries (CaPP) focuses on both mitigation and adaptation to climate change. Within the framework of the fourth phase of the programme, emphasis is being placed in supporting the ability of developing countries to adapt to climate change. The German programme is particularly interesting because of its explicit emphasis on trying to identify adaptation synergies across related activities. The aim is to first determine the extent to which adaptation measures are already being implemented in ongoing projects, either as targeted measures or as back-up measures in the field of climate protection. In addition, guidelines are under development regarding how such measures can be integrated into project planning and implementation and how their impacts can be assessed. Collaboration with other GTZ projects – especially on the Biodiversity and Desertification Conventions are key priorities. A total of 30 developing countries are participating in the programme, which had funding of 4.5 million euros for the period 2001 to 2005.

92. The Dutch National Climate Assistance Programme (NCAP) is a bilateral assistance programme whose aim is to assist in the development of activities that can effectively address adaptation to climate change. The programme includes 15 countries and is designed to address adaptation issues in the wider context of poverty alleviation, vulnerable systems, and policy development. NCAP projects seek to ensure adequate stakeholder representation, identify a set of climate change adaptation initiatives, establish country-driven criteria by which to evaluate and prioritise adaptation initiatives, make consensus-based recommendations for adaptation activities, and as needed, recommend capacity building, and policy, programme and institutional integration, as part of adaptation priority activities. The current phase of the programme is about the urgent actions that developing countries must take to adapt to the negative impacts of climate change (extreme fluctuations in the climate; more frequent and powerful cyclones and hurricanes, more frequent and intense floods and droughts), which are already occurring. Like the German programme, the Dutch NCAP explicitly seeks to link activities with any complementary activities taking place, particularly NAPA efforts.

93. Understanding and exploiting potential synergies between the multilateral and bilateral framework above is critical for promoting technology transfer processes that are effective and efficient. At least three activities - synthesis, networking, and innovative financing - will be needed help to facilitate bringing the various facets of adaptation technology transfer together into a coherent strategy, as outlined below.

- ***Synthesis:*** As indicated above, there are numerous initiatives, projects, and/or strategies already proposed or in effect, upon which future technology transfer processes could build. They are represented in Action Plans meeting multilateral environmental agreement (MEA)

and specific projects undertaken as part of development assistance. A systematic synthesis regarding the types of technologies priorities that are emerging form these activities and which can meet multiple objectives, including climate adaptation, would be helpful is structuring an approach for matching funding with projects that are able to satisfy multiple adaptive capacity objectives. The synthesis of appropriate information can facilitate and promote the transfer of adaptation technologies within and across countries and can help foster integration with indigenous technologies.

- ***Networking:*** It would be particularly help for networks to be established to facilitate a structured exchange of information regarding various initiatives. At present, the multilateral environmental agreements are implemented independently from each other. With the possible exception of the bilateral programmes described above, this is also largely true of development assistance. A process of developing communication networks amongst Parties involved across the various MEAs and development assistance programmes could help to facilitate the emergence of key lessons, insights, and complementarities.
- ***Innovative financing:*** As has been the case with the mitigation aspects of the UNFCCC, it will be necessary to explore innovative financing mechanisms that can promote, facilitate, and support increased investment in adaptation technologies. At present, most of the attention regarding innovative financing has been devoted to the mitigation side of the climate change challenge. Several financing mechanisms have emerged that aim to catalyze important change agents, facilitate trading of credits (i.e., carbon or renewable energy), and provide greater overall flexibility for the private sector to invest in environmentally sustainable technologies (van Aalst, 2004). Nothing comparable has thus far emerged for the adaptation side where potential technology transfer investments are associated with insufficient incentive regimes, increased risks, and high transaction costs. At least two areas would need to be scrutinized to begin the process or developing innovative financing models for adaptation. First, it will be essential to clearly define basic objectives for innovative financing for transferring technologies for adaptation. The underlying motivation for these objectives could be to help countries enhance their resilience to climate change by helping businesses and the public sector invest in risk-reducing strategies that capture commercial opportunities. Second, progress will need to made on the dual processes of synthesis and networking activities described above in order to help educate and link private sector investors, creating stable environments to catalyze investment flows, and minimise risk and uncertainty.

5.2. Dimensions of Adaptation Technology Transfer

94. Technology transfer processes are complex. Lessons learnt from the overall development process of technology transfer have shown mixed results. For example, computer or mobile cell phone technologies from industrialised countries have shown almost universal acceptance and penetration in the developing countries. But in the cases of many industrial or energy technologies the results depended on many factors including skill base at the recipient countries, appropriate market conditions, technology levels and assured supply of services such as electricity and water, appreciation and implementation of quality control, availability of spare pasts etc. Often it is a variety of interconnected issues - socio-economic, institutional and governance – that have determined the degree success of technology transfer, rather than the technologies themselves. Hence the assessment of appropriateness of technology in the given context is of utmost importance in the transfer of environmentally sound technologies.

95. Technology transfer processes between and among North and South countries can have several dimensions. Some of the possible permutations include flows of technology from Northern countries to Southern countries (and vice versa) and from Southern countries to Southern countries. Three-way technology flows are also possible between Northern and groups of Southern countries. But appropriate institutional setting and roles of key stakeholders are of primary importance.

96. There are several stages to co-operation or transfer of environmentally sound technologies. These include technology innovation and development, technology transfer and adaptation, technology diffusion, marketing and acceptance to ensure wide-ranging replication. This whole package can be called Technology Empowerment. A community, an enterprise or an institution can successfully participate in adaptation technology transfer or empowerment process if these technologies are appropriate to the needs of the key stakeholders, are financially viable or adequately supported, are part of the adaptation strategies which are complementary to their development process, benefits to stakeholders are evident and the system is, well monitored. Hence adaptation technology transfer has to be assessed, guided, monitored and embedded in the development process.

97. Governments can create incentives for the transfer of environmental sound technologies by improving national information systems to disseminate information on ESTs, and expanding credit and savings schemes to assist farmers and other communities to manage the increased climate variability in their environment. Establishing the use of financial incentives and disincentives are government actions that can promote their transfer.

98. Much attention has been focused in recent years on the barriers facing the transfer of mitigation technologies that can be integrated in sustainable development strategies. These include limited financing, limited institutional capacity, jurisdictional complexity, and the need for community involvement. Each of these applies to some extent to the issue of adaptation technologies. In addition, the transfer of adaptation technologies face other barriers that include the additional institutional complexity associated with an expanded stakeholder community and the present unwillingness to commit serious funding due in part to the fact that climate change adaptation has only recently move into the spotlight for the climate negotiations.

99. Creating enabling environments for adaptation technologies is critical. By this what is meant is the building and strengthening of national capacity. While many such activities will necessarily need to be initiated by government agencies, the beneficiaries will likely be the private sector and an assortment of community groups. Aspects of enabling environments are varied but will likely need to include training, local adaptation assessments, and different types of information exchanges.

5.3. Integrating Technology Transfer for Adaptation and Development

100. Though climate change is likely to have significant impacts on sectors such agriculture, water, human settlement and health, biodiversity and infrastructure, it is difficult to make climate change as central and urgent in the political decision-making process in most countries. This is a reflection of the time scale difference between climate change and immediate demands of most developing countries, which is mostly a short-term orientation.

101. The adverse impacts of climate stimuli will falls disproportionately on the most vulnerable in least developed and developing countries. This implies that poverty alleviation – a primary goal for many countries – as well as the pace of the development will likely be adversely affected due to climate change. “Most analysts in the less-developed countries believe that the urgent need, in the face of both climate variation and prospective climate change, is to identify policies which reduce recurrent vulnerability and increase resilience. Prescriptions for reducing vulnerability span drought-proofing the economy, stimulating economic diversification, adjusting land and water uses, providing social support for dependent populations, and providing financial instruments that spread the risk of adverse consequences from individual to society and over longer periods. For the near term, development strategies should ensure that livelihoods are resilient to a wide range of perturbations.” (Rayner and Malone, 1998).

102. Many developing and developed countries have coping experiences and are being adopting different technologies to reduce impacts of extreme events like floods, droughts and cyclones. Integrating adaptation technology into development plans and programmes is necessary to promote sustainable development and avoid maladaptation in the long run. In order to facilitate integration of adaptation technology, a process is necessary for identification of possible area for technology development and transfer considering development priority, vulnerability of priority

sectors, and possible measures to address vulnerability. One initial but limited approach is the National Adaptation Programme of Action (NAPA), which was an outcome of COP-7 decision. It is anticipated that National Adaptation Programme of Action (NAPA) by Least Developed Countries (LDCs) would identify projects those are action oriented, complementary to and building upon existing plans and programmes, promote sustainable development, consider sound development and environmental practices, and be cost-effective.

6. CONCLUSIONS AND WORKSHOP DISCUSSION POINTS

103. This background paper has sought to provide a summary overview of the current understanding of adaptation to climate change, the availability and applicability of environmentally sound technologies for adaptation, and the potential to develop and transfer such technologies. It is hoped that it can serve as a useful starting point for a more comprehensive technical paper on the development and transfer of environmentally sound technologies for adaptation to climate change.

104. This paper has argued that it is now well recognised that climate change poses a threat to important development issues such as water supply, food security, human health, natural resources and protection against natural hazards. This recognition has moved adaptation from being the "handmaiden to impacts research in the mitigation context" to an activity that is considered crucial within the broader context of sustainable development (Burton *et al.*, 2002). The link between adaptation and sustainable development has been emphasised as particularly relevant when seeking to enhance the capacity of countries and communities to adapt to climate change, which is often limited by lack of resources, poor institutions and inadequate infrastructure, amongst other things.

105. There are several key conclusions that emerge from the background paper. First and foremost, technology is not a panacea. The process of building adaptive capacity to climate change is a complex process that, while involving technology, also requires attention to issues such as private sector engagement, removing barriers to information availability, creating enabling institutional contexts, and the promotion of innovative and flexible financing instruments.

106. Second, it is important to understand that adaptation technologies span the range of hard and soft technologies. As emphasised in this paper, adaptation technologies aim to minimise the adverse local effects of climate variability and change through either "hard" technological interventions such as the introduction of drought-resistant seeds to a community, or through "soft" interventions such as new crop rotation patterns, livestock pastoral herding changes, and information systems. There has been a growing recognition of the benefits of "soft" technologies, and both types should be considered as desirable for technology transfer.

107. Third, adaptation involves more than merely the implementation of a particular technology. Adaptation to climate change is an ongoing and reiterative process that includes information development, awareness raising, planning, design, implementation and monitoring. Reducing vulnerability requires not only having access to technology, but also having the mechanisms, expertise and other resources available that are needed to make the technology useable and sustainable. The mere existence of adaptation technologies does not mean that every vulnerable community, sector or country has access to these options or is in a position to implement them. An increasing reliance on technologies to develop and manage information is critical to this process.

108. Fourth, the paper has illustrated the range and dimensions of adaptation technologies that can be considered though a focus on coastal zones. There are many examples of important technologies that can be used to collect data, provide information and increase awareness for coastal adaptation to climate change. Similar lists and descriptions will be useful for considering options in other vulnerable systems and sectors.

109. Finally, the paper presents the process for transferring adaptation technologies as a complex one that involves multiple stakeholders, a variety of perspectives, and is highly interdisciplinary. It argues that for environmentally sound adaptation technologies, the technology transfer

process should emphasise the exploitation of opportunities represented in various multilateral and bilateral frameworks, understanding the various dimensions for promoting the transfer of adaptation technologies, and making the overall process more integrated in national development processes.

110. In closing, it is important to note that this background paper is not intended to impose or prescribe a new framework for the UNFCCC or any of its partners. However, the review in the background paper suggests several issues/questions for consideration. These are several open questions that emerge from the above conclusions that would be useful for participants at the Tobago meeting to consider. Such discussions could assist in identifying how the convention process could direct its energy regarding the transfer of technologies for adaptation. Specifically, the following issues/recommendations would greatly benefit from the active engagement of participants:

- *Soft versus. Hard technology distinctions*. A focus on equipment (i.e., hard technologies) alone is unlikely to be sufficient to addressing the emerging risks and implementing effective responses for adapting to climate change. Strategic planning for technology transfer should embrace an expansive definition of technology in order to present policy makers with robust choices.

- *Simplified framework or alternative frameworks*. The current presumption, as reflected in this Background Paper, is that the proposed 4-step simplified framework could be effectively used in future evaluation processes for selecting/transferring technologies for adaptation. Other frameworks could be used, each with own unique vocabulary, definitions, and specialised tools. Effectively providing input to policymakers charged with managing technologies for reducing climate risks almost certainly requires that the framework used be at the same time be highly focused, sufficiently flexible, and amenable to a broad range of national planning contexts.

- *Innovative financing versus conventional financing*. Potential investments in the transfer of technologies for adaptation are currently burdened with insufficient incentive regimes, increased risks, and high transaction costs. These factors provide major hurdles for access to financing, lead to high costs of financing, undermine confidence in the process, and are becoming increasingly crucial issues - especially when one takes into account declining trends in official development assistance. With limited resources available and competing development priorities, it seems urgent that serious efforts be devoted to the development of an innovative, creative approach for financing adaptation technology transfer. The two-step process proposed in this Background Paper represents an initial effort toward this end.

- *Sectoral versus livelihoods approach*. The challenge in transferring technologies for adaptation begins with an understanding of current vulnerability and the multiple stresses that affect communities, livelihoods, ecosystems, and economic sectors. An approach to technology transfer that focuses exclusively on economic sectors may be insufficient to understanding the emerging risks and implementing effective technological responses. For instance, the NAPA approach links rapid assessment of adaptation priorities with multi-criteria evaluation of urgent options that are focused on communities and groups that are the most vulnerable to climate change. Strategic thinking about the proper focus for transferring adaptation technology transfer may be needed to ensure that the needs of the most vulnerable are prioritized.

REFERENCES

[to be provided]

ANNEX 1: TECHNOLOGY TRANFER DECISIONS RELATED TO THE UNFCCC

Decision	Key Features
13/CP.1: Transfer of technology	It is decided to provide continuous advice to improve the operational modalities for the effective transfer of technology (4.b); and to support and promote the development of endogenous capacities and appropriate technology relevant to the objectives of the Convention in developing countries which are Parties to the Convention (4.c).
7/CP.2: Development and transfer of technologies	Request the Convention Secretariat to give high priority to the development and completion of a survey of the initial technology needs, as well as technology information needs, of Parties not included in Annex I to the Convention (non-Annex I Parties), with a view to providing a progress report to the Subsidiary Body for Scientific and Technological Advice at its fourth session; Paragraph 3 of the decision requested the Subsidiary Body for Implementation to evaluate and report on the transfer of technologies being undertaken between Annex II Parties and other Parties, and to do so by drawing on a roster of experts as referred to above, and to take into account the planned technical report of the Intergovernmental Panel on Climate Change on methodological and technical aspects of technology transfer.
9/CP.3: Development and transfer of technologies	Requests the convention secretariat to continue its work on the synthesis and dissemination of information on environmentally sound technologies and know-how conducive to mitigating, and adapting to, climate change; for example, by accelerating the development of methodologies for adaptation technologies, in particular decision tools to evaluate alternative adaptation strategies, bearing in mind the work programme on methodological issues approved by the Subsidiary Body for Scientific and Technological Advice at its sixth session, which was priority should also be given to methods for evaluating and monitoring the effectiveness and effects of specific policies and measures and for assessing adaptation strategies and technologies.
4/CP.4: Development and transfer of technologies	The decision recognised the need for continued efforts by Parties to promote and co-operate in the development, application, diffusion and transfer of technologies. It has also recognised that the private sector plays, in some countries, an important role in the development, transfer and finance of technologies, and that the creation of enabling environments at all levels provides a platform to support the development, use and transfer of environmentally sound technologies and know-how. Paragraph 3 of the decision requests Annex II parties to the convention (a) To take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of environmentally sound technologies and know-how to developing country Parties and their access thereto; (b) To support capacity-building and the strengthening of appropriate institutions in developing countries to enable the transfer of environmentally sound technologies and know-how; Paragraph 4 of the decision requests Annex I Parties of the convention and in particular Annex II Parties: (a) To assist developing country Parties in their efforts to build capacity and institutional frameworks to improve energy efficiency and utilisation of renewable energies through multilateral and bilateral co-operative efforts; (b) To provide assistance to developing country Parties to build capacity for sustainable management, conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases not controlled by the Montreal Protocol, including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems; (c) To assist developing country Parties to build capacity to adapt to the adverse effects of climate change; (d) To assist developing country Parties to strengthen their endogenous capacities and capabilities in the areas of technological and socio-economic research and systematic observation relevant to climate change and its associated adverse effects; (e) Taking into account Article 6 of the Convention, to co-operate in and promote capacity-building of developing country Parties at the international, regional, sub-regional and national levels through co-operation programmes supported by United Nations and other multilateral agencies, as well as bilateral agencies.
Decision 5/CP.4 Implementation of Article 4.8 and 4.9 of the Convention (decision 3/CP.3 and Articles 2.3 and 3.14 of the Kyoto Protocol)	Decides that the basic elements for further analysis should include the following: (a) Identification of the adverse effects of climate change; (b) Identification of the impacts of the implementation of response measures under the Convention; (c) Identification of the specific needs and concerns of developing country Parties arising from such adverse effects and impacts defined through inter alia the national communications from non-Annex I Parties; (d) Identification and consideration of actions, including actions related to funding, insurance and the transfer of It has also decided to the work programme with 6 actions
Decision 9/CP.5: Development and transfer of technologies: status of the consultative process	Invites Parties not included in Annex I to the Convention that have not already done so to report their technology needs, in their national communications, to the extent possible; Urges Parties included in Annex II to the Convention to give particular attention to reporting on technology transfer activities, as specified in part II of the revised guidelines for reporting by Parties included in Annex I to the Convention.
Decision 4/CP.7: Development and transfer of	Decides to establish an expert group on technology transfer to be nominated by Parties, with the objective of enhancing the implementation of Article 4, paragraph 5, of the Convention, including, inter alia, by analysing and identifying ways to facilitate and advance technology transfer activities and making

technologies.	recommendations to the Subsidiary Body for Scientific and Technological Advice. See Annex for details Framework for meaningful and effective actions to enhance the implementation of Article 4, paragraph 5, of the Convention
Decision 5/CP.7 Implementation of Article 4, paragraphs 8 and 9, of the Convention (decision 3/CP.3 and Article 2, paragraph 3, and Article 3, paragraph 14, of the Kyoto Protocol)	Under information and methodologies it is decided strengthening existing and, where needed, establishing national and regional systematic observation and monitoring networks (sea-level rise, climate and hydrological monitoring stations, fire hazards, land degradation, floods, cyclones and droughts); Strengthening existing and, where needed, establishing national and regional centres and institutions for the provision of research, training, education and scientific and technical support in specialised fields relevant to climate change, utilising information technology as much as possible. Under vulnerability and adaptation it is decided (iii) Enhancing capacity, including institutional capacity, to integrate adaptation into sustainable development programmes; (iv) Promoting the transfer of adaptation technologies; (v) Establishing pilot or demonstration projects to show how adaptation planning and assessment can be practically translated into projects that will provide real benefits, and may be integrated into national policy and sustainable development planning, on the basis of information provided in the national communications from non-Annex I Parties and/or other relevant sources, and of the staged approach endorsed by the Conference of the Parties in its decision 11/CP.1; (vi) Supporting capacity building, including institutional capacity, for preventive measures, planning, preparedness of disasters relating to climate change, including contingency planning, in particular, for droughts and floods in areas prone to extreme weather events; (vii) Strengthening existing and, where needed, establishing early warning systems for extreme weather events in an integrated and interdisciplinary manner to assist developing country Parties, in particular those most vulnerable to climate change
Decision: 10/CP.8 Development and transfer of technologies	Request SBSTA Chair to conduct consultations and facilitate collaboration among expert groups established under the Convention, to the extent practicable, on their work programmes on crosscutting issues, including those relating to technology transfer and capacity-building activities.
Decision: 1/CP.10 Buenos Aires programme of work on adaptation and response measures	Paragraph 4(b): Vulnerability and Adaptation: decided to (i) carrying out pilot and demonstration projects under decision 5/CP.7, paragraph 7 (b) (v), in particular to take forward adaptation projects identified in national communications and other relevant sources, including activities that strengthen adaptive capacity; (ii) Enhancing technical training for integrated climate change impact and vulnerability assessment across all relevant sectors, and for environmental management relating to climate change under decision 5/CP.7, paragraph 7 (b) (ii); (iii) Promoting the transfer of technologies for adaptation under decision 5/CP.7, paragraph 7 (b) (iv), on an urgent basis in priority sectors, including agriculture and water resources, for example through the exchange of experiences and lessons learned in enhancing resilience to the adverse effects of climate change in key sectors; (iv) Building capacity, including institutional capacity, for preventive measures, planning, preparedness and management of disasters relating to climate change, including contingency planning, in particular for droughts and floods and extreme weather events, in accordance with decision 5/CP.7, paragraphs 7 (b) (vi) and 8 (c).
Decision 6/CP.10 Development and transfer of technologies	Decides to encourage Parties to explore the opportunity for further joint research and development programmes/projects between Annex II Parties and Parties not included in Annex I to the Convention for the development of environmentally sound technologies to respond to the requirements of Article 4, paragraph 5, of the Convention;