## Handbook for Conducting

# Technology Needs Assessment for Climate Change










This TNA handbook was jointly developed by UNDP and UNFCCC Secretariat, under the auspices of the Expert Group on Technology Transfer (EGTT), in cooperation with the Climate Technology Initiative (CTI). It builds on the earlier edition published in 2004. This TNA handbook should be considered a living document and is subject to improvements based on field-testing, after which an updated edition will be made available.

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# Technology Needs Assessment for Climate Change

Advance document
September 2009

This advance document of the updated Technology Needs Assessment Handbook (TNA) was first endorsed in June 2009 by the Expert Group on Technology Transfer. The current version, dated September 2009, includes several modifications in terms of editorial corrections while the main content remains exactly the same as the June edition.

By the United Nations Development Programme

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# Foreword

In 2004, the Expert Group on Technology Transfer and the UNFCCC secretariat worked with the United Nations Development Programme to prepare the first Handbook for conducting technology needs assessments for climate change. The handbook supported the preparation of technology needs assessments by developing countries which have stimulated a wide range of technology transfer initiatives in developing countries.

To share best practices and lessons learned with conducting technology needs assessments and to identify specific needs and practical actions that could assist Parties in implementing the results of TNAs, a workshop on best practices with conducting TNAs was organized by the EGTT and UNFCCC secretariat in Bangkok, Thailand on 27-29 June 2007.

The workshop provided an opportunity for countries' experts to exchange views with representatives from the private sector in particular the financial community on possible ways to enhance access to funding for the implementation of the results of TNAs. In this context, regional training sessions on project development are being conducted for participants from developing countries utilizing a UNFCCC guidebook for preparing technology transfer projects for financing.

Lessons learnt from the workshop have been drawn upon in developing this updated Handbook on technology needs assessments for climate change. The updated Handbook provides a more detailed framework for the development and implementation of technology needs assessments and in particular in the development of technology programmes and strategies in developing countries. It also seeks to support capacity building and to help with the establishment of the enabling environments for technology transfer.

The publication of this handbook is the result of the dedicated efforts of all those involved in its production, the United Nations Development Programme and the Secretariat of the United Nations Framework Convention on Climate Change in collaboration with the Expert Group on Technology Transfer and numerous practitioners engaged in the development of technology transfer projects in developing countries.

Arthur Rolle
EGTT Chair
June 2009

# Acknowledgement

This advance document of the updated Technology Needs Assessment Handbook (TNA Handbook) was jointly prepared by the United Nations Development Programme and the United Nations Framework Convention on Climate Change Secretariat, under the auspices of the Expert Group on Technology Transfer (EGTT) and in cooperation with the Climate Technology Initiative. This updated Handbook was developed as a response to the request from the United Nations Framework Convention on Climate Change Conference of Parties (COP) Decisions as reflected in 3/CP.13 and 2/CP.14.

The Handbook builds on and expands the scope of the first Handbook, entitled "Conducting Technology Needs Assessment for Climate Change" that was published in 2004 and prepared by United Nations Development Programme. The first Handbook was designed to provide practical guidance on how to conduct a technology needs assessment in developing countries.

This updated Handbook is the result of close collaboration with experts from the Joint Implementation Network, the University of Edinburgh-Centre for Environmental Change and Sustainability and the Stockholm Environment Institute (USA-Boston) each of which contributed substantially to the drafting of the handbook. Members of the Expert Group on Technology Transfer provided valuable comments and guidance throughout the development of this handbook.

The Handbook also went through a number of iterative processes and received substantive comments and contributions from experts from the Global Environment Facility Secretariat, United Nations Development Programme, United Nations Environment Programme, United Nations Environment Programme Risoe Centre on Energy, Climate and Sustainable Development, and the World Bank.

Acknowledgement is also due to experts from the National Renewable Energy Laboratory and University of San Martin — Centro de Ideas, who provided substantive comments throughout the development of this advance copy and also drafted some key sections of the Handbook.

Special acknowledgement is to due to the Sustainable Energy Programme of Environment and Energy Group of United Nations Development Programme and the Technology team within the United Nations Framework Convention on Climate Change Secretariat. These two teams spearheaded the conceptualization of the updated handbook and led the production process and coordinated a number of technical drafting meetings to develop this advance document.

The drafting and production of this advance document of the TNA Handbook was financed by the United Nations Development Programme, with contribution from the Climate Technology Initiative.

# Glossary

| | |
|---|---|
| **Adaptation** | Adaptation is defined as an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects. |
| **Large scale technologies** | See 'Small scale and large scale technologies'. |
| **Long term technologies*** | Technologies that are still in an R&D phase or a prototype. |
| **Medium term technologies*** | Technologies which would be pre-commercial in a market context comparable to that of the country concerned in the TNA (available between 5 years to full marketing). |
| **Mitigation** | An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases. |
| **Multi-Criteria Decision Analysis** | A technique used to support decision making which enables evaluation of options on criteria, and makes trade-offs explicit. It is used for decisions with multiple stakeholders, multiple and conflicting objectives, and uncertainty. |
| **Non-market-based ('soft') technologies** | Technologies for mitigation and adaptation which contain soft elements such as organization, behavior, information, knowledge networks, indigenous coping strategies, insurance schemes, and environmental dispatch protocols for electricity supply, etc, which are connected to the use of a technical solution. For example, an early-warning system for adaptation 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. |
| **Portfolios of technologies** | In order to provide a basis for comparison across the technologies and to provide a basis for a strategy to meet a country's climate and development priorities in the short and medium to long term, technologies are categorized in portfolios according to their applicability over time and in the market and their scale/size of application. |
| **Short term technologies*** | Technologies which have proven to be a reliable, commercial technology in a similar market environment. |
| **Small scale and large scale technologies** | Technologies that are applied at the household and/or community level, which could be scaled up into a program. For the sake of simplicity, this Handbook considers all technologies applied on a scale larger than household or community level as large scale technologies. |
| **Technologies for mitigation and adaptation** | All technologies that can be applied in the process of minimizing greenhouse gas emissions and adapting to climatic variability and climate change, respectively. |

| | |
|---|---|
| **Technology needs** | The evolving need for new equipment, techniques, practical knowledge or skills to meet development priorities through provision of low greenhouse gas services or reduction of the vulnerability of sectors to promote sustainable livelihoods and minimize the extent and adverse impacts of climate change. Technology needs are further defined by both the context of national development priorities and the extent of international opportunities. |
| **Technology transfer** | The flow of experience, know-how and equipment between and within countries, which would typically combine market and non-market based technologies. |
| **TechWiki** (under development) | An online information exchange system which serves as an online encyclopedia to which visitors can add new information. The site is targeted at basically all decision and policy makers, in developing, as well as industrialized countries, who are responsible for or involved in taking decisions on low carbon technology investments. |
| **TNAssess** (under development) | An interactive system for conducting multi-criteria assessments in a stakeholder context. |

* *It is noted here that the terms short, medium, and long term are context-specific. Technology that is fully commercial in some markets may not be a commercially viable technology in another country or market. For example, utility scale wind power is a demonstrated commercial technology, but in smaller, isolated markets (even where there is a good resource) the technology may not be truly "commercial". Therefore, the short, medium, and long term applicability has to be defined specifically for each country.*

Part I

# Context and organization of the TNA process

# 1. Introduction

## 1.1. Context: technology needs in light of a changing climate

Climate change and the accompanying threat of ocean acidification from anthropogenic emissions of greenhouse gases (GHGs) are among the most daunting environmental problems confronting the world today.[1] The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) has confirmed earlier conclusions that no country and no region of the world will be unaffected, and in many countries the consequences for all human activities will be profound unless action is taken urgently to reduce GHG emissions. According to the IPCC (2007), the GHG concentration in the atmosphere would need to stay below the level of 450 parts per million (ppm) in order to prevent average global temperatures from rising by more than 2°C above pre-industrial levels. This is widely considered the maximum temperature increase to avoid irreversible damage to global climate and ecosystems (IPCC, 2007).

Moreover, the latest scientific knowledge on climate change indicates that the world is on a GHG emissions trajectory which is worse then the IPCC worst case scenario and that there is a risk of severe disruption of the climate system. For instance, the International Association of Research Universities (IARU) congress "Climate Change: Global Risks, Challenges and Decisions", held in Copenhagen in March 2009 (IARU, 2009), ended with six key message statements formulated as a result of the conference. The first is a key message for this analysis and is repeated in **Box 1-1**.

**Box 1-1 Key Message 1: Climatic Trends**

Recent observations confirm that, given high rates of observed emissions, the worst-case IPCC scenario trajectories (or even worse) are being realized. For many key parameters, the climate system is already moving beyond the patterns of natural variability within which our society and economy have developed and thrived. These parameters include global mean surface temperature, sea-level rise, ocean and ice sheet dynamics, ocean acidification, and extreme climatic events. There is a significant risk that many of the trends will accelerate, leading to an increasing risk of abrupt or irreversible climatic shifts.

In addition to the GHG emission and climate change projections, the International Energy Agency (IEA) *Energy Technology Perspectives 2008* report has estimated global energy demand will double from present levels by around 2030 (IEA, 2008).

Figure 1-1 shows the challenge which the above two developments imply. On the one hand, there is likely to be a doubling of global energy demand with an accompanying increase in energy-related $CO_2$-equivalent emissions, whereas, on the other hand, GHG emissions must be strongly reduced in order to avoid irreversible changes associated with dangerous levels of climate change. These two developments can only be combined when low carbon technologies (both 'hard' technologies such as equipment and 'non-market based' technologies such as behavioral change) are successfully implemented.

[1] Acidification of the oceans is a simple chemical consequence of increasing GHG concentration levels.

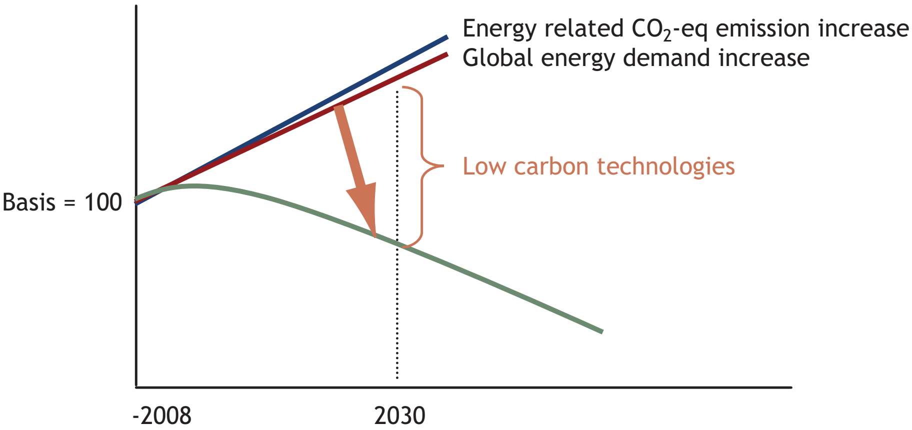



**Figure 1-1. The global energy and climate challenge**

In light of the above, in the report prepared for the Expert Group on Technology Transfer (EGTT) on *"Future Financing Options for Enhancing the Development, Deployment, Diffusion and Transfer of Technologies under the Convention"* (EGTT, 2009) the additional financing needs for climate change mitigation technologies are estimated to span a range of USD 262–670 billion per year, which is around three to four times greater than the current global investment levels. Of this increase, 40–60%, or an additional USD 105–402 billion per year, is projected to be needed in developing countries.

At the same time, it will be a priority to reduce countries' vulnerability to climate change impacts, so that sustainable livelihoods can be ensured and ecosystem services on which people depend protected. This will require adaptation measures in order to increase countries' resilience and for this, again, both market and non-market based technologies will be required. The following areas can be identified where adaptation strategies will be necessary: health and social systems; agriculture; biodiversity and ecosystems; and production systems and physical infrastructure, including the energy grid. On adaptation to climate change impacts, a number of developed countries have already carried out their own assessments, which can be used to inform other countries.[2]

The overall climate change and energy context, as summarized above, has made clear that the identification and development of technologies, practices, and policies, both for mitigating GHG emissions as well as for adapting to the adverse physical impacts associated with climate change, are of key importance to avoid irreversible changes associated with dangerous levels of climate change. The increasing importance of technology issues has been reflected by the agenda of negotiations on a future climate policy regime. It is noteworthy that two of the five pillars of the **Bali Plan of Action**[3] (adopted at the thirteenth Conference of the Parties to the UNFCCC, COP13, December 2007) focus on enhanced actions on technology development and transfer and on the provision of financial resources to enable technology transfer.

The need for enhanced action on technology transfer to developing countries has been recognized by EGTT (2009) as follows:[4]

"…not all countries have the technologies needed or the ability to innovate new technologies to mitigate and adapt to climate change. Those countries that are lacking in the technologies or capacity, mainly the developing countries, need to be helped not merely to adopt the existing environmentally friendly technologies but also to develop the capacity to innovate new technologies and practices in cooperation with others…. Technology transfer includes not merely

[2] See for example CEC (2009).

[3] Decision 1/CP.13; FCCC/CP/2007/6/Add.1

[4] FCCC/SB/2009/INF.1, p.11.

transfer of hardware but also of best practices, information and improvement of human skills, especially those possessed by specialized professionals and engineers. The acquisition and absorption of foreign technologies, and their further development, are complex processes that demand considerable knowledge and efforts on the part of those that acquire them. It is the capacity of the countries and the enabling environment in those countries that will enable them to change to a low carbon economy."

Under the Bali Plan of Action, the progress on development and transfer of technologies for mitigation and adaptation is supervised by the UNFCCC Subsidiary Bodies for Scientific and Technological Advice and for Implementation (SBSTA and SBI, respectively, as per Decision 3/CP.13). The EGTT coordinates activities to support technology transfer; EGTT was established at COP7 (Marrakech, 2001) and reinstated at COP13 for another period of five years. Finally, at COP14 (Poznań, December 2008) the **Poznań Strategic Program on Technology Transfer** was adopted as a step towards scaling up the level of investment in technology transfer in order to help developing countries address their needs for environmentally sound technologies.[5]

The following box provides background information on emerging technology developments.

**Box 1-2 Emerging technology developments**

Since the 2004 edition of the TNA handbook there have been substantial changes in technology markets. Independent market research companies have become increasingly active in providing analysis on technology issues across all GHG-emitting sectors (but particularly energy) to document trends in a rapidly changing environment. Such information offers executives, managers, and professionals, both in the public and private sector, up-to-date information that they need to make technology decisions, and can be useful to country teams undertaking a TNA.

For example, international GHG emission reduction and finance agreements, increasing awareness of climate change among policymakers, the latest scientific knowledge on climate change patterns, as well as the prospect of additional GHG emission reduction mandates, have had the effect of spurring policy innovations in industrialized countries to increase the penetration of renewable energy technologies and the use of energy-efficient appliances. Renewable portfolio standards, environmental portfolio standards, net metering initiatives, and increasing consumer desire for more environmentally sound energy sources are driving energy suppliers to take a hard look at using renewable energy to meet electricity supply requirements.

Meeting the challenge described this Section (a growing global energy demand and the need to reduce global GHG emissions) without incurring excessive costs will require intensive and extensive technology innovation. Coupled with technology advances have been advances in innovative financing for technology transfer. Despite some progress in renewable energy penetration in some countries, the fact remains that its increased share in the global energy mix has been negligible. The same applies to energy efficiency, which can be far more cost-effective than building new energy supply infrastructure. Energy efficiency investments around the world are similarly lagging behind. Underlying these trends is the fact that projects on energy efficiency and renewable energy face significant difficulties in raising commercial funding, related mainly to a lack of risk capital, which multilateral and bilateral funding sources are insufficiently able to mobilize. Leveraging private sector finance through innovative financing is therefore essential and being explored (Muller (2008), EGTT (2008)).

[5] Decision 2/CP.14

## 1.2. Technology Needs Assessment: why, how, what and who?

In this Handbook, the role of low carbon technologies in meeting the climate change challenge is addressed by assessing technology needs in developing countries, with a view to both mitigation and adaptation. This process is known as technology needs assessment (TNA) and is essentially a systematic approach by which to identify, evaluate, and prioritize technological means for achieving sustainable development ends.

### Why a TNA?

The purpose of a TNA is to identify, evaluate, and prioritize technological means for achieving sustainable development in developing countries, increasing resilience to climate change, and avoiding dangerous anthropogenic climate change. Properly conceived and implemented, a TNA can achieve a number of additional desirable ends, namely contributing to enhanced capacity in developing countries to acquire environmentally sustainable technologies, developing important links among stakeholders in developing countries to support future investment and barrier removal, and diffusing high priority technologies throughout key sectors of the national economy. Moreover, TNAs also assist in acquiring a broader picture of technology needs for a region or group of countries, so that international technology support programs or initiatives could possibly be oriented towards a more cross-country or regional approach (e.g., based regional circumstances such a river basin through multiple countries and inter-country energy transport and delivery).

The TNA process forms the basis for identifying environmentally sustainable, low carbon technologies in the implementation of Article 4.5 of the United Nations Framework Convention on Climate Change (UNFCCC).

This Handbook also responds to the request from the *UNFCCC Ad Hoc Working Group on Long Term Cooperative Action*, as reflected in Decision 3/CP.13, which encouraged non-Annex I Parties to carry out TNAs and requested the UNFCCC Secretariat, "*…in collaboration with the EGTT, United Nations Development Program (UNDP), United Nations Environment Program (UNEP) and CTI, to update the handbook for conducting technology needs assessments before SBSTA 28…*" In Section 1.1 it was already explained that two of the five pillars of the Bali Plan of Action[6] focus on technology development and transfer and on the provision of financial resources to enable technology transfer.

Finally, the TNA Handbook contributes to meeting the urgency of technology transfer in the context of the *Poznań Strategic Program on Technology Transfer* (see above).

### How?

When assessing technology needs with a focus on reducing GHG emissions and adaptation to climate change it is important that the technologies selected are clearly in line with the countries' development strategies. This addresses the concern that without consideration of development priorities in host countries there will not be sustainable transfer of technologies or proper use of limited resources. *Therefore, this Handbook first assists in describing a country's development needs and priorities before moving to the actual technology assessment*. These priorities will also be formulated in light of long term economic and social trends in the countries, such as an increased industrialization and increased urbanization, as these trends will have an impact on the eventual technology choices.

[6] Decision 1/CP.13; FCCC/CP/2007/6/Add.1

Another important aspect of a TNA is that when generating plans and strategies for the future for mitigation and adaptation and to ensure maximum development benefits, climatic changes already observed and possible changes in the future need to be taken into account. For example, if hydropower was proposed as a priority technology then future effects of climate change on water supplies in the country may cause that mini or micro hydro or run of river hydro would be the best investments and more resilient in the medium to longer term and have less impact on downstream activities.

Therefore, an analysis based on only current climate conditions is liable to fail to prioritize the relevant sectors affected by future climatic changes and the corresponding technology needs. It is therefore suggested that before prioritizing technologies for mitigation and adaptation the expected scale and type of climatic change are considered for the country. From that the expected implications for environmental and social, as well as economic, impacts can be deduced.

In most countries, information on the impacts of climate change is already available. For example, in their national development strategies, several countries have described their vulnerability and/or resilience profile with regard to future climate change impacts. During the TNA process this information could be assessed and discussed, so that in the overall TNA process for the country a clear long term background is described, including climate change impacts.

Another basic principle of this TNA Handbook is that technology needs are specific to the country contexts and as such, technology solutions have to be tailored to countries' specific needs. Consequently, technology solutions can differ between developing countries, as well as between developing and industrialized countries. Country contexts can differ between countries in terms of technical, financial, natural and even cultural circumstances in which the technologies will operate. Some points that are worth being kept in mind include:

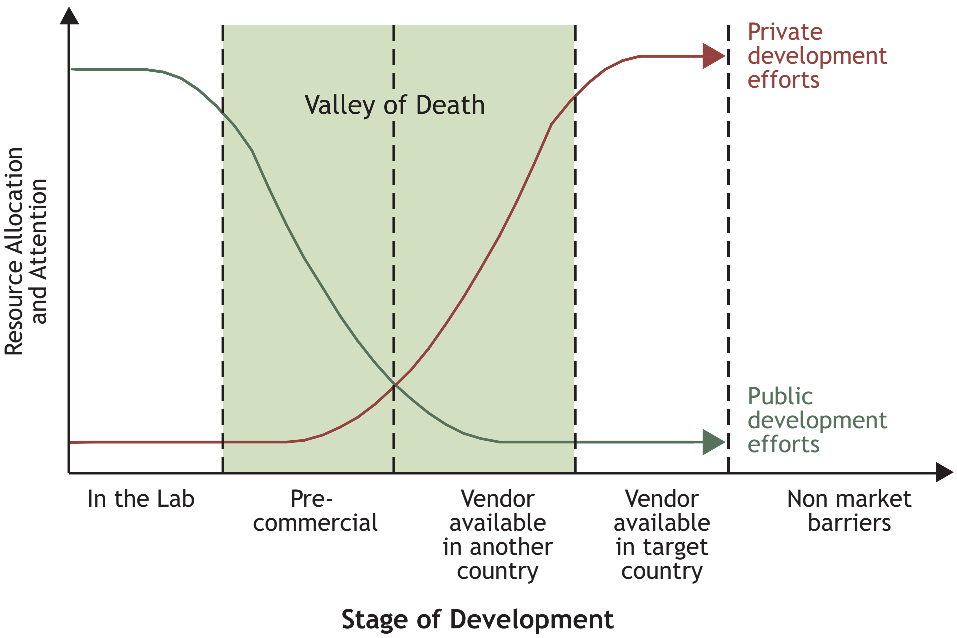
- Optimizing use of locally-available natural resources (*e.g.*, plentiful, more direct sunlight; local biomass; micro and pico-hydro; and low-velocity wind);
- Observing that technical complexity is constrained by the manufacturing and maintenance capabilities of the areas they serve;
- Serving the demands on local customs, lifestyles and cultural patterns; these are usually end-use technologies (i.e., cook stoves);
- Realizing that decentralized power generation would meet off-grid energy demand and provide backup power in areas with currently unreliable electricity supply;
- Matching of the up-front capital costs with local purchasing power, even if at the expense of reduced performance and less elaborate design features; and
- Providing energy services while concurrently meeting other critical societal needs (*e.g.*, shaft power and electricity from small-hydro and wind; improved local air quality from improved stoves; biomass generators supporting local agriculture).

In prioritising technology options, it is important to sufficiently consider how technologies — both existing and new, advanced options — could adapt to and take advantage of those specific contexts.

Finally, this TNA Handbook acknowledges that a prioritization of technologies based on national development priorities and in light of a changing climate could result in priority technologies which are not yet available in the short term as these are still in a Research and Development (R&D) stage or in a pre-commercialization stage. Therefore, throughout the technology prioritization steps in Chapters 3 and 4 in this Handbook, a distinction is made between technologies available in the short term (technologies with proven reliability in similar market circumstances), medium term (*e.g.*, available between 5 years to full marketing), and in the long term (technology now in an R&D phase or existing as a prototype).

As an example, Figure 1-2 shows the phases that technologies generally go through from the research stage to the eventual market implementation stage. The Figure also indicates the division of work between the public and private sector, with the first spending most of the resources during the research and development phases and the latter becoming more active during and after the pre-commercialization phase. Commercialization of any technology requires passing through a number of stages from basic research to widespread deployment. There are challenges at every stage but one part of this process represents a key stumbling block. This is the so-called "Valley of Death" which lies between proof of scientific concept by basic, mostly publicly funded research and the uptake by the private sector to develop a commercial, profitable product. Neither government nor private sector has the proper motivation or resources to advance technologies in this stage and, as a result, otherwise promising options can languish.

**Figure 1-2. Overview of stages of development of a technology from research to market implementation.**




*Source: World Bank*

While the "Valley of Death" is a substantial impediment to timely technology commercialization in all parts of the world, it is even more pronounced in developing countries. In addition to the usual barriers to commercialization (e.g., lack of viable $CO_2$ price, management short-termism, and unappreciated spillover effect), there are conditions specific to developing countries that make energy technology commercialization particularly difficult in those contexts. These impediments include:

- Technical capacity for R&D, manufacture and O&M support;
- Overall cost of "doing business";
- Lower public energy R&D spending;
- Subsidies for conventional fuels;
- General regulatory capacity (*e.g.*, fair and enforceable power purchase agreements);
- Market entry;
- Intellectual Property Rights (IPR) concerns;
- Absence of credit-worthy off-takers;
- Access to early-stage financing; and
- Less wealthy consumers with reluctance to pay premiums for "green products".

With a view to these technology development stages and the possible impediments to timely technology commercialization, Chapter 5 identifies activities to improve and accelerate the development, deployment and diffusion of the technologies which have been identified in Chapters 3 and 4 as priority technologies for mitigation and adaptation actions. Chapter 5 takes a whole system approach and explores the enabling environment for the implementation of the priority technologies. Finally, Chapter 6 indicates how these identified activities can be formed into a national strategy for accelerating the achievement of a low carbon future in the country concerned.

### What? Goals and objectives of a TNA

The primary goal of a TNA is to prioritize technological means for achieving a country's development priorities in a sustainable manner. To achieve this, the focus has to be on technologies which provide the required development services with low or zero GHG emissions and on technologies which address adaptation needs. The specific objectives of a TNA are as follows:

- Identify countries' development priorities based on existing sustainable development strategies and plans (such as sectoral development plans, agricultural plans, strategic plans for sustainable development of coastal and marine resources, sustainable development action plans, and other plans that would be important precursors to the TNA process), National Adaptation Programs of Action (NAPAs), National Communications to the UNFCCC, and low carbon development strategies;
- Engage a suitable group of stakeholders to elicit inputs into the TNA process and develop a robust and diverse network of stakeholders within each sector (both public and private sectors) and nationally (including the finance sector) to address the tasks required for technology transfer;

- Identify and characterize strategic sectors for technology assessment to reflect the national development priorities;
- Identify and familiarize with sustainable low carbon technologies to meet a country's development needs through demonstration and detailed information on relevant technologies;
- Select and prioritize technology portfolios categorized in terms of small and large scale technologies and availability in short or medium to long term timescales (see above for definition of these timescales) in the context of national development needs, resource availability, and market opportunities;
- Accelerate innovation and diffusion of technologies through identification of activities to develop and support enabling frameworks and capacity development, including the identification of international technology cooperation opportunities. Enhanced international cooperation would enable developing countries to become more actively involved in the process of designing and testing new low carbon technologies (*e.g.*, North-South and South-South-North technology cooperation). This would enhance their capacity to implement new technologies in the longer term.
- Develop strategies at national, sector and technology level for implementation and acceleration of development, deployment and diffusion of prioritized technologies for adaptation and mitigation; and
- Prepare a report that succinctly summarizes the results of the effort, together with critical information on the high-priority technologies selected, and that provides specific information for direct engagement and participation of technology providers and project developers.

### Who?

The TNA process is managed by a national taskforce, called the National TNA Team in this document. It works closely together with a core group of stakeholders, as well as with wider stakeholder groups (see Sections 2.1 and 2.2). It is recommended that the National TNA Team and core stakeholder group members be selected on the basis of their expertise and background, but that they take part in the prioritization of low-carbon technologies and formulation of national strategies in their personal capacity. This is recommended in order to prevent that the prioritization of technologies is influenced by stakeholders' views and perceptions on technology implementation. In the structure of this Handbook the main output is a portfolio of prioritized technologies for mitigation and adaptation and a strategy for accelerating the development, deployment and diffusion of these technologies in the country, and this output is subsequently transferred to people taking part in the actual implementation phase, including project developers, national and local governments, communities, etc. Consequently, this Handbook does not focus on technology implementation but on selecting technologies for a low-carbon future. Therefore, it is recommended that the National TNA Team maintain a clear distinction between making technology choices during the TNA process and the technology implementation phase following the TNA, even though there could be persons who take part in both phases.

## 1.3. Key steps elaborated in this Handbook

### Prioritization of portfolios of technologies for mitigation and adaptation

This revised version of the handbook is intended to provide specific guidance in the preparation of national TNAs. It is divided into three main parts (see **Figure 1-3**):

- Part I (Chapters 1 and 2) addresses organizational matters related to the preparation of a TNA. It outlines how to get ready for and organize a TNA and provides an overview of the various technical support systems that are being made available to country teams.
- Part II (Chapters 3 and 4) focuses on the operational requirements for making strategic choices to derive priority technologies and measures. Chapters 3 and 4 discuss how to identify priority sectors, situate technologies within national development processes, and structure the technology prioritization process.
- In Part III (Chapters 5 and 6), issues related to overall enabling frameworks for innovation and diffusion pathways for the prioritized technologies are discussed. This includes R&D needs for prioritized technologies for mitigation and adaptation applicable in the medium to long term, acceleration of deployment of technologies in the market, and acceleration of diffusion of technologies up to the point that they reach commercial applicability. This Part supports countries in guiding the generation of plans and strategies for building and/or supporting national R&D capacity in developing countries and international cooperation, improving technology deployment and diffusion systems in developing countries, and designing possible national strategy development processes for moving to a low carbon sustainable and resilient future.

Finally, the activities carried out throughout the TNA need to be compiled and communicated through a final synthesis report. The reporting requirements, including an annotated outline for the final TNA report, are provided in Chapter 6. Finally, the Annexes contain additional technical details regarding information, tools and methods for TNA.

**Figure 1-3. Key steps in this TNA Handbook**

| | |
|---|---|
| **Part I Organization of TNA** | |
| Establish a National TNA team | **Chapter 2** |
| Develop process for the stakeholder engagement | **Chapter 2** |
| ↓ | |
| **Part II Making Strategic Choices for Priority Sectors and Technologies** | |
| Portfolios with prioritized mitigation technologies | **Chapter 3** |
| Portfolios with prioritized technologies for adaptation | **Chapter 4** |
| ↓ | |
| **Part III Moving Forwards to a Low carbon Future** | |
| Accelerating Technology Development, Deployment and Diffusion: enabling frameworks and capacity building | **Chapter 5** |
| From Technology Needs to Technology Strategies | **Chapter 6** |
| Main TNA report | **Chapter 6** |

## Formation of networks

The process of performing the TNA involves the formation of a network of stakeholders who are involved in energy, climate change planning, and adaptation activities, as well as technology owners and practitioners, entrepreneurs, communities, and sector representatives. It is strongly recommended, that in the networks, stakeholders are involved from both the rural and urban areas in developing countries. Through such integrated networks the exchange of expert knowledge among public and private sector stakeholders, indigenous and tacit knowledge and a range of perspectives can lead to the development of a shared vision for moving forward. It will be particularly important that people in rural communities are provided with the necessary resources and infrastructure to access and use this TNA Handbook.

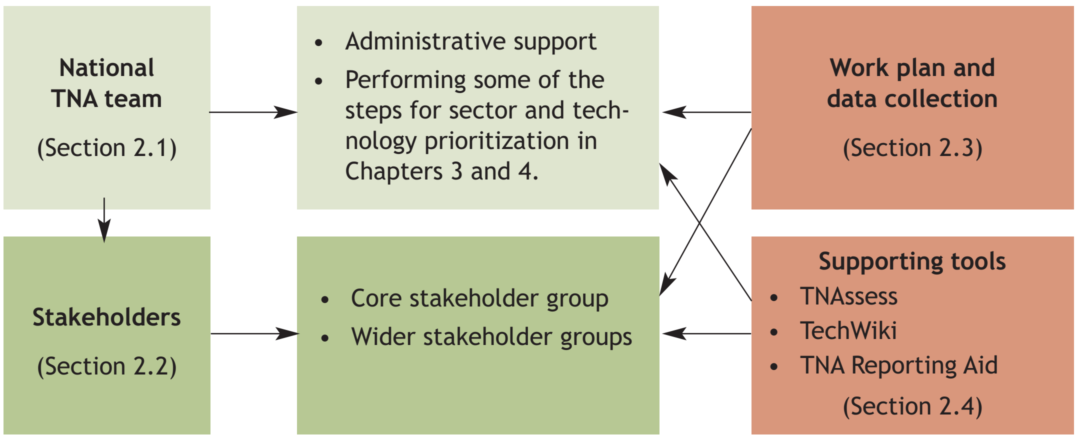
The key role of networks for implementing change has been recognized in many studies (*e.g.*, Lundvall *et al*, 2002, IPCC 2000, ENTTRANS, 2008) which indicate that new ways of operating can emerge from exploratory activities combined with deliberative processes. Therefore, such social networks are important for transformation in a system. During the TNA exercise the networks of stakeholders should be encouraged to form as robust a system as possible. Ideally, a 'technology transfer' community will be created capable of addressing the tasks needed for the implementation plan within the country when this initial TNA exercise is complete.

In **Box 2-1** in Chapter 2 an overview is given of potential stakeholders in a TNA, and this could be a useful indication of the eventual composition of the networks. Obviously, the formation of networks will be the full responsibility of the countries.

# 2. Organizing a National TNA Process

This chapter addresses organizational matters related to the preparation of a TNA. It outlines how to get ready for and organize a TNA and provides an overview of the various elements involved in organizing a TNA. It corresponds to the step in **Figure 1-3** in Chapter 1 on the TNA team (i.e., *Establish a National TNA team*) and the step on stakeholder engagement (i.e., *Develop process for the stakeholder engagement*). A diagram illustrating the organizational elements involved in carrying out a national TNA is provided in Figure 2-1.

**Figure 2 1. TNA organizational elements**




## 2.1. A suitably structured National TNA Team

Assembling a suitably configured national assessment team is one of the first operational tasks to perform in a TNA. In this Handbook it is assumed that a TNA generally requires around 24 months to be completed, including preparation and reporting time (see Section 2.3), which requires a solid organizational structure with participants in the project team committing themselves to the process, although this does not require a full-time task for all.

### Responsible ministry

The decision of who will hold the responsibility for the TNA project in a country is probably the most important initial decision that needs to be made. Indeed, successfully conducting a TNA cannot be expected without strong national leadership, and the selection of a lead ministry/coordination entity will have to be judged based on national circumstances. The ministry in which the GEF and climate change focal points are located may or may not be the ideal entity for the effort, because the ultimate mandate of TNA extends beyond the mandate of the Ministry of Environment. One possibility is that the TNA process is led by an inter-ministerial committee that includes experts from all relevant ministries and/or agencies for the TNA (*e.g.*, Ministries of Industry, Local Government, Rural Development, Finance and Economic Planning, Energy, Environment and Natural Resources, *etc.*), as well as experts from the private sector. Alternatively, depending on the governance structure of the country concerned, the National TNA Team and the project coordinator could be placed under the Office of the Prime Minister or Vice President.

It is recommended that as a first step an institutional characterization for the country is made, based on which the decision can be made on the responsibility for the TNA process.

### Project coordinator

The responsible ministry or inter-ministerial committee will have to appoint a Project Coordinator whose tasks will be those of a focal point for the effort and manager of the overall TNA process. This will involve providing vision and leadership for the overall effort, facilitating the tasks of communication with the National TNA Team members, and managing outreach to stakeholders, formation of networks, information acquisition, and coordination and communication of all work products.

The leadership of the project coordinator is critical for the success of the TNA in each country. It is therefore recommended that the skill set of the Project Coordinator include facilitation skills, project management and some scientific or engineering background, as these will likely be advantageous in terms of familiarity with technology specifications and performance characteristics.

### National TNA team

The project coordinator will lead a small **National TNA Team** which, if possible, is familiar with national development objectives and sector policies, overall insights in climate change science, and potential climate change impacts for the country, and adaptation needs. It is important for the National TNA Team to have a multi-sector and multi-disciplinary scope, with representatives from communities outside the areas of development policy making and climate change, as well as from the private sector.

While the project coordinator should be familiar with the climate change negotiations, particularly SBSTA and SBI discussions regarding technology transfer, evolving innovative financing mechanisms, and the pillars associated with the *Bali Plan of Action* and the *Poznań Strategic Program on Technology Transfer*, such detailed knowledge is not a prerequisite for the National TNA Team members. The project coordinator will communicate the international climate negotiation developments with National TNA Team members throughout the TNA progress.

This National TNA team functions as task force supervising the TNA process in the country and as a hub through which all TNA activities are coordinated. While the 'ownership' of the National TNA team is national and the team led by the government, the team's staff could, next to government officials, also include non-governmental experts (e.g. local or regional consultants and/or regional centers of excellence) who could support the analytical parts of the TNA process, the collection and processing of information, and the preparation of documents (see below for further suggestions for recruitment of staff).

The role of the TNA team is to undertake TNA activities such as administrative support through a secretariat, workshop and focus group organization, and discussion moderation, as well as research, analysis, and synthesis in support of the TNA exercise (these tasks are introduced below, and explained in detail in Chapters 3 and 4). Note that the National TNA team is distinct from the larger group of stakeholders that are involved (see Section 2.2).

During the TNA exercise, the following specific tasks are envisaged for the National TNA Team, as outlined in the chapters of this handbook:

- In Chapters 3 and 4: to undertake an overview of national development priorities on the basis of such documents as 5-year plans, National Communications, energy plans, previous TNAs, and low carbon development studies[7], as well as identification and categorization of the country's sectors, and identification of potential technologies for mitigation and adaptation. By doing this work, the National TNA team will prepare the work for the stakeholder teams in Chapters 3 and 4, which involves prioritization of sectors and prioritization of technology portfolios. This division of tasks is further explained in Chapters 3 and 4.

[7] It is acknowledged here that not all countries will have prepared such low carbon development studies or TNA reports, but where these are available, their use is recommended.

- In Chapter 5: to lead the process of analyzing with the stakeholder groups how the technologies prioritized in Chapters 3 and 4 can be implemented in the country and how implementation circumstances could be improved from R&D to deployment and diffusion to overcome barriers.
- In Chapter 6: to explore how the insights from Chapter 5 could lead to a national strategy on low carbon technology development, deployment and diffusion.
- Finally: to prepare the main TNA report for the country (see Chapter 6).

Technical information and data will be available from the data sources provided within the TNA (as specified in Chapters 3 and 4), but accessing and using international sources of technology cost and performance data is also useful.

It is recommended that the composition of the National TNA team remains flexible as the TNA process unfolds; that is, it may become evident at a certain stage that additional expertise on a certain technology or sector is needed. The TNA team can be expanded as needed to address emerging issues, subject to resource constraints. For example, one country's strategic focus resulting from a TNA may address all geographic areas and a broad range of sectors. In such a case, representative analysts could be recruited who have broad familiarity with the technology issues involved. In another country the sector prioritization may result in a focus on a key region (*e.g.*, coastlines) to address critical vulnerabilities (e.g., more frequent storm surges, or future sea level rise) or a focus on a particular sector (*e.g.*, energy supply) to address institutional, regulatory, and planning issues related to the use of new technologies (*e.g.*, solar thermal electric power generation). There, representative analysts could be recruited from either the public or private sector.

### Personnel recruitment

With a view to the tasks of the National TNA Team as explained above, the required skills of National TNA Team members will include:

- Survey development and management;
- Data acquisition, and information synthesis;
- Experience with participatory processes;
- Familiarity with current technologies in operation in the country's sectors and the regulatory and policy context for technology transfer; and
- Some experience in Multi Criteria Decision Analysis for prioritizing technology portfolios.

The choice of appropriate personnel to recruit for the National TNA Team will need to take account of the need for both mitigation and adaptation. Adaptation and mitigation represent different entry points to a TNA, so different skill sets and levels of experience are needed. Data familiarity, stakeholder networks, barriers confronted, and key affected sectors will likely be quite different, and careful attention to team composition will be required.

It is important that candidates for the National TNA Team have experience in working from a cross-cutting perspective within the country's overall development context, and have local expertise as needed on specific technology areas identified in the TNA.

In addition, it is recommended that there be good skill set coverage within the National TNA Team regarding qualitative assessments (*e.g.*, Delphi techniques, stakeholder consultations, and focus groups (see Annex 4) that synthesize diverse amounts of information as well as quantitative assessments that include database development regarding cost and performance characteristics of technologies from the ***TechWiki*** and Technology database (Annex 2). Personnel that are experienced with such methods can be quite valuable during different stages of the assessment.

## 2.2. Organizing stakeholder involvement

### Stakeholder groups

Stakeholders are central to the TNA process because they will be intimately involved in any implementation activities. For example, farmers and their communities will, with the help of research stations and extension services, make use of the priority technologies to adapt to climatic patterns. A suggested, non-exhaustive starting set of potential stakeholders is shown in Box 2-1.

**Box 2-1. Potential stakeholders to engage in a TNA**

- ✓ *Government departments* with responsibility for policy formulation and regulation (e.g., power supply) and vulnerable sectors (e.g., agriculture);
- ✓ *Private and public* sector industries, associations, and distributors that are involved in the provision of GHG-emitting services or are vulnerable to climate change impacts;
- ✓ *Electric utilities and regulators;*
- ✓ Within the private sector, *technology users and/or suppliers* who could play a key local role in developing/adapting technologies in the country;
- ✓ *Organizations* involved in the manufacture, import and sale of technologies relevant to mitigation or adaptation;
- ✓ *The finance community*, which will likely provide the majority of capital required for technology project development and implementation;
- ✓ *Households, communities, small businesses and farmers* that are or will be using the technologies and who would experience the effects of climate change;
- ✓ *NGOs* involved with the promotion of environmental and social objectives;
- ✓ *Institutions* that provide technical support to both government and industry (*e.g.*, universities, industry R&D, think tanks, and consultants);
- ✓ *Labor unions, consumer groups, and media;*
- ✓ *Country divisions* of international companies responsible for investments important to climate policy (*e.g.*, agriculture and forestry); and
- ✓ *International organizations/donors.*

It is recommended that at an early stage of the TNA process significant efforts be made in the recruitment and engagement of an appropriate set of stakeholders. A communication and involvement strategy by the National TNA Team is required with a structured approach that:

a) identifies relevant parties at an early stage;
b) communicates objectives of the TNA;
c) delineates roles and responsibilities;
d) establishes a process for ongoing engagement; and
e) continues to engage with all stakeholders throughout the assessment and implementation process.

Some additional resources on stakeholder analysis, and information on different types of engagement processes, tools, and methods for selecting and promoting the active participation of stakeholders are provided in Annex 4.

When structuring the participation process and engaging with stakeholders, the National TNA Team (through the project coordinator) should bear in mind the need to develop robust networks of stakeholders to carry forward an implementation plan after completion of the TNA (see Section 1.3). This will involve making sure that active and competent centers for linkages are fostered so that the National TNA Team is not the only linking point and the networks remain connected and empowered. The network of stakeholders would be expected to start with the National TNA Team and, while working together with stakeholder interest groups, develop over time as the range of issues increases.

A successful engagement of stakeholders can result in a number of important benefits. It can lead to transfer of new knowledge, especially local knowledge, and insights on specific technology challenges and opportunities that might otherwise have been missed. Moreover, it will likely be easier to implement TNA recommendations, as stakeholders, especially facility- or sector-specific ones, will have already been exposed to proposed actions and provided some level of "buy-in."

### Process for active stakeholder engagement

As noted above, for an active, inclusive stakeholder dialogue that is sustained over the course of the assessment, five major steps are required. Guidance on each of the steps is provided below:

1. The first step is the **identification of stakeholders**. The extent to which all stakeholder types are represented will differ by country, but it is important that as many of these types of stakeholders as is practical are involved from an early stage of the TNA effort. From a practical point of view, since such a large number of people are legitimately classified as stakeholders in some of these categories, only representative members (**core team**) will likely be able to be involved. If possible, these representatives should report back to a wider group of stakeholders (*e.g.*, a (sub)sector association) and be informed by them. The division of activities between the *core* and *wider* teams is explained further in step 3 below.
2. The second step is to adequately **define the goals and objectives** of the process for the stakeholders. This involves setting up a transparent process in which the purpose of the TNA is discussed along with the expectations and privileges of stakeholder involvement. Once agreed upon, this will lead to a clear sense of the goals and objectives of the overall TNA effort.
3. The third step is to **clarify stakeholder roles**. Defining roles and responsibilities is an important part of the process of stakeholder engagement. The core team of stakeholders could be up to 20-25 persons at a maximum, of which 10-15 maximum would be involved in any particular sector or technology analysis. In addition, *a wider group of affected and interested parties* would also be involved and some might even join the core team temporarily depending on competences. It is therefore important to be flexible and identify activities that will require direct and detailed input from these two groups, and ensure that relative strengths and expertise are utilized as effectively as possible. The National TNA Team needs to facilitate the active participation of all relevant stakeholders in the prioritization steps in Chapters 3 and 4, in the discussions on accelerating technology development, deployment and diffusion (Chapter 5), and on national strategies (Chapter 6).

   The division of tasks between the National TNA Team, the core stakeholder group, and wider stakeholder groups is explained in each of the steps in Chapters 3 through 6, though this is flexible depending on the circumstances.

   The core stakeholder team will, in collaboration with the National TNA Team, deal with the most substantive issues of the TNA process such as resource assessment, technology costing, market assessments, *etc*. The wider groups may prove effective, following preliminary consultations, in pushing ahead in specific areas. Their involvement in the process also prevents that the TNA process and its outcomes remain within a small group of people only; instead, it is recommended that the information from the TNA is communicated to all stakeholders in the countries through workshops, public hearings, and consultation papers depending on requirements.

The division of tasks between the core and wider stakeholder groups may have advantages in terms of manageability. However, the extent and usefulness of this approach will depend on country circumstances, such as the capacities (human and financial) of different departments and sectors involved, and the need for establishing robust networks of stakeholders.

It is also important to ensure that the TNA process does not become 'compartmentalized' or fragmented at too early a stage; the assessment must initially consider all development priorities. It is likely that only after completing a preliminary assessment will it be appropriate for countries to identify action teams in priority areas. For example, the core team could compare vulnerabilities across sectors, regions, or populations in order to set priorities.

4. The next step is to establish an **ongoing process for stakeholder engagement**. It is almost inevitable that a number of problems and difficulties will befall the stakeholder engagement process. There are a number of key points that, if addressed in advance, can help to establish an effective process for engaging stakeholders. These are as follows:

- *Anticipate competing priorities*. Active engagement of a relatively large number of stakeholders, some with interests and agendas (including those of different government departments) that are at odds with others, might give rise to conflict and some difficulty with decision-making.
- *Keep to a focused timeline*. It is possible that a relatively long timeframe required for effective technology transfer may militate against continued engagement from some stakeholders, notably some private sector participants.
- *Keep control of the process*. It is also possible, even likely perhaps, that some stakeholders will attempt to drive the engagement process to promote their own exclusive set of interests  so-called "capture" of the process by interest groups. This can be avoided by ensuring that decision processes such as technology ranking are transparent, and balanced representation is sought early in the stakeholder selection process.
- *Guard resources*. TNA can absorb a large amount of skilled staff time and financial resources in countries where these are both in short supply.

5. **Stakeholders need to be involved in each stage of the process**, not merely at the beginning to provide direction and/or at the end to provide approval to the initiatives proposed, although in some of the steps in Chapters 3 and 4, the National TNA Team will collect the basic information and knowledge for stakeholders to base their prioritization analysis on.

A number of steps can be taken to ensure from the outset that the stakeholder engagement process works effectively, helping to avoid some of the difficulties described above. These include:

- Enact measures to assist manageability — work with a small core stakeholder groups with regular feedback from wider stakeholder groups, as explained above;
- Establish clear lines of command at an early stage, with the project coordinator and National TNA Team agreed and provided with a clear leadership structure, thus keeping the process on track;
- Define clear objectives at an early stage based on the steps in Chapters 3 through 6;

- Ensure transparency in all decision-making and consultation activity;
- Ensure ongoing involvement of all stakeholders;
- Set realistic goals for each of the stages in the TNA process; and
- Carry out outreach, education and engagement with a wide cross-section of stakeholder groups.

## 2.3. Work plans and data collection

### Work plans

Once a suitable National TNA Team has been established and stakeholder engagement arranged, it will be important to develop a detailed work plan with clearly defined tasks, schedules, and budgets. The typical time required for a complete TNA is approximately 24 months, with resource availability varying by country depending on in-kind contribution levels.

It is recommended that a clear schedule of milestones for deliverables is prepared. Such deliverables would address pre-assessment activities (*e.g.*, training, some data collection) as well as actual assessment activities (*e.g.*, stakeholder meeting reports, initial draft of ranked technologies). Important elements of the work plan are: time, budget, and any other important resource constraints.

It is suggested that the 24-month period is divided as follows:

| | |
|---|---|
| • TNA preparations (including National TNA Team member recruitment and work preparations) | 6 months |
| • Prioritization of technologies for mitigation and adaptation | 12 months |
| • Identification of activities for accelerating technology development, deployment and diffusion and exploring ways to move forward from technology needs to national technology strategies | 9 months (with 3 months overlap with Ch.3-4 activities) |

The length of the preparation time could vary if, for example, data availability is problematic (see below). It is suggested that the last two parts of the TNA partly overlap because of possible synergy effects between the technology prioritization phase and the analysis of accelerating technology development, deployment and diffusion.

In Figure 2-2 a Gantt chart is presented with an indicative plan for carrying out a TNA in a country.

Finally, it could be remarked that the uncertainty regarding climate change impact on a country and the dynamic nature of technological development complicates a focus on specific technologies in the short term and a direction of the technologies for the medium and long term. This Handbook addresses this by recommending analyses of the medium to long term economic and demographic trends in the country, and by suggesting that both short and medium and long term technologies are considered. Moreover, countries may wish to revisit the TNA outcomes periodically (*e.g.* every five years) and review technological developments.

## Figure 2-2. Overview of TNA steps and tasks in this Handbook

| TNA preparations (Chapter 2) | | Prioritizing technologies for mitigation and adaptation (Chapters 3-4) | | | | From technology needs to national strategies (Chapters 5-6) | |
|---|---|---|---|---|---|---|---|
| **Month 1-3** | **4-6** | **7-9** | **10-12** | **13-15** | **16-18** | **19-21** | **22-24** |
| • Responsible ministry<br>• National TNA team<br>• Stakeholders networks | • Training TNAssess<br>• Training TechWiki<br>• Work plan<br>• Data collection | | | | | | |
| | | • Assessment of long term climate change impacts in the country<br>• Identification of develop-ment priorities<br>• Identification of high-GHG sectors or high vulnerability sectors | • Prioritization of sectors on potential GHG reduction/ increased resilience and sustainable development improvement | | | | |
| | | | | • Technology identification for priority sectors<br>• Technology familiarization<br>• Technology prioritization using multi-criteria analysis | | | |
| | | | | | • Accelerating technology development, deployment and diffusion From Technology Needs to National Technology Strategies | | |
| | | | | | | | Reporting |

### Data issues

Undertaking a TNA does not necessarily require an abundance of high-quality data or generous amounts of time and funding. However, posing pertinent scoping questions up front in order to define and meet the data requirements is indispensible.

It is recommended that in order to support the overall TNA process in developing countries, resources are devoted to acquire three key types of general data, namely data on the status of technologies currently in use, data on the cost, benefits and performance characteristics of potential low carbon technologies, and socioeconomic and market data needed to address potential barriers to technology transfer. These data are to a certain extent generic, but technology and market data can also be very specific to the region where the technology is implemented. Therefore, it is important that the data contain information about technologies implemented under circumstances which are comparable to those of the country concerned.

For technologies that are currently in use in the country where the TNA is carried out, it will be necessary to contact the appropriate national departments or agencies to assess modalities for access to available data. This will be a task for the National TNA Team. For low carbon technologies and measures for mitigation and adaptation, a list of technologies is supplied in a structure according to the sectors where technologies can be applied, their availability in the short or medium to long term and their applicability on a small or large scale (see Sections 3.4 and 4.4). In addition, technology information sources are available in the *TechWiki* facility described below.

Some information may require pre-processing, and tools and resources will need to be accessed to do this. For example, some industrial facilities maintain databases that contain fuel usage, efficiency, operating hours, and pollution emission levels, which may require specific kinds of software to review (*e.g.*, Microsoft Access). Sector-wide data may include the results of a past technology survey which are viewable in statistical software (*e.g.*, SPSS).

Examining these types of questions offers an idea as to the host of issues that the Project Coordinator and the National TNA Team will face when dealing with data acquisition issues. While not costless in terms of time and resources, neither do these activities represent an unmanageable burden. For most countries, addressing information availability will be a strategic aspect of conducting the TNA.

## 2.4. Training and support tools supplied for TNA

In order to support the TNA process described in this Handbook, three tools have been made available: *TNAssess*, *TechWiki*, and the *TNA Report Formulation Aid*. These tools are described below.

### TNAssess

For technology prioritization within a TNA process, multi-criteria decision analysis (MCDA) is recommended. MCDA facilitates taking a decision by analyzing how well different options for the decision score on a set of criteria, which is followed by a discussion among decision makers and other stakeholders on the relative importance of different criteria. MCDA provides decision makers and other stakeholders with a framework around which they can structure their thinking. Above all it allows focused communication on a problem so that different perspectives and experiences can be applied to its solution.

As a companion to this Handbook, a decision support tool called *TNAssess* is provided for undertaking the prioritization process. *TNAssess* is an interactive system for conducting a multi-criteria assessment using MCDA in a stakeholder context. Some more information on MCDA and some examples of its application are provided in Annex 5. It aims to support a transparent, user-friendly process for applying evaluation criteria, scoring and weighting to prioritize technologies for mitigation or adaptation, and has been designed specifically for use in national TNA processes. It uses an easy to understand 'wizard' to support the group through the assessment process. It also incorporates lessons learned and experience gained from the initial round of TNAs.

A series of in-country training workshops can be held based on workshop materials made available to the Project Coordinator. Training workshops can also be held at regional locations, where an international expert will provide training. *TNAssess* offers the advantage of being developed specifically to help National TNA Teams and the stakeholder groups conduct the critical technology prioritization process in the TNA process. It is intended to serve and inform the prioritization process, not drive it.

### TechWiki and mitigation and adaptation technology database

The purpose of *TechWiki* is to provide descriptions of low carbon technologies in different sectors and categories[8], which are easily accessible for a broad audience and which will contain the following information:

- General description of how the technologies work, including examples of application in actual projects in different regions;
- The sustainable development contribution of the technologies in terms of economic, environmental and social benefits in different regions;
- The status of the technologies in terms of market penetration in different regions/countries;
- The required capital and operating and management costs of the technology, explored for different circumstances and regions, so that a country can collect this information from comparable circumstances;
- The future market potential of technologies in different country contexts;
- A list of global and regional experts on technology transfer or on selected technologies for mitigation and adaptation;
- A glossary of technology terms; and
- Videos (via You-Tube) and/or photos (via Flicker) of different types of technologies for mitigation and adaptation.

*TechWiki* is based on an online information exchange system which serves as an online encyclopedia to which visitors can add new information online. The site is targeted at basically all decision and policy makers, in developing, as well as industrialized countries, who are responsible for or involved in taking decisions on low carbon technology investments. A second group of visitors and contributors are technology developers and technology project developers who can share their knowledge and expertise with other users of the system. For example, the US National

[8] For example, electricity production, energy saving, heating, cooling/climate control, transport, waste management, and industrial production for mitigation technology categories; coastal zone management, water resource management, agriculture and public health for adaptation technology/measure categories. See Annex 2 for an overview of technology categories.

Renewable Energy Laboratory (NREL) is actively undertaking an Energy Efficiency and Renewable Energy (EERE) technology cost and characterization effort, which could be linked to the *TechWiki*.

For the purpose of the TNA, the *TechWiki* database will also be made available on CD-Rom, especially for the facilitation of the technology familiarization phase in Chapters 3, 4, and 5. *TechWiki* will be set up as a stand-alone database which can be consulted independently from the TNA processes, but TNAs will be the first application of *TechWiki*.

### TNA Report Formulation

Finally, a format has been made available for the National TNA Team to prepare a *TNA National Synthesis Document* with the following Table of Contents (see Section 6.5):

1. TNA process overview;
2. Key sectors & technologies;
3. Technology prioritization;
4. Enabling frameworks and strategies;
5. From technology needs to national technology strategies and work plan; and
6. Final conclusions & recommendations.

## 2.5. Checklist

It is recommended that the country's TNA project coordinator prepare and complete a checklist to ensure that the issues addressed above regarding organizing the TNA are suitably addressed. The checklist below is an example that could be applied.

Have the TNA preparatory activities:

- ✓ Identified the host ministry from which the assessment will be conducted?
- ✓ Recruited the National TNA Team and defined their roles and responsibilities?
- ✓ Identified and invited stakeholders and secured their commitment to engage throughout the process, both for the core stakeholder groups and wider groups?
- ✓ Initially identified required information, sources and access, as well as potential data gaps?
- ✓ Developed a detailed work plan with clearly defined tasks, schedule, and budgets?
- ✓ Established a network structure of stakeholder groups and communication strategy?
- ✓ Integrated training and support opportunities into the work plan?

Part II

# Making Strategic Choices – priority sectors and priority technologies for mitigation and adaptation

# 3. Making Strategic Choices: priority sectors and priority technologies for climate change mitigation

## 3.1. Introduction

This chapter describes the required process in prioritization of technologies for climate change mitigation in a TNA and it corresponds to the step from **Figure 1-3** on making strategic choices on Portfolios with prioritized mitigation technologies. The technologies prioritized in this Chapter will be taken for further analysis in Chapter 5 where activities (*e.g.*, developing enabling conditions and building capacity) will be identified to improve and accelerate the development, deployment and diffusion of these technologies. These activities would subsequently provide information to the discussion on Nationally Appropriate Mitigation Actions (NAMAs) which can monitored, verified and reported on.

This chapter focuses on mitigation. Adaptation to climate change follows a parallel process but is dealt with separately in the next chapter.

The process starts with an identification of a country's development and sustainability priorities, with particular attention to GHG emission reduction potentials. It is important that the identification of development priorities takes into consideration long term economic and social trends in the country (*e.g.* urbanization and increasing industrialization), as well as the expected scale and type of climatic change for the country context. This is followed by an identification of priority sectors on the basis of the GHG emission reduction potential and contribution from low carbon technology investments in these sectors to sustainable development. For these priority sectors, low carbon technologies are identified and characterized.

With respect to the latter it is highlighted that within the resulting portfolios of identified low carbon technologies, 'new' technologies are also considered, *i.e.*, technologies which country stakeholders are not yet familiar with. In order to make stakeholders knowledgeable about previously unfamiliar technologies, a technology familiarization process is envisaged, which consists of workshops on technologies, expert lectures, and visiting demonstration projects. This process will be supported by the technology information available in the *TechWiki* (see Section 2.4).

The technologies identified for the priority sectors are also categorized according to their short or medium to long term availability and whether their implementation takes places on a small or large scale. The categorization allows a method for a technology strategy to be formulated over time, and assists in identifying key technologies that may not necessarily have the highest priority in the sectors, but would be useful across a number of sectors. Finally, the sector technologies in each category will be prioritized through a multi-criteria decision assessment method.

This process described in this chapter aims at providing clear win-win opportunities as the priority technologies contribute both to the country's sustainable development (*e.g.*, energy efficiency improvement, low carbon energy production for rural communities, improved waste management techniques, and cheaper treatment of sewage effluents) and to the mitigation of climate change. The results from this chapter provide important inputs for the analysis in Chapters 5 and 6 on enabling environment, capacity building and national strategies for low carbon technologies and which establishes direct links to future NAMA discussions/developments at the country level.

It is emphasized that this process requires the formation of stakeholder groups and is a participatory process at every step described in this chapter. More details about the organization of the stakeholder consultation and the participatory process can be found in Chapter 2 of the handbook. It is important that the decision conferences conducted with the group/s are planned in advance with full commitment from stakeholders and that targets are set for each session.

## Overview of steps

For the process of prioritizing sectors and low carbon technologies described in this chapter, two main objectives are considered:

1. The need to meet a country's development priorities, and
2. The need to maximize sustainability outcomes, particularly GHG emission reduction.

The process takes place in two main stages, involving the following main steps:

1. **Steps 1, 2, 3:** The prioritization of the sectors, and
2. **Steps 4 and 5:** The prioritization of technologies and the development of a portfolio of environmentally sustainable technologies.

These five main steps are explained in detail in Sections 3.3 and 3.4. Before starting the sector and technology prioritization, however, it is recommended that the National TNA Team, together with the stakeholder groups, reflect on the *possible impacts of climatic changes* for their country. The main reason for this, as explained in Section 1.2, is that in the light of a changing climate, technology needs in a country to meet development priorities may change over time. Section 3.2 provides guidance for this action. Figure 3-1 shows the stages in this chapter and Figure 3-2 shows a Gantt chart with an indicative work plan for this chapter.

Finally, it is mentioned here that at the end of this chapter there is a summarizing table for the technologies prioritized and a description of their contribution to GHG mitigation (**Table 3-6**).

**Figure 3-1. Supporting diagram for this chapter**

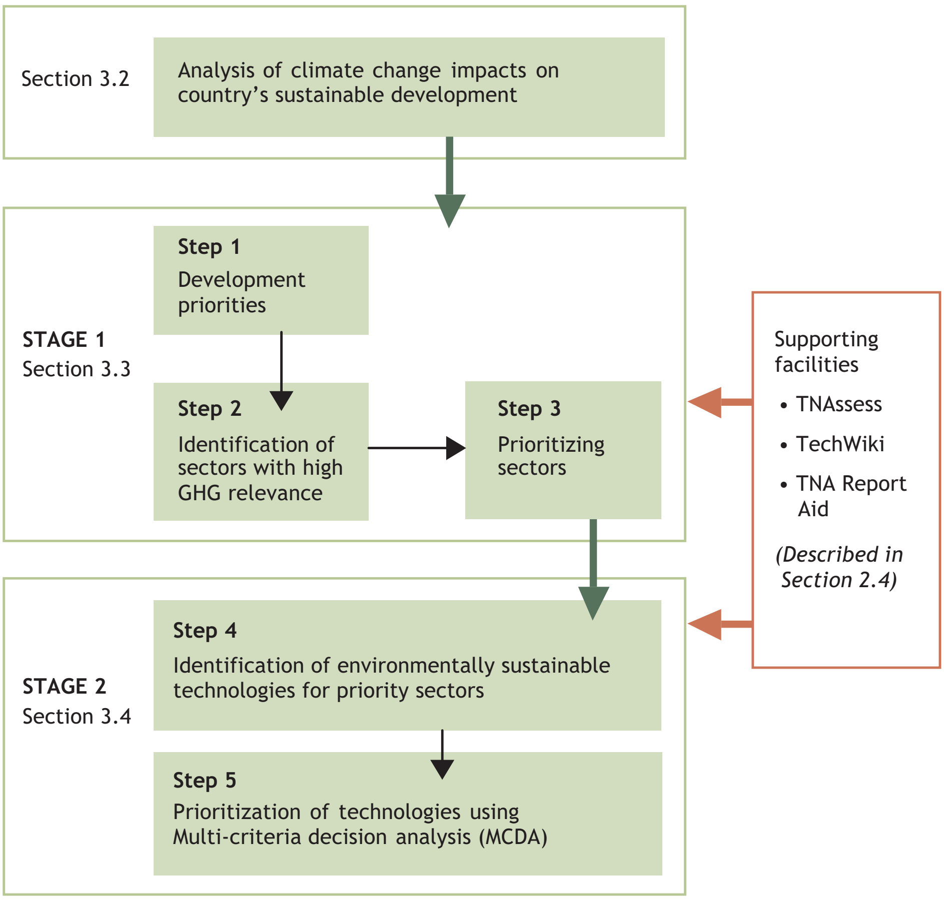


**Figure 3-2.** Gantt chart with indicative work plan for this chapter

| Activity | Preparation (3 months) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Data** | **Data availability check (see Section 2.3)** | | | | | | | | | | | | |
| Climate change impact assessment<br>National TNA team/ core stake-holders | | View on possible climate change impact on country<br>• List of develop-ment priorities for country | | | | | | | | | | | |
| Develop-ment priorities<br>(Step 1)<br>National TNA team with core stake-holders | | • Clustering into environmental, economic, and social priorities | | | | | | | | | | | |
| High GHG Sector iden-tification<br>(Step 2)<br>National TNA team | | | | | • IPCC sector division<br>• Identification of subsectors in country<br>• Screening (sub)sectors on GHG emissions | | | | | | | | |
| Sector prioritiza-tion<br>(Step 3)<br>National TNA team & stake-holders | | | | | • Characterizing sectors: existing technologies, impact on country's SD<br>• Rating sectors on GHG and SD improvement potential | | | | | | | | |
| Identifying low carbon technolo-gies for priority sectors<br>(Step 4)<br>National TNA team | | | | | | | • Identification of low carbon technologies<br>• Familiarization with new technologies<br>• Categorization technologies into small/large scale and short/long term | | | | | | |
| Robust decisions for priori-tizing tech-nologies<br>(Step 5)<br>National TNA team and stake-holders | | | | | | | | | | • Familiarization<br>• MCDA for prioritizing technologies<br>• Making final decisions<br>• Preparing final summary table | | | |

## 3.2. Before you start — preparatory stage for technology prioritization

**Why?** An analysis based on only current climate conditions is liable to fail to prioritize relevant sectors affected by future changes in climate and the technologies which will be needed.

**How?** Assessment of available information about climate change impacts on the country from national development strategies. It is recommended to assess this information and discuss it with the stakeholder groups, so that in the overall TNA process for the country a clear long term background is described including climate change impacts, and so that the technology prioritization processes in this and the following chapter take notice of a changing climate.

**Who?**
- National TNA Team — assessment
- Stakeholder groups — discussions

### Making choices in a changing global climate

In Chapter 1 it was explained that the latest scientific knowledge on climate change indicates that the world is on a GHG emissions trajectory which is worse then the IPCC worst-case scenario and that there is a risk of severe disruption of the climate system. In the light of a changing climate, technology needs in a country to meet development needs may change over time (Annex 1-1 shows examples of possible climate change impacts on sustainable development) and TNAs should result in a portfolio of priority technologies which meet these future development needs and priorities.

It is therefore recommended that the National TNA Team, together with the stakeholder groups, before starting with the prioritization of technologies for mitigation (this chapter) and adaptation (next chapter), reflect on the possible impacts of a changing climate for their country. Obviously, such a reflection is needed for prioritizing technologies for adaptation in Chapter 4, but since a changing climate will have an impact on resources such as water and demand for energy services with implications for the organization of the energy system, this knowledge also needs to be taken into account for mitigation technology prioritization in this chapter.

Within the prioritization process for sectors and technologies, scenarios can be developed around the analysis to explore the effect of different futures, in order to have some idea of the expected scale and type of climatic change for the country context. From that, the expected implications for environmental and social as well as economic impacts can be deduced. This will enable the analysis to be conducted with at least the expected range of regional climate changes already in the pipeline and the knowledge that the actual changes will be more severe if mitigation activities stall. An analysis based on only current climate conditions is liable to fail to prioritize the relevant sectors affected by future changes in climate and the technologies which will be needed.

In most countries information on the impacts of climate change is already available. For example, in their national development strategies, several countries have described their vulnerability and/or resilience profile with regard to future climate change impacts. The National TNA Team can assess this information and discuss it with the stakeholder groups, so that in the overall TNA process for the country a clear long term background is described, including climate change impacts, so that the technology prioritization processes in this and the following Chapter take notice of a changing climate.

Should such information not be available in a country, the National TNA Team is encouraged to carry out or commission an analysis of the impacts of climate change on the country. This analysis should be performed within a future scenario of possible effects for the country and timescale for the effects. For example, development priorities on sea level rise and land use perhaps would be given the highest importance in view of the expected shifts, where currently it may have a lower priority, and this would affect the choice of sectors and technologies to prioritize. Another example could be an increased demand for cooling services in the future due to climate change, which would give a higher priority to such technologies as heat pumps. This would also have the implication that if these technologies are already available now, the TNA recommendation would likely follow that these technologies would need to be implemented in the short run.

*It is recommended therefore that where a vulnerability assessment has not yet been performed, the country team carry this out before progressing to the strategic choices on sectors and technologies in the next chapters.*

### Specific links with further steps in this chapter

The insights gained in this preparatory stage will be used when assessing long term development priorities (Step 1), prioritizing sectors on their contribution to development and sustainable mitigation priorities (Step 3), and when assessing technologies on the first category of criteria in Step 5 ("contribution to development goals in the light of climate impact scenarios for the country").

**Output from this preparatory stage:**

Insights into the expected scale and type of climatic change for the country context, and its impact on the country's environmental, social, and economic development.

## 3.3. First stage of analysis — strategic choice of priority sectors

In the first stage of the process, consideration is given to the key factors that are important in the selection of the priority sectors or areas in the country. In this section these key factors are addressed for **mitigation actions**, and then this information is used to identify priority sectors for further study on their technology requirements.

Upon completion of the activities in this stage of the TNA process, country teams will have defined the priority sector(s) for their country and developed a solid justification for why these sectors — and not others — have been selected for consideration within the TNA.

The steps for this first stage of analysis, as well as the outputs, are summarized in **Figure 3-3**. The description of each step starts with a short overview of why the step is needed, how the work will be carried out, and who will do the work.

**Figure 3-3: Supporting diagram for Stage 1 of the process**

**STRATEGIC CHOICE OF PRIORITY SECTORS**

| Steps | Description | Output |
|---|---|---|
| Step 1 | **Identifying development priorities**<br>• Priorities in light of changing climate | • List of development priorities, which are consistent and which take account of environmental (including climate change), technical, economic/market risks and uncertainties. |
| Step 2 | **Identification of sectors that have a high GHG relevance** | • List of high GHG emitting sectors (sub)sectors |
| Step 3 | **Prioritizing (sub)sectors in terms of development and sustainable mitigation priorities** | • A final short list of prioritized sectors with large contribution to GHG emission reduction and to sustainable development |

## → Step 1 Identifying development priorities

**Why?** It is important that the eventual technology choices are clearly in line with the long term development priorities in developing countries.

**How?** Identification of development needs already formulated in national development strategies for a country

**Who?** National TNA Team in cooperation with stakeholders and sector experts

### Development priority examples

In this step, an overview is prepared of the country's development priorities. It is recommended that the TNA's starting point stresses the importance of understanding and identifying for a country which development needs are already formulated in national development strategies, as reflected in documents such as 5-year National Plans, sector policies, countries' National Communications to the UNFCCC, and country profiles prepared in co-operation with UNDP and the World Bank.

Based on the above-mentioned official publications the National TNA Team will generate a list of development priorities which they consider most applicable to their country's sustainable development, both with a view to the short and longer term. These priorities could, if desired, be discussed with the stakeholder groups.

It is noted here that Step 1 focuses only on development priorities of the country concerned, which do not necessarily have to include the contribution to global GHG emission reduction. However, when exploring for a range of sectors/areas in Step 3 how improvements would contribute to the country's sustainability priorities, the effect of these improvements on GHG emission reduction is explicitly included.

### Identifying development priorities in light of a changing climate and social and economic changes: short — long term dimension

As explained above, it is important that the TNA not only focus on short term needs, but also take into consideration that in light of climate change (see Section 3.2), as well as technical, economic, demographic and market changes, development needs may change over time. Therefore, in this Step 1, development priorities for the country will be identified both with a view to the short and the long term.

The main objective in this respect is that stakeholders keep a clear eye on the long term development perspective in their country in light of a changing climate and social and economic changes. For example, an expected temperature change may require an increased need for cooling services in the future and heat pumps may therefore be an immediately available technology option to be prioritized. However, no extensive additional assessments in terms of scenario development are required.

### Clustering development priorities

In order to facilitate the analysis, it is recommended that the development priorities should, where possible, be grouped under economic, environmental and social priorities both from a short term and a medium to long term perspective, as is done in the hypothetical example below (**Table 3-1**). Table 3-1 is simply an overview table for the development priorities with short comments, but a description is also required to define what is meant by each of the priorities in detail and this should be available for use in Step 3.

**Table 3-1. Example of development priority clusters for short and medium/long term**

| | |
|---|---|
| | **Environmental development priorities** |
| Dev priority 1 | Reduced air pollution |
| Dev priority 5 | Reduced soil degradation |
| Dev priority 8 | Reduced water pollution |
| | **Economic development priorities** |
| Dev priority 2 | Increased energy security of supply |
| Dev priority 7 | Improved employment |
| Dev priority 10 | Affordable energy supply |
| | **Social development priorities** |
| Dev priority 3 | Improved health conditions |
| Dev priority 6 | Strengthened empowerment |
| Dev priority 9 | Contribution to education |

It is noted here that the objective of Step 1 is not to rank development priorities. Therefore, the order of development priorities is random at this stage and does not reflect a weighting or scoring of priorities.

**Output from STEP 1:**

A list of clustered development priorities for the country concerned.

Definitions of each priority.

## ➔ Step 2 Identification of sectors with a high GHG-relevance

**Why?** Identification of (sub)sectors helps focus on those areas in a country's economy with relatively high GHG emissions

**How?** PCC categorization of sectors with high GHG relevance & sub-sectors identified for the country

**Who?** National TNA Team

In this step the sector breakdown relevant to the countries is identified following the guidance set out in Annex 1-2 following IPCC sector definitions as far as possible. The sectors are then screened on the basis of GHG emissions and on future changes expected before prioritizing them based on development priorities. This step can be carried out by the National TNA Team and is explained in Annex 1-3.

**Table 3-2. Identification of country sectors with high GHG relevance**

| (sub)sectors | GHG emissions in year x (megatons $CO_2$-eq) whether diverse or point emission sources | Percentage share of subsector in country's annual GHG emissions |
|---|---|---|
| Subsector 1 | | |
| Subsector 2 | | |
| Subsector 3 | | |
| Etc. | | |

**Output from Step 2:**

Identification of sectors with an initial screening on their GHG emissions. The sectors which will be assessed for a prioritization in terms of contribution to sustainable development mitigation priorities would have a cumulative share of 75% of the country's overall GHG emissions

For these (sub)sectors the information on existing technologies and sustainable development impact could then be collected and summarized in **Table 3-2**.

| | |
|---|---|
| **Why?** | Shortlisting of sectors in terms of high GHG reduction potential and high contribution to sustainable development shows where the largest contributions to mitigation and meeting development priorities can be made |
| **How?** | Make a selection of sectors to be prioritized using a simple performance matrix procedure, as indicated below |
| **Who?** | National TNA Team & stakeholders |

## ➔ Step 3 Prioritizing (sub)sectors in terms of contribution to development and sustainable mitigation priorities

Step 2 has resulted in an overview of main GHG emitting sub-sectors in the country. In this Step 3 the (sub)sectors will be prioritized on the basis of how low carbon technology implementation would contribute to GHG emission reductions and to delivering environmental, social and economic benefits. A tool for describing the sectors' present environmental, social and economic impacts is presented in Annex 1-4.

When performing this part of the analysis to make the final selection of sectors to be prioritized, a simple performance matrix procedure may be followed as indicated below in a workshop environment.

### Prioritization approach

From the sectors listed in Step 2 those sectors are identified where improvements (*e.g.*, in terms of low carbon technologies) would make a large or very large contribution to sustainable development priorities and GHG emission reductions.

Based on the information above the analysis in this step explores how improving the situation in each of the (sub)sectors would contribute to each of the development priorities identified in Step 1 (clustered as in **Table 3-1**) and contribute to GHG reductions. For each (sub)sector, stakeholders could rate these contributions comparing down through the (sub)sectors for each development priority criterion in turn identified from Steps 1 and 2 through the following rating scheme:

1 — very small contribution

2 — small contribution

3 — medium contribution

4 — large contribution

5 — very large contribution.

Obviously, what is a small or large contribution is fully left to the judgment of the stakeholders and National TNA Team, as these assessments are country-specific (*e.g.*, a 5% GHG emission reduction might be considered a very large contribution in one country, whereas in another country it would mean a small contribution only).

**Table 3-3** shows a purely hypothetical example of a completed analysis after Steps 1 through 3. If cement is identified through this rating process as a priority (sub)sector then in Step 4 the low carbon technologies suitable for this (sub)sector will be identified.

From this approach four types of sectors can result:

1. There could be sectors in which improvements to modern technologies would contribute strongly to the development priorities of Step 1, but relatively little in terms of GHG emission reductions.
2. Sectors could contribute relatively little in terms of development priorities, but much in terms of GHG abatement.
3. Improvements of technologies could contribute little in both respects.
4. If existing technologies in a sector result in high GHG emissions and high adverse impacts on the country's sustainable development, then technology improvements in such a sector can result in maximum benefits in GHG emissions reductions and sustainable development improvement.

Therefore, the focus will be on these high-GHG and high sustainable benefit sectors (as under 4 above), although care needs to be taken not to exclude those sectors which deliver a high development benefit, even though they may not be the highest GHG emitters.

It is the stakeholder group that decides what the thresholds for choice of priority sectors will be. One possibility is that all (sub)sectors with a score of 4 or higher on potential GHG emission reduction and a total score of 12 or higher on development priority benefit delivery will be considered priority areas for which technologies will be identified in Step 4. The sectors can be listed in priority order.

**Table 3-3: Example - 'STEP 3 - SECTOR RATING'**

| Sector | Subsector | Improvement by low carbon technologies beyond baseline/existing situation) (Steps 2 and 3) | | | |
|---|---|---|---|---|---|
| | | Impact in relation to development priorities (**Step 1**) | | | |
| | | Maximize economic development priorities | Maximize environmental development priorities | Maximize social development priorities | GHG reduction potential |
| 1. Industry | Chemical | 3 | 2 | 3 | 4 |
| | Iron & steel | 2 | 3 | 2 | 4 |
| | Cement | 3 | 2 | 4 | 4 |
| 2. Energy | Electricity supply | 4 | 3 | 3 | 5 |
| | Heat supply | 4 | 3 | 5 | 4 |
| 3. Transport | Rail | 4 | 2 | 2 | 4 |
| | Bus | 2 | 4 | 3 | 3 |
| 4. Etc. | 4a | | | | |
| | 4b | | | | |

Where the prioritization approach is not conclusive in terms of an easily justified prioritization of the sectors, then a simplified swing weighting of the criteria or an MCDA can be undertaken (for this, see Annex 5).

**Outputs from Step 3:**

This step provides a short list of (sub)sectors according to their development benefits and GHG reductions and whether sectors have a balanced sustainable development contribution and deliver the maximum benefits and reductions.[9] These sectors with their (sub)sectors, are then analyzed in the second stage of the analysis (Steps 4 and 5) to develop portfolios of technologies in the categories of short or medium to long term availability and small or large scale applicability which are prioritized using the MCDA.

## 3.4. Second stage of analysis — strategic choice of portfolios of priority technologies

The first stage of the analysis dealt with the strategic choice of priority sectors and provided a process for undertaking this analysis. This section builds on that work and moves on to the second main activity in this chapter, exploring the **technologies** required to move to a low carbon future for those prioritized sectors/areas.

As explained above, it is important that the mitigation technologies eventually identified through a TNA are in line with countries' development priorities and needs. This establishes the scope of the TNA. Carefully selected technologies based on such priorities and needs are more likely to have knock-on effects on the economy and energy systems. TNAs which identify technologies without a clear link to the country's sustainable development have a higher chance of ending up as one-off projects with no long term potential in the country.

In assessing technologies in a changing climate there is a need for resilience in the system, and this leads to the suggestion that technologies need to be prioritized within portfolios of technologies suitable for a low carbon sustainable future.

### Defining categories for technologies

In order to provide a basis for comparison across the technologies and to provide a basis for a strategy to meet the climate and development priorities in the short and medium to long term, these portfolios are categorized according to their applicability over time and in the market and their scale/size of application. By applicability of a technology in the **short term** is meant that it has proven to be a reliable, commercial technology in a similar market environment. The technologies in the **medium term** would be pre-commercial in that given market context (5 years to full marketing) and a **long term** technology would still be in an R&D phase or a prototype.[10] For a general overview of the technology phases, see Figure 1-2.

[9] This is an initial prioritization, but with further discussion in the next stage, it may be that other sectors will be added. Thus, the process is flexible and iterative.

[10] It is noted here that the terms short, medium, and long term are context-specific. Technology that is fully commercial in some markets may not be a commercially viable technology in another country or market. For example, utility scale wind power is a demonstrated commercial technology, but in smaller, isolated markets (even where there is a good resource) the technology may not be truly "commercial". Therefore, the short, medium, and long term applicability has to be defined specifically for each country.

Small scale technologies are those that are applied at the household and/or community level, which could be scaled up into a program. For the sake of simplicity all technologies applied on a scale larger than household or community level are considered large scale technologies.

Based on these definitions, the categorization used is as follows:

1. Small scale application, with a short term market availability;
2. Small scale application, with a medium to long term market availability;
3. Large scale application, with a short term market availability; and
4. Large scale application, with a medium to long term market availability.

To simplify the analysis, it is suggested that medium and long term availability is considered one category, as it represents a continuum from R&D to pre-commercial phase.[11]

Technologies include not only market technologies, such as wind energy, but also non-market technologies, such as behavioral change in decreasing energy consumption.

## Key steps in prioritizing technologies through an MCDA

The step-wise process in this section is again an interactive process which is carried out with stakeholders (as described in Section 2.2). The process is best conducted by an independent facilitator with the stakeholder groups. It is important that the decision conferences conducted with the group/s (see Step 5 below) are planned in advance with full commitment from stakeholders, and targets set for each session.

The steps in this second stage of the analysis continue on from the end of the first stage on the priority sectors. In Step 4, relevant low carbon technologies for the prioritized sectors from the first stage will be focused on in order of priority. This will be done by first identifying technologies for each of the prioritized sectors and then enabling stakeholders to familiarize themselves with technologies that are unknown or not commonly used in the country.

The categorization of the technologies as described above forms the basis of a strategy and allows technologies to be optimally compared and assessed later on in Step 5. In Step 5, MCDA will be used for prioritizing mitigation technologies because it is the most appropriate approach for evaluation of problems involving multiple stakeholders and trade-offs between multiple and conflicting objectives, where assessments can be difficult to quantify and there is uncertainty. In order to analyze to what extent a technology contributes to improvements in the sector beyond the baseline situation, it needs to be assessed across a range of development and sustainability criteria, hence a multi-criteria analysis. For a background explanation of MCDA, see Annex 5.

**Figure 3-4** shows the main steps for this Stage of the process.

[11] As defined in the FCCC/SB/2009/INF.1 paper (EGTT, 2009).

**Figure 3-4: Supporting diagram for Stage 2 of the process**

STRATEGIC CHOICE OF PORTFOLIOS OF PRIORITY TECHNOLOGIES

| Steps | Description | Output |
|---|---|---|
| **Step 4** | **Identify and characterize relevant technologies for priority sectors**<br>→ Technology identification<br>→ Technology familiarization<br>→ Technology categorization | → Overview per (sub)sector of technologies categorized as having small or large scale and short or long term applicability with justification for selection |
| **Step 5** | **Prioritize the technologies identified for implementation for each of the 4 categories of portfolios of technologies**<br>→ Using MCDA<br>→ If lists of technologies in Step 5 categories become too large, then a tool for first prioritization of technologies can be useds | → A final portfolio of prioritized technologies |

## → Step 4 Identify and categorize relevant environmentally sustainable technologies for prioritized sectors

**Why?** To acquire an overview of low carbon technologies in the priority sectors and to enable National TNA Team members, core stakeholder groups and wider stakeholder groups to become familiar with new, unknown technologies.

**How?**
- → *Identification*: TechWiki database
- → *Familiarization*: technology information, workshops, expert lectures, demonstration projects
- → *Categorization* of technologies in small/large scale applicability and short/medium/long term availability

**Who?**
- → *National TNA Team*: technology identification, familiarization, categorization
- → *Core stakeholder groups*: technology familiarization
- → *Wider stakeholder groups*: information exchange and feedback with core stakeholder groups on unfamiliar technologies

## Identification

Once the priority sectors and areas have been identified as an output of Step 3, for each of these (sub)sectors, the range of environmentally sound, low carbon technologies relevant to these sectors needs to be identified. This part of the exercise can be fairly brief but requires stakeholder input at all stages. This step relies on the list of low carbon technologies for mitigation. Examples are shown in Annex 2, which is structured according to sector/subsector/energy service, scale of technology and availability in the short, medium to long run. Annex 2 is currently only indicative, as the technologies will be selected from an extensive database on low carbon environmentally friendly technologies which can be evaluated through *TechWiki* (see Section 2.4). From the *TechWiki* database, for each of the priority (sub)sectors identified in Step 3 relevant low carbon technologies can be identified. Note that in this step no prioritization of technologies takes place; only possible low carbon technologies that could contribute to the priorities in the sector are identified.

It will also be important at this stage to ensure not only that the list of possible technologies is as wide as possible, but also that they are relevant to the country conditions now and under the climate change impact scenario for the country (see Section 3.2). It is also assumed that these resources (*e.g.*, insolation levels for concentrating solar power) have already been identified in other country studies. Most countries already have explored the type and extent of resources available to them, but where a technology is relatively new some additional studies may have to be undertaken. Links to appropriate sources of information for possible technologies are provided in the *TechWiki*. The information for the next step of familiarization will also come from the *Tech Wiki*.

## Familiarization

In this Step 4 it is important that all relevant technologies are considered and that the exercise is not limited to those technologies stakeholders are familiar with or know the benefits of. Also, people may have negative perceptions about a technology because of negative experiences with that technology in the past or incomplete or outdated information about it, such as system reliability and costs. In reality, very few people are aware of all available sustainable technologies in all contexts.

Therefore, this technology identification stage is supported by a familiarization phase during which stakeholders will be able to acquire information about technologies which are potentially useful but unfamiliar to them. It has been shown in similar assessments that without this, unfamiliar technologies will not be considered. For example, there are many new and existing technologies/measures which are not commonly used. As a result decision makers and other stakeholders are not necessarily able to judge their merit for a country application without further information and familiarization. As Winskel, *et al.*, (2006) pointed out, "Organizations operate in embedded socio-technical networks and tend to re-invest in established competences; disruptive technologies (*e.g.*, renewable energy) rarely make sense to incumbents so their development tends to be left to small outsider organizations."

This familiarization phase is designed to present additional information on technologies which are either in pilot or pre-commercialization phases, or newly emerging, or established but not familiar in the country context. Information on early stage technologies may not be as comprehensive as for established technologies but Box 3-1 shows a list of data that could be used to inform stakeholders during the phase of becoming familiar with new technologies. These data will be made available as far as possible in the *TechWiki* but should also be supplemented by participants and TNA team information. Uncertainties arising from lack of data will be explored in the MCDA assessment phase.

**Box 3-1. Information availability existing and pre-commercial technologies**

National TNA teams could consider the following information during the process of becoming familiar with new technologies and comparing them to existing options:

- Cost: Cost data should include capital costs, fuel costs and operation & maintenance costs.
- Performance: Performance should include efficiency (when applicable), technical measurements, capacity factors, lifetime, and degree of technical sophistication required for manufacturing, installation and operation.
- Reliability: This is a key parameter for new technologies and, while difficult to predict, should be pursued to assess whether the technology can be sufficiently relied upon.

Obtaining objective sources of information on advanced energy technologies as they relate to these parameters is not simple. Given both their forward-looking nature and the vested interests of different information sources, evaluations of new technologies present a sizable challenge in this regard. By synthesizing as much as possible from multiple sources, a clear picture can be established:

- Literature Review: For most technologies, there are reports, analyses and articles providing estimates of the required data.
- Demonstration projects: Any data gleaned from actual demonstration projects is particularly helpful, keeping in mind both that performance and costs change with economies of scale, and that technology performance will differ under different conditions.
- Other governments: Many governments face similar lack of information regarding new technologies and some may have taken steps to redress their lack of knowledge. Sharing this information between governments can be very effective.
- Multilateral institutions: Multilaterals have the advantage of working in multiple countries and can act as a conduit to transfer objective, up-to-date information.
- Manufacturers: Technology manufacturers are often best placed to accurately predict technology performance and cost. However, they have an inherent conflict of interest and incentives to promote their own technology, and should never be taken as a sole source for technology information.

Activities mentioned in Box 3-1 such as visits to demonstration projects, engagement with experts on the technologies, review of detailed information sheets and searches for further information sources, as well as discussions of experiences within the stakeholder groups are all required in order to fully consider low carbon sustainable energy technology options to meet the energy service needs identified. In addition, it is important to remember that confidence to invest is grounded in seeing the technologies or measures in action, preferably in the country context. In this respect the development of regional centers for adaptation and mitigation expertise and technology demonstrations would be very useful.

A graphical representation of the familiarization process is shown in Figure 3-5. In terms of the work plan, the familiarization activities could take place during the second half of this part of the TNA process when technologies for prioritized sectors are identified, categorized and prioritized (see also Figure 3-2). It is important that National TNA Team members and core group stakeholders are strongly involved in each of these activities, and that the information is regularly communicated with wider stakeholder groups (*e.g.*, sector organizations).

**Figure 3-5. The process of technology familiarization**


*Note that although these familiarization activities are an important part of Step 4, they are recommended to continue into Step 5 where they could support the MCDA process.*

## Categorization of technologies

With a categorization of technologies, there can be an optimal comparison and assessment of technologies in Step 5 when technologies are prioritized using MCDA. From a strategic point of view, categorization would also be useful in case technologies are common for more than one sector so that the output from this step could be used for these other sectors. In some cases this simple categorization may not be easily applied. Sometimes, the difference between technologies in terms of availability in the short term (commercial phase) versus the medium to long term (demonstration or pre-commercialization) and between small and large scale applicability might sometimes not be very clear as this also depends on the context of technology application. In the example of the sub-sector of cement given in **Table 3-4**, the scale small to large may not apply.

In Step 4 it is recommended that the diversity of technologies is preserved so that, while the list becomes progressively narrower, there will be a portfolio of priority technologies in each of the categories for 'application timescales' and 'scale of application' which can at some later stage all be considered for implementation.

**Output from Step 4:**

The results from Step 4 are presented in **Table 3-4** which includes the example of the cement sector where the technologies are categorized in terms of 'large /small scale' and 'availability in the short /medium to long term'. When selecting technologies in **Table 3-4** basic information will be gathered from *TechWiki* about the applicability of the technologies in terms of timing and scale (see the last two columns in **Table 3-4**).

**Table 3-4: 'STEP 4-TECH CATEGORIES'**

| Priority sector (STEP 3) | | Technology identification (STEP 4) | | |
|---|---|---|---|---|
| **Sector** | **Subsector** | **Technology** | **Scale of application** | **Short-, medium/long term availability** |
| **Industry** | **Cement** | **SMALL SCALE/SHORT TERM** | | |
| | | Improved process control | Small scale | Short term |
| | | Optimizing heat recovery in clinker coolers | Small scale | Short term |
| | | Lowering fossil fuel consumption | Small scale | Short term |
| | | **LARGE SCALE/SHORT TERM** | | |
| | | Co-production of power & cement | Large scale | Short term |
| | | Wet-to-dry clinker production | Large scale | Short term |
| | | High efficiency classifiers/separators | Large scale | Short term |
| | | **LARGE SCALE/MEDIUM TO LONG TERM** | | |
| | | Advanced kiln concepts | Large scale | Medium to long term |
| | | Advanced milling technologies | Large scale | Medium to long term |
| | | **SMALL SCALE/MEDIUM TO LONG TERM** | | |

A final remark on Step 4 is that the technologies identified in **Table 3-4** may have to be seen in a broader picture. For instance, where it would be foolish to improve one part of an industrial process without improving another crucial step, as otherwise the full benefit of the technologies could not be gained, then the technologies might have to be grouped such as 'technologies for lowering fossil fuel consumption' or 'for reducing air pollution.' These groupings could be included in **Table 3-4**, and the applicability information be filled in manually.

## ➔ Step 5 Facilitating robust decisions for prioritizing technologies: MCDA

**Why?** To find the best technologies for maximizing benefits in terms of sustainable development priorities and mitigation potential while minimizing costs

**How?**
- Multi-criteria Decision Assessment
- Discussion and exploration of prioritizing options

**Who?**
- *National TNA Team*: formulation of criteria for technology prioritization, facilitation of MCDA
- *Core stakeholder groups*: eliciting criteria for MCDA, scoring and weighting of technologies against criteria, explore decisions from MCDA, and agreeing on a way forward.
- *Wider stakeholder groups*: exploring decisions from MCDA, agreeing on a way forward

In this Step 5 the technologies within the categories assembled in Step 4 are compared, based on criteria to be elicited from groups using an MCDA participatory approach.

In order to keep the MCDA manageable, it is recommended that the number of technologies in each of the four categories for a (sub)sector (*i.e.*, small scale/short term, small scale/long term, etc.) should not be larger than 10 (*i.e.*, 40 total over the 4 categories). For the categories with more than 10 technologies a pre-screening is recommended and a tool for this is presented in Annex 1-7.

### Example output

**Table 3-5** gives an example of the output of this step for the hypothetical example of the prioritization of technologies in the cement sector. From the analyses, there should be technologies identified that deliver both GHG emission reduction and other development objectives, and that are available at low (even negative) costs. Special attention may need to be given to indigenous and non-market technologies, which often represent low cost solutions to local needs.

**Table 3-5. Example of MCDA results for prioritized technologies in cement sector in different categories of applicability**

| Cement | Cement technology | GHG reduction From Criterion 2 | Development Benefits From Criterion 1 | Costs per technology From Criterion 3 |
|---|---|---|---|---|
| **Short term/ Small scale** | **Highest priority technology**<br>Optimizing heat recovery in clinker coolers | | | |
| | **Next highest**<br>Technologies for lowering fossil fuel consumption | | | |
| **Short term/ Large scale** | **Highest priority technology**<br>Wet to dry clinker production | | | |
| | **Next highest**<br>Co-production of power and cement | | | |
| **Medium to Long term/ Small scale** | **Highest priority technology**<br>N/A | | | |
| | **Next highest**<br>N/A | | | |
| **Medium to Long term/ Large scale** | **Highest priority technology**<br>Advanced kiln concepts | | | |
| | **Next highest**<br>Advanced milling technologies | | | |

*Repeat for Sector B, C, etc.*

## Process for MCDA

This step uses MCDA for prioritizing mitigation technologies because it is the most appropriate approach for evaluation of problems involving multiple stakeholders and trade-offs between multiple and conflicting objectives, especially where assessments can be difficult to quantify and where there is uncertainty. MCDA provides decision makers and other stakeholders with a framework around which they can structure their thinking. Above all it allows focused communication on a problem so that different perspectives and experiences can be applied to its solution. It generates a shared understanding, allows negotiation within the group and develops a common purpose so that the group can agree on a way forward.

An MCDA exercise is usually performed with a group of stakeholders helped by a decision facilitator, through an interactive process using a computer-based decision model to aid the process and feed back to participants the effects of changes as they explore the decision, so that a shared understanding is developed. The process comprises three generic stages, and a more detailed explanation is provided in Annex 5.

**1. Defining the decision and its context:**

At this early stage in the decision the following have to be defined: '*What is the decision, and its context? What are the criteria to be used for the assessment?*'

In this handbook the *decision* is: What is the best technology, within its category of timescale of availability and size, for maximizing benefits in terms of sustainable development priorities and mitigation potential while minimizing costs? The context for the decision is the *uncertainty of the climate change impact* scenarios from Section 3.2.

The *options* to be evaluated are the technologies in each of the categories identified in Step 4, and the criteria are elicited from the group and defined as discussed below. A *communication strategy* may be needed with a wider group of stakeholders.

**2. Scoring and weighting:**

In this stage the inputs to the problem are gathered. First of all the technologies are assessed on how well they perform on the criteria (this is called *scoring*) and then the criteria are *weighted* using a pair-wise comparison method to establish the trade-offs being made. Information requirements here are focused on what is needed for the decision. Quantitative and qualitative data can be encoded.

**3. Exploring MCDA decisions:**

Once all the inputs to the model have been made, then the *decision can be explored* in terms of the uncertainties in the inputs, both in the scoring and weighting as well as in the uncertainties surrounding the decision and the range of perspectives applying to the decision. Assumptions can be challenged, key criteria identified, improvements to options created and consequences analyzed interactively so that the group achieves a true understanding of the problem and can *agree on a way forward*.

### Criteria for technology prioritization

For low carbon technology prioritization, the group must discuss and decide on criteria. However, it is recommended that at a minimum the criteria required should include the following:

→ **Criteria category 1: Contribution to development goals in the light of climate change impact scenarios for the country (as in Step 1):**

- **Environmental improvement.** This may include the following examples:
  - Reduced or avoided local air pollution
  - Reduced water pollution
  - Reduced waste
  - Reduced resource use
- **Social improvement:**
  - Health improvement
  - Improved quality of life
  - Education
  - Equality
- **Economic improvement:**
  - Poverty alleviation
  - Job creation and quality
  - Skills improvement
  - Enterprise stimulation

These improvements should be assessed bearing in mind short and long term development priorities as appropriate. The impacts of a technology on the ecosystems and the economy are generally called external costs as they do not normally have a simple monetary value. It is important to note here that the environmental, social and economic improvements do not need a monetary valuation under MCDA. If a valuation of these benefits is available it can be taken into account.

→ **Criteria category 2: GHG reduction potential in a sector of the technology**

This depends on the baseline emissions of the baseline technology (from Steps 2 and 3), GHG emissions of the substituting technology, and on the technical potential to replace successfully high GHG emitting technologies in the sector within 20 years assuming availability of supply chains in the country (*e.g.*, availability of spare parts for technology). For this calculation a spreadsheet will be available.

→ **Criteria category 3: Costs of technology**

- Capital costs
- Operational and maintenance (O&M) costs
- Indicator of profitability or pay-back potential (*e.g.*, internal rate of return and net present value). For these calculations, a spreadsheet will be available.
- Implementation costs for training, participatory planning and follow-up

It is important to emphasize that current costs of low carbon technologies and of fuel, feedstock and spare parts, as well as financial criteria (*e.g.*, interest rates) are liable to change over time as deployment increases. This uncertainty can be explored under MCDA through analysis of the sensitivity of the decision to changes.

Therefore, in Box 3-2 the application of cost criteria prioritizing low carbon technologies is further explained.

**Box 3-2. Applying cost criteria in prioritization of low carbon technologies**

*Cost effectiveness and internal rate of return*

From the outset, it must be made clear that the cost information to be assessed in this handbook will be mainly used as part of the analysis of whether a technology would be appropriate for the country concerned.

Cost-effectiveness as a concept is used when a target must be reached at the lowest cost, or when there is a budget with which as many activities must be carried out as possible. However, in terms of the TNA the aim is not to look for the lowest cost options, but to identify the most appropriate technologies within a country. Then, a high cost figure in terms of a USD figure per ton of GHG reduction would show that it might not be appropriate to invest in the technology, especially if the technology does not score well on other criteria either. When a technology is expensive (USD/GHG) but has a strong sustainable development contribution then there could be a stronger argument to consider it. Therefore, when calculating for identified technologies the costs in terms of tons of GHG abatement, it should be done for the purpose of exploring the appropriateness of the technology.

A second cost criterion which will be added to the MCDA analysis is Internal Rate of Return (IRR). IRR shows the profit from an investment (expressed as a percentage) for a given period of time, *e.g.*, 10 years. It is derived from calculating the interest rate for which the net present value[12] of an investment project for the given period of time is equal to zero:

$$NPV = \sum_{t=0}^{N} \frac{C_t}{(1+r)^t} = 0$$

In combination with the USD/GHG cost figure, the IRR could provide a more complete overall cost assessment for a technology. For instance, a project with a high USD/GHG cost figure could still have a high IRR (*e.g.*, small scale CHP), whereas a project with a low USD/GHG figure could also have a low IRR (*e.g.*, landfill gas capture). In terms of roll out potential, the IRR would be a stronger indicator of appropriateness than USD/GHG. In Annex 9 a spreadsheet example is shown for the cement sector, which calculates IRRs for different technologies. Through sensitivity analysis, account can be taken of the impact of the lifetime on an IRR.

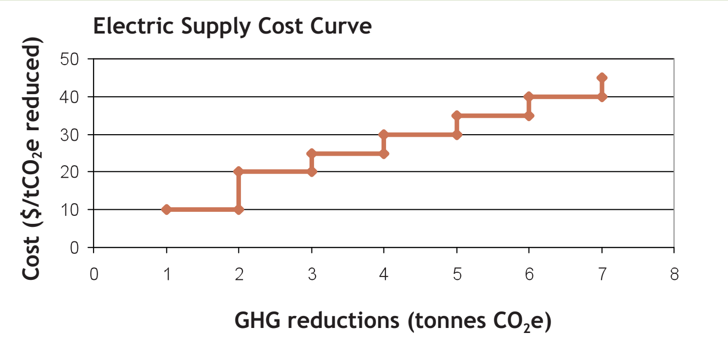
*Marginal abatement cost curves and project-level assessment*

As an example of a MAC, consider the case of energy supply technologies. A cost-effectiveness analysis will essentially develop a GHG abatement cost curve which will rank each technology in the order of its cost effectiveness for reducing a ton of $CO_2$-equivalent emissions. This ranking is typically represented in the form of a curve that is similar conceptually to the one shown in Figure 3-6.

[12] Net present value is the valuation of the expenses and revenues from an investment over a period of time, discounted to the present-day value, thereby taking account of the time preference of money.

The identification of priority sectors and technologies could use as a criterion a combination of technologies' contribution to GHG emission reduction and cost, which is similar to a cost-effectiveness criterion. This analysis can be performed in terms of USD/ton GHG abatement or Marginal Abatement Cost (MAC) curves. A MAC curve would calculate for a country or a group of countries the cost of one additional ton of GHG reduction. These costs depend on the technology with which that marginal emission reduction effort is achieved. A cost-effectiveness analysis based on costs/ton GHG abatement could be carried out at the project or plant level, and it would involve total capital costs and operating and management costs divided by the project's total GHG emission reduction. This could be expressed on an annual basis. In both cases, technologies at the lower end of the MAC curve and/or projects with the lowest costs per ton GHG abatement would be prioritized.

**Figure 3-6 — Example of MAC for electricity production technologies.**




Each point on this curve represents the cost-effectiveness of a given technology relative to the cumulative GHG reduction potential achieved when compared to the technology currently used in the country. The points on the curve appear sequentially, from most cost-effective in the lower left area of the curve, to the least cost-effective options located higher in the cost curve in the upper right area.

There are several sources of MACs and it is important to be aware of the following caveats on their use:

1. They do not represent abatement technologies to meet development needs. They are constructed to explore particular issues not necessarily in line with the needs of the country being studied. It may not be valid to use them out of the context in which they were derived.

2. Many MACs cover mainly $CO_2$ reduction. The USEPA (2006) study covers other GHG; methane, HFCs and nitrous oxide reduction technologies are covered by Wetzelaer et al (2007).

3. In terms of sectors for $CO_2$ emissions mainly the electricity supply sector is analyzed though some industry efficiency, transport, and forestry may also be included (*e.g.*, Wetzelaer, *et al.*, 2007). The focus tends to be mainly on large scale technologies used in centralized grid systems. The decision on which technology is selected by the authors who have constructed the MAC graph in some studies is based on model simulations (Ellerman, *et al.*, 1998) and expert judgment, and in others on CDM project costs and abatement (Wetzelaer, *et al.*, 2007) to derive abatement potential and average costs. Application of low carbon technologies is not necessarily based on the most appropriate technology for the country or on a comprehensive consideration of all the options. Technologies tend to be categorized so that individual technologies are not explicitly analyzed and there may also be incomplete coverage of all the possible options.

4. Time: Some data on which the MACs are based can be quite old and recent data has been based mainly on the national communications to the UNFCCC. New low carbon technologies may not be included. Studies can become out of date quite quickly.
5. Land Use, land use change and forestry (LULUCF) afforestation, deforestation and (in the future 'avoided forestry') is usually not included but is dealt with by Wetzelaer, *et al.*, (2007).
6. The original data for calculations may cover a range of methods and assumptions that are not necessarily all robust or compatible.
7. In some cases, no-regret options are not identified so these activities, which would save money and reduce emissions but face other barriers, do not appear on the cost curve. If they are not on the MAC it does not mean they do not exist.

Similar cost curves can also be developed for other priority sectors. In the case of demand side technologies to reduce GHG emissions from fossil fuel combustion, there are many technologies whose cost-effectiveness results are located below the horizontal axis in Figure 3-6, indicating a negative cost technology (*i.e.*, there are net societal benefits from introducing the technology as opposed to net societal costs).

It is important to note that a decision to include cost-effectiveness as a criterion in the MCA process commits a country to some fairly rigorous analysis, the expertise for which may or may not be available in country. For this reason, training on such analysis is being made available in the suite of technical support programs being offered to country teams undertaking TNAs. It is recommended that country teams avail themselves of such training opportunities.

*Cost Benefit Analysis*

The main alternative to MCDA is a cost-benefit analysis which would need to be carried out for each technology. However, cost-benefit analysis is relatively complex as it requires that all benefits are expressed in monetary values, which is not necessarily possible in a coherent way for some benefits. Where this is feasible it can be used anyway under an MCDA exercise, such as, for example, for the costs in terms of GHG abatement or employment gains, income gains, energy savings, etc.

The process steps for the MCDA are aided by the use of a decision analysis model for displaying results and facilitating an interactive exploration of the model results. More details on these steps and typical model outputs are provided in Annex 5. Exploration of uncertainties is particularly important and sensitivity analysis on scores and weights which are uncertain either due to differing perspectives or uncertain information is a key activity. The possible changes due to occur through climate change can also be explored by placing an alternative scenario over the first pass results to see what would change and how the final outputs are affected. Through this iterative process robust choices of portfolios of technologies for each category of technology can be generated for each (sub)sector. Improvements in the options can be considered from an exploration of the advantages and disadvantages of options and how well balanced they are on the major objectives.

Each portfolio set **for each sector** and category (small scale/large scale and short/medium to long term) can be assessed in this way to provide a final short list in each category for each sector. It may be that in some categories there is a clear 'winner' while in others there is a diverse set of technologies which are appropriate. These can be followed up at a later stage in the implementation plan after the initial priority technologies have been dealt with.

The output in this form may also be used to generate a strategy for implementation. Outputs from the analysis are summarized below.

**Outputs from Step 5:**

At the end of the process the outputs will be:

- A prioritized portfolio of technologies for each category for each sector or subsector, which is ready to be fed into an implementation plan. **Table 3-5** provides a sample output.
- An audit trail justifying the judgments made. This is a transparent record of the justifications made for the scores given and the weights assigned as well as the variations in perspectives, the results, sensitivity analyses conducted and the insights gained.

### Discussing and exploring prioritization options

As explained above under 'process for MCDA' it is important that the outcomes found in this step are discussed by stakeholders in terms of the uncertainties in the inputs, both in the scoring and weighting as well as in the uncertainties surrounding the decision and the range of perspectives applying to the decision. As explained, assumptions can be challenged, key criteria identified, improvements to options created and consequences analyzed interactively so that the group achieves a true understanding of the problem and can move forward to making final decisions.

### Making final decisions

At the end of prioritization process, country teams should have a prioritized portfolio of technologies in each category of small and large scale technologies for the short and medium to long term for each sector of interest that enjoys broad support from the stakeholders participating in the process. This prioritized portfolio will have undergone the sensitivity analyses discussed above to assess the robustness of the results relative to the weights and scores applied and other uncertainties.

Prioritizing technology portfolios in each category as opposed to selecting individual technologies provides the opportunity to start to formulate a strategy for implementation over time within the (sub)sector and across sectors. Clear winners able to be implemented right away can be identified, though in some sectors groups of technologies may be more appropriate (*e.g.*, in the cement sector example). Depending on climate impact scenarios, activities can be put in place for transfers over time for medium to longer-term mitigation options. In addition, comparison across the sectors may identify technologies which are not necessarily the highest ranked, but nevertheless highly ranked in a range of sectors, which indicates that they may be a useful choice for technology transfer in the short and medium to long term. Through the formulation of a strategy encompassing the institutional, legal, policy, fiscal, market and financial supporting actions, transfers of appropriate technologies to meet development and mitigation priorities can be addressed.

The acceleration of innovation is considered in Chapter 5 where these activities are discussed in more detail.

## Summary of results

The output of the overall exercise should be summarized. For this the following **Table 3-6** should be used (the completion of the table is supported by a spreadsheet for the further calculations required). This will allow a comparison across sectors to identify technologies which may not be the highest priority in their sector, but which are nevertheless highly rated in different sectors (see **Table 3-7**). These will also be useful technologies for deployment. For Chapter 5, which will move from technology consideration to implementation and strategic considerations, the highest priority technologies from each of the four main categories are taken plus two cross-sectoral technologies if these are available. Under each sector, **Table 3-6** documents the portfolio of prioritized technologies which may be implemented over time in a strategy. The exercise in Chapter 6 is the beginning of this process.

**Table 3-6. Summarizing table for prioritizing mitigation technologies**

| Sector A | Technology | **Potential for mitigation in sector in timescale** (e.g., 20-years; cumulative GHG emission reductions)<br><br>(for this calculation a spreadsheet will be available) | **Benefits Output from MCDA assessment** | **Estimated investment costs per technology times the technical potential in sector**<br><br>(for this calculation a spreadsheet will be available) |
|---|---|---|---|---|
| Short term/ Small scale | Highest priority technology<br><br>Next highest | | | |
| Short term/ Large scale | Highest priority technology<br><br>Next highest | | | |
| Medium to long term/ Small scale | Highest priority technology<br><br>Next highest | | | |
| Medium to long term/ Large scale | Highest priority technology<br><br>Next highest | | | |

**Table 3-7. Summarizing table for cross-sector mitigation technologies**

| | **Technology** | **Potential for mitigation in sector in timescale** (e.g., 20-years; cumulative GHG emission reductions) (for this calculation a spreadsheet will be available) | **Benefits Output from MCDA assessment** | **Estimated investment costs per technology times the technical potential in sector** (for this calculation a spreadsheet will be available) |
|---|---|---|---|---|
| Short term | Cross-sectoral technology | | | |
| Medium to long term | Cross-sectoral technology | | | |

*Note that for the analysis in Chapter 5 only short term and medium to long term cross-sector technologies are used.*

## Factsheets

In addition to the summarizing tables above, the National TNA Teams can prepare factsheets for each of the priority technologies. The purpose of the factsheet is to create a succinct document that synthesizes essential information for each priority technology within the context of the country. The National TNA Team could consider the research and information that would be most pertinent to an audience of non-specialists, keeping in mind the need to be direct, succinct, and descriptive. In Annex 6, examples are provided that further illustrate the intent of the factsheets.

# 4. Making Strategic Choices: priority sectors and priority technologies for adaptation

## 4.1. Introduction

This chapter describes the required process in prioritization of technologies for adaptation and it corresponds to the step from **Figure 1-3** on making strategic choices on portfolios with prioritized technologies for adaptation. The technologies prioritized in this chapter will be taken for further analysis to Chapter 5 where activities will be identified for improvement and acceleration of the development, deployment and diffusion of these technologies.

The process is parallel to that for mitigation technologies in Chapter 3. Important reasons for a parallel process are that it creates consistency in the prioritization processes for technologies for mitigation and adaptation and that it takes into consideration that both processes may involve different stakeholders.

The chapter starts with an identification of a country's development and sustainability priorities with particular attention to adaptation needs in the context of the appropriate country scenarios on climate change. It is also important that the identification of development priorities takes into consideration long term economic and social trends in the country (*e.g.*, urbanization and increasing industrialization). This is followed by an identification of priority sectors and identification and characterization of relevant technologies for adaptation for these sectors.

With respect to the latter it is highlighted that within the resulting portfolios of identified technologies or measures for adaptation, 'new' technologies are also considered, *i.e.* technologies or measures that country stakeholders are not yet familiar with. In order to make stakeholders knowledgeable about previously unfamiliar technologies, a technology familiarization process is envisaged which consists of workshops on technologies, expert lectures, and visiting demonstration projects. This process will be supported by the technology information available in the *TechWiki* (see Section 2.4).

The technologies/measures identified for the priority sectors are also categorized according to their short or medium to long term availability and whether their implementation takes places on a small or large scale. The categorization allows a strategy to be formulated over time and assists in identifying key technologies which may not necessarily have the highest priority in all sectors but would be useful across a number of sectors. Finally, the sector technologies in each category will be prioritized through a multi-criteria decision assessment method.

It is emphasized that this process requires the formation of stakeholder groups and is a participatory process at every step described in this chapter. More details about the organization of the stakeholder consultation and the participatory process can be found in Chapter 2 of this handbook. It is important that the decision conferences conducted with the group/s are planned in advance with full commitment from stakeholders and that targets are set for each session.

### Overview of steps

The process of prioritizing sectors and technologies for adaptation is parallel to that used for mitigation in Chapter 3 and takes place in two main stages, involving the following main steps:

1. **Steps 1, 2, 3:** The prioritization of the sectors, and 1.
2. **Steps 4 and 5:** The development of a portfolio of prioritized technologies for adaptation.

These five main steps are explained in detail in Sections 4.3 and 4.4. Before starting the sector and technology prioritization, however, it is recommended that the National TNA Team, together with the stakeholder groups, reflect on the *possible impacts of climatic changes* for their country. The main reason for this, as explained in Section 1.2, is that in the light of a changing climate, technology needs in a country to meet development priorities may change over time. Section 4.2 provides guidance for this action.

Figure 4-1 shows the stages in this chapter and Figure 4-2 shows a Gantt chart with an indicative work plan for this chapter.

Finally, it is mentioned that at the end of this chapter there will be a summarizing table for the technologies prioritized and a description of their contribution to reducing a country's vulnerability to climate change and to enhancing the country's resilience in this respect (**Table 4-5**).

**Figure 4-1. Supporting diagram for this chapter**

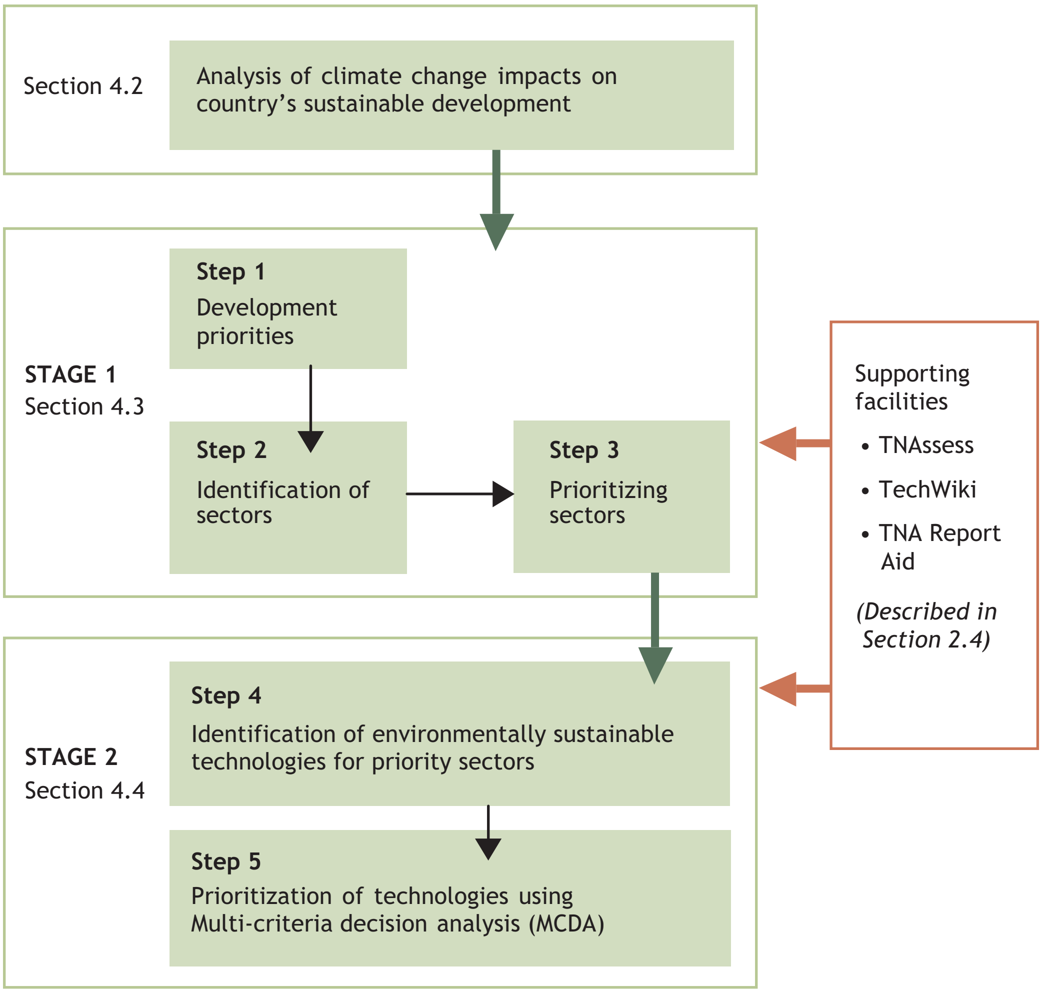


**Figure 4-2. Gantt chart with indicative work plan for this chapter**

| Activity | Preparation (3 months) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Data** | **Data availability check (see Section 2.3)** | | | | | | | | | | | | |
| Climate change impact assessment<br>National TNA team/ core stake-holders | | View on possible climate change impact | | | | | | | | | | | |
| Develop-ment priorities<br>(Step 1)<br>National TNA team with core stake-holders | | • List of develop-ment priorities for country<br>• Clustering into environmental, economic, and social priorities | | | | | | | | | | | |
| Sector identifica-tion<br>(Step 2)<br>National TNA team | | | | | • Identification of (sub)sectors in country<br>• Screening (sub)sec-tors on vulnerabil-ity to climate change | | | | | | | | |
| Sector prioritiza-tion<br>(Step 3)<br>National TNA team & stake-holders | | | | | • Characterizing sectors: existing technologies,imp-act on country's SD<br>• Rating sectors increasing resilience and SD improvement potential | | | | | | | | |
| Identifying adaptation technolo-gies for priority sector<br>(Step 4)<br>National TNA team | | | | | | | • Identification of adap-tation technologies<br>• Familiarization with new technologies<br>• Categorization technologies into small/large scale and short/long term | | | | | | |
| Robust decisions for priori-tizing tech-nologies<br>(Step 5)<br>National TNA team and stake-holders | | | | | | | | | | • Familiarization<br>• MCDA for prioritizing technologies<br>• Making final decisions<br>• Preparing final summary table | | | |

## 4.2. Before you start — preparatory stage for technology prioritization

### Making choices in a changing global climate

**Why?** An analysis based on only current climate conditions is liable to fail to prioritize relevant sectors affected by future changes in climate and the technologies which will be needed.

**How?** Assessment of available information on climate change impacts on the country from national development strategies. It is recommended to assess this information and discuss it with the stakeholder groups, so that in the overall TNA process for the country a clear long term background is described including climate change impacts, and so that the technology prioritization processes in this and the following chapter take notice of a changing climate.

**Who?** National TNA Team — assessment

Stakeholder groups — discussions

In Chapter 1 it was explained that the latest scientific knowledge on climate change indicates that the world is on a GHG emissions trajectory which is worse then the IPCC worst-case scenario and that there is a risk of severe disruption of the climate system. Against this backdrop, TNAs should not result in a portfolio of priority technologies which meet only current development needs and priorities. In the light of a changing climate, technology needs in a country to meet development needs may change over time (Annex 1-1 shows examples of possible climate change impacts on sustainable development).

**It is therefore recommended that the National TNA Team, together with the stakeholder groups, before starting with the prioritization of technologies for adaptation reflect on the possible impacts of a changing climate for their country.**

Within the prioritization process for sectors and technologies, scenarios can be developed around the analysis to explore the effect of different futures, in order to have some idea of the expected scale and type of climatic change for the country context. From that, the expected implications for environmental and social as well as economic impacts can be deduced. This will enable the analysis to be conducted with at least the expected range of regional climate changes already in the pipeline and the knowledge that the actual changes will be more severe if mitigation activities stall. An analysis based on only current climate conditions is liable to fail to prioritize the relevant sectors affected by future changes in climate and the technologies which will be needed.

In most countries information on the impacts of climate change is already available. For example, in their national development strategies, several countries have described their vulnerability and/or resilience profile with regard to future climate change impacts. The National TNA Team is recommended to assess this information and discuss it with the stakeholder groups, so that in the overall TNA process for the country a clear long term background is described including climate change impacts so that the technology prioritization processes in this and the following chapter take account of a changing climate.

Should such information not be available in a country, the National TNA Team is encouraged to carry out or commission an analysis of the impacts of climate change on the country. This technology analysis should be performed within a future scenario of possible climate change effects for the country and timescale for the effects. For example, development priorities on sea level rise and land use perhaps would be given the highest importance in view of the expected shifts, where currently it may have a lower priority, and this would affect the choice of sectors and technologies to prioritize. Another example could be an increased demand for cooling services in the future due to climate change, which would give a higher priority to such technologies as heat pumps. This would also have the implication that if these technologies are already available now, the TNA recommendation would likely follow that these technologies would need to be implemented in the short run.

*It is recommended therefore that where a vulnerability assessment has not yet been performed, the country team carry this out before progressing to the strategic choices on sectors and technologies in the next chapters.*

### Specific links with further steps in this chapter

The insights gained in this preparatory stage will be used when assessing long term development priorities (Step 1), prioritizing sectors on their contribution to development and sustainable mitigation priorities (Step 3), and when assessing technologies on the first category of criteria in Step 5 ("contribution to development goals in the light of climate impact scenarios for the country").

**Output from this preparatory stage:**

Insight into the expected scale and type of climatic change for the country context, and its impact on the country's environmental, social, and economic development.

## 4.3. First stage of analysis — strategic choice of priority sectors for adaptation

### Background

The approach to conducting TNA for adaptation differs from the approach to mitigation largely due to the issues involved. Whereas Chapter 3 addresses technologies which address both sustainable development and mitigation priorities for which there is adequate literature on technologies, adaptation issues tend to be less well defined in terms of technology options and solutions.

It is clear, though, that adaptation is not a stand-alone activity but needs to be integrated into sustainable development plans. This has been emphasized by the IPCC (2007). Examples include the protection of water resources and efficiency improvements in water distribution systems, while also adapting energy and economic systems to a changing climate (*e.g.*, using less hydro in areas with reduced precipitation and changing crops in agricultural areas at risk of drought). In this respect adaptation can be considered a broader risk management concept. Contrary to prioritization of the mitigation technologies in Chapter 3, where the main risk is increased climate change, adaptation measures are meant to protect a country against projected climate change damage.

There are few technologies that can be clearly and unambiguously labeled as technologies for adaptation, per se, except perhaps for coastal engineering technologies and genetically designed seed varieties. Most technologies appropriate to achieving adaptation objectives are also appropriate to meeting sustainable development objectives. Indeed, it should be kept in mind that suitable indigenous technologies should be considered as far as possible since these would be more effective as tried and true coping mechanisms (UNFCCC, 2006).

### Key steps in the first stage

In the first stage of the process, consideration is given to the key factors that are important in the selection of the priority sectors or areas in the country. In this section these key factors are addressed for **adaptation actions**, and then this information is used to identify priority sectors for further study on their technology requirements.

Upon completion of the activities in this stage of the TNA process, country teams will have defined the priority sector(s) for their country and developed a solid justification for why these sectors - and not others - have been selected for consideration with the TNA.

The steps for this first stage of analysis, as well as the outputs, are summarized in **Figure 4-3**. The description of each step starts with a short overview of why the step is needed, how the work will be carried out, and who will do the work.

**Figure 4-3: Supporting diagram for Stage 1 of the process**

**STRATEGIC CHOICE OF PRIORITY SECTORS**

| Steps | Description | Output |
|---|---|---|
| Step 1 | ***Identifying development priorities***<br>→ Priorities in light of a changing climate | → List of development priorities, which are consistent and which take account of environmental (including climate change), technical, economic/market risks and uncertainties. |
| Step 2 | ***General identification of (sub)sectors***<br>***Characterizing (sub)sectors***<br>→ Vulnerability risks and adaptive capacity<br>→ Existing technologies and coping strategies<br>→ Impact on sustainable development priorities technologies | → List of (sub)sectors<br>→ Baseline description for each (sub)sector |
| Step 3 | → Prioritizing (sub)sectors in terms of development and sustainable adaptation priorities | → A final short list of prioritized sectors for adaptation |

## ➔ Step 1 — Identifying development priorities

**Why?** It is important that the eventual technology choices are clearly in line with the long term development priorities in developing countries.

**How?** Identification of development needs already formulated in national development strategies for a country

**Who?** National TNA Team, in cooperation with the stakeholders

### Development priority examples

In this step, an overview is prepared of the country's development priorities. It is recommended that the TNA's starting point stresses the importance of understanding and identifying for a country which development needs are already formulated in national development strategies, as reflected in documents such as 5-year National Plans, sector policies, countries' National Communications to the UNFCCC, and country profiles prepared in co-operation with UNDP and the World Bank.

Based on the above-mentioned official publications the National TNA Team will generate a list of development priorities which they consider most applicable to their country's sustainable development, both with a view to the short and longer term. It is recommended that this list is discussed with the stakeholders.

### Identifying development priorities in light of changing climate: short — long term dimension

As explained in Chapter 3, it is important that the TNA not only focus on short term needs but also take into consideration that in light of climate change (see Section 4.2), as well as technical, economic, and market changes, development needs may change over time. Therefore, in this Step 1, development priorities for the country will be identified both with a view to the short and the long term.

The main objective in this respect is that stakeholders keep a clear eye on the long term development perspective in their country in light of a changing climate and social and economic changes. For example, an expected climate change may require protection of water resources, efficiency improvements in water distribution systems, but also adapting energy and economic systems to a changing climate. However, no extensive additional assessments in terms of scenario development are required.

### Clustering development priorities

In order to facilitate the analysis, it is recommended that the development priorities should, where possible, be grouped under economic, environmental and social priorities both from a short term and a medium to long term perspective, as is done in the hypothetical example below (**Table 4-1**). It is not required to explain each of the priorities in detail; just an overview as in **Table 4-1** would be sufficient (possibly, if desired, with short comments).

**Table 4-1. Example of clustering development priorities for short and long term**

| | |
|---|---|
| | **Environmental development priorities** |
| Dev priority 1 | Reduced air pollution |
| Dev priority 5 | Reduced soil degradation |
| Dev priority 8 | Reduced water pollution |
| | **Economic development priorities** |
| Dev priority 2 | Increased energy security of supply |
| Dev priority 7 | Improved employment |
| Dev priority 10 | Affordable energy supply |
| | **Social development priorities** |
| Dev priority 3 | Improved health conditions |
| Dev priority 6 | Strengthened empowerment |
| Dev priority 9 | Contribution to education |

It is noted here that the objective of this Step 1 is not to rank development priorities. Therefore, the order of development priorities is random at this stage and does not reflect a weighting or scoring of priorities.

**Output from Step 1:**

A list of clustered development priorities for the country concerned.

## ➔ Step 2 — Identification and characterization of sectors

**Why?** To explore existing technologies used in sectors and the impacts of sectors on the country's sustainable development

**How?** Use of existing data, such as vulnerability assessments if they are available, or from the National Adaptation Program of Action (NAPA)

**Who?** National TNA Team

In this step the sector breakdown relevant to the countries is identified and the existing information to characterize the sectors is collected. The details of these steps are listed in the Annex 1-5. These steps can be carried out by the National TNA Team.

**Output from Step 2:**

Background information on sectors, including existing technologies used in the sectors, and impacts on the country's sustainable development.

## ➔ Step 3 — Prioritizing (sub)sectors in terms of contribution to development and sustainable adaptation priorities

**Why?** Shortlisting of sectors in terms of high contribution to reducing vulnerability risks and high contribution to sustainable development shows where largest contribution to adaptation and meeting development priorities can be made

**How?** Make a selection of sectors to be prioritized using a simple performance matrix procedure as indicated below.

**Who?** National TNA Team & stakeholders

Step 2 has resulted in an overview of sectors and sub-sectors and a description of the present status of vulnerability to direct and indirect climate change impacts and adaptive capacity. This will assist in identifying the improvement that sustainable adaptation measures and technologies would deliver to the sector in terms of improved resilience and minimizing environmental, social and economic impacts.

When performing this part of the analysis to make the final selection of sectors to be prioritized, a simple performance matrix procedure may be followed as indicated below.

### Prioritization approach

The output from step 2 is used to identify those sectors where improvements would make a large or very large contribution to sustainable development priorities and to minimizing vulnerability to climate change.

Based on the information above, the analysis explores how improving the situation in a (sub)sector would contribute to each of the development priorities identified in Step 1 and contribute to adaptation resilience along with environmental, social and economic improvement. It should be noted here that all measures and technologies should also minimize GHG emissions whenever possible. For each (sub)sector, stakeholders could indicate how large a contribution improvements in a sector could make to each of the development, adaptation resilience and sustainability criteria comparing down through the (sub)sectors for each criterion in turn identified from Steps 1 and 2, through the following rating scheme:

1 — very small contribution

2 — small contribution

3 — medium contribution

4 — large contribution

5 — very large contribution.

Obviously, what is a small or large contribution is fully left to the judgment of the stakeholders and National TNA Team, as these assessments are country-specific

**Table 4-2** shows a purely hypothetical example of a completed analysis after Steps 1 through 3. If agriculture is identified through this rating process as a priority (sub)sector, then in the second stage in Step 4 the technologies suitable for this (sub)sector will be identified.

From this approach four types of sectors can result:

1. There could be sectors in which adaptation measures would deliver an important contribution in terms of the development priorities of Step 1, but a relatively small contribution in terms of adaptation benefits.

2. Sectors could contribute relatively little in terms of development priorities, but much in terms of adaptation benefits.
3. Improvements of technologies could contribute little in both respects.
4. If existing technologies in a sector result in a high vulnerability to climate change and high adverse impacts on the country's sustainable development, then improvements in these technologies can result in maximum benefits in increased resilience and sustainable development benefits.

Therefore, the focus will be on these maximum increased resilience and sustainable development benefit sectors, although care needs to be taken not to exclude those sectors which deliver a high development benefit, even though they may not be the highest in terms of adaptation benefits.

It is the stakeholder group that decides what the thresholds for choice of priority sectors will be. One possibility is that all (sub)sectors with a score of 4 or higher on vulnerability improvement and a total score of 12 or higher on development priority benefit delivery will be considered priority areas for which technologies will be identified in Step 4.

**Table 4-2: Example — STEP 3 — SECTOR RATING**

| Sector (STEP 2) | Subsector | Improvement by EST beyond sustainability baseline (Steps 2 and 3) | | | |
|---|---|---|---|---|---|
| | | Impact in relation to development priorities (**Step 1**) | | | |
| | | Maximize economic development | Maximize environmental development | Maximize social development | Vulnerability improvement potential |
| 1. Agriculture | Food production | 3 | 2 | 3 | 4 |
| | Fisheries | 2 | 3 | 2 | 4 |
| | Animal Husbandry | 3 | 2 | 4 | 4 |
| 2. Coastal | Dikes and dams | 4 | 3 | 3 | 5 |
| | Coastal protection | 4 | 3 | 5 | 4 |
| 3. Water resources | Harvesting | 4 | 2 | 2 | 4 |
| | Irrigation | 2 | 4 | 3 | 3 |
| 4. | 4a | | | | |
| | 4b | | | | |
| Etc. | | | | | |

Where the prioritization approach is not conclusive in terms of an easily justified prioritization of the sectors, then an MCDA can be undertaken (for this, see Annex 5).

**Output from Step 3:**

This step provides a short list of (sub)sectors according to their development benefits and adaptation benefits and whether sectors have a balanced sustainable development contribution and deliver the maximum benefits and vulnerability reductions.[13] These sectors with their (sub)sectors are then analyzed in the second stage of the analysis (Steps 4 and 5) to develop portfolios of technologies in the categories of short or medium to long term and small or large scale which are prioritized using MCDA.

## 4.4. Second stage of analysis — strategic choice of portfolios of priority technologies

### Defining categories for technologies

The first stage of the analysis dealt with the strategic choice of priority sectors and provided a process for undertaking this analysis. This section builds on that work and moves on to the second main activity in this chapter, exploring the **technologies or measures** required to reduce vulnerability risks and contribute to sustainable development priorities for those prioritized sectors/areas.

As explained above, it is important that the technologies for adaptation eventually identified through a TNA are clearly in line with countries' development priorities and needs. This establishes the scope of the TNA. Carefully selected technologies based on such priorities and needs are more likely to have knock-on effects on the economy and energy systems. TNAs which identify technologies without a clear link to the country's sustainable development have a higher chance of ending up as one-off projects with no long term potential in the country.

In assessing technologies in a changing climate there is a need for resilience in the system, and this leads to the suggestion that technologies need to be prioritized within portfolios of technologies suitable for a low carbon sustainable future.

In order to provide a basis for comparison across the technologies and to provide a basis for a strategy to meet the climate and development priorities in the short and medium to long term, these portfolios are categorized according to their applicability over time and in the market and their scale/size of application. By applicability in the **short term** it is meant that the technology has proven reliability elsewhere. The technologies in the **medium term** would be pre-commercial (5 years to full marketing) and a **long term** technology would still be in an R&D phase or a prototype. For a general overview of the technology phases, see Figure 1-2.

Small scale technologies are those that have been applied at the household and/or community level, which could be scaled up into a program. For the sake of simplicity all technologies larger than household or community level are considered large- scale technologies.

Based on these definitions, the categorization used is as follows:

1. Small scale application, with a short term market availability;
2. Small scale application, with a medium to long term market availability;
3. Large scale application, with a short term market availability;
4. Large scale application, with a medium to long term market availability.

[13] This is an initial prioritization, but with further discussion in the next stage, it may be that other sectors will be added. Thus, the process is flexible and iterative.

To simplify the analysis, it is suggested that medium and long term availability is considered one category, as it represents a continuum from R&D to pre-commercial status of a technology.[14]

Technologies include not only hard technologies, such as wind turbines for water pumping, but also non market technologies, such as changes in consumer behavior regarding food.

## Key steps

The step-wise process in this section is again an interactive process which is carried out with stakeholders (as described in Section 2.2). The process is best conducted by an independent facilitator with the stakeholder group/s. It is important that the decision conferences conducted with the group/s are planned in advance with full commitment from stakeholders, and that targets are set for each session.

The steps in this second stage continue on from the end of the first stage on the priority sectors. In Step 4, relevant technologies/measures for adaptation for the prioritized sectors from the first stage will be focused on. This will be done by first identifying technologies for each of the prioritized sectors and then enabling stakeholders to familiarize themselves with technologies that are unknown or not commonly used in the country.

The categorization of the technologies as described above forms the basis of a strategy and allows technologies to be optimally compared and assessed later on in Step 5. In Step 5, MCDA will be used for prioritizing adaptation technologies because it is the most appropriate approach for evaluation of problems involving multiple stakeholders, and trade-offs between multiple and conflicting objectives, where assessments can be difficult to quantify and there is uncertainty. In order to analyze to what extent a technology contributes to improvements in the sector beyond the baseline situation, it needs to be assessed across a range of development and sustainability criteria, hence a multi-criteria analysis. For a background explanation of MCDA, see Annex 5.

**Figure 4-4** shows the main steps for this stage of the process.

**Figure 4-4: Supporting diagram for Stage 2 of the process**

**STRATEGIC CHOICE OF PORTFOLIOS OF PRIORITY TECHNOLOGIES OR MEASURES**

| Steps | **Description** | **Output** |
|---|---|---|
| ***Step 4*** | ***Identify and characterize relevant 'technologies' for relevant sectors***<br>→ Identification<br>→ Familiarization<br>→ Characterization | → Overview per (sub)sector of technologies categorized as having small or large scale and short or long term applicability |
| ***Step 5*** | ***Prioritize the' technologies' identified for implementation***<br>→ Using MCDA<br>→ If lists of technologies in Step 4 categories become too large, then a tool for first prioritization of technologies can be used | → A final portfolio of prioritized technologies and measures for each technology category |

[14] As defined in the FCCC/SB/2009/INF.1 paper.

## ➔ Step 4 — Identify and characterize relevant technologies and measures for adaptation for prioritized sectors

**Why?** To acquire an overview of adaptation technologies in the priority sectors and to enable National TNA Team members, core stakeholder groups and wider stakeholder groups to become familiar with new, unknown technologies

**How?**
- → *Identification*: TechWiki database
- → *Familiarization*: technology information, workshops, expert lectures, demonstration projects
- → *Categorization* of technologies in small/large scale applicability and short/medium/long term availability

**Who?**
- → *National TNA Team*: technology identification, familiarization, categorization
- → *Core stakeholder groups*: technology familiarization
- → *Wider stakeholder groups*: information exchange and feedback with core stakeholder groups on unfamiliar technologies

### Identification

Once the priority sectors and areas have been identified as an output of Step 3, for each of these sectors/areas, the range of environmentally sound technologies and coping measures for adaptation relevant to these sectors needs to be identified. This part of the exercise can be fairly brief but requires stakeholder input at all stages. This step also relies on the list of low carbon technologies for adaptation and on local knowledge of local coping strategies. These technologies may be "non-market" (know-how) or "hard" (physical assets). The list should also include specific information on the technology itself (*e.g.*, costs, scale, livelihood applicability, durability, longevity). Examples are shown in Annex 2, which is structured according to (sub)sector/energy service, scale of technology and availability in the short, medium to long run. Annex 2 is currently only indicative as the technologies will be selected from an extensive database on low carbon technologies for adaptation which can be evaluated through *TechWiki* (see Section 2.4). From the *TechWiki* database, for each of the priority sub-sectors/areas identified in Step 3 relevant technologies can be identified and categorized. Note that in this step no prioritization of technologies takes place; only possible technologies/measures for adaptation that could contribute to the priorities in the sector are identified.

These lists especially for adaptation measures have to be augmented with local knowledge of local solutions and strategies. Such response measures will typically include technologies (*e.g.*, drought-resistant seed varieties for an agriculture sector subject to more frequent drought episodes) but should also include changes in established practices, and may not necessarily involve the direct use of technology or may utilize technology in an indirect manner (*e.g.*, computerized data management systems) This list should be as exhaustive as possible.

New ideas can also be added as the group discusses what appropriate activities can be applied in the sector to minimize vulnerabilities. This can also be informed by any NAPAs and climate change vulnerability assessments. It may be that a group of measures forming a coherent strategy is appropriate rather than individual measures and these should then be given an overall title and defined and justified.

It will also be important at this stage to ensure not only that the list of possible technologies/measures is as wide as possible, but also that they are relevant to the country conditions. An assumption being made is that technologies and measures to be short-listed are realistic in the context of the resources available in the country now and under the climate change impact scenario for the country (see Section 4.2). It is also assumed that these resources (*e.g.*, water for crop management) have already been identified in other country studies. If such a resource assessment has not yet been carried out for the country, then it is recommended that this be performed before proceeding further. Links to appropriate sources of information for possible technologies are provided in the *TechWiki*. The information for the next step of familiarization will also come from the *Tech Wiki*.

### Familiarization

In this step it is important that all relevant technologies are considered and that the exercise is not limited to those technologies that stakeholders are familiar with or know the benefits of. Also, people may have negative perceptions about a technology because of negative experiences with that technology in the past or incomplete or outdated information about it, such as system reliability and costs. In reality, very few people are aware of all available sustainable technologies in all contexts.

Therefore, this technology identification stage is supported by a familiarization phase during which stakeholders will be able to acquire information about technologies which are potentially useful but unfamiliar to them. It has been shown in similar assessments that without this, unfamiliar technologies will not be considered. For example, there are many new and existing technologies/measures which are not commonly used. As a result decision makers and other stakeholders are not necessarily able to judge their merit for a country application without further information and familiarization. As Winskel, *et al.*, (2006) pointed out, "Organizations operate in embedded socio-technical networks and tend to re-invest in established competences: disruptive technologies (*e.g.*, renewable energy) rarely make sense to incumbents, so their development tends to be left to small outsider organizations."

This familiarization phase is designed to present additional information on technologies which are either in pilot or pre-commercialization phases, or newly emerging, or established but not familiar in the country context. Information on early stage technologies may not be as comprehensive as for established technologies but Box 4-1 shows a list of data that could be used to inform stakeholders during the phase of becoming familiar with new technologies. These data will be made available as far as possible in the *TechWiki* but should also be supplemented by participants and TNA team information. Uncertainties arising from lack of data will be explored in the MCDA assessment phase.

Activities mentioned in Box 4-1 such as visits to demonstration projects, engagement with experts on the technologies, review of detailed information sheets and searches for further information sources, as well as discussions of experiences within the stakeholder groups, are all required in order to fully consider low carbon sustainable energy technology options to meet the energy service needs identified. In addition, it is important to remember that confidence to invest is grounded in seeing the technologies or measures in action, preferably in the country context. In this respect the development of regional centers for adaptation and mitigation expertise and technology demonstrations would be very useful.

**Box 4-1. Information availability existing and pre-commercial technologies**

National TNA teams could consider the following information in during the process of becoming familiar with new technologies and comparing them to existing options:

- Cost: Cost data should include capital costs, fuel costs and operation & maintenance costs.
- Performance: Performance should include efficiency (when applicable), technical measurements, capacity factors, lifetime, and degree of technical sophistication required for manufacturing, installation and operation.
- Reliability: This is a key parameter for new technologies and, while difficult to predict, should be pursued to assess whether the technology can be sufficiently relied upon.

Obtaining objective sources of information on low carbon technologies and measures as they relate to these parameters is not simple. Given both their forward-looking nature and the vested interests of different information sources, new technologies present a sizable challenge in this regard. By synthesizing as much as possible from multiple sources, a clear picture can be established:

- Literature Review: For most market and non-market technologies, there are reports, analyses and articles providing estimates of the required data.
- Demonstration projects: Any data gleaned from actual demonstration projects is particularly helpful, keeping in mind both that performance and costs change with economies of scale, and that technology performance will differ under different conditions.
- Other governments: Many governments face similar lack of information regarding new technologies and some may have taken steps to redress their lack of knowledge. Sharing this information between governments can be very effective.
- Multilateral institutions: Multilaterals have the advantage of working in multiple countries and can act as a conduit to transfer objective, up-to-date information.
- Manufacturers: Technology manufacturers are often best placed to accurately predict technology performance and cost. However, they have an inherent conflict of interest and incentives to promote their own technology, and should never be taken as a sole source for technology information.

This process is backed by the *TechWiki* (see Section 2.4). A graphical representation of the familiarization process is shown in Figure 4-5. In terms of the work plan, the familiarization activities could take place during the second half of the TNA process when technologies for prioritized sectors are identified, categorized and prioritized (see also Figure 4-2). It is important that National TNA Team members and core group stakeholders are strongly involved in each of these activities, and that the information is regularly communicated with wider stakeholder groups (*e.g.*, sector organizations).

**Figure 4-5. The process of technology familiarization**


*Note that although these familiarization activities are an important part of Step 4, they are recommended to continue into Step 5 where they could support the MCDA process.*

## Categorization of technologies

With a categorization of technologies in terms of 'application timescales' and 'scale of application', there can be an optimal comparison and assessment of technologies later on in Step 5, when technologies are prioritized using MCDA. From a strategic point of view categorization would also be useful in generating a strategy for implementation over time to meet targeted priorities and where technologies are common for more than one sector so that the output from this step could be used for these other sectors.

In some cases this simple categorization may not be easily applied. Sometimes, the difference between technologies or measures in terms of availability in the short term (commercial or proven phase) versus the medium to long term (trial or demonstration or pre-commercialization) and between small- and large scale applicability might sometimes not be very clear as this also depends on the context of the adaptation requirement. In some cases, not all the categories will make sense.

In Step 4 it is recommended that the diversity of technologies/measures is preserved so that, though the list becomes progressively narrower, there will be a portfolio of priority technologies in each of the categories for 'application timescales' and 'scale of application' which can at some later stage all be considered for implementation.

**Output from Step 4:**

The result of Step 4 is presented in a format as shown in **Table 4-3** which includes an indicative example from the agricultural sector where the technologies are categorized in terms of 'large /small scale' and 'availability in the short /medium to long term'. When selecting technologies in **Table 4-3** basic information will be gathered from *TechWiki* about the applicability of the technologies in terms of timing and scale (see the last two columns in **Table 4-3**).

Table 4-3: 'ADAP-STEP 4-TECH CATEGORIES'

| Priority sector (STEP 2) | | Technology identification (STEP 3) | | |
|---|---|---|---|---|
| Sector | Subsector | Technology | Scale of application | Short-, medium- and long-run availability |
| Agriculture | Food production | SMALL SCALE/SHORT TERM | | |
| | | Water saving measures | Small scale | Short term |
| | | Irrigation strategies | Small scale | Short term |
| | | Animal feed changes | Small scale | Short term |
| | | LARGE SCALE/SHORT TERM | | |
| | | Improved drought resistance crop strains | Large scale | Short term |
| | | Improved animal husbandry practices | Large scale | Short term |
| | | Irrigation and water collection | Large scale | Short term |
| | | LARGE SCALE/MEDIUM TO LONG TERM | | |
| | | Advanced seed varieties | Large scale | Long term |
| | | Land use practices | Large scale | Long term |
| | | Changes in consumer behavior to food | Large scale | Long term |
| | | SMALL SCALE/MEDIUM TO LONG TERM | | |
| | | Changes in location or animal type | Small scale | Long term |

A final remark on Step 4 is that the technologies identified in **Table 4-3** may have to be seen in a broader picture. For instance, where it would be foolish to improve one part of an agricultural process without improving another crucial step, as otherwise the full benefit could not be gained, then the technologies and measures might have to be grouped such as 'Water Saving measures'. These groupings could be included in **Table 4-3**, and the applicability information filled in manually.

## ➔ Step 5 — Facilitating robust decisions for prioritizing technologies: MCDA

**Why?** To find the best technologies for maximizing benefits in terms of sustainable development priorities and adaptation while minimizing costs

**How?**
- → Multi-criteria Decision Assessment
- → Discussion and exploration of prioritizing options

**Who?**
- → *National TNA Team*: formulation of criteria for technology prioritization, facilitation of MCDA
- → *Core stakeholder groups*: eliciting criteria for MCDA, scoring and weighting of technologies against criteria, exploring decisions from MCDA, and agreeing on a way forward.
- → *Wider stakeholder groups*: exploring decisions from MCDA, and agreeing on a way forward.

In this Step 5, the technologies within the categories assembled in Step 4 are compared, based on criteria to be elicited from groups using an MCDA participatory approach. The output should be a prioritized portfolio of technologies under each category.

In order to keep the MCDA manageable, it is recommended that the number of technologies in each of the four categories for a (sub)sector (*i.e.* small scale/short term, small scale/long term, *etc.*) not be larger than 10 (*i.e.* 40 total over the 4 categories). For the categories with more than 10 technologies a pre-screening is recommended and a tool for this is presented in Annex 1-8.

### Example output

**Table 4-4** shows what the output of this step looks like for the hypothetical example of the prioritization of technologies in the agricultural sector. From the analyses there should be technologies identified that deliver both climate vulnerability reduction and other development objectives, and are available at low (even negative) costs. Special attention may need to be given to indigenous and non-market based technologies, which often represent low cost solutions to local needs.

A spreadsheet is provided under TNAssess to aid the calculation of potentials and total costs.

**Table 4-4. Example of MCDA results for prioritized technologies in agriculture sector in different categories of applicability**

| Agriculture | Agriculture measures | Reduction in vulnerability or increased adaptation in sector From Criterion 2 | Benefits Output from MCDA assessment From Criterion 1 | Costs per technology From Criterion 3 |
|---|---|---|---|---|
| **Short term/ Small scale** | **Highest priority technology**<br>Water saving measure<br>**Next highest**<br>Irrigation strategies | | | |
| **Short term/ Large scale** | **Highest priority technology**<br>Improved drought resistance crop strains<br>**Next highest**<br>Improved animal husbandry practices | | | |
| **Long term/ Small scale** | **Highest priority technology**<br>Changes in location or animal type<br>**Next highest**<br>N/A | | | |
| **Long term/ Large scale** | **Highest priority technology**<br>Advanced seed varieties<br>**Next highest**<br>Land use practices | | | |

*Repeat for Sector B, C, etc.*

## Process for MCDA

This step uses MCDA for prioritizing mitigation technologies because it is the most appropriate approach for evaluation of problems involving multiple stakeholders, and trade-offs between multiple and conflicting objectives, especially where assessments can be difficult to quantify and where there is uncertainty. MCDA provides decision makers and other stakeholders with a framework around which they can structure their thinking. Above all it allows focused communication on a problem so that different perspectives and experiences can be applied to its solution. It generates a shared understanding, allows negotiation within the group and develops a common purpose so that the group can agree on a way forward

An MCDA exercise is usually performed with a group of stakeholders helped by a decision facilitator, through an interactive process using a computer-based decision model to aid the process and feed back to participants the effects of changes as they explore the decision, so that a shared understanding is developed. The process comprises 3 generic stages, and a more detailed explanation is provided in Annex 5.

**1. Defining the decision and decision context:**

At this early stage in the decision the following have to be defined: *'What is the decision and its context? What are the criteria to be used for the assessment?'*

In this handbook the *decision* is: What is the best technology, within its category of timescale of availability and size, for maximizing benefits in terms of sustainable development priorities and mitigation potential while minimizing costs? The context for the decision is the ***uncertainty of the climate change impact*** scenarios from Section 4.2.

The *options* to be evaluated are the technologies in each of the categories identified in Step 5 and the criteria are elicited from the group and defined as discussed below. A *communication strategy* may be needed with a wider group of stakeholders.

**2. Scoring and weighting:**

In this stage the inputs to the problem are gathered. First of all the technologies are assessed on how well they perform on the criteria (this is called *scoring*) and then the criteria are *weighted* using a pair-wise comparison method to establish the trade-offs being made. Information requirements here are focused on what is needed for the decision. Quantitative and qualitative data can be encoded.

**3. Exploring MCDA decisions:**

Once all the inputs to the model have been made then the *decision can be explored* in terms of the uncertainties in the inputs, both in the scoring and weighting as well as in the uncertainties surrounding the decision and the range of perspectives applying to the decision. Assumptions can be challenged, key criteria identified, improvements to options created and consequences analyzed interactively so that the group achieves a true understanding of the problem and can *agree on a way forward*.

### Criteria for adaptation measures prioritization

For prioritization of portfolios of technologies and measures for adaptation, the group must discuss and decide on criteria and the following are only **examples** of criteria for assessing the improvements. The main objectives on which a measure or technology can be judged would be expected to include the following:

- to maximize the resilience of the sector and others liable to be impacted indirectly,
- to minimize any GHG emissions,
- to maximize development priority benefits in terms of environmental, social and economic benefits and minimize adverse impacts due to the measure relative to inaction.

It is recommended that at a minimum the criteria required should include the following:

→ **Criteria category 1: Contribution to development goals in the light of climate change impact scenarios for the country (as in Step 1):**

- **Environmental improvement.** This may include the following examples:
  - Reduced or avoided local air pollution
  - Reduced water pollution
  - Reduced waste
  - Reduced resource use
- **Social improvement:**
  - Health improvement
  - Improved quality of life
  - Education
  - Equality
- **Economic improvement:**
  - Poverty alleviation
  - Job creation and quality
  - Skills improvement
  - Enterprise stimulation

These improvements should be assessed bearing in mind short and long term development priorities as appropriate.

Normally, the impacts of a technology on the ecosystems and the economy are called external costs as they do not normally have a simple monetary value. It is important to note here that the environmental, social and economic improvements do not need a monetary valuation under MCDA. If a valuation of these benefits is available it can be taken into account.

→ **Criteria category 2: Reduction of vulnerability to climate change scenarios**

- To water shortages
- To increased temperatures
- To change in energy services
- To increased pests and disease
- To loss of land
- To other impacts

→ **Criteria category 3: Costs of technology**

- Capital costs
- Operational and maintenance (O&M) costs
- Indicators of profitability or pay-back potential (*e.g.*, internal rate of return and net present value). For these calculations, a spreadsheet will be available.

It is strongly recommended that capital costs of technology and reduction of vulnerability to climate change scenarios are applied under the MCDA in this step, as cost information will be of crucial importance for taking financial decisions on allocation of resources, in relation to the benefit of the measure in terms of reduced vulnerability to climate change. It is important to emphasize that current costs of technologies for adaptation, as well as financial criteria (*e.g.*, interest rates), are liable to change over time as deployment increases. This uncertainty can be explored under MCDA through analysis of the sensitivity of the decision to changes. Therefore, in the box below, the application of cost criteria prioritizing low carbon adaptation solutions is further explained.

**Box 4-2. Applying cost criteria in prioritization of adaptation measures**

*Cost assessment*

From the outset, it must be made clear that the cost information to be assessed in this handbook will be mainly used as part of the analysis of whether a technology would be appropriate for the country concerned.

Cost-effectiveness as a concept is used when a target must be reached at the lowest cost, or when there is a budget with which as many activities must be carried out as possible. In terms of the TNA, the aim is not to look for the cheapest options, but to identify the most appropriate technologies within a country. However it is difficult to see how cost effectiveness can be used for adaptation unless an exercise is carried out to quantify and value in monetary terms all the vulnerability benefits from the adaptation action across all the sectors. Such monetary valuations are always subject to problems. This would take a lot of time and resources and for the purposes of this analysis would be duplicating the MCDA where all the benefits are already valued and included in the analysis, including any quantitative values available. Such a measure could in theory be generated and explored within an MCDA at the end of the first pass if required. The difference is that the values in the MCDA are preference values.

*Capital costs and IRR*

Capital costs are normally expressed in net present value terms using a discount rate over the lifetime of the project to express the value of money now and in the future. However when allocating resources, the actual up front capital required for an investment may be the key challenge and it is then this figure which should be included in the analysis.

A second costs criterion which could be added to the MCDA analysis is Internal Rate of Return (IRR). IRR shows the profit from an investment (expressed as a percentage) for a given period of time, *e.g.*, 10 years. It is derived from calculating the interest rate for which the net present value of an investment project for the given period of time is equal to zero:

$$NPV = \sum_{t=0}^{N} \frac{C_t}{(1+r)^t} = 0$$

The IRR could provide a more complete overall cost assessment for a technology or measure. In terms of rollout potential, the IRR could also be a strong indicator of appropriateness. In Annex 9 a spreadsheet example is shown.

However, it must be noted that for many adaptation measures there will be no classical IRR and avoided costs may be the appropriate measure. In addition, in the context of adaptation measures, costs may not always be a good indicator of appropriateness. For example, if a country turns out to be really vulnerable to a changing climate and needs to improve its coastline, then this investment is required and cost only becomes a criterion when there are different options for coastline protection.

Cost-effectiveness could be an indicator if the improved coastline protection would have benefits that can be valued. However, as explained above, since the MCDA already values the benefits and assesses costs as well, cost-effectiveness is sufficiently covered by the MCDA.

*Cost Benefit Analysis*

The main alternative to MCDA is a cost-benefit analysis, which would need to be carried out for each technology. However, cost-benefit analysis is relatively complex, as it requires that all benefits are expressed in monetary values, which is not necessarily possible in a coherent way for some benefits, such as valuing a human life when assessing a coastline protection plan. Where this is feasible it can be used anyway under an MCDA exercise, such as, for example, for the costs in terms of GHG abatement or employment gains, income gains, energy savings, etc.

The process steps for the MCDA are aided by the use of a decision analysis model for displaying results and facilitating an interactive exploration of the model results. More details on these steps and typical model outputs are provided in Annex 5. Exploration of uncertainties is particularly important and sensitivity analysis on scores and weights which are uncertain either due to differing perspectives or uncertain information is a key activity. The possible changes due to occur through climate change can also be explored by placing an alternative scenario over the first pass results to see what would change and how the final outputs are affected. Through this iterative process robust choices of portfolios of technologies or measures for each category of measure can be generated for each (sub)sector. Improvements in the options can be considered from an exploration of the advantages and disadvantages of options and how well balanced they are on the major objectives.

Each portfolio set **for each sector** and category (small scale/large scale and short/medium to long term) can be assessed in this way to provide a final short list in each category for each sector. It may be that in some categories there is a clear 'winner' while in others there is a diverse set of technologies or measures which are appropriate. These can be followed up at a later stage in the implementation plan after the initial priority technologies have been dealt with.

The output in this form may also be used to generate a strategy for implementation. Outputs from the analysis are summarized below.

**Outputs from Step 5:**

At the end of the process the outputs will be:

- A prioritized portfolio of technologies for each category for each (sub)sector ready to be fed into an implementation plan. **Table 4-5** provides a sample output.
- An audit trail justifying the judgments made. This is a transparent record of the justifications made for the scores given and the weights assigned as well as the variations in perspectives, the results, sensitivity analyses conducted and the insights gained.

## Discussing and exploring prioritization options

As explained above under 'process for MCDA' it is important that the outcomes found in this step are discussed by stakeholders in terms of the uncertainties in the inputs, both in the scoring and weighting as well as in the uncertainties surrounding the decision and the range of perspectives applying to the decision. As explained, assumptions can be challenged, key criteria identified, improvements to options created and consequences analyzed interactively so that the group achieves a true understanding of the problem and can move forward to making final decisions.

## Making final decisions

At the end of prioritization process, country teams should have a prioritized portfolio of technologies and measures in each category of small and large scale technologies for the shot and medium to long term for each sector of interest that enjoys broad support from the stakeholders participating in the process. This prioritized portfolio will have undergone the sensitivity analyses discussed above to assess the robustness of the results against the uncertainties.

Bearing in mind that adaptation measures are country — and sector-specific, and that adaptation measures are largely determined by national and sector circumstances, it is to be expected that there will be different applications of technology in different cases, and that what may work in one set of circumstances would be totally unsuited for another. Hence, the final prioritized list should also include uncertainties related to the assessments/impacts, investment timing, level of risk, and scale of application.

Prioritizing technology portfolios in each category as opposed to selecting individual technologies provides the opportunity to start to formulate a strategy for implementation over time within the (sub)sector and across sectors. Clear winners able to be implemented right away can be identified, though in some sectors groups of technologies may be more appropriate (*e.g.*, in the agricultural sector example). Depending on climate impact scenarios activities can be put in place for transfers over time for medium to longer-term adaptation options. In addition, comparison across the sectors may identify technologies not necessarily the highest ranked but nevertheless highly ranked in a range of sectors indicating that they may be a useful choice for technology transfer in the short and medium to long term. Through the formulation of a strategy encompassing the institutional, legal, policy, fiscal, market and financial supporting actions, transfers of appropriate technologies to meet development and adaptation priorities can be addressed.

The acceleration of innovation is considered in Chapter 5 where some of these supporting activities are discussed in more detail. In addition, Chapter 6 uses these acceleration activities and moves forward to sectoral and national strategy characterization.

**Table 4-5. Summarizing table for prioritizing technologies for adaptation**

| Sector A | Technology | **Potential scale of investment in technology for adaptation in sector** (e.g., 20-years) (uncertainties will be made explicit in a spreadsheet provided where possible) | **Benefits Output from MCDA assessment** | **Estimated investment costs per technology times the potential scale of investment in the sector** (for this calculation a spreadsheet will be available) |
|---|---|---|---|---|
| Short term/ Small scale | Highest priority technology<br>Next highest | | | |
| Short term/ Large scale | Highest priority technology<br>Next highest | | | |
| Long term/ Small scale | Highest priority technology<br>Next highest | | | |
| Long term/ Large scale | Highest priority technology<br>Next highest | | | |

Not all of these categories will be filled by the priority technologies depending on the sector characteristics and therefore if there is time working further down each prioritized technology portfolio list would be beneficial.

The calculation of the potential in the sector can only be an estimate dependent on many uncertainties which must be made explicit and gives a maximum value for the sector which in the light of other possible innovations may not be reached.

**Table 4-6. Summarizing table for cross-sector technologies for adaptation**

| | **Technology** | **Potential for adaptation in sector in timescale** (e.g., 20-years) (uncertainties will be made explicit in a spreadsheet provided where possible) | **Benefits Output from MCDA assessment** | **Estimated investment costs per technology times the technical potential in sector** (for this calculation a spreadsheet will be available) |
|---|---|---|---|---|
| Short term | Cross-sectoral technology | | | |
| Long term | Cross-sectoral technology | | | |

Note that for the analysis in Chapter 6 only short term and long term cross-sector technologies are identified.

## Factsheets

In addition to the summarizing tables above, the National TNA Teams can prepare factsheets for each of the priority technologies. The purpose of the factsheet is to create a succinct document that synthesizes essential information for each priority technology within the context of the country. The National TNA Team could consider the research and information that would be most pertinent to an audience of non-specialists keeping in mind the need to be direct, succinct, and descriptive. In Annex 6 examples are provided that further illustrate the intent of the factsheets. Much of the information should already be available through the *TechWiki*.

Part III

# Moving forward to a low carbon future

# 5. Accelerating Technology Development, Deployment and Diffusion: enabling frameworks and capacity building

## 5.1. Introduction

Developing and transferring technologies and measures successfully and accelerating their adoption are a complex process. This involves country specific national institutional structures and social networks of actors such as technology providers and private project developers operating under policies and regulations and supported by a range of market services, such as quality and assurance practices, R&D, and financial services, underpinning the operation of the system.

Such technology transfers will be dependent on the technology being introduced and the country specific context. For instance, small scale measures which have particular relevance to many developing country economies tend to have a large number of actors in the transfer chain, while large scale technologies tend to have a small number of market actors (ENTTRANS, 2008). The suitability of a technology for country conditions may also require that it is adapted to suit the long term implications of climate change within the country, or to the country's supply chain constraints.

Low carbon technology innovation may be developed within a country or involve country-to-country transfers, either South-South or North-South. Whichever model of transnational transfer is appropriate, it will require international partnerships and cooperation along the innovation chain, particularly in the design and testing of technologies to ensure that new low carbon technologies are suitable and can be embedded in the economic development of the country through integration of cooperative activities into the whole innovation chain within the country. This will help to maximize the sustainable development opportunities from the transfer and the adoption of the technology with benefits of capacity building, employment opportunities and sustainable resource use. In this process attention should be paid to strengthening national capacities ("technological capabilities") to select, adapt, buy, and manage suitable technologies. This new paradigm for innovation and technology development should involve developing countries from the start as participants in a networked process of innovation, following the examples of Brazilian scientists contribution to biofuels, and Chinese manufacturing contributions to the solar and wind industries, as discussed in Annex 7.

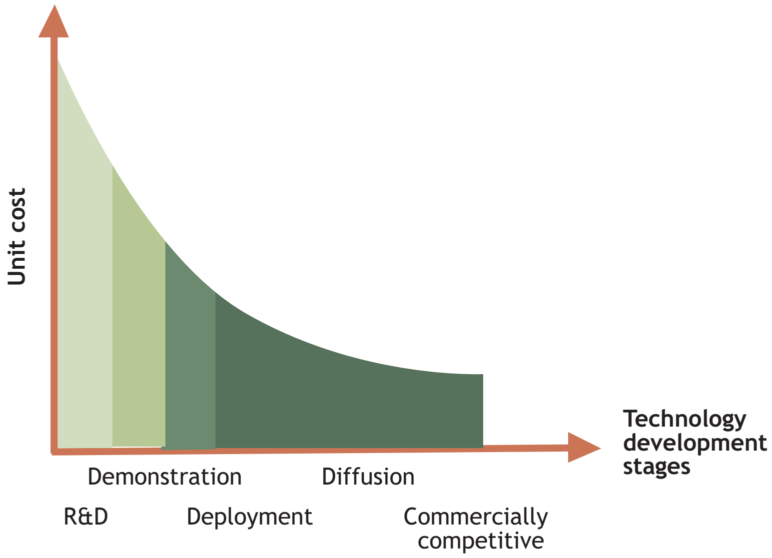
The stages usually defined for technology innovation are:

- **Research and Development** (R&D), which is the very early stage of an invention
- **Demonstration,** which is when prototypes are proven and scaled up to the applicable demonstration scale for final proving before
- **Deployment** into a market, and,
- **Diffusion** of the technology within the market to the point where sufficient numbers are deployed to make the manufacture and sale commercially competitive.

These descriptions are very broadly based as in practice they form a continuum where phase boundaries are blurred depending on the technology and circumstances. This is usually described as a learning curve for technology innovation and is illustrated in Figure 5-1.

In this chapter the technologies identified in Chapters 3 and 4 as priority technologies for mitigation and adaptation actions will be further analyzed with a view to the implementation circumstances in the country concerned. These priority technologies have been identified as providing the largest contribution to the sustainable development in the country in combination

**Figure 5-1. Learning curve for technology innovation**




*Source: EGTT, 2009.*

with a significant reduction of GHG emissions (mitigation technologies) or vulnerability to climate change (adaptation technologies). Chapters 3 and 4 stopped short of discussing the implementation circumstances in the country, and requirements for successful implementation and future roll out in the country.

This chapter takes a whole system approach, and will explore the enabling environment in its widest sense for the implementation of the priority projects; it continues the analysis to provide **options on the way forward** for:

a. implementation programs of activities and projects at the technology or sector specific level;

b. implementation programs of activities and projects across sectors; and

c. implementation programs of activities and projects at the national level for accelerating technology innovation and overcoming barriers for the selected technologies:

    - at the RD&D stage,
    - the deployment stage, and
    - the diffusion stage.

The implementation circumstances in the country will be analyzed in terms of the system for innovation and the barriers presented within that system for the highest priority technologies in the categories 'available in the short term' and 'available in medium to long term'. This will be done for each sector. Next, for these technologies, what activities are needed to improve and accelerate the process of technology deployment and rollout in the country will be analyzed.

In addition, consideration is given to the non-market technologies and their introduction, as well as to cross-sectoral technologies identified as highly rated across the sectors. Chapter 6 will indicate how the activities identified in this chapter can be formed into a strategy for accelerating the achievement of a low carbon future.

## 5.2. Process for this chapter

Chapters 3 and 4 illustrate that the successful transfer of technologies requires suitability to the country context. Priority technologies have been identified as appropriate in terms of sustainable development contributions in the short and long term at the country level and GHG emission reduction/reduced vulnerability to climate change. In both chapters, when prioritizing technologies, a categorization was used for the applicability of a technology in the short and medium/long-term and on a small and large scale.

In this chapter, since small and large scale technologies for mitigation and adaptation basically follow the same process for identifying activities to facilitate implementation of the technologies (though they may well produce significantly different types of activities), the priority technologies identified in Chapters 3 and 4 will be categorized in this chapter only under:

- *Priority technologies '**available in the short term**' for mitigation and adaptation*

  This means that a technology is either commercially available now (in a local or other market), or is very close to market implementation, or that the measure or non-market technology is reasonably well developed. With reference to the stages of innovation, this technology may already have diffused into markets in other countries or it may be moving from a successful demonstration phase.

  In Chapters 3 and 4, the costs and all the benefits (not just monetary) of the technologies have been explored, as well as the technical potential in the country, and a start has been made on transferring technology information and know-how by the familiarization step in the TNA process. The familiarization relies on the availability of opportunities for stakeholders and decision makers to obtain detailed information and case studies for the 'new' technologies as well as seeing them in action, if at all possible. Here, any existing demonstration projects or regional demonstration and expertise centers can play a vital role.

- *Priority technologies '**available in the medium to long term**' for mitigation and adaptation*

  This category of technologies combines the pre-commercial technologies at the demonstration phase and technologies at a promising early R&D prototype stage. These may well have time to be implemented to reduce GHG emissions further, or increase resilience in the longer term and before severe climate effects occur, provided activities are undertaken to ensure that their progress to the commercialization stage is properly supported. In order to utilize the medium to longer-term mitigation and adaptation benefits of these technologies and measures, this process should also start at the same time as the already commercially available technologies.

- *Non-market technologies*

  It is recognized that some adaptation and mitigation measures involving activities such as behavioral change are not market-related and require a different approach. These measures usually involve a process of social change and participatory measures interacting with social networks and individuals directly. These types of the measures are more related to coping strategies in organizations and communities.

**For all these technology categories** it is suggested that in order to analyze the activities required for each priority technology in each sector to accelerate their adoption in the country context, three main areas for consideration should be used. These areas are based on the above-mentioned key steps in the technology development cycle:

- **Acceleration of *Development*: Research and Development**

  For all the technology categories R&D activities are required, whether to support fundamental research for long term promising technologies at the R&D and/or demonstration phase, or existing market technologies that need to be adapted and demonstrated in the context of the country concerned. International cooperation with developing countries on enhancing in country R&D capacity and activities is recommended.

- **The acceleration of technology *Deployment* in the country**

  The practicalities of deployment must recognize that transfers will be enacted mainly through private sector agents and include consideration of facilitation of the process for investors and users through such factors as funding for the technology, further familiarization with the technology on a wider scale, the type of transfer to be enacted and the other practicalities associated with supply chains and capacity building for appropriate skills and training. Within this consideration, the question of Intellectual Property Rights (IPR) may arise. Protection of IPR and cooperation on this issue for the type of transfer envisaged is fundamental for sustainable technology transfer. International cooperation on building technological capacity on these and other transfer issues is another key factor. The market 'pull' for these technologies is also important in terms of affordability, demand for these technologies, availability of finance, and commercial presence of entities able to deploy the technologies.

- **The acceleration of Technology *Diffusion* in the country context**

  The acceleration of technology diffusion in a country requires consideration of the whole system, including the enabling business environment of institutions, policies and regulations surrounding the transfer, the market chain involved in the sector concerned, and the supporting activities which allow the market to function. This follows the market mapping approach originally proposed by Albu and Griffith (2005) and which describes the system for technology diffusion by dividing it into three elements: the business enabling environment; the market chain; and the market supporting services. In Annex 8, the market mapping technique is explained in further detail and illustrated by an example of the type of output expected from market mapping. The UNCTAD definition of enabling environment refers to the underlying macroeconomic environment bringing together technology suppliers and consumers in a cooperative manner (UNCTAD, 1998), which is equivalent to the whole system approach described above.

Behavioral, organizational or institutional change non-market technologies will not be fully amenable to this type of analysis, though a description of the networks involved is a useful starting point for exploring the systems relevant to their introduction. A possible approach for these non-market technologies is described in Section 5.6.

As explained above, in this chapter the portfolios of prioritized technologies or measures for each of the four categories (short and medium to long term availability and small to large scale applicability for each sector) are taken as inputs for the analysis of how the adoption of mitigation technologies or adaptation measures may be accelerated successfully in the host country context.

In principle, the portfolios or sets of priority technologies derived from the process in Chapters 3 and 4 in each category should all be implemented over time. However, for the purposes of this TNA it is recommended that the initial number of technologies examined is limited and covers the range of technology categories already described, to ensure manageability of the exercise. If sufficient resources are available, then additional numbers of technologies can be explored in this TNA stage. It is suggested that, for each sector, the following processes should be applied to the **highest priority technologies in each of the four categories:**

- small scale/ 'available in the short term',
- small scale/ 'available in the medium to long term',
- large scale/'available in the short term', and
- large scale/'available in the medium to long term'.

In addition, it is suggested that two **'cross-sectoral' technologies (from Chapters 3 and 4)** will be included in the analysis, which, though not occupying the most preferred position, are nevertheless highly rated and are common across more than one sector.

In the following sections the 'available in the short term' and 'medium to long term' prioritized and cross-sectoral technologies are taken and the issues in each case explored through addressing the main stages of innovation as described above. These stages include what R&D is required to bring the technology to the point of deployment, whether in a market or non-market environment, then how technology deployment can be managed, followed by exploration of how the whole technology transfer system in the country can be improved to accelerate diffusion. This latter aspect would also benefit other low-carbon mitigation and adaptation technologies, and there will be commonalities across the technologies.

The three main stages for technology development used in the analysis and applied to the mitigation and adaptation technologies are represented by:

- **Step 1** — Acceleration of **development**: Research and development activities
- **Step 2** — Acceleration of **deployment**: Practicalities of technology level deployment
- **Step 3** — Acceleration of **diffusion** at the system/national level

These are used to structure the analysis and applied in turn for the short and medium to long term technologies. *The purpose of the analysis is to identify for the country context the activities required to ensure successful accelerated development, deployment and diffusion of the selected technologies at the sector and national level.*

The steps in the process for each technology stage for the short term and medium to long term market technologies are illustrated in **Figure 5-2**. Non-market technologies are discussed in Section 5.6.

**Figure 5-2. Supporting diagram for this chapter (market technologies)**

Activities required to ensure successful accelerated development, deployment and diffusion and capacity building

| Stages of technology development | Technology available in: | |
|---|---|---|
| | Short term | Medium to long term |
| **Step 1**<br>Technology development | **Step 1a**: Adaptation of the technology to country conditions | **Step 1b**: Initial characterization of development system for pre-commercial or long term technologies<br>**Step 1c**: Identification of activities for strategy |
| **Step 2**<br>Technology deployment | • **Step 2a:** develop networks and information dissemination and awareness raising<br>• **Step 2b:** new technology familiarisation<br>• **Step 2c:** financing model to minimize risk for implementation of technology<br>• **Step 2d**: appropriate model of technology transfer or cooperation<br>• **Step 2e:** training for supporting skills | |
| **Step 2**<br>Technology diffusion | • **Step 3a:** formation of network: preliminary market mapping<br>• **Step 3b**: type of transfer<br>• **Step 3c:** map the national market system in the country context to identify barriers and inefficiencies<br>• **Step 3d:** elements of a strategy for improving country deployment and diffusion | |

## Outputs from the analysis

In the following sections, for each prioritized technology activities are identified in the analysis that would improve and accelerate the development, deployment and diffusion of the technologies. These activities can then be prioritized. This can be done relatively simply. The prioritization does not imply that all the activities are not required, but rather identifies where to start the process of change.

Once prioritized, the activities can be placed in an action plan and grouped in terms of the relevant parts of the system (*e.g.*, R&D) and cross-cutting activities, as well as timescale. For each activity, starting with those prioritized, further elaboration of the following are needed:

- what should be done,
- why it is important,
- who should do it,
- how they should do it,
- by when,
- what **monitoring, reporting and verification** indicators/actions can be put in place,
- An **estimate of the costs** to do this,

- The **timescale** envisaged for actions (up to 5 years, 10 years and 15 years from the current date), and
- The uncertainties and risks.

This is represented in Table 5-1 for both short and medium to long term market technologies (Table 5-2 at the end of the chapter shows an example of what a completed table would look like).

A rough estimate of resources is required, along with a determination on how to measure progress on the activity in terms of what can be appropriately monitored, verified and reported on, to ensure that activities can be modified if they are not progressing, and lessons can be learned and shared.

Collecting this information and assessing activities delivers a clear picture of the capacity building needs in the country for the acceleration of technology R&D, deployment, and diffusion. This holds in particular for the 'Who should it' and 'How should they do it' entries in Table 5-1, as well as for 'Estimated costs'.

Table 5-1 applies to all three steps listed in Figure 5-2 for market technologies available in the short and medium to long term at the small and large scale. Specific tables are given at the end of the sections.

**Table 5-1. Required enabling activities and capacity building activities**

**Sector**

**Specific Technology and category**
(*e.g.*, Small or large scale/short term/medium to long term, cross-sectoral or non-market)

| Activity | Why important | Who should do it | How should they do it | Time scale | Monitoring, reporting and verification for activity | Estimated costs |
|---|---|---|---|---|---|---|
| Acceleration of development R&D | | | | | | |
| ***E.g. Network development*** | | | | | | |
| Acceleration of deployment: technology deployment | | | | | | |
| ***E.g. Training*** | | | | | | |
| Acceleration of diffusion: national system level | | | | | | |
| ***E.g. Policies and measures*** | | | | | | |

## 5.3. Step 1 — Acceleration of technology development: R&D activities

It is recommended that a stakeholder group of relevant technology experts, policymakers, sector experts, and community representatives should be convened to consider the issues. Using the networks of sector stakeholders already available from the TNA process and extending them to relevant experts could be a good way forward. However, there will also be variations from the original group membership depending on the issues and whether it is the technology/sector or system level being addressed. Where cross-sectoral groups are needed, representatives from the sector groups can be brought together for that part of the analysis. Stakeholder analysis techniques (Annex 4) can be used to identify the most suitable composition of the groups. For micro, small and medium scale enterprises, involvement and support of representatives is essential.

The activities recommended and discussed in the steps for the analysis for short term and medium to long term technologies in the following sections are suggestions to guide the analysis. Other steps may be added as there will be variations with technologies and country context.

## ➔ Step 1a — Adaptation of short term technology to country conditions

The main activity required for a technology being introduced to a country is to ensure that it is robust under country conditions and in the context of future climate impact scenarios. In this stage it will be important to carry out an activity on "Adaptation of the technology to country conditions and to ensure robustness to future climate change". This activity is explained in Figure 5-3.

**Figure 5-3. Adaptation of the technology to country conditions and to ensure robustness to future climate change**

| Acceleration of Development: **Research & Development** → | **STEP 1a Adaptation of technology to country conditions:** |
|---|---|
| | • Visits to demonstration projects and discussions with experts<br>• Agreement on modifications with technology supplier with further testing and iteration as required<br>• Establishment of credibility of supplier and training program for operation with continued follow up for first year<br>• Building capacity to enable adaptation of technology to country |


Some technologies may well need no further adaptation to be applied in a sustainable manner in the host country but some technologies may require some R&D to ensure that they operate reliably under country conditions and are robust to future climate conditions. It is therefore important that:

- Country experts visit demonstration projects operating under similar country conditions where possible to see the plant in action and to discuss with operators and installers any issues relevant to the host country conditions now and in the future.
- Modifications to the technology can be made and testing in the country carried out in collaboration with manufacturers without invalidating warranties and compromising operator safety. Who should do this needs to be agreed as well as appropriate funding for this activity
- Supplier capability, support, and service record can be demonstrated and training in the use of technology under field conditions is available. It is very important that when a new technology is introduced there is sufficient manufacturer back up support over a period of time to ensure that all the problems are overcome as operators and managers start to gain experience. This process should involve back up visits after the initial intensive training every one or two months for the coming 6 months to a year after installation. Otherwise the technology may fail after all the investments made.

- Building capacity. The skills required to successfully operate and maintain the technology need to be identified to enable deployment. The current training programmes can then be reviewed to ensure the skills required are available in the timescales.

The stakeholder group can develop an action plan to proceed on these issues defining who does what, how, and when, and how it can be monitored, reported and verified, with an estimation of costs as described for input in Table 5.2. This activity would imply funding support from international organizations or host governments. The technology at the end of this exercise can then be available to investors.

**Output from Step 1a:**

For each priority technology where this is deemed to be an issue, an estimate of the need for adaptation to the country context and indications from suppliers on modifications and testing, as well as capacity building activities, including training, back up visits, service agreements and warranties. For all activities the outputs required are as described above for input to Table 5.2.

## ➔ Step 1b: Initial characterization of development system for pre-commercial or long term technologies.

In the case of technologies for mitigation and adaptation available in the medium to long term (from long term to pre-commercial stage), the acceleration of development of a technology through R&D is the key activity, as these technologies are not ready for the market yet, but will at some stage have to enter that market.

It is suggested that the process in Figure 5-4 will allow exploration of the problem and lead to formulation of appropriate supporting activities which can form part of an overall strategy for acceleration of development to deployment. The figure shows activities for an initial characterization of the development system for medium to long term technologies, and for identification of activities for formulating a strategy. The first of these activities are explained in Step 1b, whereas the second set of activities are addressed below in Step 1c.

**Figure 5-4. Adaptation of the technology to country conditions and to ensure robustness to future climate change**

**Step 1b:** Initial characterization of development system for pre-commercial or long term technologies

**Step 1c:** Identification of activities for strategy

In order to decide on the activities required to promote the technology, its actual stage of development has to be ascertained and it may fall into the following categories for mitigation or adaptation as suggested above:

- Promising prototype to demonstration model (*e.g.*, 5-15 years to market), or
- Early stage market entry pre-commercialization demonstration phase (up to 5 years to full market).

The technology developers may or may not be in the host country concerned but activities to foster roll out could be carried out in-country. It may be that independent funds are required to accelerate the R&D process, and that capacity building support is required, depending on the country where the technology is being developed. The new model of cooperative international action on technology development and transfer as described in Section 5.1 and Annex 7 may be needed and could be considered by the stakeholder group.

For medium to long term technologies, it is necessary to:

- **Establish the exact stage of development and roll out and experience to date** — This is self-explanatory and determines the scope of the activities required to bring the technology to market or instigate behavioral change.
- **Characterize the system in which the technology is being developed through mapping** - This is a system characterization for identifying the barriers and inefficiencies which developers have to cope with and could involve a similar process to **market mapping** discussed above in Section 5.2 except in this case it is applied to the stage before the market to characterize the development system so that it is clear:
    - Who are the main stakeholders?
    - What are the networks involved?
    - What are the links between the enabling and supporting environments and the development chain?
    - Who has the power in the development chain?
    - What are the policies and regulations surrounding this stage and how can they be improved?
    - How can the required R&D be supported?
    - What other supporting activities are required?
    - What are the barriers, blockages and inefficiencies?
    - What activities can minimize investment risks and reduce overall costs in the supply chain, and what capacity building activities are needed for that?

Where a technology is deemed to be important and promising, incentives and support structures may need to be put in place to allow developers to access additional funding to support the pre-commercialization phase with regard to identifying low-cost routes for supply chains and manufacturing or even subsidizing the technology until economies of scale come into play. Demonstration projects will be important to develop, and activities related to a program for demonstration could be considered by the stakeholder group.

For early stage technologies continued guaranteed support for development will be needed involving national and international cooperative programs especially on R&D. At this stage maintaining diversity in design to cope with future uncertainties and to develop robust technology alternatives will also need support for the developers.

It is suggested that the sector stakeholder groups could address this problem and use experience from developers in similar situations to identify at what level the support is required. This could be at the international national or regional level. They could also identify what activities, at what stage, would work best under which conditions. This activity is not necessarily only at the country level, but may be country context dependent. Best practices and experiences with other technologies and sectors are also important to take into consideration.

**Output from Step 1b:**

The outputs from this step carried out by the stakeholder group are the determination of the stage of development of the technology, and a mapping exercise to characterize the development system for moving from research to demonstration. These outputs are fed into the next step.

### ➔ Step 1c Identification of activities for strategy

Based on Step 1b, outputs, the following activities can be identified:

- Activities required to make the technology available on the scale and in the timescale required
- Identification of risks, especially investment risks, and how to minimize them.

These activities can be undertaken within the stakeholder groups through focused discussion and may already have started to emerge from discussions of the development system for the technology.

**Output from Step 1c:**

The output is a list of activities to accelerate the research and development stage through to the demonstration phase and can be in a format suggested in Table 5.1. Note that activities for pre-commercial or future long term technologies should be grouped separately.

The stakeholder group, on the basis of the analysis in Step 1c, can identify activities under each heading which can be assembled into a strategy by prioritizing the activities and justifying why they are important, and allocating who should perform the activities, when and how, and what resources and monitoring, reporting and verification indicators/actions will be required, as described in Section 5.2.

**Overall output for Steps 1b and 1c: Strategy for medium to long term technology acceleration of R&D activities**

The group should be able to devise an action plan based on the prioritized activities (presented as in the format of Table 5.1) by formulating options based on consideration of the implication of allocating resources to activities to form a coherent strategy to attain the objectives.

## 5.4. Step 2 — Acceleration of technology deployment

The activities involved in this stage are summarized in Figure 5-5. As shown in Figure 5-2, there is no difference between short term and long term technologies with respect to activities needed in the deployment and diffusion stages. For the sake of simplicity, Steps 2 and 3 focus only on the short term technologies for mitigation and adaptation prioritised in Chapters 3 and 4.

For the short term technologies prioritized, the following main areas need to be addressed to ensure successful deployment in line with sustainable development priorities:

- Develop networks and further information dissemination and awareness raising;

- New technology familiarization through programs of demonstration, targeted training and commercial exchanges;
- The financing model to reduce the risks for implementation of the technology chosen and investors selected by the project developer;
- The type of transfer suitable for the technology and the developing country and its development goals selected (a specific issue to be addressed within this is cooperation on IPR); and,
- Training for the supporting skills for operating and maintaining the technology with associated standards designed and put in place.

The medium to long term technologies can follow this process at a later date depending on the progress on accelerating R&D.

**Figure 5-5. Step 2 - Acceleration of deployment: Technology deployment activities**

| | |
|---|---|
| **Step 2a**: develop networks and information dissemination and awareness raising | |
| **Step 2b:** new technology familiarisation | |
| **Step 2c:** financing model to minimize risk for implementation of technology | |
| **Step 2d**: appropriate model of technology transfer or cooperation | |
| **Step 2e:** training for supporting skills | |

## → Step 2a: Develop networks and information dissemination and awareness raising

Existing social networks relevant to the implementation of the technology in the country context need to be identified, resources put in place to ensure that existing networks are supported, and new networks created if necessary by identifying relevant stakeholders. It is also important to encourage the development of robust networks over time with more than one hub or coordinating institution. The stakeholder group for the TNA can act as a starting point for relevant sector and technology network development. For rural enterprises at the micro and small to medium scale this step is very important.

Through these networks and other national regional and local institutions, information dissemination strategies and awareness raising campaigns can be developed.

**Output from Step 2a:**

Formation of networks of relevant actors for technology deployment and estimation of resource support needed to create and maintain networks, *e.g.*, through regular meetings and newsletter, *etc*. Stakeholder recommendations can also be made on possible information dissemination mechanisms. For all activities, the outputs required are as described above for input to Table 5.1.

### ➔ Step 2b: New technology familiarization

New technologies unfamiliar to decision makers are unlikely to be chosen unless there is a program in place to ensure that they can see the technology operating successfully under country conditions or an equivalent context. Being able to observe and even try out the new technology is very important for the adoption process. The stakeholder group needs to identify the decision makers relevant to the technology and consider devising a program of familiarization activities, or plug into existing national or international programs to facilitate adoption. In-country demonstration pilot plants are important in this context and should be supported where possible.

This step is in line with the familiarization activities in **Step 4** in **Chapters 3 and 4** on Identifying and characterizing relevant technologies for prioritized sectors.

**Output from STEP 2b:**

Programs for familiarization to have confidence to invest in the technology are required and support may be needed from several sources. Regional centers of excellence are important for this activity. For all activities the outputs required are as described above for input to Table 5.1.

### ➔ Step 2c: Financing model to minimize risk for implementation of the technology

The financing model to be used for implementation of the technology, whether joint venture, manufacture and operation under license, leasing, micro-finance, grant funding, or incremental funding, has to be decided and the process of gathering the investments necessary for deployment put in place. The financing arrangements can be a constraint on the type of technology transfer model to be applied to the technology and this is discussed in the next activity.

Private sector investors, public utilities or international organizations are the main decision makers for this aspect for individual project implementation. The stakeholder group therefore has to consider ways in which developers can be supported in this process to ensure that opportunities are realized. Awareness needs to be raised on the utilization of capital markets. In Box 5-1 some of the available sources of assistance are listed. Notable among these is the Climate Technology Initiative (CTI) on a Private Financing Advisory Network able to provide reality checks on project viability and provide a fast track route to implementation. However some projects may not conform to current investment criteria but are nevertheless important for development and low carbon/adaptation and these types of technology projects need to be considered under alternative financing arrangements. A Guidebook for investors on preparing technology transfer projects for financing is also available from EGTT (2008). Moreover, an analysis of financing models and funding sources including the Clean Development Mechanism can be found in the report prepared for the EGTT on "Future Financing Options for Enhancing the Development, Deployment, Diffusion and Transfer of Technologies under the Convention" (EGTT, 2009).

To support project investors in this process, consideration by the host country and by international agencies can be given to providing information and financial or other incentives for minimizing investor risk and assisting in assembling sufficient investment capital. IPR may also be an issue here and the implications of IPR vary across different technologies as discussed in Tomlinson, *et al.*, (2008) affecting the particular business model used.

How this is done and what can be provided can be discussed by the relevant stakeholder group to determine actions to be undertaken and monitored.

**Box 5-1. Available sources of assistance for utilization of capital markets**

Financing advice and sources for project developers will be available through the support systems for the TNAssess. Selected sources are provided here for general information, and can be passed on through the stakeholder networks and through the specific dissemination and awareness raising activities in Step 2a.

1. CTI's Private Financing Advisory Network, which can review the priority actions at a relatively early stage in their identification. Most individuals familiar with the technical aspects of a project are not experts in project financing. This facility helps structure the projects being identified and assists in preparing supporting business plans.
2. A Guidebook for investors on preparing technology transfer projects for financing is available from EGTT (2008).
3. Financing models and funding sources are available in the EGTT (2009).

Activities to minimize risks for developers through market pull could also include creation of situations for roll out under low-risk conditions for developers through dedicated demonstration pilot scale applications, such as in refugee camps or new estates. Other market pull activities for consideration could include raising the ability to pay for technology services for consumers, and the commercial presence of entities able to deploy the technologies.

**Output from Step 2c:**

Stakeholder recommendations on each of the prioritized technologies on appropriate activities to minimize investor risk on financial, IPR and other issues. For all activities the outputs required are as described above for input to Table 5.1.

## ➔ Step 2d: Appropriate model of technology transfer or cooperation

Cooperation between countries will be required if the transfer process is to suit the development needs of the country. Private sector transactions may need to be incentivized to provide the technology in the most useful form for the country. The type of technology transfer for the technology in the country context will also depend on the funding arrangements and the constraints placed upon the transfer by those arrangements.

However, there are different possible approaches. For example, the transfer, whether a South-South or North-South transfer, could involve the import and installation of a fully functioning turnkey technology, or the adaptation of existing in-country technologies, or construction by in-country manufacturers and suppliers through IPR agreements. Where the whole technology can be manufactured in the developing country or parts of the supply chain can be transferred only, then these have to be included in the whole system for accelerated diffusion in Step 3. This decision therefore affects the system boundaries for the implementation and acceleration activities in the next phase of the process. It has also implications for the capacity building requirements in the country, which would become clear from the overall Table 5.2.

The decision on the appropriate type of transfer depends on

- How the project is funded and by whom,
- Incentives for transfer and supply chain development,

- The technology to be transferred,
- The existing supply chain base in the country and capacity for expansion,
- The skills base required and training needs,
- The development priorities of the host country.

The final decision depends on the investor/s. However, there are national implications for development and the stakeholder group could assist in defining activities to enable and incentivize appropriate transfers for the development priorities of the country. Ensuring that investors consider the national benefits may require national policies and incentives to be put in place and this can be considered by the group. Lessons may also be learned from past projects in the country.

**Output from Step 2d:**

Recommendations from the stakeholder group on appropriate models of transfer for each of the prioritized technologies and incentives required to make them practical in the country context, for consideration by the host government and other funding bodies. For all activities, the outputs required are as described above for input to Table 5.1.

### → Step 2e: Training for supporting skills

As mentioned above in this Chapter, the deployment of a technology in the market in a country requires domestic capacity, next to funding, which was elaborated in Step 2d. An important capacity requirement in the country for technology deployment is that training is provided by anticipating the skills required for the new technology, and the timescales required, and by exploring the existing system and availability of skills to improve the required throughput. In addition, training requirements can be identified that are not currently available, and training program requirements for national or international funding set out.

**Output from Step 2e**:

Specific recommendations on training and capacity building requirements for each of the prioritized technologies, bearing in mind synergies across different sectors and technologies. For all activities, the outputs required are as described above for input to Table 5.1.

**Output from Steps 2a-e:**

Possible strategy for prioritized activities to facilitate deployment of low carbon technologies for mitigation and adaptation available in the short term and medium to long term. Steps 2a-e can form the basis for a strategy to facilitate deployment of technologies by identifying all the required activities to accelerate deployment from each step, prioritizing them, and determining who should do them, when, and what monitoring, reporting and verification indicators/actions are needed. Decisions can also be taken on allocation of resources from the Table 5.1.

## 5.5. Step 3 — Acceleration of technology diffusion in the country context

The processes involved in adoption of a technology and accelerating adoption are associated with the specific country system of types of market actors with their specific norms rules and firm-to-firm interactions, and their decision making requirements for adoption (Rogers, 2003) with issues such as relative advantage, compatibility, complexity, observability, ability to try out the technology, and risk being important decision determinants.

In Figure 5-6, a process is suggested for each of the short term market technologies in order to identify activities which will improve and accelerate adoption and implementation of the priority technology in the relevant national context and sectors/s. The process can therefore be applied to each of the chosen technologies whether large or small. The process will also apply to the medium and long term technologies but at a later stage.

**Figure 5-6. Acceleration of Diffusion: National System level for market technologies**

**Step 3a:** formation of network: preliminary market mapping

**Step 3b**: type of transfer

**Step 3c:** map the national market system in the country context to identify barriers and inefficiencies

**Step 3d:** elements of a strategy for improving country deployment and diffusion

The steps described in this section are a major activity for the stakeholder group. It could be argued that the resulting strategy for this stage should be prioritized for action as the removal of barriers tends to be perceived as low cost but is not without significant effort. This national system level analysis is usually associated with identifying the barriers (financial, regulatory, policy, institutional, cultural, technological, etc.) restricting the diffusion or even the initial deployment of a new technology and suggesting ways to overcome the barriers. However, this system approach not only allows the obvious barriers to be identified but also allows the structure of the existing system to be revealed and explored, enabling stakeholders to create new links and additional structures to make the system operate more efficiently or to support it in key areas. This is a key activity in promoting deployment and diffusion of a technology and the following steps are suggested for exploring how it can be improved, what capacity building needs can be identified, and to develop a strategy of activities to accelerate diffusion.

Consideration within the group is first of all given to the identification of the actors involved in the market chain. Part of this will have been carried out in step 3a.

The next stage is to explore the 'enabling business environment' as defined by Albu and Griffith (2005, 2006) using their Participatory Market Chain Analysis Approach (PMCA) as described in Section 5.2. This involves for the technology in question, a characterization of the policies and regulations, legal and institutional structures, infrastructure and processes that shape the market system. This will involve successive meetings of the stakeholder group as they explore in detail all the issues affecting this business environment. Depending on the group, concurrently or sequentially the supporting environment for the market is analyzed. This will include the business and extension services which will support the operation of the market chain.

The process is carried out through the following steps identified by Albu and Griffith (2006).

### ➔ Step 3a: Formation of a network: preliminary market mapping

Form a stakeholder group by identifying, for the process, from import/adaptation/indigenous manufacture of the technology to its use, the key players in the system for sector/s or market segment/s for the technology (with supply chains). If possible this step should build on existing networks. Information is collected on the market system by the TNA team and a preliminary map can be drawn. This can be used to identify the initial actors that will be invited to the PMCA workshops. An initial map of this type need not be shown to the stakeholder group as it tends to anchor perceptions and it is better to establish with the stakeholder group the market map envisaged by the group in the following steps.

### ➔ Step 3b: Type of transfer

Make decisions on the type of transfer envisaged. This has been discussed in the project deployment for implementation in Step 2d and the decision should feed into the deliberations on system boundaries. This is not critical for the analysis but can be amended at a later date.

### ➔ Step 3c: Map the national market system in the country context to identify barriers and inefficiencies

This is the main activity of this part of the analysis. Market mapping (see Annex 8) is one technique for doing this in a workshop environment but others such as world café or other techniques can be applied. At the workshops the range of market-chain actors can meet 'to share their perspectives, problems, and expectations; build common understandings and trust; and identify blockages, challenges and opportunities in the market system' (Albu and Griffith, 2006).

For the type/s of transfer, characterizing the system will involve the stakeholder network group in identifying the enabling policy and regulatory environment, the key players in the market from Step 2a with the market chain and any supply chains and the supporting market environment such as financial sector, R&D, market information networks etc and to drill down into the complexity of the prevailing system.

An example of an initial market map for transfer of small scale biomass gasification stoves in Kenya is provided in Annex 8. This is followed by the activities identified for improving the system and overcoming barriers identified from the map by the group in the workshop environment. In addition the opportunities identified by the group are listed and common barriers found in several countries.

The output from Step 3c allows the whole system to be explored **to identify:**

- **key players** with market power,
- **barriers**, bottlenecks and inefficiencies (*e.g.*, in current regulations and policies),
- **missing elements** (*e.g.*, regulation and enforcement),
- **legal rights**,
- **market support** structures (*e.g.*, good Q&A standards and enforcement, *etc.*),
- **quick wins and longer term activities**

**Output from Step 3c:**

Characterization of the market system into which the technology will diffuse, with key players barriers and inefficiencies, as described above, with full market map (see Annex 8) showing the linkages.

## ➔ Step 3d: Elements of a strategy for improving country deployment and diffusion

At this point the stakeholder network group could move forward towards the formulation of an **action plan to improve the innovation process for the whole system**. We address this issue in the next steps.

In generating a strategy for acceleration at the sectoral and/or national level, the group should bear in mind the sustainable development objectives of implementing the technology from Chapter 3 or 4. These objectives can be augmented with further discussions on what could be achieved by the technology. In the next steps the delivery of these benefits should be used to inform the development of the country system characterized above, and an action plan to accelerate transfer, as discussed in this section. Techniques to aid this process are listed in Annex 4 on participatory techniques.

The characterization of the system into which the technology is to be deployed and diffused from Step 3c allows the identification of actions for improving the system, for promoting efficient and accelerated innovations, and for strengthening the stakeholder networking. These actions can then be grouped under relevant headings. Suggested groupings are:

- Networks development,
- Organizational/behavioral change,
- Policies and measures,
- Supporting actions for the market,
- New financing models and sources,
- Activities to improve system efficiency and overcome barriers,
- Capacity building for skills, and
- External links and partnerships and IPR issues.

In this step, the group should ensure that the activities which can improve the operation of the whole system and overcome barriers identified in Step 3c above also lead to attaining the development objectives of implementing the technology.

The activities identified from Step 3c can then be reviewed as above in terms of policy, regulatory, fiscal, legal and governance improvements, improvements in market networks, structures and institutions, and improvements in supporting systems for the operation of the market. Additional considerations such as international links and partnerships could also be included, and barriers at the international level, such as IPR.

These activities can then be prioritized within their groups using simple discussion methods to enable people to rate each activity. The prioritized activities can then be assessed according to the inputs required for Table 5.1 in terms of action plan requirements, including estimates of resources.

Although four technologies per prioritized sector are to be analyzed for mitigation and adaptation in this way (see Section 5.2) and potentially all the prioritized technologies, it will become clear that many actions to improve the system are common across all technologies, and only some will be technology and sector specific. This means that time can be saved in subsequent analyses.

*It would also be expected that feedbacks will be required within the process and across the sectors to minimize duplication and ensure efficiency.*

**Output from Step 3d:**

**1. A list of actions to improve the whole system including overcoming barriers in all parts of the system,** grouped as described.

**2. Technology strategy through prioritization of activities** for improving the market system and overcoming barriers as described above for specific input to Table 5.1.

**Overall Output from Steps 3a-d: Overview of capacity building needs and a possible strategy of prioritized activities to overcome barriers and facilitate diffusion of low carbon technologies for mitigation and adaptation at the sector/national level for all the technologies initially prioritized.**

From the activities identified and prioritized in Table 5.1 with their implications for each technology, resources can then be allocated to the activities, gradually working through the priority list of activities identified in Step 3d. In practice, it is likely that this will be an ongoing process and all activities will be required to ensure success. Management of the action plan generated in this way will be required to ensure completion of the transfers in the country context.

## 5.6. Priority measures for mitigation and adaptation involving non-market technologies

This group of technologies is discussed separately here but requires the same stages as the short term and medium to long-term technologies discussed above and will use many of the same steps. However, as these tend to be non-market technologies, such as behavioral change, this section deals with some possible alternative approaches which could be applied within Steps 1, 2 and 3 (Sections 5.3, 5.4 and 5.5).

These additional considerations are by no means exhaustive and only serve to indicate that usually a different approach, involving exploration mainly through participatory processes at an organization, community or household level, would be required for technologies involving organizational and behavioral change. The main stages of interest under this set of technologies are the same as for market technologies:

1. **Research and Development on appropriate behavioral change mechanisms in relevant countries**
2. **The acceleration of deployment of existing and new approaches**
3. **The acceleration of diffusion of these priority measures**

Each are taken in turn, and issues additional to those already considered under the Sections 5.3-5.4 for short and medium to long term technologies are discussed.

### Research and development activities

The non-market technologies and behavioral change activities covered in this section tend to be diffuse and difficult to enact and measure. However, there is experience in many countries of successful initiatives (as seen by the adaptation techniques identified by EGTT), and research can be funded to explore specific current activities and the effects on other social and economic issues such as gender equality, equity and poverty alleviation, as well as to gather best practices. Pilot studies can be initiated in countries for specific prioritized initiatives with an action research agenda built in to obtain maximum benefit from the process. Reviews of current progress and information can be commissioned and disseminated to stakeholders. These activities and any others identified by the stakeholder group can be prioritized and costs estimated in a similar manner to that described in Table 5.1 to form a strategy to be funded.

This can be done using stakeholder groups as in Section 5.3 (Step 1) as appropriate.

### Acceleration of Deployment

This is similar to that under the previous categories of technologies in Step 2 (Section 5.4) for short and medium to long term technologies. However, as these non-market approaches usually involve public engagement processes it is important for a strategy for this engagement process to be worked out in advance for eventual funding, as a diverse set of approaches will need to be coordinated for different receptor groups with a range of experiences and cultural backgrounds. Again, in-country demonstration applications will be important to learn lessons and raise awareness. Follow up visits once the technology is installed over a period of 6 months to a year are needed to ensure that all teething problems are overcome and expertise and experience in making the technology work is gained.

### Accelerating diffusion of priority measures

In this case there is no market structure but there will be institutional structures and social networks which will have to be mobilized to create change. It will therefore be important to carry out a mapping process as described in Step 3 (Section 5.5) above. Even though these are non-market technologies, a similarly structured mapping process can elicit the networks, processes, policies, regulations and other features of the system in a similar way. This should provide the basis for characterizing this type of system in order to undertake the following activities:

- Identify key players at all levels and champions, if any,
- Identify the processes and activities to be changed,
- Create new champions,
- Identify the dimensions of the problem for adoption of the change,
- Identify information and training requirements, and
- Create a strategy for change, with people given responsibility to manage the process, allocate resources, develop training programs and guidelines, and support the innovation through the champions.

**Additional outputs from non-market technologies:**

The outputs from this section should be placed within the exercise carried out under Steps 1 to 3 and will include additional R&D development activities, and deployment and diffusion activities supported by the alternative mapping exercise in Section 5.5 to characterize the development and diffusion system for moving from research to diffusion. These outputs are prioritized and assessed in the same manner as described in Section 5.2 and placed in the output summary Table 5.1.

## 5.7. Main outputs from this chapter

The outputs from the Sections 5.3 to 5.6 provide a list of activities in the format of Table 5.1 that have been prioritized for each of the technologies and these are brought together in the overview Table 5.2 as shown below for the market and non-market short and medium to long term prioritized technologies for mitigation and adaptation. This table therefore amalgamates all the analyses undertaken for all the prioritized technologies.

The table illustrates how the activities which make up a national strategy across sectors and technologies, could be grouped to find those activities which need to be started in the short term from the current date and carried out within the next 5 years (green), activities which can be completed up to 10 years from the current date (yellow) and longer term activities which can be planned for completion within 15 years from the current date (blue). Such a system can indicate groupings of actions over the timescale. The table also provides an indication of the capacity needs in the country for carrying out the activities identified for technology development, deployment, and diffusion.

The table as it stands cannot accommodate the complexity of the individual activities under the headings nor the resources required and other details needed for the complete strategy. All the details were identified at the same time as the activities. These would be included in spreadsheets based on the output formats presented for Steps 1, 2 and 3, which would be supplied to participants as part of the TNA system. This would allow the stakeholders to provide an indication of total resources and time required. It would also allow participants to use the activities from Table 5.1, which have been prioritized and assessed, to explore the strategies emerging for the following:

- Strategies for accelerating R&D adaptation for short term technologies and for R&D and demonstration for medium to long term market and non-market technologies for mitigation and adaptation at the sector or national level, from Step 1.
- Strategies for accelerating deployment of market and non-market short term technologies either at the project, sector or national level, from Step 2 for mitigation and adaptation;
- Strategies for accelerating diffusion through overcoming barriers and system inefficiencies for short term market and non-market technologies for mitigation and adaptation at the sector or national level, from Step 3. A strategy for this stage may be prioritized as activities here may be low cost as barriers are removed.

Alternatively the activities can also be grouped in terms of the technologies, providing the following sub-strategies for both mitigation and adaptation; *these strategies or action plans, as well as capacity building aspects, apply directly to the prioritized technologies identified in Chapters 3 and 4 and can be specific to the technology to ensure its implementation:*

## Table 5-2 Main required enabling activities and capacity building activities

| Strategic Activity | Accelerating Innovation R&D | | | Acceleration of deployment at technology/sector level | | | | | Accelerating deployment and diffusion at system/national level | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Specific actions from analysis grouped under headings** | Adaptation to country conditions | For Pre commercial to market | For developing future new technologies | Information and awareness | 'New' technology familiarization | Training for skills for technology | Offset investment risk | Develop networks | Networks for markets adaptation and R&D | Organisational and behavioural change | policies and measures | Supporting actions for market e.g. Q&A, info | New financing models and sources | Overcoming barriers and inefficiencies | Capacity Building for skills | International links and partnerships, IPR |
| Sector A SHORT TERM Technologies | | | | | | | | | | | | | | | | |
| Highest priority (HP) Technology | | | | | | | | | | | | | | | | |
| Sector B SHORT TERM Technologies | | | | | | | | | | | | | | | | |
| HP Technology etc | | | | | | | | | | | | | | | | |
| Cross sectoral SHORT term technologies | | | | | | | | | | | | | | | | |
| Technology | | | | | | | | | | | | | | | | |
| Sector A MEDIUM to LONG TERM technologies | | | | | | | | | | | | | | | | |
| HP Technology | | | | | | | | | | | | | | | | |
| Sector B MEDIUM to LONG TERM technologies | | | | | | | | | | | | | | | | |
| HP Technology | | | | | | | | | | | | | | | | |
| Cross-sectoral MEDIUM to LONG term technologies | | | | | | | | | | | | | | | | |
| Technology | | | | | | | | | | | | | | | | |

1. a strategy for the short-term market and non-market prioritized technologies from Section 5.3-5.6;
2. a strategy for medium to long-term market and non-market prioritized technologies from Section 5.3-5.6;
3. a strategy for cross-sectoral market and non-market technologies (for both short or medium to long term from Section 5.3-5.6); and,
4. strategies for sector or technology activities common across the substrategies.

The strategies are characterized by the following components

- GHG reduction potential or adaptation potential for sectors covered;
- Financial resources required;
- Capacity building activities;
- Timeline;
- Monitoring, reporting and verifications; and
- Risks

Exact strategies for implementation will depend on development priorities and resources of the country as well as availability of international support. National strategies are discussed in the next chapter.

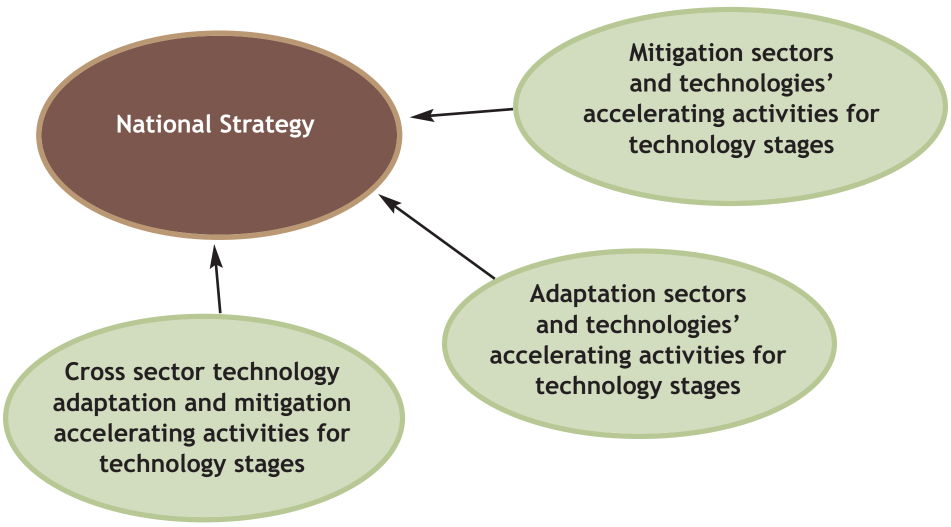
# 6. From Technology Needs to Technology Strategies

TNA results need to be fed directly into national visions and strategies for addressing mitigation and adaptation challenges, such as Nationally Appropriate Mitigation Actions (NAMAs) and National Adaptation Plans of Action (NAPAs) as well as for international funding support. The analysis carried out so far in Chapters 3, 4 and 5 has resulted in prioritization of technologies for mitigation and adaptation. The activities to support and accelerate their adoption at each main technology stage have been identified and characterized in terms of resources, timeline, risks and monitoring, reporting and verification activities to ensure progress is achieved.

In this final chapter, for the priority technologies in each sector, the activities to accelerate technology adoption are now aggregated across the technologies/sectors for mitigation and adaptation and structured to identify the elements of an overall strategy which either will be specific to the sector/technology or will be common across sectors and technologies at the system or national level. Sector or technology specific activities can be grouped separately and highlighted as separate strategies, and should already have been identified as described in the strategic outputs in Section 5.7.

The process is summarized in Figure 6.1 for the main elements of national strategies for accelerating technology innovation identified above, aggregated over the sectors and technologies for mitigation and adaptation.

**Figure 6-1. Main elements of national technology accelerating strategies.**




## 6.1. Developing a national strategy for acceleration of technologies

Developing a national strategy on technology transfer will involve three main considerations: a clear vision or set of objectives to be attained by the strategy; the elements of the strategy; and monitoring and evaluation to move the strategy towards reaching the objectives.

### Objectives for the national technology strategy for mitigation and adaptation,

The discussions in previous chapters have focused on the need to accelerate the three major stages of technology transfer. In forming a national strategy, though these are still the fundamental activities to be undertaken, it is important for the TNA team and stakeholder networks to determine where they want to be in the short, medium and long term on these priorities. To this end the stakeholder groups or representative stakeholder group need to revisit the development priorities identified in Chapters 3 and 4, and may wish to set up some aspirational targets at the sector or national level for their achievement. Whether or not interim targets or benchmarks are needed or can be set, this step refreshes the overall vision on development goals for which the national strategy is being devised.

### Elements in overall strategy for mitigation and adaptation

The activities to address these issues will have been identified in the process carried out in Sections 5.3-5.6 by the stakeholder groups. These activities were in the form of a prioritized set of activities forming a strategy for accelerating the different technology development stages (R&D, deployment and diffusion) for technologies for mitigation and adaptation with a short or medium to long term applicability, while distinguishing between market and non-market technologies, and considering cross-sector applicability.

The activities identified in Chapter 5 are now agglomerated across all technologies and sectors for mitigation and adaptation, and grouped under the general technology stage headings already used at the technology level analysis in Chapter 5, as shown in Figure 6.2 to form an overall strategy.

During this synthesis stage the group may discover overlaps to be resolved or new activities to be included. In general terms the following are suggested for structuring the overall strategy:

→ **Accelerating Development: Research and Development**

- Adapt existing technologies to country;
- Long term R&D for hard and soft technology;
- Pre-commercial to market (*e.g.*, demo/training);
- Technological capacity development and skills training;
- Offset investment risks;
- Develop national and international technology cooperation networks.

→ **Practicalities of deployment at technology level**

- Information and awareness raising;
- 'New' technology familiarization program;
- Technological capacity development and training for specific technology operation;
- Offsetting investment risk especially for programs of small scale;
- Develop and foster market and non-market innovation networks and public engagement processes.

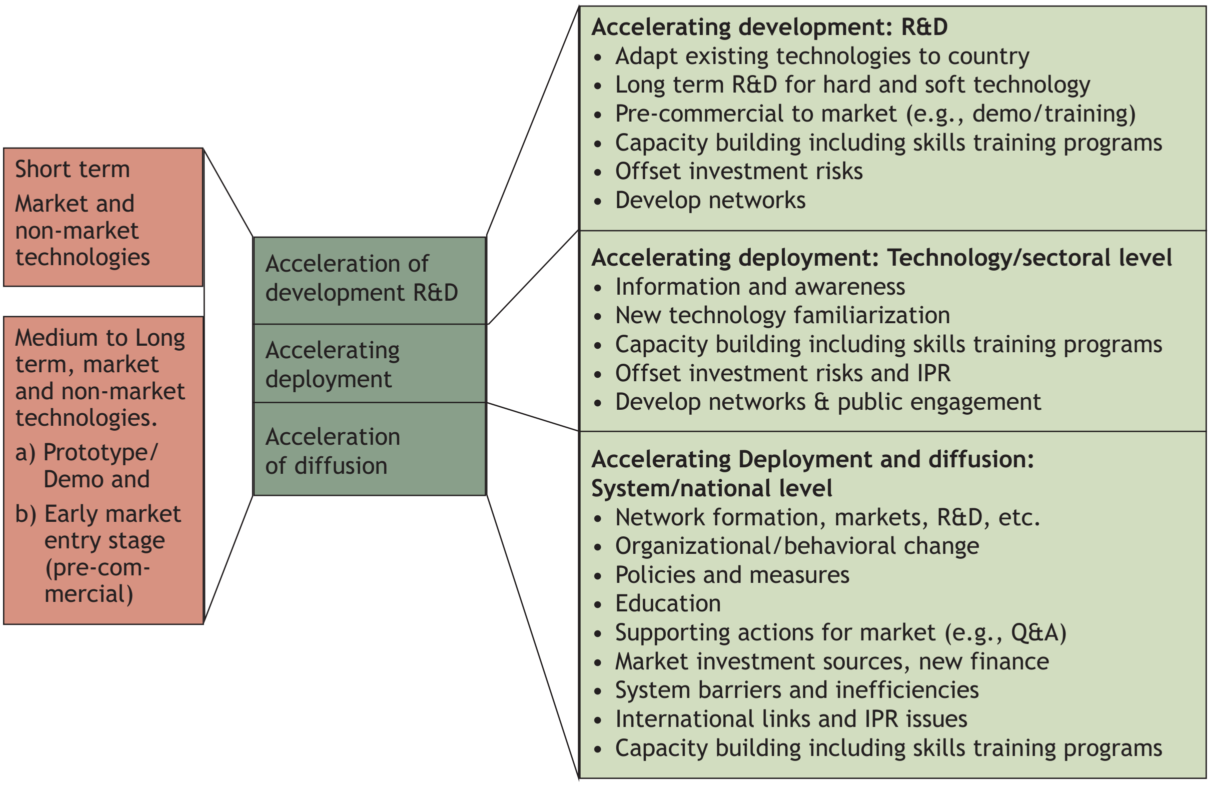
→ **Accelerating diffusion at system/national level**

- Develop and foster market and other national and international cooperation networks;
- Organizational and behavioral change activities (*e.g.*, transparency in governance practices);
- Policies and measures to overcome barriers, improve system and fill gaps;
- Supporting measures for the market to overcome constraints from inadequate Q&A, financing, market information services, etc.;
- Market chain support to overcome barriers on investment risks, finance sources and new models;

- Activities to address specific barriers and system inefficiencies in the overall system of transfer mapped by the groups;
- Capacity building for national technology capacity, training trainers and basic skills specific to technology and management;
- International links and partnerships and activities on IPR issues to overcome barriers on these issues.

The amalgamation process within and across sectors would be expected to reveal duplication in activities so that the coverage of the activity may change in terms of technologies to which it applies, the sectors affected, and the associated resources, but there will be no need to repeat activities so that the strategies can be rationalized.

**Figure 6-2. Main elements of national acceleration strategies for mitigation and adaptation and of capacity building**




## National Strategy: allocation of resources, and monitoring and verification needs

The activities identified by the stakeholder groups will have been prioritized into a strategy and action plan under each heading, as discussed in Chapter 5, identifying clearly:

**What should be done, why, who should do it, when and how it should be done along with estimated resource implications, timescale, MRV, and risks, so that progress can be monitored and activities changed if required, as in Table 5.1 and Table 5.2.**

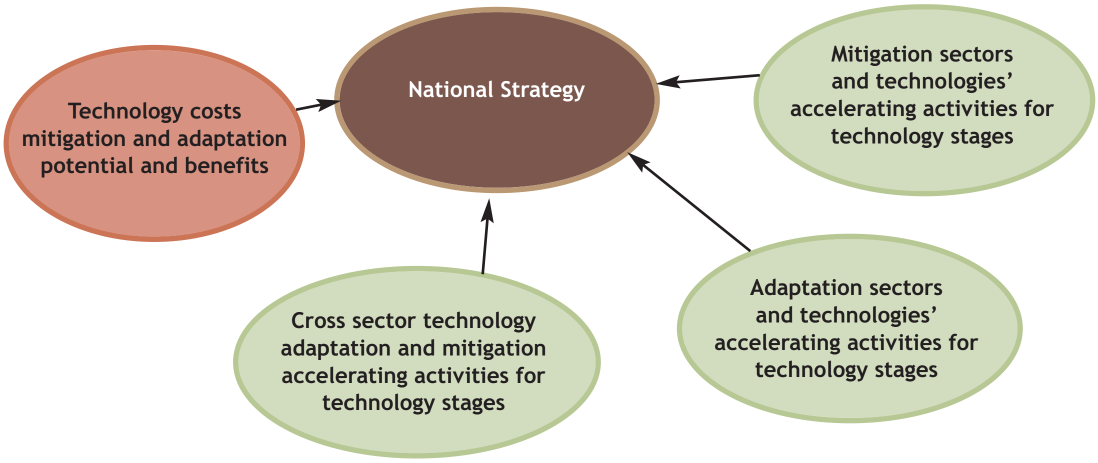
From this work, the activities for the main strategy elements identified can be characterized and summarized to provide information at the sector or national strategy level across the short and medium to long term prioritized technologies, cross-sectoral and non-market technologies for mitigation and adaptation, as well as information about capacity requirements to carry out the activities identified. Separate categories such as mitigation vs. adaptation can also be maintained.

Sector or technology specific strategies have been characterized separately in Section 5.7.

## 6.2. Developing combined technology implementation and acceleration strategies

In this section, we bring together the information on the technologies derived in Chapters 3 and 4 and the information on accelerating the technologies from Chapter 5 and Section 6.1 above to provide an overall implementation plan. This is shown schematically in Figure 6.3.

**Figure 6-3: Developing an overall national technology implementation and acceleration strategy**




### Mitigation or adaptation potential

From Chapter 3 and Tables 3.6 and 3.7 for the categorized small and large scale/short and medium to long term availability prioritized technologies and cross-sectoral technologies, the potential GHG mitigation for the technology in the sector is provided. Similarly, the adaptation potentials for the prioritized technologies are given in Tables 4.5 and 4.6. In both cases the figures can be used to provide information on the particular sectoral or national strategies being explored.

### Financial resources required

From Chapters 3 and 4, the total investment costs required for the technologies for the sectors have been estimated and to this can be added the estimated resource requirements from Chapter 5 (Section 5.7) for the activities making up the overall strategy for accelerating their development, deployment and diffusion.

This can provide an overall total estimated cost at the national level. Resource allocation decisions can then be made so that a work plan can be devised for an overall strategy at the national level made up of a combination of sectoral strategies across technologies and technology stages. Alternatively specific sectors can be targeted in the work plan. The outputs from this chapter and Chapter 5 will allow countries to explore possible ways forward at the technology, sector and national level.

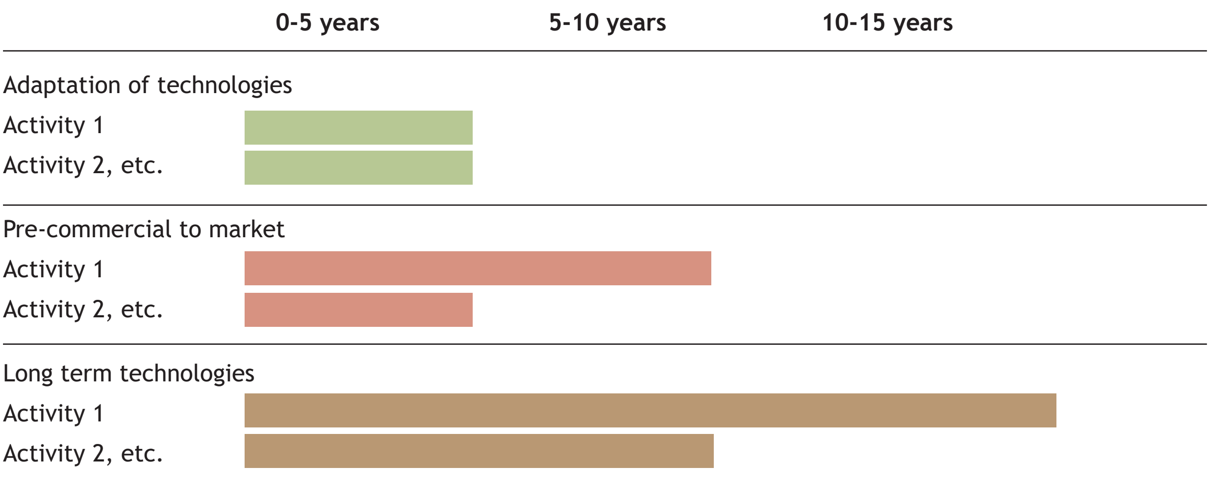
### Capacity development

As mentioned in Chapter 5 and this Chapter, the activities in the strategies identified relate strongly to capacity building in the countries at all the technology stages, and the capacity building components identified ('who' and 'how' and 'costs') can be combined to provide sectoral or overall national requirements for each stage, with costs.

### Timeline

Using the activity information within the overall strategy structure, or at the sector/technology strategy level, activities can be grouped in terms of a timeline for action within the next 5, 10 and 15 years. Table 6-1 indicates a possible way of doing this, but other database techniques can be applied.

**Table 6-1. RESEARCH AND DEVELOPMENT NATIONAL STRATEGY for Mitigation and Adaptation**




### Monitoring, reporting and verification actions

When launching a strategy at any level, it is important to ensure that appropriate monitoring, reporting and verification indicators/actions are put in place so that if the strategy is failing in some way, such as in terms of the implementation or financing, then monitoring can pick it up and adjustments can be made and lessons learned. Indicators/actions suitable for every activity were identified in Chapter 5, and can be combined as appropriate for any level of strategic action.

### Risks and uncertainty

The major assumptions on which the strategies have been characterized should be questioned and explored in sensitivity analysis, key defining risks identified, and measures to manage these risks considered. It should be noted that the costs and the mitigation potentials can only be estimated at this stage, and some indication of the uncertainty surrounding the figures should be given. Feedback from initial experiences in implementing technologies will be important in refining these estimates.

## 6.3. Development of projects or sector combined implementation and acceleration programs

Specific implementation of prioritized technology projects or programs can also be developed from the analyses undertaken. These may initially apply to the 'available in the short term' technology group in the relevant mitigation and adaptation sectors for market and non market technologies. The activities related to this group of technologies were identified and listed with the details of their implementation requirements in Section 5.3 and Table 5.1. Particularly the activities related to the 'adaptation to country conditions R&D' (Step 1a) and 'activities for acceleration of deployment' (Step 2) and 'activities for acceleration of diffusion' (Step 3) can be assembled. The deployment activities are supported by the activities identified for 'accelerating diffusion' in Step 3, so that an overall strategy can be compiled as described in Section 5.7, in terms of technology type or the technology stages for the activities to accelerate their innovation.

These acceleration strategies at the technology/sector level can be combined with the outputs of Chapters 3 and 4 where the main parameters associated with a particular technology can be isolated from Tables 3.6, 3.7, 4.5 and 4.6, along with its overall performance on GHG mitigation, reduction in vulnerability, estimated technology potential, costs and benefits.

By accessing the information at the technology or sector level, activities required for project level implementation of a technology or programs of technologies within or across sectors for mitigation or adaptation can be generated, along with their resource requirements and other information required for making decisions at the technology or sub-national level for allocation of resources.

## 6.4. Funding sources

From Sections 6.1, 6.2 and 6.3, as well as from Section 5.6, the following strategies have been devised:

- Strategies at the national, sectoral and technology level for acceleration of development, deployment and diffusion of prioritized technologies for mitigation and adaptation; and
- Strategies at the national, sectoral and technology level for combined implementation and acceleration of development, deployment and diffusion of prioritized technologies for mitigation and adaptation.

Low carbon technologies may in some cases be more expensive than high carbon counterparts and additional funding sources will be required for their implementation while other activities may even produce net savings. In practice, there will be a range of activities which will need to be undertaken, and information to be transferred to developers (see Box 5-1).

A very important source of information when seeking funding for technology transfer projects is "*Preparing and presenting proposals: UNFCCC Guidebook on Preparing Technology Transfer Projects for Financing*" which has been published by UNFCCC (2006). This guidebook assists project developers in preparing project proposals following a structured, step-wise approach. It helps with formulating a solid project proposal by first, guiding people through the process of composing a balanced project team with a clear division of tasks, which is followed by a clear explanation of the project characteristics:

- Where will the proposal be implemented?
- What is being proposed?
- Where will the proposal be implemented?
- Who will champion the proposal and see it to completion, and who else must be involved?
- How will the proposal be implemented?
- Why is the proposal important and why should it be supported?
- What if things do not go as planned?
- To whom is the proposal addressed?

The guidebook introduces important accounting and finance concepts and asks the project leaders to assess his or her experience base and motivation. It sets forth a step-by-step approach to the issues to be addressed and questions to be answered, followed by the requirements of getting a well-prepared proposal in front of the right audience. Finally, the guidebook addresses the needs of proposals specifically targeted to donors who require a logical framework presentation, carbon professionals who require special information, and proposals made to lenders and investors. In this respect benefit can be taken from the stakeholder networks already formed as part of the TNA process. In addition, most of the steps recommended by the Guidebook on assessing technology projects in terms of contribution to sustainable development, GHG emission reduction and cost and economic viability, have already been carried out under the TNA when prioritizing technologies for adaptation and mitigation.

Finally, Table 6.2 shows an example of a cost overview for a technology transfer project for the construction/pre-operations phase; similar tables are shown in the guidebook for the planning and permit acquisition and operational phases.

**Table 6-2. Example of a project cost overview construction/pre-operations phase**

| Construction/ pre-operations costs | Year -2 months 1-12 | Year -1 months 13-24 | Year 0 months 25-36 | Year 1 months 37-48 | Year 2 months 49-60 | Total |
|---|---|---|---|---|---|---|
| C1 Land acquisition | 240,000 | | | | | 240,000 |
| C2 Final engineering and design | 110,000 | | | | | 110,000 |
| C3 Machinery | 2,381 | | | | | 2,381 |
| C4 Machinery | | 200,000 | | | | 00,000 |
| C5 Machinery | | 111,000 | | | | 111,000 |
| C6 Machinery | | 22,333 | | | | 22,333 |
| C7 Testing | | | 300,000 | | | 300,000 |
| C8 Testing | | | 33,333 | | | 33,333 |
| *Subtotal* | *352,381* | *333,333* | *333,333* | | | *1,019,047* |
| C9 Annual interest during construction (5%) | 17,619 | 16,667 | 16,667 | 0 | 0 | 50,952 |
| Total | 370,000 | 350,000 | 350,000 | 0 | 0 | 1,070,000 |

## 6.5. TNA National Synthesis Document

This section focuses on reporting requirements combining all the outputs from each of the chapters.

### Aim of the TNA report

The aim of reporting the results of the TNA process is to summarize the outputs of the process in a coherent, policy-relevant document that provides a basis for follow-up implementation activities. The national synthesis report should be a well-edited and comprehensive report suitable for presentation to policy makers and members of the international donor community considering technology transfer possibilities.

The national synthesis report should also follow a specific format in order to facilitate country comparisons. It is strongly recommended that an 8-part synthesis report, as described below, be prepared. An annotated outline of the report structure is provided below, together with suggested page lengths which can be considered minimums.

### Executive Summary

This would be a standard executive summary following conventional protocols on depth of coverage and length. Its aim is to present the key findings of the assessment without copying and pasting from the main report, and is meant to be digested within no more than a 30-minute period. The Executive Summary is very important and should provide a sense of "national actions" to move forward. Specifically, the following items should be addressed:

- Overview of development priorities and climate change impact scenarios for the country;
- Justification of the priority sectors selected;
- Overview of the status of technologies currently in use in the priority sectors from mitigation and adaptation perspectives;
- Discussion of the evaluation criteria used to develop the ranked list;
- A summary of the priority technologies selected in each of the four categories, small and large scale, short and medium to long term availability, together with a tabular summary of key characteristics on mitigation or adaptation potential, investment costs and benefits as in Tables 3.6 and 4.5 for mitigation and adaptation technologies and Tables 3.7 and 4.6 for cross-sectoral technologies;
- Overviews of activities for accelerating development, deployment and diffusion of priority technologies available in the short and medium to long term within sectoral and national strategies, grouped under the technology stages, with GHG mitigation and adaptation potentials, resource requirements, timelines, capacity building requirements and monitoring, reporting and verification indicators/actions defined;
- An overview of ways forward for national strategies.

The intent is for the Executive Summary to ultimately be incorporated into the web-based technical support platform. This will allow for cross-country comparisons, aggregation, and/or disaggregation based on the information contained in the summary from each of the country TNA reports. A page length of 2-3 pages is recommended.

### Main Report

The main report should be based mainly on the outputs specified within each chapter of the handbook. These will have been collated within the TNA support systems in databases which can be accessed and analyzed for the TNA process, so that this stage should not be onerous. At all stages the TNA outputs are transparent and accessible.

1. **TNA process overview (3-5 pages)**

    This section should discuss the process followed by the country team in undertaking the assessment. It should address the fundamental objectives of the effort, preferably in a way that links it the COP decisions as well as to operational guidance provided by the UNFCCC Secretariat and EGTT.

    It should also address the process by which stakeholders were identified, recruited, and engaged throughout the process, including a list by stakeholder type (it will be important to be able to show that the process was inclusive), and distinctions between mitigation and adaptation processes (from Chapter 2).

    Finally, this section should describe the major steps followed in conducting the TNA process **including any climate change impact scenario studies**. This need not be in great detail but should make clear that the process was embedded in a multi-stage process, the origins of which were based on guidance provided by identified sources. A page length of 3-5 pages is recommended.

2. **Key sectors & technologies (3-5 pages)**

    This section should discuss the scope of the assessment, namely the sectors that have been considered, for mitigation and adaptation. The discussion of these sectors should focus first on the development context and priorities identified in order to provide background regarding the sector-specific plans and priorities currently in place and into which new, environmentally friendly technologies would be introduced.

    The discussion should then cover the prioritization process adopted with the criteria used and the output of the assessment made for the identification of priority sectors. The section should also include a detailed review of the key sectors themselves, with the discussion focusing on technology-related aspects (*e.g.*, types/vintages of technologies in use, and plans, if any, for bringing specific technologies online) based on the outputs from Chapters 3 and 4, particularly Tables 3.3 and 4.2. A length of 3-5 pages is recommended.

3. **Technology prioritization (10-15 pages)**

    This section should be the audit trail for the MCDA exercise, defining the criteria used, the value tree, the scores and justification for the scores on the criteria, the weightings derived and their justification, followed by the initial results and subsequent sensitivity analysis, to explore the uncertainties and differences in perspectives and identify robust priority technologies.

    The section should also include a tabular summary of the priority technologies for each of the categories, with the total GHG reduction/adaptation potential for technology in the sector, and total investment costs and benefits from the MCDA exercise, as in final Tables 3.6 and 4.5 for mitigation and adaptation in Chapters 4 and 5. Similarly the cross-sectoral technologies with the costs benefits and potential from Tables 3.7 and 4.6 should also be included. A page length of 10-15 pages is recommended.

4. **Enabling frameworks and strategies (8-10 pages)**

    This section should discuss the results from Chapter 5 in terms of the activities for strategies at the sectoral and overall national level for the technology stages of development, deployment and diffusion, for the future transfer of the priority technologies and their penetration in the national economy. Tables 5.2 and 5.3 provide overall summaries of the outputs of the analysis but it will be important to also document the outputs from the Steps 1-3, showing the detailed activities associated with the technologies in the categories of short and medium to long term as well as non-market technologies for the sectors. The possible strategies emerging from this set of accelerating activities should also be documented as in Section 5.6. A page length of 8-10 pages is recommended.

5. **From technology needs to technology strategies and work plan (5-8 pages)**

   In Chapter 6, the common elements in a national technology strategy derived from Chapter 5 are summarized and key information on resource requirements, timelines, capacity requirements and monitoring, reporting and verification indicators/actions for the strategies is aggregated so that decisions can be taken on resource allocation for a follow-up work plan on acceleration of the technologies/sectors. Possible plans could then be devised, if required, by combining these resource requirements for acceleration with those at the technology/sector level from Chapters 3 and 4. This can provide strategies at the sectoral or national level for the technologies for implementation and acceleration, as well as technology implementation level strategies. Mitigation and adaptation technologies can be aggregated or kept separate. A page length of 5-8 pages is recommended.

6. **Final conclusions & recommendations (1-2 pages)**

   This section should be brief and highlight the main conclusions and recommendations of the assessment. A page length of 1-2 pages is recommended.

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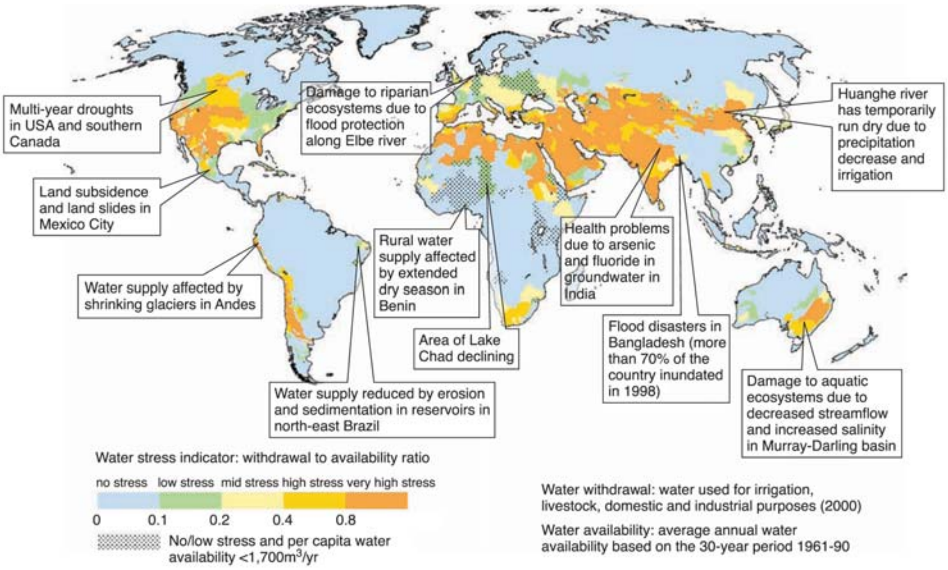
# Annexes

# Annex 1 Technical Annexes to Chapter 3 and 4

## Annex 1-1. Impacts of climate change on national sustainable development (Section 3.2)

The IPCC Fourth Assessment report for Working Group II on impacts highlighted the range of effects climate change could have on nations' ability to attain sustainable development. This is presented in Figure A1-1 below.

**Figure A1-1. Range of effects of climate change on nations' ability to attain sustainable development**




Looking specifically at the problem of water, the IPCC FAR report produced figures for water runoff, which indicate the severity of some of the changes expected. This work did not use the worst-case scenarios for emissions, which is the current level of global emissions (see Figure A1-2).

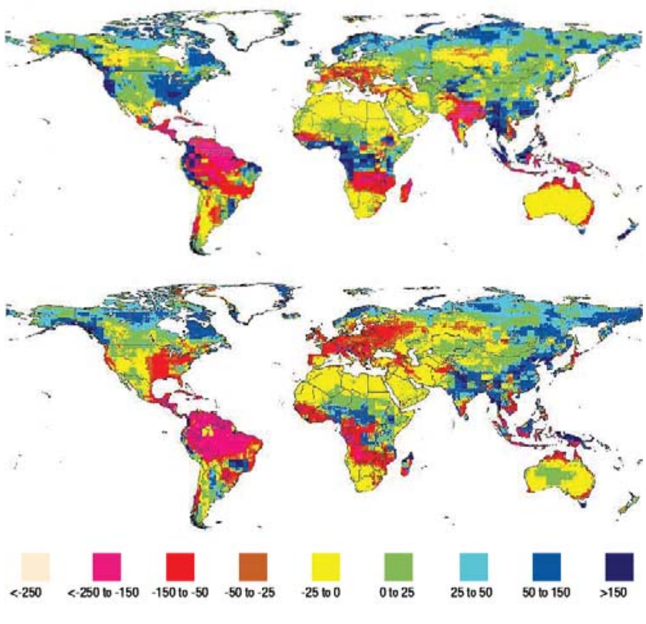
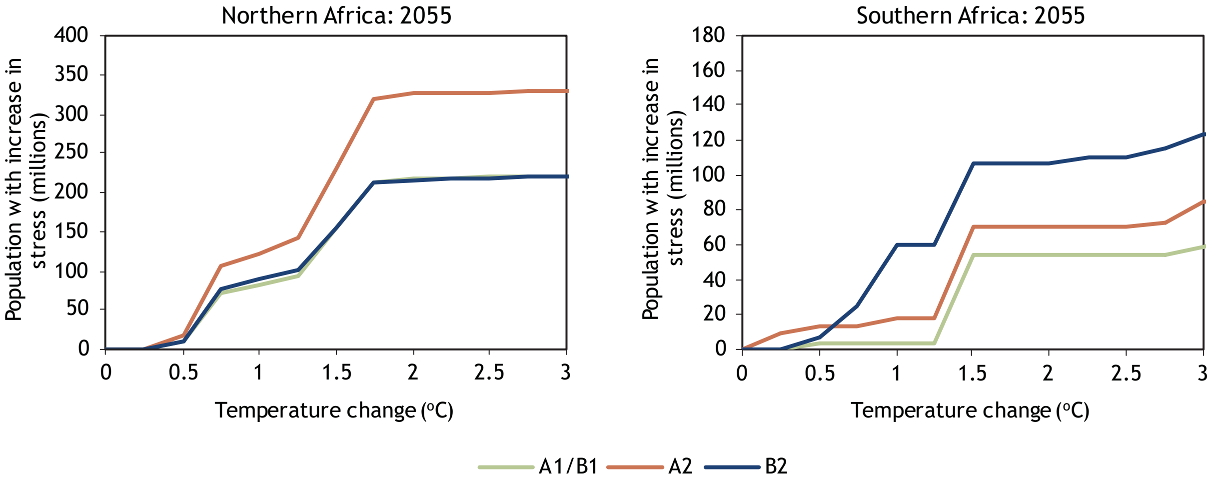



**Figure A1-2. Projected changes in average annual water run-off by 2050 (compared to 1960-90)**

Some regional estimates of impacts have also been reported in IPCC (2007), for Africa, Asia, South America, Small Island States and other regions. Figure A1-3 shows the number of people affected by the increases in water stress predicted in Africa. However, as the map above shows, these effects will not apply just to Africa, but also to many other developed and developing countries.

**Figure A1-3. Number of people (millions) living in watersheds exposed to an increase in water stress, compared to 1961-1990 (Arnell, 2006).**[15]




Coastal Effects are also of concern, with sea level rise projected to be higher and faster than predicted in IPCC (2007), according to more recent observations. The IPCC FAR report provides this risk map on the vulnerability of coastal deltas.

**Figure A1-4. Relative vulnerability of coastal deltas as indicated by the indicative population potentially displaced by current sea-level trends to 2050 (Extreme > 1 million; high 1 million to 50,000; medium 50,000 to 5,000)**


[15] Water-stressed watersheds have runoff of less than 1,000 $m^3$/capita/yr. Populations are exposed to an increase in water stress when runoff is reduced significantly due to climate change. Scenarios are derived from HadCM3, and the red, green and blue lines relate to different population projections. Note that projected hydrological changes vary substantially between different climate models in some regions. The steps in the function occur as more watersheds experience a significant decrease in runoff (IPCC, 2007, WGII Figure 9.3).

## Annex 1-2. General identification of (sub)sectors for Chapter 3, Step 2.

In this sub-step, the stakeholder groups prepare an initial overview of (sub)sectors in the country. This initial assessment should involve the collection of existing data and information. It does not necessarily involve research to collect new data and information, which, in fact, should be avoided because of cost implications.

### Sectors

Different countries divide their sectors in different ways, and further on in this appendix some examples are given. It is recommended, however, that for this step the sector identification is used as in the Working Group III Report "Mitigation of Climate Change" of the Fourth IPCC Assessment Report (IPCC, 2007):

- Energy Supply;
- Transport and its infrastructure;
- Residential and commercial buildings;
- Industry;
- Agriculture;
- Forestry;
- Waste management.

The advantage of using the IPCC sector identification is that it is based on the generally high relevance of these sectors for mitigation policies.

Obviously, a country's National TNA Team together with the stakeholder groups, could decide to add some further sectors, depending on the importance of the sector in terms of GHG emissions within the country context, such as for example:[16]

- Services;
- Tourism;
- Government.

### Sub-sectors

Subsequently, these sectors could be divided into subsectors. Taking ***Industry*** as an example, this division could be as follows:

- Chemical;
- Iron and Steel;
- Cement;
- Waste processing;
- Petrochemical refineries;
- Manufacturing (e.g., cars, technologies);
- Coal Mining.

**Output:** A list of (sub)sectors for the country.

[16] As an alternative, McKinsey (2009) identifies five main clusters of sectors: Power, Emission Intensive industries, Buildings and appliances, Transport, and Agriculture and Forestry.

## Annex 1-3. Screening of sectors on GHG emissions for Chapter 3, Step 2

The urgency of mitigating GHG emissions means that screening sectors on the basis of GHG emissions before prioritizing on the basis of development priorities is important to maximize benefits from the investment. The information will be collected as follows (this can be carried out by the National TNA Team):

With the current urgency to act to mitigate GHG emissions and minimize risks of severe climate change, it will be important to characterize sectors in terms of GHG emissions, and to give an initial overview of the contribution of sectors to the total national inventory of GHG emissions.

In this respect, it is important that the stakeholder group discussions also involve representatives of sectors that contribute highly to the national GHG inventory. The sector-wise GHG emission data collection and analysis process will be as follows:

- ***Review national GHG inventory:*** It is important to first review the country's GHG inventory, established as part of the National Communications process, to identify relatively high GHG-emitting sectors that may have significant mitigation potential, and to identify any data/information gaps. Given that for most countries the above sources are likely to be rather dated, the collection of information on new or emerging mitigation technologies is highly encouraged.
- ***Identify key GHG emitting sectors:*** This step involves an analysis of the interrelationships between emission sectors to identify potential synergies. For example, mitigation options in the transport sector can have implications for fuel production and consumption, and associated GHG emissions. Moreover, certain sectors can have important linkages with poverty reduction strategies identified in national Poverty Reduction Strategy Papers.
- ***Review Plans:*** This step involves a review of national and sectoral development plans and policies in the identified sectors. The aim is to develop an understanding of the expected future growth in GHG emissions, long term mitigation potential, as well as financial constraints that may impact on mitigation initiatives.

A suggested way of limiting the effort in this step could be to list (sub)sectors by taking the (sub)sector with the largest GHG emission share first, followed by the second-largest, etc., until a cumulative share of 75% of the country's overall GHG emissions has been reached. For these (sub)sectors the information on existing technologies and sustainable development impact could then be collected and summarized in Table Annex 1-3-1.

**Table Annex 1-3-1. 'STEP 3-GHG screening'**

| (sub)sectors (transported from TNAssess) | GHG emissions in year x (megatons $CO_2$-eq) | Percentage share of subsector in country's annual GHG emissions |
|---|---|---|
| Subsector 1 | | |
| Subsector 2 | | |
| Subsector 3 | | |
| Etc. | | |

**Output**: A description of GHG emissions in each of the sectors identified.

## Annex 1-4. Data collection needed for sector prioritization in Chapter 3, Step 3

### Characterizing (sub)sectors - the baseline sustainability situation for mitigation activities

In order to prioritize sectors in terms of contribution to sustainable development in the country, in each (sub)sector the 'baseline situation' is described, *i.e.*, what is the present status of the sector? This characterization requires two key information blocks:

1. **What are the existing technologies used in the (sub)sectors?**

Relevant information related to technologies currently used in the priority mitigation sectors should be collected and documented. For example, when describing the subsector 'electricity supply for urban areas', an inventory of the type, age, and performance characteristics of power stations and distribution network currently operating should be conducted. This description must also cover inefficiencies of the technologies used in the sector, in order to be able to assess improvements that could be brought by environmentally sound technologies.

2. **What impacts do the (sub)sectors have on the country's sustainable development and where could the largest improvements be achieved?**

With this question the analysis explores how the (sub)sectors, in the present situation, support the country's development priorities. For each of the *high level key objectives* identified in Step 1, the present impact of the sector could be described as follows:

- When a high-level key objective concerns **protection of the environment**, the information should provide a qualitative and, to the extent feasible, quantitative description of the sector's environmental impact in terms of pollution (air, soil, water), and use of natural resources.
- When a high-level key objective concerns **improvements in social structures**, the information should cover the importance of the sector in terms of employment, health, building of infrastructure, knowledge gathering, empowerment, etc.
- When a high-level key objective concerns **strengthening of the economy and economic structures,** the information should cover the importance of the sector for the country's overall economy or for the economy of a particular region within the country (should the sector mainly have a local impact) in terms of economic output (*e.g.*, percentage of GDP), import requirements, export opportunities, international capital flows, employment (see also under social impacts), etc.

Some high level objectives will involve more than one of these areas.

It is worth pointing out at this stage that though the sectors with high GHG emissions can be identified in this process, this picture only shows the currently high-emitting sectors. Therefore, since future development may favor other areas, this picture may change so that sectors not currently high emitters should be assessed for future plans as well.

This information should be gathered from existing sources and through a participatory process, with the involvement of relevant government departments, *e.g.*, industry and trade, sector representatives including hands-on managers, NGOs, and relevant industry and community representatives. Some of this information will already be available, but some will need to be gathered or will require input of local knowledge.

**Output**: This step produces a baseline description in terms of existing technologies and sustainable development contributions for the main GHG emission sectors.

## Annex 1-5. Appendix to Chapter 4, Step 2 — Sector identification and description for adaptation

### General identification of (sub)sectors

In this step, the National TNA Team prepares an initial overview of sectors that could provide the most effective actions in terms of adaptation. This overview will contain areas in which improvements would contribute to reducing vulnerability to climate change impacts, and sectors where behavioral change would reduce impacts. This initial assessment should involve the collection of existing data and information. It does not necessarily involve research to collect new data and information, and in fact such exercises should be avoided because of cost implications.

To facilitate this process, it will be important to identify these key sectors. This should be informed by existing vulnerability assessments, if they are available, or by the National Adaptation Program of Action (NAPA), if one was carried out. Sustainable development plans are also relevant here, and have to be reviewed in the light of climate impacts if this is not already included. National Communications to the UNFCCC will also be relevant to this exercise.

Possible areas to be identified for adaptation strategies are: **health** and **social systems**; **agriculture**; **biodiversity** and **ecosystems**; and **production systems** and **physical infrastructure,** including the energy grid.[17] This is one possible classification, but it is recommended here that sectors are first of all identified and characterized.

Different countries divide their sectors in different ways. One possibility is as follows:

- Energy;
- Industry;
- Transport;
- Built environment (Domestic, Commercial and Public);
- Agriculture forestry and fisheries;
- Waste management;
- Services;
- Tourism;
- Government;
- Finance;
- Water.

Subsequently, these areas or sectors could be divided into subsectors. Taking *Agriculture* as an example, this division could be as follows:

- Food production;
- Fisheries;
- Forestry production;
- Carbon storage;
- Bio-fuels.

For adaptation, the areas of interest tend to impact across these sectors in particular ways. For example, for agriculture, projected climate change may mean a water shortage and irrigation

[17] CEC, 2009.

problems with implications for the location of agriculture, crop yields and livestock. Extreme weather event risks will be increased, affecting crop production. The fisheries sector will be affected both by acidification of the oceans and the warming of the oceans leading to further stress on marine ecosystem health already vulnerable from pollution and overfishing. Knock-on effects on human health and biodiversity are clear, and it will be important to account for all the direct changes within a sector and the implications for other sectors.

**Output:** A list of (sub)sectors.

## Annex 1-6. Data collection for Chapter 4 (Step 3): characterizing (sub)sectors — the baseline sustainability situation for adaptation activities

For adaptation, there are two main areas of concern:

- **Areas vulnerable** to climate change where climate change impacts are expected, and
- **Behavioral changes** to adapt to climate change.

The preliminary assessment of the current status of sectors should be carried out by the National TNA Team assisted by the stakeholders and it should focus on those two areas, encompassing sectors that are considered to be most vulnerable to the impacts of climate change, and sectors or areas where behavioral change can enhance resilience.

The overall output of Step 2 will be an assessment of how adaptation measures in the sectors identified above will contribute to the country's sustainable development, and, given that assessment, which (sub)sectors would provide the strongest sustainable development and resilience benefits. In order to be able to do such an assessment, in each (sub)sector the 'baseline situation' is described, *i.e.*, what is the present status of the sector? This characterization requires several key information blocks:

1. Existing climate vulnerabilities in the sectors and existing technologies or measures for adaptation used in the (sub)sectors if any;
2. Adaptive capacity in terms of ability to withstand projected climate change effects;
3. Cross-cutting issues and indirect effects on other sectors which need to be taken into account;
4. Impacts of the (sub)sectors on the country's sustainable development priorities.

This process of 'Identifying key vulnerable sectors' will also involve extensive stakeholder consultations within each of the sectors. This assessment is inevitably fraught with unknowns about the true extent and types of climate change impacts to be expected, as discussed in the earlier sections on climate change scenarios. It will therefore be important to have performed a vulnerability assessment, as described in Chapter 3.

This is not intended to be a long or complex task but rather a broad overview of the low carbon adaptation services which will need to be provided.

To do this the 'baseline situation' in each (sub)sector is described, *i.e.*, what is the present status of the sector? Key information required should cover the information blocks identified above:

- **Sector specific vulnerabilities and technologies/measures in use for adaptation —** Each sector should be considered in turn and the relevant information related to the vulnerabilities of the systems within the sector, (*e.g.*, the food production chain and the technologies including non-market technologies such as coping strategies, currently being used in the sectors should be collected and documented. This aspect of the assessment is particularly dependent on the stakeholder group for local knowledge. For example, when describing the subsector food production, an inventory of the crop and animal production types, land use practices, irrigation practices and dependencies, energy requirements, inputs, (e.g., animal feed, locations and soil conditions, etc.), should be conducted. This description should identify clearly where the vulnerabilities of the sector lie, together with an indication of how to improve resilience, either through hard or soft technologies. This assessment is inevitably based on scenarios approach projecting the types and extent of climate change impacts, and the rate of change, as well as where it is likely to impact, as discussed earlier.

- **Adaptive capacity of vulnerable sectors —** Each sector can be then be examined in the light of the above to identify where the effect on some systems will be more serious than others, either due to the presence of a wide range of alternatives or through innate resilience in the systems, or through available adaptive measures and technologies, *e.g.*, alternative varieties of crops.
- **Cross-cutting issues and indirect impacts on other sectors —** Subsequently, cross-cutting issues can be identified which are generally relevant to all sectors, such as impacts of poverty and impacts on poverty alleviation efforts. With these impacts, an indication of the sustainable livelihood situation is obtained, i.e., what are the interrelated influences that affect how people, particularly rural, poor people, create livelihoods for themselves and their households. Much of this will have emerged during the discussions on the specific sectors, but further consideration can be given to activities which would benefit several sectors at once. Indirect impacts and vulnerabilities, along with possible adaptation measures, should be discussed by the stakeholder groups to augment and develop the outcomes from the sector specific considerations.
- **Indirect sustainable development impacts** (M*uch of this may already be available from* Annex 1-4).
    - **Environmental impacts**: this information includes a qualitative and, to the extent feasible, quantitative description of the sector's environmental impact in terms of pollution (air, soil, water), and use of natural resources.
    - **Key social impacts**: this information covers the importance of the sector in terms of employment, health, building of infrastructure, knowledge gathering, empowerment, etc.
    - **Key impacts on economy**: this shows the importance of the sector for the country's overall economy, or for the economy of a particular region within the country (should the sector mainly have a local impact), in terms of economic output (*e.g.*, percentage of GDP), import requirements, export opportunities, international capital flows, employment (see this also under social impacts), etc.

This information should be gathered from existing sources and through a participatory process with the involvement of relevant government departments, e.g., industry and trade, sector representatives including hands-on managers, NGOs and community representatives. Some of this information will already be available, but some will need to be gathered or will require input of local knowledge. The information can be summarized and collected in a worksheet showing for each sector and subsector what the direct vulnerabilities are, any existing coping strategies or technologies, adaptive capacity in terms of the resilience of the existing system, and indirect effects, as well as an indication of the measures which could be applied. This can be done, if necessary, for a range of scenarios on possible climate changes.

## Annex 1-7. First prioritization of mitigation technologies before MCDA only if numbers are large (Chapter 3 — Step 5)

In Step 3 of Chapter 3, priority sectors/areas have been identified by exploring how investments in low carbon technologies would improve the situation beyond the baseline situation in these sectors/areas. Improvements have been expressed in terms of development priorities, and GHG emission reductions and other environmental impacts, as well as economic and social impacts. In Step 4, potential technologies have been identified and categorized for the priority sectors/areas, and with the help of a number of activities and the *TechWiki*, a familiarization with 'new' technologies has taken place. The result is a set of technologies categorized per priority sector/area, and in terms of their applicability in time and scale.

In Step 5, these technologies will be prioritized using the MCDA, as outlined in Annex 5. However, in order to keep the MCDA manageable, it is recommended that the number of technologies in each of the four categories for a subsector (i.e., small scale/short term, small scale/long term, etc.) should not be larger than 10 (i.e., 40 total over the 4 categories). If for all categories for all sectors, the number of technologies would be smaller than 10, then this step can be skipped, and this is preferable. In other cases, for the categories with more than 10 technologies a pre-screening will be carried out on the basis of the following criteria:

- Technical potential of technology;
- GHG abatement potential of technology;
- Costs (USD/ton; IRR) of technology;
- Contribution to key development priorities of technology.

For each technology, stakeholders could indicate the contributions to these criteria through the following rating scheme:

1 — very small contribution;

2 — small contribution;

3 — medium contribution;

4 — large contribution;

5 — very large contribution.

These ratings can be inserted in the worksheet in the CD-Rom.

**Output**: Background information on sectors, on existing technologies used in the sectors, and impacts on the country's sustainable development

## Annex 1-8. First prioritization of technologies for adaptation before MCDA, only if numbers are large (Chapter 4 - Step 5)

In Step 3 of Chapter 4, priority sectors/areas have been identified by exploring how investments in technologies for adaptation would improve the situation beyond the baseline situation in these sectors/areas. Improvements have been expressed in terms of development priorities, and adaptation benefits and other environmental impacts, as well as economic and social impacts. In Step 4, potential technologies have been identified and categorized for the priority sectors/areas and with the help of a number of activities and the TechWIKI, a familiarization with 'new' technologies has taken place. The result is a set of technologies categorized per priority sector/area, and in terms of their applicability in time and scale.

In Step 5, these technologies will be prioritized using MCDA, as outlined in Annex 5. However, in order to keep the MCDA manageable, it is recommended that the number of technologies in each of the four categories for a subsector (i.e., small scale/short term, small scale/long term, etc.) should not be larger than 10 (i.e., 40 total over the 4 categories). If for all categories for all sectors, the number of technologies would be smaller than 10, then this step can be skipped, and this is preferable. In other cases, for the categories with more than 10 technologies, a pre-screening will be carried out on the basis of the following criteria:

- Technical potential of technology;
- Increased adaptation resilience;
- Costs (net present value; internal rate of return) of technology;
- Contribution of technology to key development priorities.

For each technology, stakeholders could indicate the contributions to these criteria through the following rating scheme:

1 — very small contribution;

2 — small contribution;

3 — medium contribution;

4 — large contribution;

5 ±- very large contribution.

These ratings can be inserted in the worksheet in the CD-Rom.

**Output:** For those categories in Step 4 with more than 10 technologies, a prescreening has taken place, so that for these categories 10 technologies at most result.

# Annex 2 Mitigation & adaptation technology options

## Mitigation technologies

Below is a list of technologies which are arranged firstly in terms of energy service, then renewables/fossil/energy saving, etc. The list also indicates whether technologies are small ("S") or large ("L") scale, and available in the short, medium or long term. Technology descriptions are included to clarify the particular form of the technology. For those technologies which may apply to more than one energy service, these are duplicated in the list to make sure they are not omitted.

By applicability of a technology in the **short term** is meant that it has proven to be a reliable, commercial technology in a similar market environment. The technologies in the **medium term** would be pre-commercial in that given market context (5 years to full marketing) and a **long term** technology would still be in an R&D phase or a prototype.[18] By small scale technologies are meant those that are applied at the household and/or community level, which could be scaled up into a program. For the sake of simplicity all technologies applied on a scale larger than household or community level are considered large scale technologies.

| Energy service | Category | Technology | Small / large scale | Short, medium or long term potential |
|---|---|---|---|---|
| Electricity production | Renewable technologies | Micro-cogeneration systems for heat and power (1 kw, could be based on green gas) | S | Short |
| | | Ocean, wave and tidal energy | S-L | Medium |
| | | Energy towers | L | Long |
| | | Wind turbines (onshore, offshore) | S-L (on) and L (off) | Short (on), short to medium term (off) |
| | | Geothermal electricity production | L | Short |
| | | Biomass – dedicated, co-firing, integrated gasification combined cycle | L | Short to medium term |
| | | Biomass Combined Heat and Power | S-L | Short |
| | | Green gas (biogas from biomass purified to give calorific value = natural gas) for heat and power | L | Medium term |
| | | Solar Thermal – CSP; Central Receiver tower, parabolic trough collector and dish | S-L | Short to medium |
| | | Solar Photovoltaic - Single Axis Flat Plate, concentrating, BIPV, grid-connected, stand-alone | S-L | Short |

[18] It is noted here that the terms short, medium, and long term are context-specific. Technology that is fully commercial in some markets may not be a commercially viable technology in another country or market. For example, utility scale wind power is a demonstrated commercial technology, but in smaller, isolated markets (even where there is a good resource) the technology may not be truly "commercial". Therefore, the short, medium, and long term applicability has to be defined specifically for each country.

| | | | | |
|---|---|---|---|---|
| | | Hydro dams for large scale electricity supply | L | Short |
| | | Small scale hydro energy | S | short |
| | | Run-of-river hydro for large scale electricity supply | L | Short |
| | | Electricity storage for intermittent - enhanced power quality, flywheels | S | Medium to long term |
| | | Pumped Storage Hydraulic Turbine Reversible | S-L | Short |
| | | Batteries | S | Short to long term |
| | | Hydrogen | S-L | Long Term |
| | | Solar Ponds (electricity and storage) | S-M | Short to Medium |
| | | Biogas from anaerobic digestion | S | Short |
| | | Biomass Gasification | S-L | Short |
| | | | | |
| | **Fossil energy supply** | Conventional natural gas combined cycle | L | Short |
| | | Micro generation combined heat and power (could be based on natural gas) | S | Short |
| | | Advanced natural gas combined cycle | L | Short |
| | | Conventional natural gas combustion turbine | L | Short to medium term |
| | | Advanced natural gas combustion turbine (Steam Injected Gas Turbine) | L | Medium to long term (developing countries) |
| | | Conventional oil combined cycle | L | Short |
| | | Advanced oil combined cycle | S and L | Short |
| | | Conventional oil combustion turbine | S and L | Short |
| | | Advanced oil combustion turbine | S and L | Short |
| | | Integrated coal gasification combined cycle – without $CO_2$ sequestration | L | Long |
| | | Supercritical pulverized coal steam cycle | L | Medium to long term |
| | | Ultra-supercritical pulverized coal steam cycle | L | Long term |
| | | Coal-mine/ coal-bed methane recovery | L | Short |
| | **Fossil energy supply/ Renewable technologies** | Combined heat and power (distributed energy; CHP in power stations/industry) Could be based on, *e.g.*, biogas, natural gas, green gas, | M and L | Short |
| | **Fuel cells** | Molten Carbonate Fuel Cells | S | Long term |
| | | Polymer Electrolyte Membrane (PEM) Fuel Cells | S | Long term |
| | | Direct Methanol Fuel Cells | S | Long term |
| | | Alkaline Fuel Cells | S | Long term |
| | | Phosphoric Acid Fuel Cells | S | Long term |
| | | Solid Oxide Fuel Cells | S | Long term |
| | | Regenerative fuel cells | S | Long term |
| Heating for domestic and industry | **Fossil fuels/ renewables** | Electric heating: controls, gas conversion | S | Short |
| | | High-efficiency furnaces and boilers | S | Short |

| | | | | |
|---|---|---|---|---|
| | | Micro-cogeneration systems CHP (1 kw; could be based on natural gas) | S | Short |
| | | Condensing boilers for space heating and domestic hot water | S | Short |
| | | Combined heat and power (domestic distributed energy; CHP in power stations/industry)<br>Could be based on, *e.g.*, biogas, natural gas, green gas, solar, wind | S and L | Short |
| | Renewable technology | Solar thermal flat plate – for hot water, hot air, cooling<br>For domestic (small scale) and industrial use (large scale) | S and L | Short to medium term |
| | | Energy Storage technologies for buildings/industry | S | Long term |
| | | Heat Pumps air or ground or water sourced for industry and residential sectors<br>(also in combination with heating and cooling; hot and cold water underground storage) | S | Short term |
| | | Biomass heating, wood pellets, district heating | L | Short |
| | | Green gas from biomass (caloric value = natural gas) for heat and power (green gas is upgraded from biogas, with a higher methane content; can be connected to natural gas grid) for, e.g., CHP (caloric value < natural gas); not grid-connected | S-L | Short to medium |
| | | Heat from tarmac on roads | S-M | Medium to long term |
| | Energy saving | Ventilation: Air-to-Air Heat Recovery, demand control systems | S | Short |
| | | Insulation – exterior wall systems | S | Short |
| | | High Efficiency heating, venting, and air conditioning HVAC), free cooling, plants | S | Medium to long term |
| | | Building orientation | S | Short term |
| | | Energy Storage technologies | S | Long term |
| | | Air-sealing | S | Medium to long term |
| | | Advanced glazing, triple or membrane technology | S | Short term |
| Cooling - climate control | Renewable technology | Solar thermal – water, flat plate, hot air, cooling<br>For domestic (small scale) and industrial use (large scale) | S and L | Short to medium term |
| | | Heat Pump ground air or water sourced (in combination with PV)<br>(also in combination with heating and cooling; hot and cold water underground storage) | S | Short term |
| | Energy saving | Air-sealing | S | Medium to long term |
| | | Façade technology: advanced glazing, shading, electro-chemical | S | Short to medium |
| | | Insulation – exterior wall systems | S | Short |
| | | Ventilation: Air-to-Air Heat Recovery, demand control systems | S | Short |

| | | | | |
|---|---|---|---|---|
| | | High Efficiency heating, venting, and air conditioning HVAC), free cooling, plants | S | Medium to long term |
| | | High Efficiency window unit air conditioners | s | Short |
| | | Cogeneration in combination with liquid-desiccant systems (for indoor humidity control) | s | Medium to long term |
| **Hot water in buildings** | **Fossil fuels/ renewables** | High-efficiency furnaces and boilers | S | Short |
| | | Condensing boilers for space heating and domestic hot water | S | Short |
| | | Solar thermal – water, flat plate, hot air, cooling<br>For domestic (small scale) and industrial use (large scale) | S and L | Short to medium term |
| | **Renewable technology** | Heat pump air or ground or water sourced<br>(also in combination with heating and cooling; hot and cold water underground storage) | S | Short term |
| **Lighting** | **Energy Saving** | Compact Fluorescent Light Bulbs and LEDs | S | Short term |
| | | Solar lanterns | S | Short Term |
| | | Light tubes | S | Short Term |
| | | Smart controls | S | Short Term |
| | | Day lighting and building design | S | Short term |
| **Demand-side management for Electricity** | **Energy saving** | "Smart" Appliances and Home Automation | S | Short |
| | | Electronic power supplies | s | Short |
| | | Compact fluorescent lighting, LED | S | Short term |
| | | Solar lanterns | S | Short term |
| | | Building Automation/ Management | S | Medium to long term |
| | | system optimization, improved enthalpy sensors | | |
| | | High Efficiency Refrigeration: multi-compressor control | S | Short |
| | | High efficiency PC monitors | S | Short |
| | | High efficiency televisions | S | Short |
| | | Variable Speed Motor Control (VFD) | S | Medium to long term |
| **Cooking** | **Energy saving** | Improved cook stoves | S | Short term |
| | **Renewable technology** | Cook stoves on ethanol/methanol | S | Short term |
| | | Biomass gasification stoves | S | Short term |
| | | Biogas from waste for cooking | S | Short term |
| | | Efficient Charcoal production for cooking | S | Short term |
| | | Solar cookers | S | Short term |
| | **Fossil fuel technology** | LPG and LNG for household and commercial cooking | S and L | Short term |
| **Industrial efficiency** | **Energy saving** | Energy saving in cement industry | L | Short to medium term |
| | | Energy saving in agri-food industry | L | Short to medium term |
| | | Energy Saving in Chemical Industry | L | Short to Medium term |
| | | Energy saving in iron and steel industry | L | Short to medium term |

| | | | | |
|---|---|---|---|---|
| Transport | **Energy saving / fuel switch** | Hybrid technology (cars, buses) | S | Short |
| | **Energy saving** | Vehicle add-on technologies (low friction oil, fuel-efficient tires) | S | Short |
| | | Black carbon control technologies (e.g., particulate traps) | S | Short |
| | | Vehicle technology improvements (e.g., aerodynamics) | S | Short to medium term |
| | | Freight logistics improvements / geographic information system (GIS) | S | Short |
| | | Truck stop electrification | S | Short |
| | | Driver information technologies | S | Short |
| | | Efficient diesel engines | S | Short |
| | | Management technologies (traffic signal synchronization, intelligent systems) | S | Medium to long term |
| | **Fuel switch** | Electric plug-in technology | S | Medium to long term |
| | | LNG technology | S | Short to Medium |
| | **Fuel switch / renewable technology** | Low carbon alternative fuels (cellulosic ethanol, biodiesel, algae) | S | Short |
| | | Hydrogen | S | Medium to long term |
| | **Fuel cells** | Molten Carbonate Fuel Cells | S | Long term |
| | | Polymer Electrolyte Membrane (PEM) Fuel Cells | S | Long term |
| | | Direct Methanol Fuel Cells | S | Long term |
| | | Alkaline Fuel Cells | S | Long term |
| | | Phosphoric Acid Fuel Cells | S | Long term |
| | | Solid Oxide Fuel Cells | S | Long term |
| | | Regenerative fuel cells | S | Long term |
| $CO_2$ Capture and Storage | **$CO_2$ capture** | Chemical absorption with monoethanolamine | L | Medium to long term |
| | | Oxygen-firing | L | Medium to long term |
| | | Integrated coal gasification combined cycle – with $CO_2$ sequestration | L | Medium to long term |
| | | Biochar (gasification of biomass through pyrolysis and mixing of residue with the soil) | S-L | Medium Term |
| Agriculture | **Renewable technology** | Improving Energy Capture from Corn and Biomass Heat | S and L | Short to medium term |
| | | Bagasse CHP | S and L | Short |
| | **Energy saving** | Urban Agriculture, Community Gardens, and Green Roofs | S and L | Short to medium term |
| | **Energy efficiency** | Improvements to Increase Water Conservation | S | Short |
| | | Nutrient Management | S | Short |
| | **Carbon sequestration** | Soil Carbon Management | S | Short |
| | **Energy efficiency / renewables** | Manure Management and Utilization | S | Short |
| Forestry | **Carbon sequestration / renewables (if sustainable source and used for energy)** | Improved Mill Waste Recovery | S and L | Short |

| | | | | |
|---|---|---|---|---|
| | Renewables (if sustainable source and used for energy) | Improved Logging Residue Recovery | S and L | Short |
| | Forest conservation<br>Energy efficiency | Silviculture Improvements<br>Other mill efficiency improvement technologies | S and L<br>S and L | Short<br>short |
| Waste management | Renewable technology | Landfill methane recovery and use for heat and power | L | Short |
| | | Municipal Solid Waste combustion for district heating or electricity | L | Short |
| | | Municipal Solid Waste gasification for large scale electricity or heat<br>Digesters for biogas and Turbines or Engines | L<br>S and L | Short to medium term<br>short |
| | | Recycled Bio-Oils | S and L | long |
| | Energy efficiency | Advanced Municipal Solid Waste Management Practices (including promotion of bioreactor technology) | S and L | Short to medium term |
| | | Source reduction strategies | S and L | Short |
| | | Resource Management Contracting | S and L | Short |
| | | Enhanced Management of Organic Waste | S and L | Short |
| | | Improved Commercialization of Biomass Conversion Technologies | L | Short |
| | | Wastewater Treatment Plant Biosolids for Energy Production | S and L | Short to medium |
| | Water efficiency | Waste water management/ metering | S to L | Short |
| | | Grey water use | S to L | Short |
| | | Lower consumption and waste production/ Efficient appliances | S to L | Short |

## Technologies for adaptation

Unlike mitigation, a similar set of technological options is difficult to develop for adaptation. This is due to the fact that essentially the boundaries between adaptation and sustainable development are blurred. Another difficulty at present is that the science and technology of adaptation is, in some respects, in an even earlier stage of development than that of mitigation, and there is less operational experience to go on. Moreover, what is required in the context of technologies for adaptation varies immensely between regions, countries and sectors. Nonetheless, a comprehensive list of technologies for adaptation is included in the future financing options report to SB: FCCC/SB/2009/INF.2.

A sample of adaptation technologies is given in the table below. As with the mitigation technologies, it is indicated whether technologies are small ("S") or large ("L") scale and availability in the short, medium or long term.

## Technologies for adaptation

Unlike mitigation, a similar set of technological options is difficult to develop for adaptation. This is due to the fact that essentially the boundaries between adaptation and sustainable development are blurred. Another difficulty at present is that the science and technology of adaptation is, in some respects, in an even earlier stage of development than that of mitigation, and there is less operational experience to go on. Moreover, what is required in the context of technologies for adaptation varies immensely between regions, countries and sectors. Nonetheless, a comprehensive list of technologies for adaptation is included in the future financing options report to SB: FCCC/SB/2009/INF.2.

A sample of adaptation technologies is given in the table below. As with the mitigation technologies, it is indicated whether technologies are small ("S") or large ("L") scale and availability in the short, medium or long term.

| Sector | Category | Technology | Small / large scale | Short, medium or long term potential |
|---|---|---|---|---|
| Coastal zones | Coastal topography and bathymetry | Mapping & surveying | S-L | short |
| | | Satellite remote sensing | S-L | Medium to long |
| | | Videography | S-L | Medium to long |
| | | Airborne laser scanning (LIDAR) | S-L | Medium to long |
| | Hard coastal protection | Dikes, levees, floodwalls | L | Short |
| | | Seawalls, revetments, bulheads | L | Short |
| | | Groines | L | Short |
| | | Detached breakwaters | L | Short |
| | | Floodgates, tidal barriers | S-L | Short |
| | | Saltwater intrusion barriers | S-L | Short |
| | Soft coastal protection | Periodic beach nourishment | S-L | Short |
| | | Dune restoration | L | Short |
| | | Wetland restoration | L | Short |
| Water resources | Supply side | Increase reservoir technology | L | Long |
| | | Desalinization | L | Medium to long |
| | | High efficiency irrigation systems | L | Short |
| | | Alternative system operating rules | S-L | Medium to long |
| | Demand side | Increase "grey-water" use | S-L | Medium to long |
| | | Reduce leakage in distribution systems | S-L | Short |
| | | Non-water-based sanitation | S-L | Short |
| | | Seasonal forecasting | NA | Short |
| | | Legally enforceable water standards | S-L | Short |
| | | Demand management | | |
| Agriculture | Crops | Drought-resistant crop varieties (biotechnology) | S-L | Long |
| | | Improved distribution systems | M-L | Medium to long |
| | | Crop rotation systems | S-L | Short |
| | | Agricultural research and development | S-L | Long |
| | | Gene technology | | |
| Public health | Thermal stress | Reduce heat island effect | S-L | Medium to long |
| | | Air conditioning | S | Short |
| | Vector borne | Vaccination programs | S-L | Short |
| | | Impregnated bed nets | S-L | Short |
| | | Sustainable surveillance | S-L | Short |
| | Water-borne | Genetic/molecular screening of pathogens | S-L | Long |
| | | Improved water treatment (e.g. filters) | | |
| | | Improved sanitation (e.g. latrines) | | |

# Annex 3 Technology Information Sources

A wide range of sources for technology cost and performance information exist. These include the literature of domestic and international equipment manufacturers, websites, and other outputs of international organizations and of developed countries, information sharing between developing countries, and materials developed by specialist consultancies and research organizations. A brief list of sources available on the Internet is provided below:

**Technology Transfer Information Clearinghouse, TT:CLEAR**
http://ttclear.unfccc.com/ttclear/security/UserLogin.jsp

TT:Clear is a web-based technology information clearinghouse developed by the secretariat of the United Nations Framework Convention on Climate Change, with support from Parties and the EGTT. It enables users to find information on:

- Technology transfer projects and programs
- Case studies of successful technology transfer
- Environmentally sound technologies and know-how
- Organizations and experts
- Methods, models and tools to assess mitigation and adaptation options and strategies
- Relevant Internet sites for technology transfer
- Ongoing work of the Parties and the EGTT such as issues under negotiation, documents and meetings, and implementation of the technology framework.

**Technology information sources (provided by CTI and USEPA)**

This brief list is intended as a starting point for research on the Web. These selected sites represent only a small portion of those available on the Internet.

**DOE/EERE-EPRI Technology Characterizations Report**
http://www1.eere.energy.gov/ba/pba/tech_characterizations.html

Dated, but comprehensive. Specific technology areas covered provide technical and performance related information.

**EERE databook**

Provides a number of good examples of how to display installed capacity and technology cost data graphically. Can be found in the second box under "features" at: http://www.eere.energy.gov/

**Global Network on Energy for Sustainable Development (GNESD)**
http://www.uneptie.org/energy/act/gnesd/

This network of ten centers of excellence in developed and developing countries promotes "research, transfer and take-up of green and cleaner energy technologies to the developing world." The site provides descriptions of programs and projects, publications, events and links to other sites.

**UNIDO/Cleaner Production Centre Program**
htpp://www.unido.org/de/doc/446

The UNIDO cleaner production (CP) program aims at building national CP capacities, fostering dialogue between industry and government and enhancing investments for transfer and development of environmentally sound technologies.

**Sustainable Alternatives Network (SANet)**
http://www.sustainablealternatives.net/

This site provides case studies, best practices information, planning tools, finance information, and a directory of experts.

**African Rural Energy Enterprise Development**
http://www.areed.org/

AREED supports new enterprises that "use clean, efficient, and renewable energy technologies to meet the energy needs of under-served populations." The site provides information on AREED services, including training, enterprise start-up support, as well as links to related sites.

**An Annotated Summary of Climate Change Related Resources**
http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterResourceGuide.html

"The information contained in this resource guide is intended to assist researchers and decision makers, particularly those from developing countries, in their efforts to develop, implement, and evaluate climate change programs and conduct climate change studies (e.g., emission inventories, mitigation assessments, vulnerability and adaptation analysis)."

**United Nations Development Program (UNDP):** http://www.undp.org/

**United Nations Environment Program (UNEP):** http://www.unep.org/

**United Nations Framework Convention on Climate Change (UNFCCC):** http://unfccc.int/

**United States Environmental Protection Agency (USEPA):** http://www.epa.gov/

**Financing Sustainable Energy Directory**
http://www.uneptie.org/energy/publ/sustfunds_files/sustfunds.htm

This directory is a listing of lenders and investors around the world that finance renewable energy and energy efficiency projects. Each entry includes the name of the lender, a brief description of the kinds of project the lender finances and contact information. There is also a list of other financing resources available on the Web.

The following online databases provide descriptions and contact information for suppliers of climate-related technologies and services around the world. These sites allow you to search databases by geographical region, technology classification, or company name.

**GREENTIE**
http://www.greentie.org/index.php

**James & James database of Renewable Energy Suppliers and Services**
http://www.jxj.com/suppands/renenerg/index.html

**Source Guides Renewable Energy Businesses in the World**
http://energy.sourceguides.com/businesses/index.shtml

The following sites provide information resources on technologies for adaptation for water resource management and drought response:

**http://www.cgiar.org**

"The CGIAR's research agenda focuses on both strategic and applied research. This agenda includes the entire range of problems affecting agricultural productivity and links these problems to broader concerns about poverty reduction, sustainable management of natural resources, protection of biodiversity, and rural development. More than 8,500 CGIAR scientists and scientific staff conduct research to improve the productivity of tropical agriculture. This research focuses on higher-yielding food crops and more productive livestock, fish, and trees; improved farming systems that are environmentally benign; better policies; and enhanced scientific capacities in developing countries."

**http://www.fao.org/agris/**

FAO: Center Information Management for International Agricultural Research: AGRIS/CARIS works on the development and strengthening of national agricultural information management programs using Internet-based technologies.

**http://www.fao.org/spfs/**

The Special Program for Food Security: "The Special Program for Food Security (SPFS) aims to help those living in developing countries, in particular the low-income food deficit countries (LIFDCs) to improve their food security through rapid increases in food production and productivity, by reducing year-to-year variability in food production on an economically and environmentally sustainable basis…"

**http://www.cimmyt.cgiar.org**

CIMMYT — International Maize and Wheat Improvement Center. The CIMMYT conducts "research on maize and wheat to help people overcome hunger and poverty and to grow crops without harming the environment". CIMMYT conducts research on two crops — maize and wheat — that provide about 25% of all food calories consumed in poor countries."

**http://www.cimmyt.cgiar.org/worldwide/CIMMYT_Regions/CIMMYT_Africa/index.htm**

This site lists a variety studies on how improved maize varieties help increase harvests in selected African countries.

**http://www.iita.org/**

IITA — International Institute of Tropical Agriculture: "The International Institute of Tropical Agriculture (IITA) was founded in 1967 with a mandate for improving food production in the humid tropics and to develop sustainable production systems. It became the first African link in the worldwide network of agricultural research centers supported by the Consultative Group on International Agricultural Research (CGIAR), now known as the Future Harvest Centers."

**http://www.icarda.cgiar.org/**

ICARDA — International Center for Agricultural Research in the Dry Areas: "ICARDA's mission is to improve the welfare of people and alleviate poverty through research and training in dry areas of the developing world, by increasing the production, productivity and nutritional quality *of food, while* preserving and enhancing the natural resource base. ICARDA is committed to the advancement of agricultural research; free exchange of… information for research; protection of intellectual property rights, including indigenous knowledge of farmers; human resources development; the sustainable use of natural resources; and poverty alleviation, particularly among women and children."

**http://www.icrisat.org/**

International Crops Research Institute for the Semi-Arid Tropics: "CRISAT's goal is to harness the power of technology for development, food security, poverty alleviation and environmental protection, targeted at poor rural families, and women in particular.

There are also a variety of useful publications to which the reader is referred, as follows.

**http://www.cgiar.org/iwmi/home/rainwater.htm**

Rainwater Management: Strategies for Improving Water Availability and Productivity in Semi-Arid and Arid Areas.

**http://www.iisd.org/pdf/cdmpfinalreport.pdf**

Case Study: Community Drought Mitigation Project in Zimbabwe.

**http://www.onu.org.cu/havanarisk/EVENTOS/cchange3/Doe.PDF**

Vordzorgbe, Seth D., Risk Management and Adaptation: Reflections with Implications for Africa, June 2002, presented at UNDP Expert Group Meeting "Integrating Disaster Reduction and Adaptation to Climate Change", Havana, Cuba, 17-19 June, 2002

**http://www.irc.nl/products/planotes35/index.html**

Case Studies: International Water and Sanitation Centre — Community Water Management. Covers topics such as participatory action development, women's involvement, watershed management, etc.

**http://www.rainwaterharvesting.org/**

Rainwater Harvesting: This CSE-sponsored site illustrates various rainwater harvesting methods according to the principle "catch water where it falls". Traditional harvesting methods are compared with modern techniques.

**http://www.rainwaterharvesting.org/methods/modern/gwdams.htm**

Groundwater Dams: Explanation and diagram of harvesting water through groundwater dams. Detailed description and illustration, including discussion of construction materials.

**http://www.cgiar.org/iwmi/pubs/pub037/RR037.htm**

Case Study: Farmer-based Financing of Operations in the Niger Valley Irrigation Schemes Case Study of a pump-based irrigation system in Niger Valley (AfDB project).

**http://www.cgiar.org/iwmi/challenge-program/pdf/paper1.pdf**

Ensuring Food Security via Improvement in Crop Water Productivity. This study suggests concepts to improve food security by increasing water use efficiency (WUE), i.e., "more crop per drop". Also discusses opportunities as well as limits of increased WUE.

**http://www.cgiar.org/iwmi/home/rainwater.htm**

Rainwater Management: Strategies for Improving Water Availability and Productivity in Semi-Arid and Arid Areas.

**http://www.iisd.org/pdf/cdmpfinalreport.pdf**

Case Study: Community Drought Mitigation Project in Zimbabwe: Also contains pictures of more efficient planting and irrigation methods and traditional crops.

**http://www.worldbank.org/html/cgiar/newsletter/Mar96/4cas2.htm**

Cassava, Africa's Food Security Crop: Promotion of Cassava to combat hunger and malnutrition in Africa.

**http://www.iita.org/research/high2000/proj6.htm**

Improving Cassava-based systems.

**http://www.iita.org/research/high2000/proj4.htm**

Improving Maize-Grain legume systems in West and Central Africa. Study discusses methodologies implemented to increase yields of maize. Successful field studies have been conducted in Africa and other countries.

**http://www.iisd.org/pdf/cdmpfinalreport.pdf**

Case Study: Community Drought Mitigation Project in Zimbabwe: Also contains pictures of more efficient planting and irrigation methods.

**http://www.worldbank.org/html/cgiar/newsletter/Mar96/4reeves.htm**

Developing Sustainable Maize and Wheat Based Production Systems: Prof. Reeves of the CIMMYT discusses characteristics of improved maize varieties.

**http://www.worldbank.org/html/cgiar/publications/issues/issues14.pdf**

Eicher, Carl K., Institutions and the African Farmer. September 1999. In the chapter titled *The New Era of Water Resources Management: From "Dry" to "Wet" Water Savings*, the author discusses ways by which real water efficiency can be achieved (a) Increasing the output per unit of evaporated water (b) Reducing water losses to sinks (c) Reducing Pollution of water, and (d) Reallocating water from lower valued to higher valued uses. He also talks about evapo-transpiration and seasonal crop coefficients.

# Annex 4 Some stakeholder engagement resources

Public participation is defined as: "forums for exchange that are organized for the purpose of facilitating communication between government, citizens, stakeholders and interest groups, and businesses regarding a specific decision or problem." (Renn, et al., 1995). This applies to the process needed to carry out the Technology Needs Assessment.

For the TNA process, it is likely that there will be a core group and subgroups to deal with specific issues in depth, with links to the core group. These groups should represent a network of technology transfer in the country, and should be maintained after the initial exercise is completed to take the implementation roadmap through to an implementation phase.[19]

The following list can only be an indication of some of the resources and techniques which can be used in order to address problems through a participatory decision process. However, it should provide a basic resource for following up on key aspects of these processes.

## A. Identification of relevant stakeholders for TNA exercise.

Stakeholder analysis is the usual first step in order to identify the people who will take the project forward, and it involves defining the groups/sectors from which stakeholders will be selected in order to have a representative group of people for the decision process.It is important to be clear that representation of the perspectives of those involved in and affected by a decision is required if robust processes and outcomes are to be produced.

The following links provide information on Stakeholder Analysis and other tools for selecting a group appropriate for the problem.

The Overseas Development Institute in the UK provides a range of tools at
**http://www.odi.org.uk/RAPID/Tools/Toolkits/Communication/Stakeholder_analysis.html**

and also refers to the following additional resources:
**http://www.stsc.hill.af.mil/crosstalk/2000/12/smith.html**

DFID Guidance note on how to do stakeholder analysis of aid projects and programs:
**www.euforic.org/gb/stake1.htm**

**http://www.scu.edu.au/schools/gcm/ar/arp/stake.html**

**http://www.scenarioplus.org.uk/stakeholders/stakeholders_template.doc**

## B. Participatory processes for eliciting knowledge

It is important to plan stakeholder meetings to maximize their usefulness and maintain engagement of participants. Time has to be used as efficiently as possible. The objective/s of the meeting must be clear and a plan for eliciting and structuring views is essential. The coordinators can either facilitate the meetings themselves or bring in an independent facilitator to help in the process. An audit trail of what was discussed and reasons for the basis of any decisions should always be written up after each event and circulated for feedback.

There are many approaches and the list below indicates a few of them which have proved useful, though to some extent it depends on the problem and the people involved.

---

[19] Renn, et al., 1995.

### 1. Market Mapping

This is technique particularly relevant to technology transfer and it has been applied in the ENTTRANS project. It allows an exploration of the market chain of market actors for the technology and the surrounding enabling business environment (in terms of policies and regulations, etc.) and the activities which support the market (e.g., professional consultancies, information exchanges, quality control standards, R&D, etc.). It therefore provides a detailed exploration for each technology of what the system problems are in terms of its transfer and integration into the country system, using information from the stakeholder groups. It was developed by Albu and Griffith (2005) in a developing country context for extending the sustainable livelihood approach to markets for rural farmers.

Albu, M. and A. Griffith, 2005, Mapping the Market: A framework for Rural Enterprise development policy and practice, Practical Action report.
**http://practicalaction.org/?id=mapping_the_market**

### 2. For a range of approaches of use for workshops and focused meetings:

**World café** for provides a very good set of methodologies to promote focused dialogue
**http://www.theworldcafecommunity.net/**

According to the website "World Café is an innovative yet simple methodology for hosting conversations about questions that matter. These conversations link and build on each other as people move between groups, cross-pollinate ideas, and discover new insights into the questions or issues that are most important in their life, work, or community. The integrated design principles provide creative ways to foster dialogue in which the goal is thinking together and creating actionable knowledge."

The **Involve** website also provides information on 'Promoting public Involvement' at
**http://www.invo.org.uk/Workshop_Reports.asp**

### 3. Specific Techniques

**Cognitive Mapping**: This helps to structure a problem and to start to see some solutions. At its simplest, it allows participants to explore a particular question by writing down their ideas on post it notes or similar and then everyone in turn places these on a board saying what it the idea is and why. The group is then asked to cluster the notes into themes which can then be further explored. Different approaches can be found at

**http://intraspec.ca/cogmap.php**

and a more complex approach is available at

**http://www.banxia.com/dexplore/pdf/GettingStartedWithCogMapping.pdf**

**H Form and Action Planning:** This is an approach which is a powerful way of investigating an issue through exploring a core question (e.g., How well does low carbon technology transfer function in this country?) Participants can explore what is good about the current system and what is poor, and from that derive actions to be undertaken to move forward.

The approaches to be used are fully explained in

Hunsberger, C. and W. Kenyon, 2008, 'Action planning to improve issues of effectiveness, representation and scale in public participation: A conference report', Journal of Public Deliberation, Vol. 4, No. 1, Article 1, 1-18, **http://services.bepress.com/jpd/vol4/iss1/art1**

Other well known processes include focus groups, citizen panels, sandpits for brainstorming.

**Delphi Techniques:** These were developed initially for forecasting, using expert input into problems, but they can be used in a simplistic form to explore judgments of groups and then compare them, to see where they agree and disagree and why, to converge on solutions. An introductory description can be found at **http://en.wikipedia.org/wiki/Delphi_method**

## C. Techniques for Supporting Decision Making

There are many methods for supporting a participatory group decision-making process. The advantages of the approaches listed and the approach recommended in TNAssess are that they: account for different types of knowledge (monetary and non-monetary, quantitative and qualitative data); consider seriously the issue of inter-generational equity; provide opportunities for learning during the appraisal process; ensure transparency of each step of the appraisal process; and have a strong element of public and stakeholder engagement.

The main approach being used in the TNA handbook and provided in TNAssess is **Multi- Criteria Decision Analysis.** It belongs to a family of approaches known as

**Multi Criteria Analysis** of which the most useful for complex problems involving multiple and conflicting objectives is a **Multi-Criteria Decision Analysis** approach with decision conferencing. This has its foundation in decision theory and therefore, performed properly, can provide a good basis for decision making. MCA techniques are described and assessed in DETR, (2000), Multi Criteria Analysis, Dodgson, J., Spackman, M., Pearman, A., & L. Phillips

**http://www.communities.gov.uk/publications/corporate/multicriteriaanalysismanual**

Other techniques, many based on MCDA, have been developed. These variations all involve wide participation and 6 techniques were recently reviewed in the 2007 report for the Sustainable Development Research Network in the UK. The techniques assessed are Social Multicriteria Evaluation, Three-stage multicriteria analysis, Deliberative monetary valuation, multicriteria mapping, Deliberative mapping, Stakeholder decision/dialogue analysis

SDRN Rapid Research and Evidence Review on Emerging Methods for Sustainability Valuation and Appraisal, Sigrid Stigl, Jan 2007

**http://sdrnadmin.rechord.com/wp-content/uploads/sdrnemsvareviewfinal.pdf**

For a detailed explanation of MCDA, see Annex 5

# Annex 5 The MCDA process

## Multi-Criteria Decision Analysis (MCDA) for selection of priority sectors (applicable to technologies for mitigation and adaptation, as well as sectors — for use in Chapters 3 and 4)

Where the analysis using a simplified approach is not leading to an easily justified prioritization of the sectors, then an MCDA approach can be taken. This will involve using all the development and GHG criteria together to judge the sectors.

### Multi-criteria decision analysis

This Handbook uses MCDA for prioritizing sectors and technologies/adaptation measures because it is the most appropriate approach for evaluation of problems involving multiple stakeholders, and trade offs between multiple and conflicting objectives, where assessments can be difficult to quantify and there is uncertainty. The technique is therefore appropriate to determine to what extent a sector maximizes GHG reductions and sustainable development priorities. MCDA has been applied to many problems. It is a mature technique grounded in Decision Analysis theory. Below, the MCDA method is described in further detail.

MCDA provides decision makers and other stakeholders with a framework around which they can structure their thinking. Above all it allows focused communication on a problem so that different perspectives and experiences can be applied to its solution. It is particularly useful where there is a complex problem with multiple and conflicting objectives, multiple stakeholders, uncertainty and possibly large amounts of information associated with it. It aids structured thinking, generates a shared understanding, allows negotiation within the group and develops a common purpose so that the group can agree on away forward.

MCDA uses criteria value functions and weightings, which are necessarily subjective concepts, requiring human judgment for their determination. It therefore acknowledges the fact that there is no such thing as an objective decision. These judgments are documented and made explicit and open, and can be subject to public scrutiny. In a cost-benefit analysis, judgments are not made explicit, though many are involved. For example, selecting system boundaries, discount rates, lifetimes and other assumptions in the analysis are less obvious, less public and more technical. The route from an objective performance measure to a value to a weighted value to a final result is clear in MCDA. The route in a cost-benefit assessment from a performance measure (e.g., GHG abatement of a project) to a monetary unit can be opaque (e.g., adding monetary value to human life or biodiversity protection).

### What an MCDA involves

MCDA should always be carried out with an independent facilitator (either from within or outside an organization) and by a group of stakeholders (preferably 8-10 but many more can be accommodated depending on the decision). This is called decision conferencing, and the process of managing the decision group is a vital part of the whole MCDA exercise. It is described in DETR (2000). Decision conferences can either be a series of targeted meetings with pre-set goals or a single 1-3 day conference, depending on the stakeholders, the problem and need for information, etc.

A communication strategy for a wide group of people may have to be worked out in advance. An example of a very elaborate approach applied in the UK-wide consultation exercise undertaken under the Committee on Radioactive Waste management is given in the report of phase 2 (CoRWM, 2006). This shows the range of techniques and approaches which can be used. However, this is a very complex example and a much simpler consultation structure would be required for a TNA.

For example, the exercise can be carried out using a core group of representative stakeholders coupled with a wider consultation exercise that has a broader range of stakeholders, either for information dissemination or elicitation of local knowledge or both. Alternatively, a set of stakeholder groups covering the range of interests identified, such as technologies assessment in a range of sectors, can be used to perform specific analysis and identify robust options.

A multi-criteria decision support tool is available to the TNA group to assist them in their assessment. This is based on an option evaluation decision model. It is embedded in the support system TNAssess with help functions and training available for each step. The use of the software decision model allows the group to explore the decision by performing sensitivity analysis on uncertainties and developing alternative options and scenarios.

1. **Establish the decision context**.
   - 1.1 Establish aims of the MCDA, and identify decision makers and other key players.
   - 1.2 Design the socio-technical system for conducting the MCDA.
   - 1.3 Consider the context of the appraisal.
2. **Identify the options to be appraised**.
3. **Identify objectives and criteria**.
   - 3.1 Identify criteria for assessing the consequences of each option.
   - 3.2 Organize the criteria by clustering them under high-level and lower-level objectives in a hierarchy.
4. **'Scoring'.** Assess the expected performance of each option against the criteria. Then assess the value associated with the consequences of each option for each criterion.
   - 4.1 Describe the consequences of the options.
   - 4.2 Score the options on the criteria.
   - 4.3 Check the consistency of the scores on each criterion.
5. **'Weighting'**. Assign weights for each of the criterion to reflect their relative importance to the decision.
6. **Combine the weights and scores for each option to derive an overall value**.
   - 6.1 Calculate overall weighted scores at each level in the hierarchy.
   - 6.2 Calculate overall weighted scores.
7. **Examine the results.**
8. **Sensitivity analysis.**
   - 8.1 Conduct a sensitivity analysis: do other preferences or weights affect the overall ordering of the options?
   - 8.2 Look at the advantage and disadvantages of selected options, and compare pairs of options.
   - 8.3 Create possible new options that might be better than those originally considered.
   - 8.4 Repeat the above steps until a 'requisite' model is obtained.

This process can be applied in Chapter 3, Step 6 for **mitigation** technology prioritization and in Chapter 5 for adaptation technology prioritization. In this Annex, an example is given for the mitigation technologies but it is also valid for technologies for **adaptation** though it would be expected that the criteria will vary for the evaluation of technologies for adaptation.

1. **Establish the decision context**: This is covered by Chapters 3 and 4 for the climate change impact scenarios and in the overall decision national and sector context from STEPS 1 to 4 of this Handbook, including the development priorities of the country (STEP 1) and GHG reductions (STEP 2). The decision to be taken is set out in STEP 6 of the handbook and is:

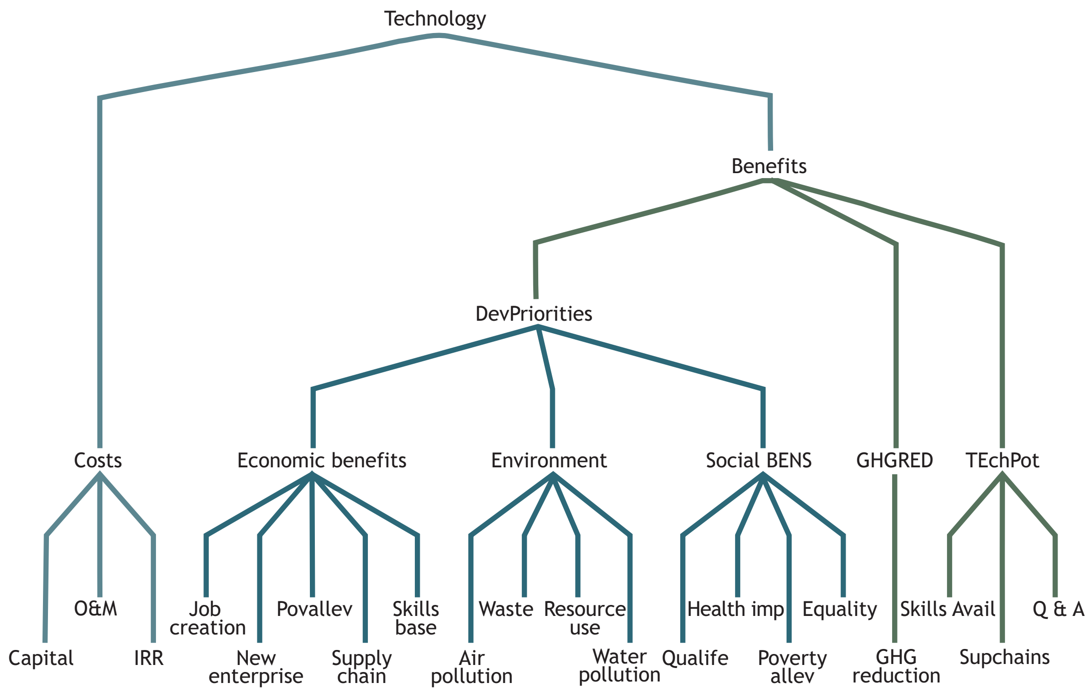
   What is the best technology, within its category of timescale of availability and size, for maximizing benefits in terms of sustainable development priorities and mitigation potential while minimizing costs?

2. **Identify the options to be appraised**: The options to be appraised are the technologies identified in STEP 5 of this Handbook.

3. **Identify objectives and criteria:** Criteria should be fundamental objectives (what you really want to achieve) and should always be fully defined so that there is no scope for misunderstanding. They answer the question 'Why is that important?' These can be grouped together to form higher-level objectives by answering the question 'Which more general objectives do these contribute to?' If high-level objectives are defined first, as in the examples shown, then they have to be fully explained through the question 'What do you mean by that?' The criteria for assessing the sectors are decided by the group and some key issues to be included are identified in Step 6.

   The criteria can be illustrated by means of a value tree generated in TNAssess (Figure A5-1 shows an example of a value tree). The middle level shows the higher objectives of the decision, for example, 'maximize development priorities'. The lowest level in the tree operationalizes the objectives, and only a selection is given here to provide an illustration.

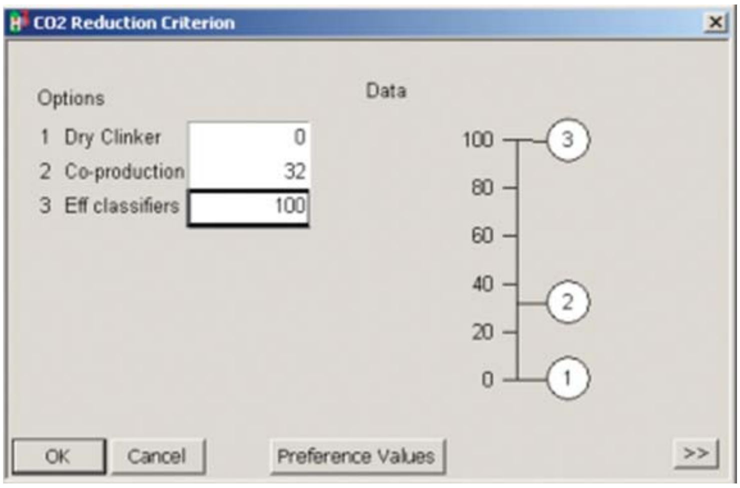
**Figure A5-1**: Example of a value tree for strategic choice of technologies



4. This value tree is by no means complete and is decided by the group and this example only illustrates the hierarchy of a value tree for the criteria suggested in Step 6.

   **'Scoring' for each criterion:** Once the set of evaluation criteria has been established (*i.e.*, contribution to development goals and contribution to GHG emission reduction), it will be important to **score** the options on the criteria depending on how well each option performs on that criterion. For this process, usually special scales are used. Value functions can also be generated with the group, and information is provided within TNAssess to assist in this process. These are described in more detail in DETR (2000) and in the functions within the decision model within TNAssess. The scores depend on how well the technology is performing on each criterion, and may require input through some background analysis or expert judgment. In the process the analysis can point to where data is required to fill important gaps.

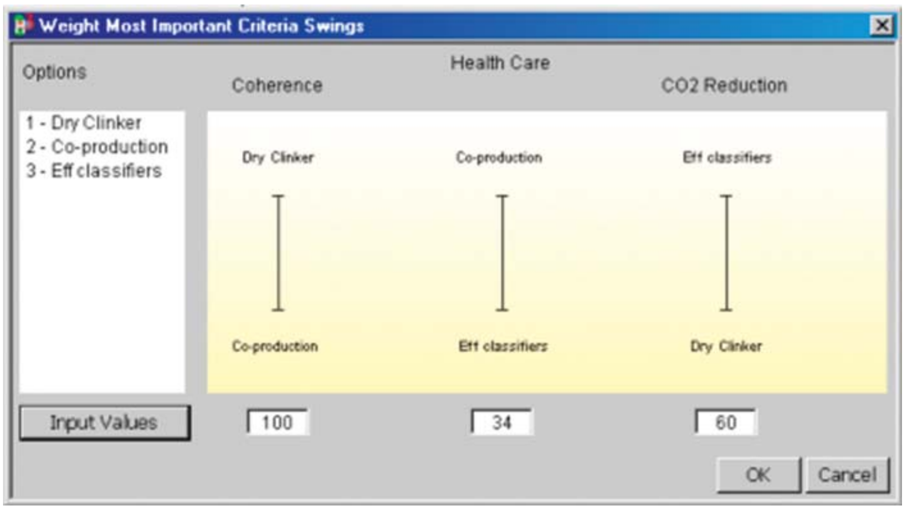
   Below is an example of the screen for scoring options within the model




   As can be seen from the above, inputs are elicited in terms of numbers representing relative performance of the option on a value scale for that criterion. It is also possible, where people are unhappy with assigning numbers, to use more qualitative judgments through the software MACBETH. This software also checks for consistency of the judgments made.

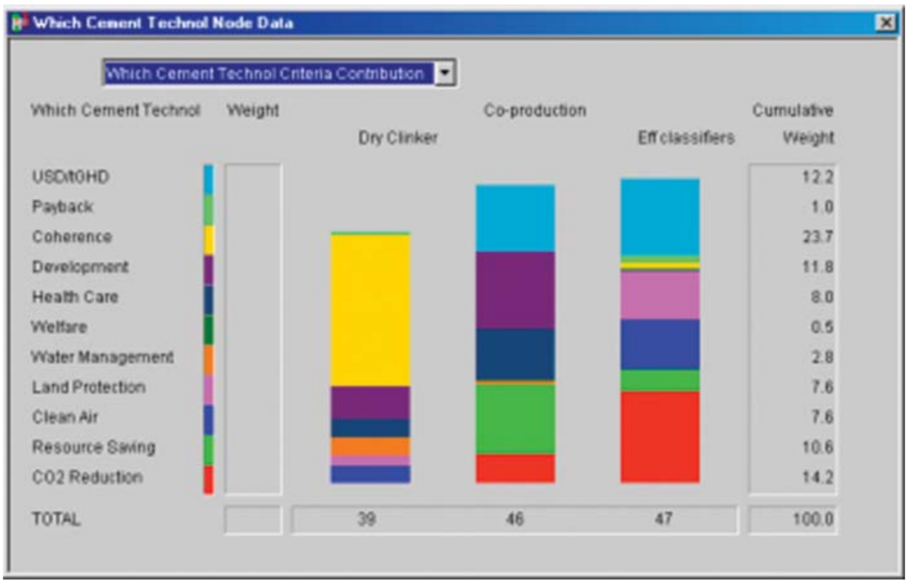
5. **Weighting:** By adding weights to the criteria, the stakeholders determine the relative importance of each criterion to improving the situation in the priority sector beyond the baseline situation. It is important that the weighting is done *after* the scoring, because the weights can only be given to criteria within the decision context. In multi-criteria assessment, evaluation criteria can be weighted by stakeholders to reflect the importance of a criterion by considering the difference between the top and bottom of the scales and how much you care about it. This is a standard 'swing weighting' method and assistance is provided in the software. The process of scoring and weighting evaluation criteria involves explicit judgments made in the context of stakeholder input within the decision group. The stakeholder group for the MCDA should ensure participation of experts, policymaker input, and stakeholder perspectives. Expert judgment may involve a number of experts which could be a separate input to the group.

Below is an example of the weighting window




6. **Combine the weights and scores for each option to derive an overall value**: This involves a multiplication of the scores (4) on the criteria with the weights in (5) and summing over all the criteria for each option. The output is the total weighted sum for each option and this provides an initial expected performance value for each option (sector in this case) but this should never be taken as the final ranking. The calculation is performed automatically by the decision model in *TNAssess* and is displayed clearly. This should be performed for each of the technologies.

   Below is an example of the display of the results from an analysis showing the final performance of each option as a bar chart with the height corresponding to the highest preferences and the colors showing the contribution of the individual criteria to these totals.

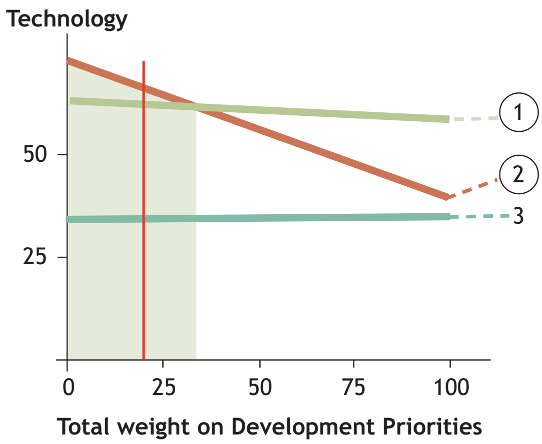


7. **Examine results** The results give the overall value of the options, with the highest totals being the most preferred. From this, an initial indication of the top-ranked technology options within each portfolio set is given, relative to the evaluation criteria, weighting system, and scores applied. However, this is regarded as a 'first pass' through the problem and should never be taken as the 'final' answer. The decision must then be explored in terms of the uncertainties in the inputs and judgments made to check for robustness in the result, and balance in the main objectives for the preferred options and to explore possibilities for improving options. For example, if a particular option is not performing well on a key criterion, then ways to improve the option can be discussed within the decision group, which can result in new options perhaps involving compensatory or other measures. Final choices can then be made after this extended examination using sensitivity analysis.

8. **Exploring uncertainties using sensitivity analysis:** At this point in the analysis the model is used to help the group explore the decision interactively. There are a number of sources of uncertainty in any analysis and these are confronted and explicitly explored in an MCDA process. They are also noted as the elicitation of inputs progresses during the decision conferences. Sources include uncertainties such as variations in scores and weights, arising either from uncertainty in information for scoring the performance of the option on some criteria, or from variations in perspectives providing a range of inputs for certain assessments, or from exploring the decision under an alternative future scenario which will affect the original assessments made under the original scenario.

   The model allows all the uncertainties to be explored, either through substitution of scores or weights, or addition of options or criteria.

   **Exploring weights**: The weighting of a particular criterion or higher level fundamental objective may be the result of much discussion in the group and the group then needs to see how robust the final decision is to variations in that weight. An example exploring the uncertainty on weights on development benefits is shown below.




In this graph the y axis is the overall weighted sum value for the options and the individual colored horizontal lines show the variation in the total value of the individual options numbered 1 to 3. The weight on the benefits criterion varies from 0 to 100 along the x-axis keeping all other weights in the same ratio. The current weight on benefits assigned in the analysis is 20 and shown by the red vertical line. In this example, option 2 is clearly more preferred than options 1 and 3, up to a weight of about 30 when option 1 would be more preferred. Option 3 is never preferred whatever the weight on development priorities.

9. **Exploring other uncertainties:**

Changes to individual scores and weights can also be made within the model and the effect on the decision explored. Alternative perspectives may be modeled in this way.

Future uncertainties may also be investigated. For example, what if the economic downturn persists? How will that affect sector GHG emissions? This will lead to a change in some inputs.

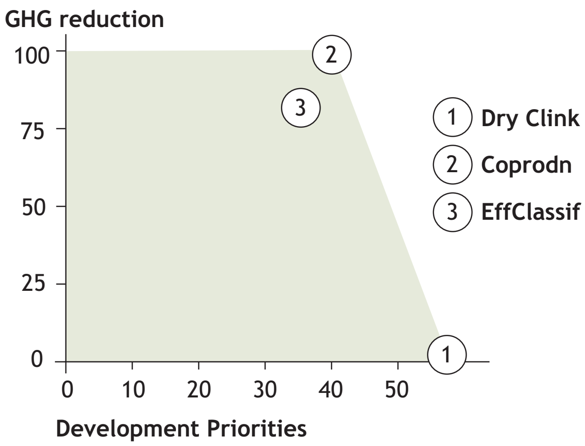
Where there are future uncertainties which are more complex, an overall scenario may be placed over the whole analysis and the scores and weighted adjusted under the new circumstances (*e.g.*, what if climate change impacts accelerated past worst IPCC scenario and oil was expensive?).

Different viewpoints can also be explored through role playing. If it is considered that a particular viewpoint is missing from the group then it can be simulated through role play and the effect on the decision explored, identifying areas there can be agreement or where further improvements are needed.

Risk as a criterion can also be incorporated explicitly in the analysis where it is felt that there is high uncertainty and risk is a factor in the decision.

## Balance

It is important to consider if the sectors are well balanced on the major trade-offs (see example) as this can lead to problems in implementation. The overall preference values for the main objectives are shown in the following graph.




Here the plot of the overall preference scores on the development priorities and GHG reductions (unweighted) show options which are balanced on these major trade-offs located at the top right hand corner of the graph. In this case, option 2 is reasonably well balanced and option 3 is also well balanced but performing less well than option 2 on these criteria. Option 1 is not balanced. At this point improving options 1 and 2 and investigating why option 3 is so poor should be investigated. Improving the options is explored below.

### Improving the options

Options can also be compared in terms of their advantages and disadvantages, which allows for consideration of ways in which options can be improved, and can lead to consideration of new options. The model allows the advantages and disadvantages of the options to be clearly identified and options can be compared relative to one another. It also allows key criteria to be identified so that the focus can be placed on what matters in the decision.

## Final Process and Outputs

The process described above is iterative and steps may be revisited and explored until the group is satisfied that they have reached a decision which is sufficient in form and content to meet the problem in hand.

Each portfolio set **for each sector** and category (small scale/large scale and short/medium to long term) can be assessed in this way to provide a final short list in each category for each sector. It may be that in some categories there is a clear 'winner' while in other there is a diverse set of technologies which are appropriate. These can be followed up at a later stage in the implementation plan after the initial priority technologies have been dealt with. In addition, comparison across the sectors or even within a sector may identify technologies not necessarily the highest ranked but nevertheless highly ranked in a range of sectors, indicating that they may be a useful choices for technology transfer.

During the process a record is kept of all the judgments and justifications for the scoring and weighting and other inputs and sensitivity analysis and this must be compiled into an **AUDIT TRAIL** for the decision.

The output in this form may also be used to generate a strategy for implementation.

# Annex 6 Factsheets for prioritized technologies

This section provides an annotated outline of the factsheets for priority technologies that have been identified through the TNA process. As indicated in Chapters 3 and 4, the National TNA Teams can prepare factsheets for each of the priority technologies proposed. At the end of this Annex, two examples are provided, one for a technology for mitigation, the other for a technology for adaptation, that further illustrate the intent of the factsheets.

## Factsheet purpose

The purpose of the factsheet is to create a succinct document that synthesizes essential information for each adaptation and mitigation priority technology. National TNA Teams should consider the research and information that would be most pertinent to an audience of non-specialists, keeping in mind the need to be direct, succinct, and descriptive.

## Recommended structure

Key sections are outlined below and discussed in the sections that follow:

- Introduction;
- Technology characteristics;
- Country-Specific Applicability;
- Status of Technology in Country;
- Barriers;
- Benefits;
- Operations;
- Costs;
- References;
- Additional information.

A maximum page length between 5 and 7 pages per factsheet is recommended, sufficient to communicate key points and issues without getting too bogged down in overly detailed technical information.

### 1 — Introduction

The aim of the introduction is to provide a broad overview of the particular technology and how it will contribute to mitigation and/or adaptation within the specific country. The section should include a basic technology description introducing the specific priority technology to a wide audience. Both a qualitative description of the technology and key technical information will be relevant for this section. A brief justification of how the technology can help the country achieve its mitigation or adaptation goals should also be included. For this section a maximum length of 1-2 pages is recommended.

### 2 — Technology characteristics

This section should provide an overview of technology characteristics such as efficiency, capacity, lifetime, and cost. Finally, there will be comments on the technology status, including current maturity and use in the country. Schematics of technology functionality, charts of mitigation potential, and resource maps are all examples of figures that could be relevant to include. For this section a maximum length of up to 1 page is recommended.

### 3 — Country-Specific Applicability

The aim of this section is to move from general description of the technology to specific application of the technology to the country. This should include a discussion of regional climate, geography, and market configurations as they relate to the applicability of the technology, how the technology can meet national sustainable development criteria, and the potential contribution of the technology towards market transformation (as feasible). For this section a maximum length of up to 1 page is recommended.

### 4 — Status of Technology in Country

The aim of this section is to discuss in more depth the status of the given technology within the country. This refers to whether the technology is non-existent, being pilot tested, being disseminated, or if it is already commercially available. Based on the current stage of development, the next steps for development of the technology should be discussed, together with a qualitative estimation of the potential for the technology for market penetration and major policies and fiscal initiatives related to the technology, if applicable. For this section a maximum length of 1/2 page is recommended.

### 5 — Barriers

The aim of this section is to briefly discuss the specific barriers expected to confront implementation, together with how these barriers could be overcome. Reference should be made to the barrier analysis already completed, as well as any barriers that apply to this specific technology. After identifying barriers, the section should describe aspects of an enabling environment that may need to be developed through new legislation or regulations to facilitate transfer or adoption of the technology. For this section a maximum length of 1/2 page is recommended.

### 6 — Benefits

The aim of this section is to provide specific evidence for the mitigation and/or adaptation benefits of the priority technology. In the case of mitigation, this would refer to GHG mitigation benefits such as amount of $CO_2$ reduced relative to technology currently in use in the country, making use of graphs and/or figures as appropriate. In the case of adaptation, this would refer to qualitative benefits such as expected physical impacts reduced, infrastructure protected, coastal erosion avoided, etc. For this section a maximum length of 1/2 page is recommended.

### 7 — Operations

The aim of this section is to identify and address operational issues that may affect the performance of the technology in the national context from engineering and scientific perspectives. This would include information on the type and frequency of maintenance needed, any subsequent requirements for technician capacity strengthening and training, the need for introduction of new supply chains for substitute parts, and new compliance requirements with international reporting standards. For this section a maximum length of 1/2 page is recommended.

### 8 — Costs

The aim of this section is to present results of research regarding the costs of the technology in a succinct way. Estimating costs is a very important step, and ultimately one of the most interesting findings of national TNA reports. A suitable estimation of costs will involve several steps, starting with fabrication costs, then applying multipliers and escalators to account for currency fluctuation, differential labor costs, resource costs, etc. Given the rather high level of uncertainty that will likely accompany technology cost estimates, it is recommended that low, mid, and high estimates be offered.

For mitigation technologies, this could be provided in the form of a table listing capital costs, operations and maintenance costs, administration costs, and other costs associated with developing an enabling environment. For technologies for adaptation, these and other categories may apply. For high cost options, it would be good to include any cost projections into the future to show capital cost decreases over time. A good example of this would be solar photovoltaic technologies that have shown steep decreases over time due to improvements in fabrication processes and economies of scale. For this section a maximum length of ½ to 1 page is recommended.

### 9 — References

This section should list the key references and sources, including communications with vendors, that were relied upon to prepare the factsheet. Such a list can provide a useful reference for follow-up activities.

### 10 — Additional information

This section should include useful websites/references and further readings. It should also include list of possible mitigation/adaptation financing sources (i.e., funds, bilateral/multilateral organizations, South-South linkages) and private sector companies.

## Factsheet examples

Two examples of technology factsheets are provided in the following pages. The factsheets provide an indication of technology characteristics, costs, advantages/disadvantages, and references for further information. The first example is a mitigation factsheet in which onshore wind technology is described. The second example is an adaptation factsheet in which agricultural adaptation practices are described.

## Priority Mitigation Technology Factsheet — Onshore Wind Technology (Mitigation Example)

### 1 — Introduction

Land based wind technologies are a proven, commercial technology broadly deployed globally for both utility scale grid applications and for distributed generation, both on and off grid. Over 100,000 MW of wind power have been deployed globally and despite the variability of wind supply, it is one of the fastest growing technologies globally. Wind turbines produce no GHG emissions over their fuel cycle.

Wind turbines are mounted on a tower to capture the most energy. At 100 feet (30 meters) or more aboveground, they can take advantage of the faster and less turbulent wind. Turbines catch the wind's energy with their propeller-like blades. Usually, two or three blades are mounted on a shaft to form a rotor.

A blade acts much like an airplane wing. When the wind blows, a pocket of low-pressure air forms on the downwind side of the blade. The low-pressure air pocket then pulls the blade toward it, causing the rotor to turn. This is called lift. The force of the lift is actually much stronger than the wind's force against the front side of the blade, which is called drag. The combination of lift and drag causes the rotor to spin like a propeller, and the turning shaft spins a generator to make electricity.

Land based wind technologies have been identified as a priority mitigation technology through the Technology Needs Assessment process, based on three primary attributes. First, wind technologies are zero carbon emission technologies that can help to meet the rapid growth in electric energy demand in "Exampleland", the name of the fictitious country that has completed a TNA process. Second, Exampleland's Ministry of Economy has identified through the stakeholder process that wind energy technologies are a near term technology option due to the modularity of their deployment, which can help to address balance of payment concerns related to the importation of diesel fuel for power generation.

Finally, initial resource assessment activities carried out by the local utility in partnership with the public utility commission have identified a large potential market for small, distributed wind systems that may be able to support a number of local, small scale wind turbine manufacturers currently seeking new market opportunities domestically and in regional markets.

### 2 — Technology characteristics

The efficiency of wind technologies is highly dependent on wind speed and as a result, the siting of wind farms is a critical factor in both the performance and cost effectiveness of these technologies. Power production is related to the cube of the wind speed so a doubling in wind speed results in an eight-fold increase in power. Although regular maintenance is required, particularly in sandy or marine environments, the reliability of wind technologies has also radically improved over the last 10 years.

Average capacity factors for both small and large scale systems are in the range of 30%-35%, again with the critical factor being where the turbine is sited. Most wind system lifetimes range from 10-20 years depending on operation and maintenance. Installed costs for wind technologies have seen a slight increase in the last two years due to global demand for steel, concrete, and fiberglass, but energy production costs generally range from 8-12 cents/kWh for utility scale systems to 15-35 cents/kWh for small scale and household systems (the smaller the system, generally the higher the cost).

Exampleland currently has only 30MW of grid-tied wind capacity installed. In addition, there is approximately 400kW of smaller-scale distributed systems currently being used for distributed or off-grid applications primarily serving captive loads in the mining industry in remote locations. While there is no domestically designed wind technology currently available, three separate firms are currently in negotiation with international suppliers of medium size wind systems for local manufacturing and sales to serve the growing regional market for this technology.

Based on analysis conducted by the TNA process in their prioritization activities, a potential for the creation of 1,200 full time jobs in manufacturing, engineering, and O&M exists in this sector, if both deployment and wind turbine manufacturing opportunities are aggressively pursued.

### 3 — Country-Specific Applicability

Based on initial wind mapping efforts carried out by the National Meteorological Agency and verified against available ground data, Exampleland has over 3 GW of wind potential that could be exploited cost-effectively based on current technology costs. The theoretical potential for wind development in Exampleland is much higher if offshore wind resources are considered, but this is viewed as a longer-term technology option for the country and was not addressed in the TNA as a viable technology option within the next 10 years. 3 GW is almost double the current installed capacity in this country, and is viewed as a near term, low carbon, technology option to help offset the importation of high cost diesel that is currently being used to meet rapid growth in energy demand.

Wind patterns and geography lend themselves to this technology, with strong wind regimes both along the Eastern and Southern coastal zones and in the highlands close to large load centers in the mining sector. In addition, the recently completed inter-coastal road network provides paved access to those coastal zones that have close access to transmission and distribution networks, population centers, and good wind resources. Although the wind regime tends to be better in the winter season in Exampleland, this pattern complements the rainy season in the summer, when both small scale and large scale hydropower resources tend to be more reliable.

Despite the fact that Exampleland has a relatively small wind sector, recent measures by the PUC and the national utility have helped to establish standard power purchase agreement (PPA) protocols for any new wind project under 50MW. This measure provides a great deal of clarity for project developers and investors, and guarantees defined power purchase guarantees for a minimum of 12 years. The Ministry of Economy also recently established a generous subsidy program for commercial and residential purchasers of wind technologies under 10kW in size to help accelerate the growth in this local market.

It is anticipated that wind technologies can directly impact the national sustainable development criteria of Exampleland and contribute to market transformation in the power sector. As a small country reliant in large part on imported coal and diesel for power generation, renewable energy technologies with no fuel costs will directly impact this country's balance of payments concern and allow it to deploy technologies within the next 12 months to address pressing energy demands, as opposed to a much longer time horizon for deploying a new coal plant.

In addition, wind technologies have the potential to significantly contribute to the country's GHG mitigation goals, as well as addressing a growing concern over increasing concentrations of criteria pollutants, including sulfur dioxide and nitrous oxides associated with thermal power plants. These pollutants are having a direct and measurable economic impact on the agricultural sector, tourism industry, and human health. Finally, economic analyses conducted by the Ministry of Economy indicate direct economic benefits to exploiting turbine manufacturing opportunities for regional distribution and sales.

## 4 — Status of Technology in Country

As noted above, Exampleland currently has approximately 30.4MW of installed wind capacity. The 30MW of utility scale wind includes a 10MW wind farm in the southern coastal zone that was developed 5 years ago through a public/private partnership with the utility. This wind farm has been operating on a commercial basis with an average capacity factor of 32%. A second 20MW wind farm was commissioned last year, financed by a local debt partner and equity investors from Exampleland in partnership with a regional wind project developer. This project is sited in the northwest to help meet the rapidly growing electric demand from the mining industry in that part of the country. Smaller scale systems in place throughout the country, primarily in the 10-60kW range, service electric loads at specific locations — again, primarily in the mining and agricultural sector. Deployment of residential systems is limited, with most of these cases being carried out on a pilot basis to service off-grid communities.

Based on quantitative and qualitative assessments carried out under the TNA process, it is estimated that more than 300MW of new wind capacity could be installed in Exampleland in the next 5 years on a cost effective basis. This assessment was carried out in partnership with the local utility to ensure that their capacity expansion modeling was consistent with this evaluation.

This assessment is also based on the current PPA policy in place for clean energy projects up to 50MW in scale and assumes that global financial markets will recover within the next 18 months. Based on initial wind mapping and grid integration opportunities, the TNA process recommends that a national program be explored to accelerate wind development in the very near term in the Southern Coastal zone, including consideration of the creation for a economic zone for energy project development that would provide additional tax incentives for project developers of clean energy technologies in that region.

## 5 — Barriers

A number of barriers exist to rapid expansion of the wind sector in Exampleland. First, the availability of reliable, high-resolution wind resource data is limited, beyond a few specific coastal zones. The development of detailed wind maps on a 1km resolution scale would greatly benefit efforts for wind prospecting and the identification of locations for gathering more localized, annual data. Second, as regional wind markets grow rapidly, project developers and financiers are being attracted to the larger wind farms (100MW and up) where transaction costs are lower relative to the total project size and cost. If possible, the bundling of requests for proposals from the utility for wind farm bids may be advantageous to attract foreign direct investment in a series of projects rather than "one-off" wind farm developments that may not be as economic. Finally, a significant market exists for smaller scale wind systems to meet the growing distributed power needs in both the agricultural and mining sectors. Specific policy and fiscal incentives still need to be designed and implemented, including the establishment of a long term production tax credit for commercial systems under 100 kW to help support this growing market and foster the growth of the local manufacturing base for small and medium size wind blade manufacturing. Each of these steps is a tangible step forward in strengthening an enabling environment for this technology in Exampleland.

## 6 — Benefits

Based on the current energy mix in Exampleland, it is estimated that every MWh of wind energy produced will offset, on average, 1 metric ton of $CO_2$. Based on a conservative capacity factor of 30%, that is the equivalent of 2,628 metric tons of $CO_2$ annually per installed MW. If a goal of

300MW of new wind capacity is reached that is a GHG benefit of 788,400 metric tons of $CO_2$ annually from this sector alone. In addition, initial co-benefits analysis indicates significant economic benefits derived through local health and agricultural productivity improvements due to reduced sulfur dioxide and nitrous oxides levels.

## 7 — Operations

There are a number of operational and human capacity issues that will need to be addressed to fully exploit the wind potential in this country. First and foremost, while the wind technologies being considered are fully commercial, there is not an established domestic network of technicians specifically trained in the operation and maintenance of wind technologies. As this sector grows, it is anticipated that a concerted education and capacity development campaign will need to be conducted with the national university system, including vocational programs that include specific technician training and certification in wind and other clean energy technologies.

Standard certification protocols, supply chain, and infrastructure constraints all also need to be addressed. Currently no national standards for certification of wind technologies are in place, so one near-term step would be to adopt a national standard for certification and testing of any wind turbine technology in order for it to be eligible for federal subsidy support or inclusion in standardized PPA programs. Supply chain issues that are currently impacting the global wind market, including fiberglass, steel, and concrete constraints, will likely be more pronounced in Exampleland's wind market in the near term due to the relatively smaller size of its market and its ability to attract capital and resources for smaller wind farms relative to some of its neighboring countries. That said, this constraint also creates an opportunity to take advantage of the country's competitive labor rates and growing manufacturing base to advance local manufacturing of wind technology components at a lower cost for regional distribution. The strategy for wind development and attracting new project development and investment should be coordinated with this domestic manufacturing initiative. Finally, infrastructure constraints related to reliable road and transmission networks are a potential barrier for wind development in the central, highland regions. While the coastal zones benefit from easier road and grid access, large scale development of multi-MW wind turbines in highland zones will require significant investments in the road and grid infrastructure in that zone. As a result, it is recommended that targeted wind farm development in this region be staged as a follow-up to initial development in the coastal zone.

## 8 — Costs

As noted above, installed costs for wind technologies have seen a slight increase in the last two years due to global demand for steel, concrete, and fiberglass but energy production costs generally range from 8-12 cents/kWh for utility scale systems to 15-35 cents/kWh for small scale and household systems (the smaller the system, generally the higher the cost).

Of these total costs, O&M has been steadily decreasing as a total percentage of the costs down to roughly 10 percent of the total operating costs of the technology for larger scale systems. Based on initial analysis for small to medium size wind technologies, a significant portion of the fabrication cost is related to labor for gearbox and wind blade manufacturing. As the market for these technologies scales up, it is anticipated that lower cost manufacturing labor will be able to provide significant competitive advantages for firms seeking to establish local manufacturing capacity for local and regional wind markets that are growing rapidly.

## 9 — References


REN21, 2008 Update, www.ren21.org

Stakeholder input, Vendor A, Exampleland

Stakeholder input, Vendor B, Exampleland

American Wind Energy Association, www.awea.org

European Wind Energy Association, www.ewea.org

National Wind Energy Technology Center at NREL, www.nrel.gov/wind


## 10 — Additional information

***Web Resources:***

American Wind Energy Association http://www.awea.org/

Wind Powering America http://www.eere.energy.gov/windpoweringamerica/

Danish Wind Industry Association guided tour and information.
http://www.windpower.org/en/tour/

***Publications:***

Ackermann, T., (ed), *Wind Power in Power Systems*, John Wiley and Sons, West Sussex, England, pp. 299-330, 2005.

Hunter, R., and G. Elliot, (ed's), *Wind-Diesel Systems,* Cambridge University Press, Cambridge, UK, 1994.

Manwell, J.F., McGowan, J.G., and A. L. Rogers, *Wind Energy Explained*, John Wiley & Sons Ltd., 2002.

Paul Gipe, *Wind Energy Basics: A Guide to Small and Micro Wind Systems*, Real Goods Solar Living Book.

AWS Scientific Inc. "Wind Resource Assessment Handbook" produced by the US National Renewable Energy Laboratory, Subcontract number TAT-5-15283-01, 1997

International Wind Energy Development, World Market Update, BTM Consultant, ApS (Denmark) — http://www.btm.dk/

***Financing Resources:***

PFAN/CTI, www.climatetech.net/

World Bank Prototype Carbon Fund, http://wbcarbonfinance.org/

E+Co, http://www.eandco.net/

HBS Project Finance Portal,
http://www.people.hbs.edu/besty/projfinportal/generalpfhtm.htm

## Priority Adaptation Technology Factsheet — Farmers Adaptation to Agricultural Practices and Variability (Adaptation Example)

### 1 — Introduction

Adaptation is widely recognized as a vital component of any policy response to climate change. Studies show that without adaptation, climate change is generally detrimental to the agriculture sector; but with adaptation, vulnerability can largely be reduced. The degree to which an agricultural system is affected by climate change depends on its adaptive capacity. Indeed, adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, to take advantage of opportunities, or to cope with the consequences (IPCC 2001). Thus, the adaptive capacity of a system or society describes its ability to modify its characteristics or behavior so as to cope better with changes in external conditions.

Adaptation to climate change requires that farmers first notice that the climate has changed, and then identify useful adaptations and implement them. Agricultural adaptations can encompass a wide range of scales (local, regional, global), actors (farmers, firms, government), and types: (a) micro-level options, such as crop diversification and altering the timing of operations; (b) market responses, such as income diversification and credit schemes; (c) institutional changes, mainly government responses, such as removal-preserve subsidies and improvement in agricultural markets; and (d) technological developments—the development and promotion of new crop varieties and advances in water management techniques. Most of these represent possible or potential adaptation measures rather than ones actually adopted. Indeed, there is no evidence that these adaptation options are feasible, realistic, or even likely to occur.

Furthermore, adaptation actions would only be possible with some knowledge of future climatic conditions. Farmers do not have this knowledge, nor have they necessarily documented any changes that have happened in the past. The following information documents an example of farmers who have to adapt to climate change in their area, which spans a river basin running across four countries in the sub-region. They decided to work with an international organization to understand issues pertaining to adaptations to climate change and variability. This will then help them to understand more clearly the expected climate change impacts, and evaluate possible adaptations, which are often assumed to be possible with little explicit examination of how, when, why, and under what conditions adaptation actually occurs in economic and social systems.

### 2 — Technology characteristics

Agricultural change does not involve a simple linear relationship between changes in a farmer's decision making environment and farm-level change. One important issue in agricultural adaptation to climate change is the manner in which farmers update their expectations of the climate in response to unusual weather patterns. This is what has been described as "the transitional cost" of adapting to climate change. The transitional cost is the difference between the maximum value of net revenues per acre following perfect adaptation and the net revenues actually experienced by farmers given that their expectations of (and therefore responses to) climate change lag behind actual climate change. A farmer may perceive several hot summers but rationally attribute them to random variation in a stationary climate. Another important issue related to adaptation in agriculture is how perceptions of climate change are translated into agricultural decisions. If farmers learn gradually about the change in climate, they will also learn gradually about the best techniques and adaptation options available. Farmers learn about the best adaptation options in three ways: (1) learning by doing, (2) learning by copying, and (3) learning from instruction. There is recognition that farmers' responses vary when faced with the same stimuli.

Such varied responses, even within the same geographic area, are partly related to the variety of agricultural systems involved and the different market systems in which farmers operate. A more important factor of varied farmers' responses is the differences between farmers in terms of personal managerial and entrepreneurial capacities and family circumstances. Also, farmers can be influenced by their peers' perceptions and by values present in their communities as well as their professional associations. A review of literature on adoption of new technologies identified farm size, tenure status, education, access to extension services, market access, credit availability, agro climatic conditions, topographical features, and the availability of water as the major determinants of the speed of adoption.

## 3 — Country-Specific Applicability

The River is one of the major river systems in the sub-region. Originating from one of the bordering countries, the River is about 1,700 kilometers long, drains an area of about 415,500 square kilometers, and is shared by four countries. In the specific country of applicability, the River Basin extends over four administrative provinces and five water management areas (WMAs). The climate in the basin ranges from temperate and semiarid in the south to arid in the extreme north. Mean annual precipitation ranges from 200 millimeters per year in the basin area WMA to more than 2,300 millimeters annually in another WMA, with temperatures ranging from 8 degrees Celsius to more than 30 degrees Celsius in the northern parts of the first WMA. Runoff levels also range from 3,539 million cubic meters, to 855 million. Farming activities in the River Basin feature both large commercial agricultural farms as well as small-scale agriculture.

The diverse climate in the basin influences the vegetation and agricultural activities in the five WMAs and the four provinces. Farming activities range from dry farming to intensive irrigation and livestock production. For example, farming in some basin areas mainly focuses on livestock and irrigation, while in others conditions are favorable for dry-land farming and livestock, as well as extensive irrigation. To facilitate the management of scarce water resources, the country has been divided into 19 catchment-based WMAs. All except one of the WMAs are interlinked with other areas through inter-catchment transfers. The interlinking of catchments gives effect to one of the main principles of the country's National Water Policy Acts, which designates water as a national resource.

## 4 — Status of Technology in Country

As indicated earlier, the farmers have decided to work with an international organization to help them understand changes in climate, and how to adapt during those changes to make their farming activities more profitable. In line with this, a wide range of data has been collected on perceptions of climate change, adaptations made by farmers, and barriers to adaptation. Another set of data has been obtained from an ongoing project entitled 'Food and Water Security under Global Change: Developing Adaptive Capacity with a Focus on Rural Areas' funded by another international development partner.

Under this collaboration, a survey has been carried out by a Center for Environmental Economics and Policy at a local University, in collaboration with an International Food Policy Research Institute, to analyze the potential impact of climate variability and climate change on household vulnerability and farm production. Monthly precipitation and temperature data was obtained from the Local Weather Service. From the data, actual adaptive behavior is advocated, even though such behavior is place- and time-specific and more likely represents a response to inter periodic climatic variability, as well as to multiple non-climatic risks and opportunities.

So far eight adaptation measures have been identified in the River Basin and have been proposed to the farmers for consideration. These are:

- Planting of different crops
- Changing of crop variety
- Changing of planting dates
- Increasing irrigation
- Water harvesting schemes
- Use of crop diversification
- Changing the amount of land under cultivation or grazed, and
- Investment in livestock by buying feed supplements.

The farmers are working with local authorities, local universities and some international development partners on these adaptation measures.

## 5 — Barriers

A number of barriers exist to adaptation of climate change by the farmers. A major barrier to adaptation is lack of access to credit. As expected, access to credit increases the likelihood of adaptation. Poverty or lack of financial resources is one of the main constraints to adjustment to climate change. In some countries, despite numerous adaptation options farmers are aware of and willing to apply, the lack of sufficient financial resources to purchase the necessary inputs and other associated equipment (e.g., purchasing seeds, acquiring transportation, hiring temporary workers) is one of the significant constraints to adaptation.

A second barrier is the lack of information about long term climate change. The farmers are not in a position to prepare or invest in getting information on long term climate change. Another barrier is the lack of knowledge concerning appropriate adaptation methods. Some of the adaptation methods that they are used to have proved to be inappropriate and this is making them to believe that all other adaptation methods may also prove inappropriate and will not yield the expected results. Lack of access to extension services is another barrier. With an increased probability of taking up portfolio diversification, farmers who have access to extension services are more likely to be aware of changing climatic conditions and to have knowledge of the various management practices that they can use to adapt to changes in climatic conditions. It appears that extension messages emphasized risk spreading and farm level risk management. Having access to extension increases the probability of choosing some of the adaptation recommendations made.

Insecure property rights are another barrier. Having secure property rights increases the probability of farmers to adapt. With proper property rights, farmers may be able change their amount of land under cultivation to adjust to new climatic conditions. Other barriers include lack of market access, where farmers are not sure whether they will be able to sell their produce when there is an increase in harvest, as well as poor transport links from farm gate to market areas.

## 6 — Benefits

With this collaboration and the data collection, farmers in the River Basin have come to recognize that temperatures have increased over the years and there has been a reduction in the volume of rainfall, thus prompting them to consider adapting to new technologies for sustainable farming. Some of the farmers have started receiving extension services and access to information about climate and weather. With more experience, farmers are more likely now to perceive change in temperature. Although farmers may be well aware of climatic changes, only a few seem to take steps to adjust their farming activities to account for the impacts of climate change. The main adaptation strategies of farmers in the River Basin are: switching crops, changing crop varieties, changing planting dates, increasing irrigation, building water-harvesting schemes, changing the amount of land under cultivation, and buying livestock feed supplements. The government has also started to promote efficient water use, and emphasis is being put on pricing reforms and clearly defined property rights, as well as on the strengthening of farm level managerial capacity for efficient irrigation. More importantly, the implementation of land reform has increased the number of new, emerging farmers who do not have the skills and information gathered by experienced farmers. Therefore, increasing farmers' access to extension services is very important.

## 7 — Operations

Generally, household characteristics are considered to have an impact on the operations farmers undertake on adaptation to climate change. These include, education level and gender of the head of the household, family size, years of faming experience, and wealth. Older farmers are more risk-averse and less likely to be flexible than younger farmers, and thus have a lesser likelihood of adopting new technologies. It could also be that older farmers have more experience in farming and are better able to assess the characteristics of modern technology than younger farmers, and hence a higher probability of adopting the practice. Higher level of education is often hypothesized to increase the probability of adopting new technologies. Indeed, education is expected to increase one's ability to receive, decode, and understand information relevant to making innovative decisions. Gender of the household head is also hypothesized to influence the decision to adopt changes. The way gender influences adaptation is location-specific. A number of studies in Africa have shown that women have less access to critical resources (land, cash, and labor), which often undermines their ability to carry out labor-intensive agricultural innovations. However, in recent times it is found that female-headed households are more likely to take up climate change adaptation methods. Wealth is believed to reflect past achievements of households and their ability to bear risks. Thus, households with higher income and greater assets are in better position to adopt new farming technologies.

Farm characteristics play a major role in adaptation to climate change. Farm characteristics that influence adaptation are farm size (large scale or small scale) and soil fertility. Adoption of an innovation will tend to take place earlier on larger farms than on smaller farms. Given the uncertainty and the fixed transaction and information costs associated with innovation, there may be a critical lower limit on farm size that prevents smaller farms from adapting. As these costs increase, the critical size also increases. It follows that innovations with large fixed transaction and/or information costs are less likely to be adopted by smaller farms.

Another factor in operations of adaptation is soil fertility. Farmers' perceptions that their lands are infertile may be a first step in the adaptation process. They may therefore be more likely to adopt any adaptation techniques that will help improve their productivity.

Other factors in adaptation for climate change include local climatic conditions and agroecological conditions that are expected to influence the decision to adapt. Temperature and rainfall are also considered as operational factors. Households living in regions with high temperatures have an increased likelihood of adapting. These households are more likely to choose the following adaptation options: (1) portfolio diversification, such as by changing their types of crops (e.g., from maize to sorghum, a more heat-tolerant crop); (2) intensification of irrigation; and (3) changing their planting dates. A decrease in rainfall is likely to push farmers to delay their planting dates.

## 8 — Costs

As noted above, eight adaptation methods have been suggested, namely,

- Planting of different crops
- Changing of crop variety
- Changing of planting dates
- Increasing irrigation
- Water harvesting scheme
- Use of crop diversification
- Changing the amount of land under cultivation or grazed, and
- Investment in livestock by buying feed supplements.

Most of these adaptation technologies cost virtually nothing, for example, changing to different crops may even mean that the price of producing the new crops is lower than that of the original crops, depending on the crop type and its availability. The cost of changing the variety or planting dates of the same crop may also not cost anything at all. The major cost will be putting in place water harvesting schemes, increasing irrigation at the farms, and also investing in livestock by buying feed supplements.

## 9 — References

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# Annex 7 A Multi-polar World of Innovation

This Annex describes how selected developing countries can take part in the energy technology revolution as innovators rather than simply technology takers. Certain middle income countries have already demonstrated success in doing so. Below, a multi-polar innovation paradigm is presented to replace the existing model of technology development in the OECD followed by transfer (with some minimal adaptation) to developing countries.

The timely commercialization of new technologies that allow low-carbon economic development and are suitable for developing country conditions will require a re-thinking of the current technology paradigm. Traditionally, new technologies emerge from OECD countries and, once established there, are transferred to developing countries. This approach has had its share of success, but also has serious limits in the context of global climate change mitigation and adaptation. One, the traditional technology commercialization process is inherently multi-stage and thus lengthy which is a problem given the urgency of climate change. Two, it produces technologies that, in their essential design, are made for conditions in industrialized countries. Three, it fails to fully make use of the emerging innovation potential that is being increasingly seen in middle income countries and low-income countries.

A preferred paradigm for new technology development allows developing country economies to be more active contributors to new technology development by involving them from the outset in design and innovation. This is already happening in certain cases for some major emerging economies such as China, India, and Brazil, but its full potential is yet to be realized. Accelerating the transition to the new innovation paradigm can be achieved through enhanced science, technology and innovation capacity in developing countries, as well as through virtual and other partnerships between major technology developers (public and private) in industrialized and developing countries. Many countries already possess the building blocks for advanced technology innovation: highly educated workforces; links with low-cost manufacturing; motivated, far-sighted governments; and local markets with high demand and a relative lack of existing infrastructure which allows entry of new products to "leapfrog" existing technology paradigms.

More active innovation from developing countries also creates a networked process of commercialization, where ideas can emerge for industrialized countries, be advanced in developing countries, and then sent back to industrialized countries for further refinement until a profitable, reliable product emerges. The contributions of Brazilian scientists to the biofuels industry and of Chinese manufacturing to the solar and wind power industries are examples of a shift towards this new paradigm.

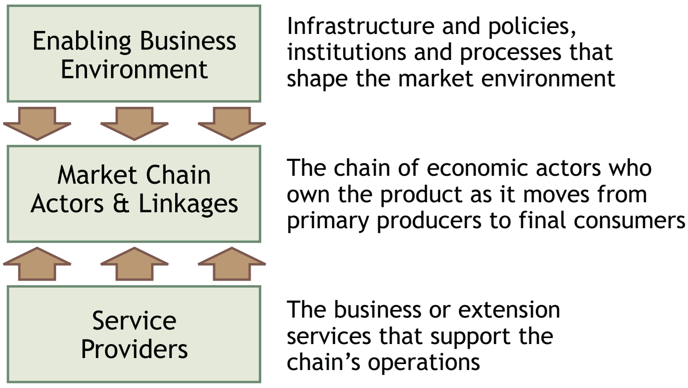
A multi-polar, or networked, approach to innovation and technology development offers global and national benefits. On the global level, it is an effective way to get suitable environmentally sound technologies as soon as possible in developing countries where the greatest GHG growth is projected under business-as-usual. On the national level, it allows major developing countries to profitably partake in the energy technology revolution, rather than simply being technology takers. This leads to economic development and creation of high-paying jobs.

# Annex 8 Market mapping for identifying barriers and inefficiencies (in support of Chapter 5)

## The Market Mapping Technique

Albu and Griffith (2005) describe the system for technology diffusion by dividing the market map into three elements: the business enabling environment; the market chain; and the market supporting services. These elements are illustrated below.

**The market map method**




*Source: Albu and Griffith, 2005.*

## The market chain

For the market chain, which is the main representation of the market system, the question being asked is: *who are the economic actors in the market chain*? This question should elicit responses which may include: primary producer, importer, trader, processor, input supplier, financier, project developer, utility, wholesaler, retailer and customer.

## Business enabling environment

The business-enabling environment should include the critical factors and trends shaping the market and the operating conditions such as infrastructure, policies, and institutions. The purpose is to identify the trends affecting the business environment and to identify who has the power in the market and who is driving change. An understanding of the market conditions including key drivers and incentives to help accelerate the scale and speed of technology transfer and deployment can therefore be developed. According to Albu and Griffith (2005), the enabling environment encompasses the following:

- Market demand,
- Consumption trends,
- Tax/subsidies and tariff regimes,
- Transformation activities and costs of doing business,
- Infrastructure constraints and investment policies,
- Transport policies and licensing,
- Technological development,

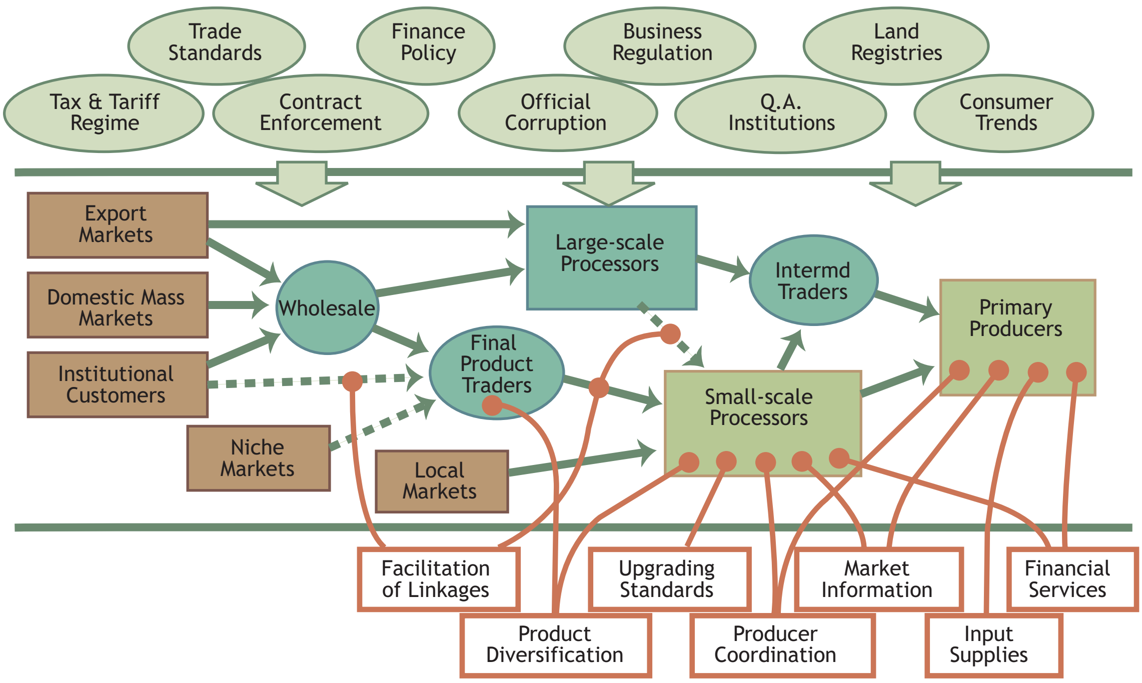
- Trade regime (import/export),
- Transaction activities,
- Systems of finance,
- Gender roles in business and finance,
- Registration of land and property,
- Legal requirements for contracts,
- Commercial law,
- Business licenses and regulation, and
- Standards quality control and enforcement.

## Supporting Services

Supporting services are the business and extension service providers supporting the market chain. The linkages to the market chain are shown in the diagram below to complete the market map. The purpose is to identify the needs for services and who the users are. This gives insights on what can be done in terms of supporting services to make the market more efficient. Such services are myriad but can include financial services, quality control, technical expertise and market information services.

Below, an example is given of the type of output expected from a mapping exercise. Figure A8-1 below is an initial market map of small scale biomass gasification stoves in Kenya and even more detailed information would be expected to be produced.

**Figure A8-1. An example of a completed market map**




*Source: Albu and Griffith, 2005*

The **opportunities** expected if the technology was implemented are listed in the following table.

| Country | Kenya |
|---|---|
| **Opportunities for small scale biomass gasification** | • Categorise as programmatic Clean Development Mechanism<br>• Opportunities for technology and innovation<br>• For technology for adaptation<br>• For locals to participate<br>• For local capacity building<br>• For financial savings at household and national level<br>• For job creation and poverty alleviation<br>• For waste management utilisation<br>• For international trade<br>• For scaling up<br>• For reduced IAP for health<br>• For reduced time and frequency of firewood collection |

Some **blockages and barriers** identified in the system were identified from the market map and discussions in the group. These are listed below as initial examples of what can be produced as a first pass through the problem. More detailed analysis would then follow.

| Country | Kenya enabling business environment |
|---|---|
| **Blockages for small scale biomass gasification** | • Financial services to support investment<br>• Facilitative import regime, Clearance of goods problem: The goods come through the customs bonded warehouses and one normally needs an accredited company or firm to help process and handle paperwork with the revenue and custom officials before goods are released. This process is called clearance of goods.<br>• Infrastructure poor: communication system<br>• Weak policies/legal framework for enforcement of laws and regulations<br>• Poor extension services<br>• Lack of awareness among stakeholders<br>• Social/cultural barriers<br>• Lack of enforcement of standards and quality control<br>• Lack of capacity for Operation and maintenance<br>• Lack of spare parts<br>• Lack of media interest in promoting technology<br>• Gender participation and integration<br>• Turnover tax in 2007/8 finance bill and this will affect SMEs disproportionately |

| Country | Kenya enabling business environment (continued) |
|---|---|
| **Blockages for small scale biomass gasification** | • R&D needs to be reviewed<br>• Monitoring and evaluation<br>• Capacity building for design<br>• Trade policies<br>• Taxation (improved and subsidies<br>• Environment policies<br>• Science and technology policies<br>• Energy policy<br>• Ministry of Trade and Industry (MOTI)/Ministry of Energy (MOE)/ Ministry of Environment (MoEnv)<br>• KRA/KEBS/KIRDI/KFS<br>• Research and training institutions<br>• Organisation to drive the process KEREA, KAM, KHA<br>• Anti-dumping<br>• Financial restrictions of low purchasing power<br>• Accessing credit<br>• High perceived risk |

**Support services** needed for the market

1. Transporters
2. Shipping Companies
3. Clearing and forwarding agencies
4. Maintainers
5. Pre shipment inspection
6. Insurance
7. Banks
8. Sales reps
9. Marketing in media
10. Ministries Ministry of Agriculture (MoA)
11. Extension workers
12. Financial institutions MFI BANKS Coops NGOs

**Market chain actors**

1. Designers
2. Raw material and product suppliers
3. Producers
4. Importers
5. Stockists/wholesalers
6. Transporters
7. Retailers
8. Sales Agents
9. Promoters
10. Installers
11. Competitors
12. Regulators for Quality control and licensing
13. Trade consumers
14. Service agents
15. Financiers
16. Technology owners
17. Consumers include Households
18. Government
19. SMEs
20. Institutions, e.g., schools, hospitals, hotels/restaurants, prisons
21. Social groups
22. Womens groups
23. Church Groups
24. Camps(xxx/IDP)/tourists
25. Aid agencies
26. NGOs

## A comparison across countries identified the following common problems

A comparison carried out mainly from the data for Kenya, Chile and Thailand identified many **common blockages** which are independent of size or technology. These are presented below in terms of the different aspects of the market map.

**Market Chain**

- Lack of technology transfer network,
- Lack of awareness of stakeholders and for large projects particularly linkages and contacts to external producers,
- Cost of new technologies and no accounting for externalities,
- Availability of cheaper high carbon alternatives,
- Need to demonstrate unfamiliar and adapt to local conditions,
- Lack of competition especially in electricity supply.

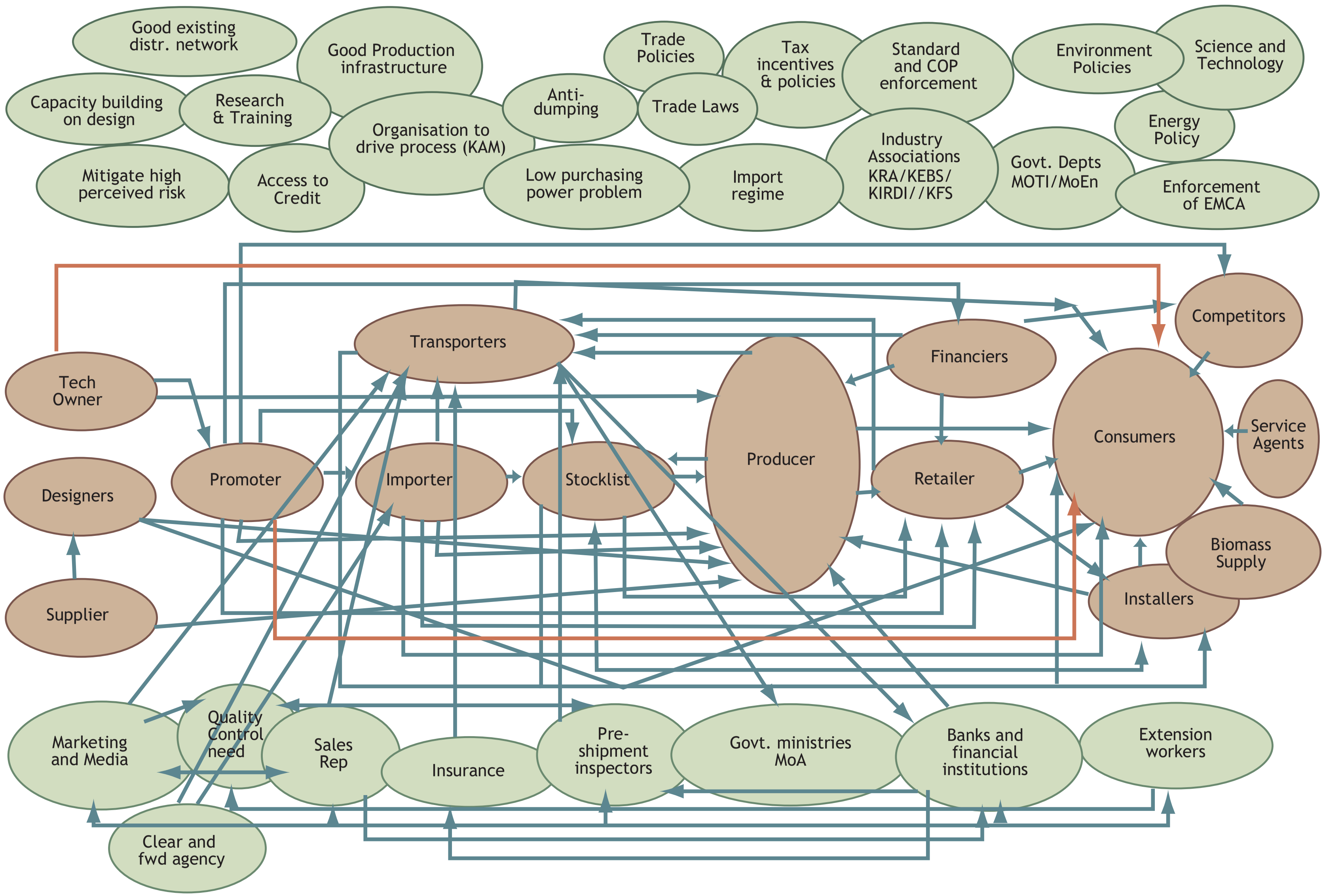
**Enabling Environment**

- Weak policies,
- Lack of regulations, standards and enforcement,
- Complex procedures,
- Import procedures need to be simplified and incentivised for these new technologies,
- Lack of integration across government, e.g., Fiscal policies and particularly tax regimes need to be aligned to encourage their adoption,
- Poor infrastructure,
- Lack of incentives.

**Support Services**

- Lack of R&D support,
- Lack of market information,
- Lack of good Quality control,
- Local capacity building to bridge expertise gaps,
- Language and cultural support,
- Finance availability for new technologies and small scale technologies and measures to offset the additional risks associated with these new technologies.

**Figure A8-1. Market map for small scale biomass gasification stoves in Kenya (ENTTRANS, 2008)**



# Annex 9 Spreadsheet example cost assessments

In Chapters 3 and 4 of this Handbook, the National TNA Team and stakeholder groups are recommended to apply the cost of technology and economic viability of a technology investment as a criterion for prioritizing technologies. The second cost criterion mentioned in these chapters is Internal Rate of Return (IRR). IRR shows the profit from an investment (expressed as a percentage) for a given period of time, *e.g.*, 10 years. It is derived from calculating the interest rate for which the net present value[19] of an investment project for the given period of time is equal to zero:

$$NPV = \sum_{t=0}^{N} \frac{C_t}{(1+r)^t} = 0$$

In combination with the USD/GHG cost figure, the IRR could provide a more complete overall cost assessment for a technology. For instance, a project with a high USD/GHG cost figure could still have a high IRR (*e.g.*, small scale CHP), whereas a project with a low USD/GHG figure could also have a low IRR (*e.g.*, landfill gas capture). In terms of roll out potential, the IRR would be a stronger indicator of appropriateness of the technology than USD/GHG.

In order to assist in making these calculations, a spreadsheet model has been prepared (included in TNAssess). It calculates IRRs for different technologies and, through sensitivity analysis, takes account of the impact on an IRR of the lifetime and prices changes (*e.g.*, raw material, fuel, carbon). In this Annex, an example is shown of how the spreadsheet can be used and how it helps in assessing the economic viability of a technology investment.

The following tables have been taken as examples from the spreadsheet model and completed with hypothetical data for the example of low-carbon technologies in the cement sector:

- Table A9-1 shows the **Data collection** sheet in which the basic data for cement production in the country concerned can be collected, such as annual cement production, price of raw material, labor costs, fuel prices, *etc.*, as well as possible subsidies for use of low-carbon technologies. Table A9-1 is repeated in different worksheets for a range of new, low-carbon technologies with corresponding new data.
- Table A9-2 shows the overall annual **financial performance** of an existing (base case) technology in the cement sector. It calculates an IRR for that technology over a lifetime of 10 years. In the model, Table A9-2 is repeated in different worksheets for a range of new, low-carbon technologies, thereby using the data collected in the data collection sheets for these technologies. It is noted that the worksheets represented by Table A9-2 are automatically completed as the formulas are already prepared; the National TNA Team only needs to complete the worksheet represented by Table A9-1.
- Table A9-3 shows the results collected from each new technology considered in terms of capital cost, fuel savings, electricity savings, and $CO_2$ emission reductions. Subsequently, the effect on IRR can be analyzed under different circumstances, *e.g.*, the IRR when only energy saving benefits are considered, the IRR when energy saving and carbon credits are included, or when subsidy schemes can be used. Users of the model can fill in 'yes' or 'no' for each circumstance and see what happens with the IRR. When a benchmark IRR is available for the country, *i.e.*, the interest rate for a regular commercial market-based investment, the IRRs can be compared with this benchmark. Any IRR higher than the benchmark represents an economically viable technology.

It is noted that these calculations are meant to provide indications of the economics of different technologies and cannot be considered official values for eventual financial market decisions. However, the spreadsheet model can be a useful tool for project developers who, after the completion of the TNA process, would prepare project proposals for the prioritized technologies for mitigation and adaptation. After all, similar cost calculations are recommended by the UNFCCC Guidebook on preparing technology transfer projects for financing (EGTT, 2008, see also Section 6.4 of this Handbook).

## Table A9-1: DATA ASSUMPTIONS

| BASE CASE | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Assumptions** | **Year** | | | | | | | | | | |
| | 0 | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| clinker production (tons / year) | | 55.000 | 55.000 | 55.000 | 55.000 | 55.000 | 55.000 | 55.000 | 55.000 | 55.000 | 55.000 |
| cement production (tons / year) | | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 |
| raw material need (tons / year) | | 96.000 | 96.000 | 96.000 | 96.000 | 96.000 | 96.000 | 96.000 | 96.000 | 96.000 | 96.000 |
| costs per ton clinker ($/t clinker) | | 15,6 | 15,6 | 15,6 | 15,6 | 15,6 | 15,6 | 15,6 | 15,6 | 15,6 | 15,6 |
| electricity price ($/kWh) | | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 |
| costs per ton raw material ($/ ton) | | 9,44 | 9,44 | 9,44 | 9,44 | 9,44 | 9,44 | 9,44 | 9,44 | 9,44 | 9,44 |
| electricity for raw materials preparation | | | | | | | | | | | |
| *electricity in coal mill (kWh/t clinker)* | | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| *electricity for crushing process (kWh/t clinker)* | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| *electricity for raw mill (kWh/t clinker)* | | 28 | 28 | 28 | 8 | 28 | 28 | 28 | 28 | 28 | 28 |
| electricity for clinker production | | | | | | | | | | | |
| *electricity for kiln & cooler (kWh/tclinker)* | | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 |
| electricity for finish grinding | | | | | | | | | | | |
| *cement mill (kWh/tcement)* | | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| electricity for miscellaneous activities | | | | | | | | | | | |
| *mining and transportation (kWh/tclinker)* | | 1,6 | 1,6 | 1,6 | 1,6 | 1,6 | 1,6 | 1,6 | 1,6 | 1,6 | 1,6 |
| *packing house (kWh/tcement)* | | 1,9 | 1,9 | 1,9 | 1,9 | 1,9 | 1,9 | 1,9 | 1,9 | 1,9 | 1,9 |
| *miscellaneous* | | 2,0 | 2,0 | 2,0 | 2,0 | 2,0 | 2,0 | 2,0 | 2,0 | 2,0 | 2,0 |
| water | | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| Other costs | | | | | | | | | | | |
| *labour* | | 84.000 | 84.000 | 84.000 | 84.000 | 84.000 | 84.000 | 84.000 | 84.000 | 84.000 | 84.000 |
| *maintenance* | | 72.000 | 2.000 | 72.000 | 72.000 | 72.000 | 72.000 | 72.000 | 72.000 | 72.000 | 72.000 |
| *marketing and sales* | | 18.000 | 18.000 | 18.000 | 18.000 | 18.000 | 18.000 | 18.000 | 18.000 | 18.000 | 18.000 |
| *packing and storage* | | 270.000 | 270.000 | 270.000 | 270.000 | 270.000 | 270.000 | 270.000 | 270.000 | 270.000 | 270.000 |
| *unforeseen expenses* | | 18.000 | 18.000 | 18.000 | 18.000 | 18.000 | 18.000 | 18.000 | 18.000 | 18.000 | 18.000 |
| *general expenses* | | 72.000 | 72.000 | 72.000 | 72.000 | 72.000 | 72.000 | 72.000 | 72.000 | 72.000 | 72.000 |
| *total* | | 534.000 | 534.000 | 534.000 | 534.000 | 534.000 | 534.000 | 534.000 | 534.000 | 53 | 534.000 |
| Fuel | | | | | | | | | | | |

## Table A9-1: DATA ASSUMPTIONS *(continued)*

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Fuel consumption (GJ/tcement)* | | 3,55 | 3,55 | 3,55 | 3,55 | 3,55 | 3,55 | 3,55 | 3,55 | 3,55 | 3,55 |
| *Fuel price ($/GJ)* | | 0,056 | 0,056 | 0,056 | 0,056 | 0,056 | 0,056 | 0,056 | 0,056 | 0,056 | 0,056 |
| Sales price cement | | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |
| CO2 price | | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| Basic capital outlay | | | | | | | | | | | |
| ***equipment grinding etc.*** | 3.000.000 | | | | | | | | | | |
| ***buildings*** | 500.000 | | | | | | | | | | |
| Subsidy | 1.000.000 | | | | | | | | | | |
| loan | 2.000.000 | | | | | | | | | | |
| interest | 0,08 | | | | | | | | | | |

## Table A9-2: BASE CASE: CEMENT PLANT

| | Year 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Expenses | | | | | | | | | | | |
| *capital outlay* | | | | | | | | | | | |
| *grinding* | 3.000.000 | | | | | | | | | | |
| *additional equipment* | | | | | | | | | | | |
| *buildings* | 500.000 | | | | | | | | | | |
| *Total capital outlay* | 3.500.000 | | | | | | | | | | |
| n $2000000 (8%) | | 160.000 | 160.000 | 160.000 | 160.000 | 160.000 | 160.000 | 160.000 | 160.000 | 160.000 | 160.000 |
| clinker | | | | | | | | | | | |
| *tons* | | 60000 | 60000 | 60000 | 60000 | 60000 | 60000 | 60000 | 60000 | 60000 | 60000 |
| *costs per ton* | | 15,6 | 15,6 | 15,6 | 15,6 | 15,6 | 15,6 | 15,6 | 15,6 | 15,6 | 15,6 |
| *Total costs* | | 936.000 | 936.000 | 936.000 | 936.000 | 936.000 | 936.000 | 936.000 | 936.000 | 936.000 | 936.000 |
| raw materials (slag,gypsum) | | | | | | | | | | | |
| *tons* | | 96.000 | 96.000 | 96.00 | 96.000 | 96.000 | 96.000 | 96.000 | 96.000 | 96.000 | 96.000 |
| *costs per ton raw material* | | 9,44 | 9,44 | 9,44 | 9,44 | 9,44 | 9,44 | 9,44 | 9,44 | 9,44 | 9,44 |
| *total costs raw material* | | 906.240 | 906.240 | 906.240 | 906.240 | 906.240 | 906.240 | 906.240 | 906.240 | 906.240 | 906.240 |
| electricity coal | | | | | | | | | | | |
| *kWh/tclinker* | | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| *tons clinker* | | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 |
| *total kWh for coal mill* | | 440000 | 440000 | 440000 | 440000 | 440000 | 440000 | 440000 | 440000 | 440000 | 440000 |
| *price/kWh* | | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0, | 0,1 | 0,1 | 0,1 | 0,1 |
| *total electricity costs coal mill* | | 44000 | 44000 | 44000 | 44000 | 44000 | 44000 | 44000 | 44000 | 44000 | 44000 |
| electricity crushing | | | | | | | | | | | |
| *kWh/tclinker* | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| *tons clinker* | | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 |
| *total kWh for crushing* | | 110000 | 110000 | 110000 | 110000 | 110000 | 110000 | 110000 | 110000 | 110000 | 110000 |
| *price/kWh* | | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 |
| *total electricity costs crushing* | | 11000 | 11000 | 11000 | 11000 | 11000 | 11000 | 11000 | 11000 | 11000 | 11000 |
| raw mill | | | | | | | | | | | |
| *kWh/tclinker* | | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 |

**Table A9-2: BASE CASE: CEMENT PLANT** *(continued)*

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *tons clinker* | | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 |
| *total kWh for raw mill* | | 1540000 | 1540000 | 1540000 | 1540000 | 1540000 | 1540000 | 1540000 | 1540000 | 1540000 | 1540000 |
| *price/kWh* | | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 |
| *total electricity costs raw mill* | | 154000 | 154000 | 154000 | 154000 | 154000 | 154000 | 154000 | 154000 | 154000 | 154000 |
| electricity clinker production | | | | | | | | | | | |
| *kWh/tclinker* | | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 |
| *tons clinker* | | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 |
| *total kWh for clinker production* | | 1540000 | 1540000 | 1540000 | 1540000 | 1540000 | 1540000 | 1540000 | 1540000 | 1540000 | 1540000 |
| *price/kWh* | | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 |
| *total electricity costs clinker pro* | | 154000 | 154000 | 154000 | 154000 | 154000 | 154000 | 154000 | 154000 | 154000 | 154000 |
| cement mill | | | | | | | | | | | |
| *kWh/tcement* | | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| *tons cement* | | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 |
| *total kWh for cement mil* | | 1800000 | 1800000 | 1800000 | 1800000 | 1800000 | 1800000 | 1800000 | 1800000 | 1800000 | 1800000 |
| *price/kWh* | | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 |
| *total electricity costs cement mill* | | 180000 | 180000 | 180000 | 180000 | 180000 | 180000 | 180000 | 180000 | 180000 | 180000 |
| transportation | | | | | | | | | | | |
| *kWh/tclinker* | | 1,6 | 1,6 | 1,6 | 1,6 | 1,6 | 1,6 | 1,6 | 1,6 | 1,6 | 1,6 |
| *tons clinker* | | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 | 55000 |
| *total kWh for mining & transportation* | | 88000 | 88000 | 88000 | 88000 | 88000 | 88000 | 88000 | 88000 | 88000 | 88000 |
| *price/kWh* | | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 |
| *total electricity costs mining & transportation* | | 8800 | 8800 | 8800 | 8800 | 8800 | 8800 | 8800 | 8800 | 8800 | 8800 |
| packing house | | | | | | | | | | | |
| *kWh/tcement* | | 1,9 | 1,9 | 1,9 | 1,9 | 1,9 | 1,9 | 1,9 | 1,9 | 1,9 | 1,9 |
| *tons cement* | | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 |
| *total kWh for packing house* | | 114000 | 114000 | 114000 | 114000 | 114000 | 114000 | 114000 | 114000 | 114000 | 114000 |
| *price/kWh* | | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 |
| *total electricity costs packing house* | | 11400 | 11400 | 11400 | 11400 | 11400 | 11400 | 11400 | 11400 | 11400 | 11400 |
| utilities: misc. | | | | | | | | | | | |
| *kWh/tcement* | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| *tons cement* | | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 |

## Table A9-2: BASE CASE: CEMENT PLANT *(continued)*

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *total kWh for misc.* | | 120000 | 120000 | 120000 | 120000 | 120000 | 120000 | 120000 | 120000 | 120000 | 120000 |
| *price/kWh* | | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 |
| *total electricity costs misc.* | | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 |
| total costs electricity consumption | | 575200 | 575200 | 575200 | 575200 | 575200 | 575200 | 575200 | 575200 | 575200 | 575200 |
| water | | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| fuel | | | | | | | | | | | |
| *GJ* | | 213000 | 213000 | 213000 | 213000 | 213000 | 213000 | 213000 | 213000 | 213000 | 213000 |
| *price per GJ* | | 0,056 | 0,056 | 0,056 | 0,056 | 0,056 | 0,056 | 0,056 | 0,056 | 0,056 | 0,056 |
| *total costs* | | 11.928 | 11.928 | 11.928 | 11.928 | 11.928 | 11.928 | 11.928 | 11.928 | 11.928 | 11.928 |
| Other costs (labor, maintenance, etc.) | | 534.000 | 534.000 | 534.000 | 534.000 | 534.000 | 534.000 | 534.000 | 534.000 | 534.000 | 534.000 |
| Depreciation | | | | | | | | | | | |
| *10 years for equipment* | | 300000 | 300000 | 300000 | 300000 | 300000 | 300000 | 300000 | 300000 | 300000 | 300000 |
| *25 years for buildings* | | 20000 | 20000 | 20000 | 20000 | 20000 | 20000 | 20000 | 20000 | 20000 | 20000 |
| *total depreciation costs* | | 320000 | 320000 | 320000 | 320000 | 320000 | 320000 | 320000 | 320000 | 320000 | 320000 |
| **Revenues** | | | | | | | | | | | |
| Cement end product | | | | | | | | | | | |
| *tons* | | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 |
| *sales price per ton* | | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |
| *sales cement annual revenu* | | 4.200.000 | 4.200.000 | 4.200.000 | 4.200.000 | 4.200.000 | 4.200.000 | 4.200.000 | 4.200.000 | 4.200.000 | 4.200.000 |
| CO2 credits | | | | | | | | | | | |
| *credit price (€/ton)* | | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| *tons reduction* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *CO2 revenues* | | - | - | - | - | - | - | - | - | - | - |
| Subsidies (meeting VA) | | | - | - | - | - | - | - | - | - | 63.435 |
| Subsidies 20% | 0 | | | | | | | | | | |
| *Annual profit* | | 750.632 | 750.632 | 750.632 | 750.632 | 750.632 | 750.632 | 750.632 | 750.632 | 750.632 | 814.067 |
| *tax (40% of gross profit)* | | 300.253 | 300.253 | 300.253 | 300.253 | 300.253 | 300.253 | 300.253 | 300.253 | 300.253 | 325.627 |
| *Annual net profit* | -3.500.000 | 450.379 | 450.379 | 450.379 | 450.379 | 450.379 | 450.379 | 450.379 | 450.379 | 450.379 | 488.440 |
| | | | | | | | | | | | |
| *IRR* | 5% | | | | | | | | | | |

**Table A9-3: Results - ENERGY SAVING TECHNOLOGIES IN CEMENT PRODUCTION EXPLORED**

| **1. High efficiency roller mills** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Assumptions** | | | | | | **Year** | | | | |
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| Investment ($/ton raw material) | 5,5 | | | | | | | | | |
| electricity saving (kWh/tcement) | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| CO2 savings (t CO2/tcement) | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 |
| **2. Energy management and process control** | | | | | | | | | | |
| **Assumptions** | | | | | | **Year** | | | | |
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| capital costs ($/tcement) | 1,7 | | | | | | | | | |
| fuel savings (GJ/tcement) | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 |
| electricity savings (kWh/tcement) | 2,5 | 2,5 | 2,5 | 2,5 | 2,5 | 2,5 | 2,5 | 2,5 | 2,5 | 2,5 |
| CO2 savings (tCO2/tcement | 0,02 | 0,02 | 0,02 | 0,02 | 0,02 | 0,02 | 0,02 | 0,02 | 0,02 | 0,02 |
| *ETC* | | | | | | | | | | |

**Table A9-3: continued**

## COMPARISON OF INTERNAL RATES OF RETURN FOR EACH TECHNOLOGY AND THEIR COMBINATIONS

| | | | | | |
|---|---|---|---|---|---|
| **General price assumptions** | | | | | |
| Electricity price ($/kWh) | 0,1 | | | | |
| Sales price cement ($/ton cement) | 70 | | | | |
| CO2 price ($/ton reduction) | 17 | | | | |
| | | | | | |
| **Single technology applications** | Choice | **Internal rate of return** | **Viability of investment** | **Benchmark** | **9%** |
| **1. High efficiency roller mills** | **1 (yes) 0 (no)** | | | | |
| energy saving only | 1 | 2% | - | | |
| energy saving + CO2 | 1 | 3% | - | | |
| energy saving + CO2+ VA grant | 1 | 3% | - | | |
| energy saving+CO2+subsidy20% | 1 | 3% | - | | |
| | | | | | |
| **2. Energy management and process control** | **1 (yes) 0 (no)** | | | | |
| energy saving only | 1 | 4% | - | | |
| energy saving + CO2 | 1 | 5% | - | | |
| energy saving + CO2+ VA grant | 1 | 5% | - | | |
| energy saving+CO2+subsidy20% | 1 | 5% | - | | |
| | | | | | |
| **3. Use of waste derived fuels** | **1 (yes)** | **0 (no)** | | | |
| energy saving only | 1 | 2% | - | | |
| energy saving + CO2low | 1 | 4% | - | | |
| energy saving + CO2 high | 1 | 10% | viable | | |
| energy saving + CO2 high + VA grant | 1 | 10% | viable | | |
| energy saving+CO2+subsidy20% | 1 | 16% | viable | | |
| ETC. | | | | | |
| ***Reference case cement plant*** | 5% | | | | |

# Abbreviations

| | |
|---|---|
| **COP** | Conference of the Parties |
| **CTI** | Climate Technology Initiative |
| **EERE** | Energy Efficiency and Renewable Energy |
| **EGTT** | Expert Group on Technology Transfer |
| **FAR** | Fourth Assessment Report of the IPCC |
| **GEF** | Global Environment Facility |
| **GHG** | Greenhouse gas |
| **IARU** | International Association of Research Universities |
| **IEA** | International Energy Agency |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **IPR** | Intellectual Property Rights |
| **LULUCF** | Land Use, land use change and forestry |
| **MACs** | Marginal abatement costs |
| **MCDA** | Multi-criteria decision analysis |
| **MRV** | Monitoring, reporting and verification |
| **NAMA** | Nationally Appropriate Mitigation Actions |
| **NAPA** | National Adaptation Program of Action |
| **NREL** | US National Renewable Energy Laboratory |
| **PMCA** | Participatory Market Chain Analysis Approach |
| **ppm** | parts per million |
| **R&D** | Research and development |
| **SBSTA** | UNFCCC Subsidiary Body for Scientific and Technological Advice |
| **SBI** | UNFCCC Subsidiary Body for Implementation |
| **SD** | Sustainable Development |
| **SME** | Small and medium scale enterprises |
| **TNA** | Technology needs assessments |
| **UNDP** | United Nations Development Program |
| **UNEP** | United Nations Environment Program |
| **UNFCCC** | United Nations Framework Convention on Climate Change |

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