Methodology for Climate Technology and Prioritization in a Global Context

Energy research Centre of the Netherlands (ECN):

L. Würtenberger

L.R. Cameron

A. International:

P. Yowargana

Q. Lu

E. van Sambeek

J. Chu

ECN-E--10-098

December 2010

Acknowledgement
This paper was written by Laura Würtenberger and Lachlan Cameron (ECN), and Emiel van Sambeek, Jenny Chu, Ping Yowargana and Qi Lu (Azure International). It has been commissioned by the World Bank to support the World Bank's work on the GEF-sponsored China Technology Needs Assessment (TNA) process. With ECN, this work is registered under project number 5.0815. The contact person at ECN is Laura Würtenberger (email: wuertenberger@ecn.nl; phone: +31 224 564 948).

Abstract
This paper is part of the preparation phase of the China Technology Needs Assessment (TNA) that is being implemented by the World Bank and financed by the Global Environment Facility (GEF) at the request of the Chinese government. The paper seeks to inform the methodology of the planned China TNA by providing suggestions for a generic process and approach based on global best practices for identifying, evaluating and prioritizing climate technologies. It reviews previous TNAs, related assessment efforts and the current UNDP TNA Handbook, and provides suggestions for the China TNA on the following key steps of a TNA process:

- Sector prioritization.
- Technology pre-selection, information gathering, and familiarization.
- Technology prioritization.
- Analyzing gaps between technology use in different countries.
- Identifying barriers to deployment of global best practice of prioritized technologies in a country with less advanced technologies.

The paper also offers some specific considerations on adaptation technologies and ends with conclusions on the key decisions that have to be taken during the organization and execution of the China TNA.

Contents

List of tables

List of figures

Summary

This paper is part of the preparation phase of the China Technology Needs Assessment (TNA) that is being implemented by the World Bank and financed by the Global Environment Facility (GEF) at the request of the Chinese government. The paper seeks to inform the methodology of the planned China TNA by providing suggestions for a generic process and approach based on global best practices for identifying, evaluating and prioritizing climate technologies. It reviews previous TNAs, related assessment efforts and the current UNDP TNA Handbook, and provides suggestions for the China TNA on the following key steps of a TNA process:
- Sector prioritization.
- Technology pre-selection, information gathering, and familiarization.
- Technology prioritization.
- Analyzing gaps between technology use in different countries.
- Identifying barriers to deployment of global best practice of prioritized technologies in a country with less advanced technologies.

The following lists the main suggestions drawn from this analysis:

Background on existing methodologies for climate technology identification and prioritization and lessons learned
- Experience from previous TNAs can only guide the China TNA process to a limited extent as few TNAs have been conducted in large emerging economies to date.
- The latest version of UNDP TNA handbook, launched mid 2010, builds on feedback from earlier versions.
- Previous TNAs identified the following points for improvement: weaknesses in approaches for addressing adaptation, a need to strengthen the follow-up process to the TNA, i.e. barrier removal, institutionalization of the process, implementation of technology transfer activities, stakeholder engagement and buy-in.

Specific considerations for adaptation technologies
- The prioritization of technologies for adaptation is dominated by the high uncertainties of vulnerability assessments on a national / local level.
- It is recommended to conduct the TNAs for mitigation and adaptation technologies separately as both categories need different stakeholders and have little overlap in terms of technologies.
- However, it is also recommended that national / local climate vulnerability assessments are taken into account for mitigation technologies that depend on certain natural resources, e.g. hydro power.

Sector Prioritization
- A TNA study that considers all technology sectors risks becoming unwieldy and as a result ineffective through a loss of focus on the key areas of technology improvement that a country should target.
- Sector prioritization is usually based on national development priorities and identification of key GHG emitting sector. The size, complexity and internal diversity of China is likely to lead to the prioritization of a range of sectors.
- The approach suggested in current UNDP TNA handbook may not be able to sufficiently take into account China's size and complexity.
- The paper describes three potential approaches for sector prioritization which would be linked to the general approach taken in the China TNA in terms of dealing with the size and diversity of the country:

- National approach with national sector selection: technologies prioritized on a national level based on national development goals and needs.
- Regional Approach with National Sector Selection: national development goals and needs determine sector selection, but technologies are prioritized at a regional level based on regional preferences.
- Regional Approach with Regional Sector Selection: each region selects priority sectors and identifies priority technologies based on their development goals and preferences.

- The choice of the approach would be done by the national TNA team, depending on preferences on involvement of regions and on available resources.

Technology pre-selection, information and familiarization

- Technology pre-selection is a crucial steps as it may pre-determine the outcome of the prioritization.
- Possibility of involving sector experts to identify most important current and future technologies.
- Lack of information regarding the specified technologies is cited as a key challenge in previous TNAs. Stakeholders tend to favour technologies they are familiar with or have heard about.
- Technology factsheets could be used as a basis for information collection and technology familiarization.
- Where practical, issues covered in the technology factsheet should already correspond to the criteria used later for the technology prioritization.
- Filling out comprehensive technology factsheets is a time and resource intensive process. A two stage approach is suggested.
- Potential information sources: existing technology databases, for example ClimateTechWiki, which is specifically being developed for TNAs and technology specific publications (e.g. by the IEA) for global parameters, for China-specific information, information more readily available for high-energy intensive sectors.

Technology Prioritization Process

- There are a number of possible approaches, each with its own benefits and limitations, for prioritizing technologies, e.g. different forms of multi-criteria decision analysis, marginal abatement cost curves, SWOT analysis and cost-benefit analysis. based on numerous different assessment criteria as is required by a TNA.
- Previous TNAs have used an MCDA approach as it allows for considering trade-offs between multiple and conflicting objectives.
- A simple linear additive MCDA approach, as recommended in the UNDP TNA Handbook, undertaken in stakeholder workshops could be an appropriate methodology for the China TNA as well, potentially supplemented by a cost-benefit analysis or a SWOT analysis.
- The choice of the stakeholders is crucial as it seems to have determined the outcome of previous prioritization processes.
- MCDA should only be used to guide the decision making process. The choice of a moderator is crucial for the quality of the process.
- TNAssess might be the most obvious choice for an MCDA software.

Criteria Selection

- Criteria selection is a crucial step, as it is expected that the outcome of the technology prioritization process will be relatively sensitive to the criteria selected.
- Therefore criteria selection is a key decision to be taken by the TNA team and the experts and national decision makers involved in the TNA process.
- The information suggested in the technology factsheet gives some guidance for criteria, as do the criteria that have been commonly used in previous TNAs and the CTF investment criteria.

- Information collection about how a technology rates according to the criteria can be combined with information collection for the technology factsheets.

How to Determine 'Gap' in Technology between China and other Countries

- Analyzing technology gaps is not a straightforward process as it highly depends on the definition of what constitutes the gap.
- However, gap analysis may be valuable in identifying technology transfer strategies
- Three approaches to gap analysis are described, i.e.
  - Best practice.
  - Benchmarking.
  - Expert Assessment.

Methodology for Identifying Barriers to Deployment

- Barrier analysis to be done on the basis of individual prioritized technologies.
- Market mapping approach suggested in the current TNA handbook especially well suited for rural environments in developing countries.
- More general approach to barrier identification based on expert interviews described.

1. Introduction

Climate change is a global problem that faces many challenges along the path to concerted and coordinated action. Enhancing technology development and transfer for mitigation and adaptation has been flagged as a key element to address climate change. However, there are large barriers associated with technology transfer, which can be observed when analysing the levels of technology implementation that are found in many countries as compared to best practice.

While certain gaps and barriers can be identified and addressed at a global level, technology deployment must happen on a national or local level, and is considered to be most effective when complemented by appropriate national policies that facilitate technology roll-out in the country in question. Technology Needs Assessments provide an instrument under the UNFCC that can be used to determine what gaps and barriers are present and prioritize the resulting identified technologies based on national development priorities.

The China Technology Needs Assessment (TNA) is a $5 million project implemented by the World Bank and financed by the Global Environment Facility (GEF) at the request of the Chinese government. During the preparation stage of the project, which began in mid 2010, the World Bank designed the China TNA in collaboration with the Chinese government. To aid in the design of the China TNA, the World Bank has commissioned five project preparation works. This particular study focuses on the *Initial design of the process and methodologies to identify and prioritize climate technologies* and forms part of one of these five project preparation works.

The overall China TNA, amongst other things, aims to accomplish the following tasks: 1) identify and prioritize climate change mitigation and adaptation technologies, 2) establish the capacity for a broad stakeholder network to institutionalize the process of technology identification and prioritization, and 3) design and pilot test novel mechanisms to accelerate the transfer, development and deployment of prioritized climate technologies for China.

Ultimately, the China TNA aims to improve the understanding of key issues in China such as: current technology developments; which technologies are needed; what are the key technical, policy and market barriers; and how to promote environmental friendly technology joint R&D, transfer and diffusion in the area of climate change mitigation and adaptation.

The main objective of this project preparation study is to provide suggestions for a generic process and methodology based on global best practice by which climate technologies can be identified, evaluated and prioritized. The study is undertaken in parallel with a partner study by a Chinese consultant that will analyze more specifically the preferred process and methodology of climate technology identification, evaluation and prioritization in a uniquely Chinese context.

1.1 Structure of Report

Chapter 1 identifies key characteristics of China that can be considered to differ significantly from other countries that have previously conducted Technology Needs Assessments under the UNFCCC. Chapter 2 reviews existing methodologies for climate technology identification and prioritization and draws key lessons learned. Chapter 3 outlines specific considerations for technology prioritization for adaptation technologies.

Chapters 4 through 8 breakdown the proposed TNA methodology and process for China, which could consist of the following key steps: Step 1) sector prioritization, Step 2) technology pre-selection and familiarization, Step 3) technology prioritization, Step 4) gap analysis between technology in different countries, and Step 5) barrier analysis (see Figure 1).

The UNDP TNA handbook (UNDP, 2010) is used as a basic foundation for building a generic process and methodology, however, the five key steps of the UNDP TNA process were modified to ensure applicability for China. It is therefore recommended that the UNDP handbook be read in parallel with Chapters 4 through 8 of this report.

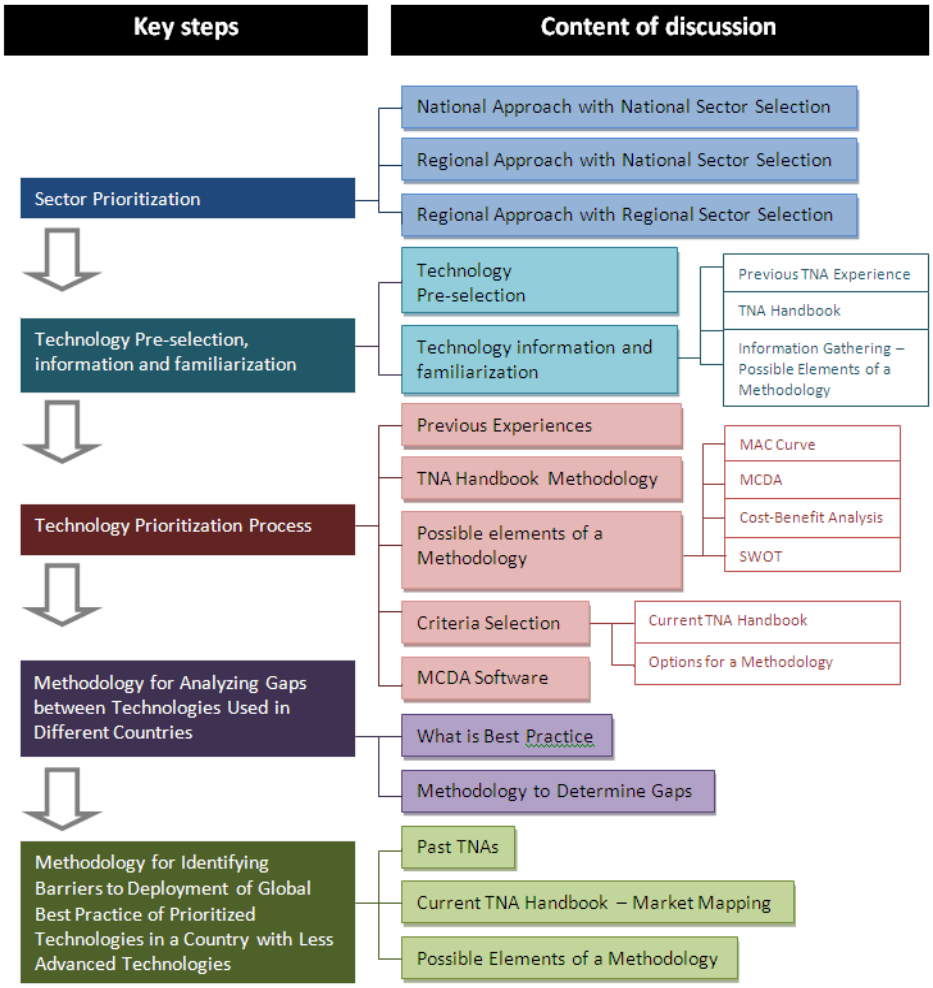


Figure 1.1 *Key stages of the TNA process and major points of consideration for the current report*

Figure 1.1 illustrates the five key stages in chronological order and outlines the main points of consideration that are addressed in this report for each step.

The study concludes with Chapter 9 which summarizes how the study's experiences and considerations could inform the TNA process in China and concludes with the key decisions to be taken by those organizing and facilitating that process.

1.2 Key features in China

The People's Republic of China is one of the world's largest countries in total land area behind Russia and Canada, and is approximately the same size as the United States. China encompasses more than 9.5 million square kilometres, which are delineated into 33 provinces, autonomous regions, municipalities and special administrative regions. Meanwhile, China is the world's most populated country with more than 1.3 billion people living inside its borders.

China's main engine of economic growth is the production of manufactured products exported globally. Experts believe that as production levels continue to grow, so will the absolute levels of embodied energy in export products. According to UNDP, exports of embodied energy increased from 209 million tons of standard coal in 2001 to 631 million tons in 2006, which reflects a relatively stable and rapid growth trend. (UNDP, 2010). This trend is expected to continue as long as China's economy relies on export oriented growth fuelled by coal, the country's primary energy source for the foreseeable future.

At present, China is at an accelerated urbanization stage, with a rapidly growing urban population. In 20 years, China's cities will have added 350 million people to their populations, more than the entire population of the United States today. (UNDP 2010) Being one of the world's fastest growing economies, China has rapidly expanding GHG emissions. China has replaced the USA as the world's biggest emitter since 2006. Since 2000, CO_2 emissions in China have more than doubled. In 2009, CO_2 emissions increased by 9% from the previous year to 8.1 billion tons (NEEA, 2010). China's GHG emissions are also projected to grow significantly in the future. Of the 11 Gt growth in global emissions between 2007 and 2030 projected by the IEA, China accounts for 6 Gt (IEA, 2009).

Currently, China is experiencing uneven economic development between its various provinces. The country's highly-populated Eastern coastal provinces (Jiangsu, Zhejiang, Guangzhou, etc.) are home to most of China's primary export industries and as a result this area experiences higher levels of GDP compared to less densely populated provinces in the West (Sichuan, Gansu, etc). China, however, is addressing this economic disparity with the implementation of the *West China Development Program* launched in 1999. Other regional economic policies include the *North-East Revitalization Plan*, a cross-province plan drafted by NDRC with assistance of relevant ministries and the governments of Liaoning, Jilin and Heilongjiang (WWF, 2010).

The socio-economic differences between China's provinces therefore need to be taken into consideration when assessing technology needs for climate change mitigation and adaptation for the country. For example, small changes in the cost of energy will have a larger impact on vulnerable, low income populations in the West compared to richer populations in the East. Any technology needs assessment done in China also has to take into consideration the varying differences in geography between provinces. Tremendous differences in latitude, longitude, and altitude give rise to sharp variations in precipitation and temperature within China. Although most of the country lies in the temperate belt, its climatic patterns are complex.

China already has a strong mix of technologies in use and these are often produced locally. The TNA therefore needs to take into consideration the existing technology mix and how to balance a promising new technology versus an established one that needs wider domestic utilization. Balancing international technology transfer and domestic/internal transfer between regions with different development level should thus be addressed in the TNA.

Another important aspect of local technology advancement is the ability to localize the transferred technology, which may lead to effective and efficient technology transfer. Such localization was successfully demonstrated in China's wind industry.

Among the areas targeted by China for change is its industrial sector. Its economic progress depends on intensive energy use, but China is targeting its industrial sector for restructuring , to become amongst other factors more energy efficient, while ensuring that it satisfies export sector and domestic consumption demands. Growth in domestic demand is expected to become one of the main pillars of the economy and a more important driver of economic growth by 2030.

By that time, the competitive capacity of China's export oriented manufacturing industry will likely weaken due to rapidly rising labour costs (UNDP, 2010).

China's economic restructuring would also lead to a gradual shift from the industrial sector to the service sector, i.e. from the secondary to the tertiary industry as they are called in China. Driven by both market demand as the consequence of China's economic growth and central government policies encouraging the development of the service sector, economic restructuring will also impact future energy consumption and GHG emissions pattern.

The strategies and policies are mainly formulated by central government departments charged with establishing broad principles to promote energy saving, energy efficiency and lower carbon consumption. Implementing the policies lies in the hands of local governments who must ensure that their local development strategies are fully consistent with the policies and measures of the central government. One of the challenges to successful implementation is that many local governments are pushing rapid economic development, which often leads to investments and measures that are at odds with central priorities (UNDP, 2010).

2. Background on existing methodologies

- Experience from previous TNAs can guide the China TNA process only to a limited extent as few TNAs have been conducted to date in large emerging economies.
- Latest version of UNDP TNA handbook, launched in October 2010, builds on feedback on earlier versions.
- Previous TNAs identified: weaknesses in approaches for addressing adaptation, a need to strengthen the follow-up process to the TNA, i.e. barrier removal, institutionalization of the process, implementation of technology transfer activities, stakeholder engagement and buy-in.

2.1 Previous TNAs under the UNFCCC between 2000 and 2008

Technology Needs Assessments (TNAs) were introduced as a tool under the UNFCCC in the technology transfer framework, which was established at COP 7 by Decision 4/CP.7 to enhance the implementation of Article 4, paragraph 5 of the United Nations Framework Convention on Climate Change. TNAs are referred to as "a set of country-driven activities that identify and determine the mitigation and adaptation technology priorities of Parties other than developed country Parties, and other developed Parties not included in Annex II [to the Convention], particularly developing country Parties. They involve different stakeholders in a consultative process to identify the barriers to technology transfer and measures to address these barriers through sectoral analyses. These activities may address soft and hard technologies, such as mitigation and adaptation technologies, identify regulatory options and develop fiscal and financial incentives and capacity-building". According to the technology transfer framework, "the purpose of [TNAs] is to assist in identifying and analyzing priority technology needs, which can form the basis for a portfolio of EST [environmentally sound technology] projects and programs which can facilitate the transfer of, and access to, the ESTs and know-how in the implementation of Article 4, paragraph 5, of the Convention" (cite).

As of mid 2008, the Global Environment Facility (GEF) had provided funding to 94 non-Annex I Parties to enable them to conduct TNAs. Of these 94 Parties, 78 were supported by UNDP and 14 by UNEP[1]. The GEF funding was part of its interim financing for capacity building in priority areas (also known as 'top-ups'). Of these past TNAs, very few were undertaken in large emerging economies, thus the experience of past TNAs can only to a limited extent be transferred to guide the planned TNA process in China.

To summarize the experiences and results of the TNAs, the UNFCCC secretariat prepared two synthesis reports on technology needs identified by non-Annex I Parties based on their TNAs (and on the technology needs identified by non-Annex I Parties in their National Communications). A first synthesis report in 2006 (UNFCCC, 2006) was based on the first 23 TNAs and a second report in 2009 (UNFCCC, 2009) was based on the 69 TNAs available by 1 December 2008. The two review reports focus on summarizing the priority sectors, technologies, barriers and follow-up activities identified. The resulting observations on the methodological approaches used for these previous TNA processes are addressed shortly.

In addition a UNFCCC technical paper on 'Best practices in TNA' (UNFCCC, 2007), as well as two reports prepared by UNDP (2008) and UNEP (2008) summarize their experiences and lessons learned.

---

[1] The national TNA reports are available at the UNFCCC website at http://unfccc.int/ttclear/jsp/TNAReports.jsp.

2.2 TNA Handbooks

To assist non-Annex I parties in undertaking TNAs, a handbook on ‘Conducting Technology Needs Assessments for Climate Change’ was made available to them. The first version, which was prepared by the Climate Technology Initiative (CTI) in 2001 and finalized in 2002, drew heavily on initial experiences with the TNA process. (CTI, 2002)

It suggested seven steps for the core needs assessment process, which have been picked up in later versions of the handbook, i.e.:
1. Establish Criteria for Selecting Technology Transfer Priorities.
2. Define Priority Sectors and Sub-Sectors.
3. Compile and Supplement Technology and Market Information.
4. Select Priority Technologies and Sectors.
5. Further Technology and Barrier Assessment, and Stakeholder Consultations.
6. Define Alternative Actions.
7. Select High Priority Actions for Further Development and Implementation.
8. Prepare Needs Assessment Report. (CTI, 2002).

Recognizing the need to give more concrete guidance on the preparation of TNAs, UNDP developed a simplified version of the handbook in collaboration the Climate Technology Initiative (CTI), the EGTT and the UNFCCC secretariat, which was made public in 2004. (Gross et at., 2004) The 2004 version of the handbook suggests similar processes for conducting TNAs to identify technology needs for mitigation and adaptation (Figure 2.1).

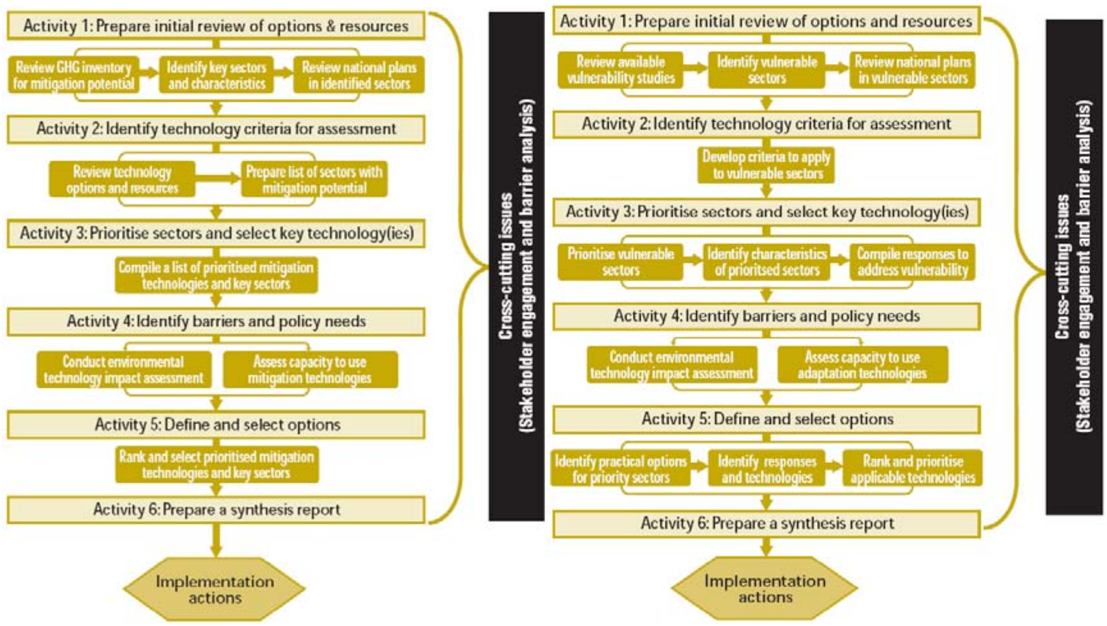


Figure 2.1 *Schematic process for TNAs for mitigation (left) and adaptation (right) technologies*
Source: Gross et al, 2004.

However, most of the 94 TNAs undertaken to date, were done before the completion and publication of the 2004 version of the TNA handbook in July 2004. They still did, to a large extent, follow an assessment process similar to that outlined in Figure 2.1. (UNFCCC, 2009).

Based on Decision 3/CP.13, Annex I. the UNFCCC Secretariat had been requested to update the handbook again taking into account experience and lessons learned indicated in the synthesis report on TNAs and latest work on innovative financing, and technologies for adaptation. (Hecl, 2009) The latest update was informed by the following thoughts:

- While most TNAs conducted by then, did follow a broadly similar process, countries did not consistently apply the suggested methodologies, which hampered cross-country comparability of the TNA results.
- There seemed to be a need for more guidance and support in applying the suggested TNA methodology.
- Due to a potential lack of awareness and knowledge on the latest technological developments among the stakeholders consulted in the process, many TNAs prioritized technologies that are available in the short term.
- Follow-up activities on TNA results were slow. In addition, many TNAs did not even go into detail in identifying the next steps to take for implementing technology transfer activities.

Therefore the updated version of the handbook contains more detailed step-by-step guides for prioritizing sectors and technologies for mitigation and adaptation, a step of preselecting priority sectors, a larger focus on a technology familiarization phase and additional chapters on how to move from technology needs to national strategies in the form of Technology Action Plans / Technology Strategies. In addition to the new handbook, an excel-based tool supporting the multi-criteria decision analysis process for sector and technology prioritization (TNAssess), and an internet based database with information on mitigation and adaptation technologies (ClimateTechWiki) will be provided. The new handbook was presented in a draft form in 2009 (UNDP, 2009), but since then has undergone another round of changes, mainly in improving the user-friendliness and lay-out. The 2010 version is planned to be launched in October 2010.

2.3 Lessons learned from previous TNAs

As discussed above, many aspects of previous TNAs may be of little relevance to the process in a large emerging economy such as China. However a couple of general lessons can be drawn that inform the whole process. In addition, lessons related to specific methodological steps will be listed in the following chapter.

The UNFCCC second synthesis report (UNFCCC, 2009) identified the following general issues:
- There are two crucial steps in the process, which are the identification of criteria to evaluate technologies and the selection of the key technologies.
- It is a good practice to consider technology needs together with national development plans. Therefore, it is also desirable to include experts from national development planning authorities and from sectoral ministries in the TNA expert team.
- Forming the national team responsible for the TNA process is a key aspect of the TNA management process.
- It is crucial to involve all relevant stakeholders from the earliest stage, clearly define and communicate their responsibilities and maintain active engagement with the stakeholders throughout the assessment and implementation process.
- Organizing workshops and conducting interviews have been identified as the favoured approaches to engaging stakeholders in all steps of the TNA process.

In general, the TNA process should be participatory and budget and running time should be sufficient to allow for such a process.

UNDP (2008) identified key challenges, including poor knowledge on adaptation technologies and approached to address adaptation in TNAs, a lack of practical approaches for conducting TNAs, as well as a need to strengthen technical capacity to be able to carry out TNA work.
In addition UNDP (2008) made a couple of further observations based on their experience with supporting TNAs processes:
1. “Stakeholder consultations and participation was a key feature of most TNA work. However, the role of stakeholders was not always clearly identified, and in most cases was mostly limited to prioritizing technology needs, initial review of needs and setting criteria for ranking

technology needs. If TNAs are to become a reliable basis for technology transfer activities, the role of stakeholders in TNA implementation should be strengthened. Guidance to ensure stakeholders´ ownership of TNA findings would be an important piece of the TNA process." (UNDP, 2008).
2. "In addition to technological options, countries also identified policies, regulations, standards and codes, but little attention was given to the non-technological options needed to create an environment conducive to the adoption of hard technologies. This area needs further development to ensure a more comprehensive TNAs addressing the policy aspects of technology transfer and adoption under the Convention. Linkages of TNAs with key policy process should be strengthened in future TNA analysis." (UNDP, 2008).
3. "TNAs should have a more clearly defined scope and targeted audience to ensure a more focused analysis and avoid unreasonable expectations. In most cases the TNA work covered many sectors and priorities but the rationale for technology choices and implementation feasibility was not always clear, thus resulting in a wide range of possible technologies." (UNDP, 2008).

Similar observations were made by UNEP (2008) in their evaluation of their experience:
"Most countries identified TNA is a helpful tool for policy and decision makers in facilitating the technology transfer process at the national level. They have also found the assessments useful in not only identifying specific technology needs, but also in providing some indications of future direction for policy formulation and enactment of regulations. For the TNA process to be very effective it must be demand driven and sector specific and embedded into the national development process. Effective participation, of key stakeholders involving government (sectoral planners and policy makers), the private sector, and civil society particularly at the early stages of the process is imperative. Addressing cross-sectoral issues, including linkages between mitigation and adaptation priorities is important." (UNEP, 2008).

2.4 Other approaches

Various other organizations have developed approaches for identifying and prioritizing technologies, both within and outside the UNFCCC context.

One of the earlier comprehensive assessments of methodological issues in technology transfer was undertaken by the IPCC in 2000 (IPCC, 2000). However, it hardly touches on the process of technology prioritization, but rather focuses on proving general clarity on the concept and identifying sector specific insights into challenges and opportunities for technology transfer. In spite of the fact that the report does not include any latest insights, the sector specific discussion may still provide a useful guidance for identifying barriers for technology transfer and diffusion.

Outside of the UNFCCC TNA process, other institutions undertake some form of technology prioritization with the aim of allocating funds for climate mitigation and adaptation programs. The Global Environment Facility (GEF) has invested into clean technologies since its creation in 1991. More specifically the GEF-run Clean Technology Fund (CTF), which was established in 2008, promotes scaled-up financing for demonstration, deployment and transfer of low-carbon technologies. The CTF project development process is mostly country driven. The CTF guidelines suggest a pre-selected range of low-carbon technologies that could qualify for investment based on their potential for substantial reductions in GHG emissions and their potential transformative nature (see GEF, 2008, p.17 for these technologies). The investment plans submitted to the GEF have to contain an assessment of how the proposed projects and programs fulfil the CTF investment criteria, which are:
- Potential for greenhouse gas reductions.
- Demonstration potential.
- Development impact.
- Implementation potential.

The criteria are broken down in more detail in Annex A, paragraph 6 of GEF (2008). The investment plans are then prioritized on the basis of this assessment.

In addition to the UNFCCC supported handbooks for technology needs assessments prepared by the CTI and UNDP, other models for TNA have been previously proposed by UNEP, the UN Commission on Sustainable Development (UNCSD) (Zou JI, 2002) and the ENTTRANS (2008) project. Although these alternate proposals are not in common use it can be informative to briefly compare their methodologies with that found in the current UNDP TNA Handbook.

The UNEP proposal chiefly differs from the TNA Handbook in its starting point. It suggests starting with a specific technology, examine the reasons why it should be implemented and then consider possible alternatives. There is no such focus on selecting priority sectors as suggested in the UNDP TNA Handbook approach. (ENTTRANS, 2008).

In contrast, the UNCSD model for conducting a TNA suggests first assessing capacity building needs for technology transfer in a country. The implementation of sustainable technology pilot projects is then part of the subsequent prioritized capacity building efforts (ENTTRANS, 2008).

In ENTTRANS (2008), an Energy Service Needs Assessment (ESNA) rather than a technology needs assessment (TNA) was conducted with developing country stakeholders focusing on mitigation only. Many of the steps observed in this ESNA process, such as a detailed familiarization phase and the idea of using market mapping to identify barriers, are included in the latest version of the UNDP TNA Handbook released in 2010.

3. Specific considerations for adaptation technologies

- The prioritization of technologies for adaptation is dominated by the high uncertainties of national / local climate vulnerability assessments.
- It is recommended to conduct the TNAs for mitigation and adaptation technologies separately as both categories need different stakeholders and have little overlap in terms of technologies.
- However, it is also recommended that national / local climate vulnerability assessments could be taken into account for mitigation technologies that depend on certain natural resources, e.g. hydro power.

The aim of TNAs is to cover both mitigation and adaptation technologies. However, previous TNAs had a stronger focus on mitigation technologies. More than a quarter of the TNAs summarized in UNFCCC's second synthesis report covered mitigation technologies only. (UNFCCC, 20090) In addition, many of the past studies except for Namibia and most of the Small Island Developing States assigned higher priority to mitigation than adaptation. This may be due to the poor knowledge on adaptation technologies and how to address them, rather than due to less need for adaptation technologies. Indeed, poor knowledge on adaptation technologies and approaches to address adaptation in TNAs were identified as a key challenge in conducting TNAs by UNDP (2008).

The current draft UNDP TNA handbook (UNDP, 2010) suggest a relatively uniform approach to prioritizing technologies for adaptation and mitigation. In Chapter 4 on sector prioritization it does distinguish, recommending to base the adaptation assessment on a climate vulnerability assessment, if available.

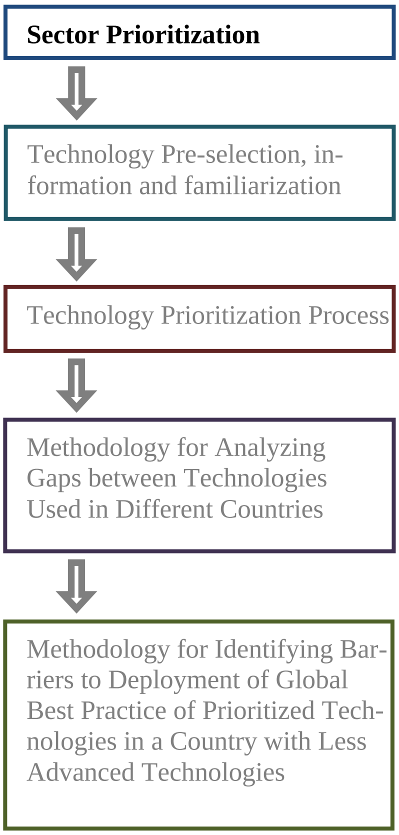
In principle, a similar approach to both seems feasible, but there are a couple of important points to take into account for adaptation technologies: The prioritization of sectors and technologies needs to be based on an assessment of a country's vulnerability to climate change. There are uncertainties around most methodological steps of these vulnerability assessments, e.g. around global temperature increases, and the resulting effects (sea level rise, more extreme weather events such as hurricanes, melting of glaciers) and even higher uncertainties around the local climate impacts that stem from the global changes (e.g. rain fall distribution patterns, local temperature changes and distribution) and around the impact of local climatic changes on local ecosystems, agricultural productivity etc. This distinguishes any adaptation assessment and strategies from mitigation related actions where it can be more reasonably assumed that any reduction in GHG emissions will have a positive impact on the global climate. Due to the large uncertainties around local climate impacts it has even been suggested to only undertake large scale investments into adaptation technologies now, if the technologies are not only justified by consideration of future climate change, but are also needed to meet today's needs (Smith, 2006).

In addition, many adaptation technologies are so-called 'soft' technologies, e.g. practices, management strategies, behavioral patterns, potentially in combination with hard technologies, such as dams and other infrastructure investments. It is therefore expected that a different group of experts is familiar with adaptation technologies than with mitigation technologies.

Due to the fact that the prioritization of adaptation technologies has to take into account high uncertainties in the fact base of the vulnerability assessment and that in most cases would rely on a different set of national experts, it is recommended to conduct the two in separate processes.

As suggested in UNDP (2010), it does make sense to consider the vulnerability assessment in the sector and technology prioritization for mitigation as well, aiming for climate resilient growth, especially for technologies that depend on resources potentially affected by climate change, e.g. hydro power. UNDP (2010) addresses this in Chapter 4.

4. Sector Prioritization



- A TNA study that considers all technology sectors risks becoming unwieldy and as a result ineffective through a loss of focus on the key areas of technology improvement that a country should target.
- Due to the size, complexity and diversity of China, there is room to cover more sectors in the TNA.
- Sector prioritization usually based on national development priorities and identification of key GHG emitting sector.
- Approach suggested in current UNDP TNA handbook may not be able to sufficiently take into account China's size and complexity.
- Sector prioritization linked to the general approach taken in the TNA for which three options are described:
  - National approach with national sector selection: technologies prioritized on a national level based on national development goals and needs.
  - Regional Approach with National Sector Selection: national development goals and needs determine sector selection, but technologies are prioritized at a regional level based on regional preferences.
  - Regional Approach with Regional Sector Selection: each region selects priority sectors and identifies priority technologies based on their development goals and preferences.
- Choice of the approach to be done by national TNA team, depending on preferences on involvement of regions and on available resources.

The dominant thinking on TNA methodology that has carried through to the current UNDP TNA Handbook is that the national process of identifying and assessing technology needs is more successful when conducted on a prioritized subset of possible economic sectors, e.g. those sectors that have the most potential for mitigation or the most pressing need for adaptation measures. Whether these are broad aggregations such as 'energy' or 'industry' or more detailed sub-sectors such as 'electricity generation' or even 'fossil fuel generation' depends on the circumstances, motivation and available resources within a country when conducting a TNA. The term 'sector' is used here to describe the level of aggregation that is considered to be the most practicable for the China TNA and corresponds to the term'(sub)sector' that is used in the UNDP TNA Handbook (2010) to indicate the possible differing hierarchical levels that could be examined.

In general, a TNA study that considers all technology sectors risks becoming unwieldy and as a result ineffective through a loss of focus on the key areas of technology improvement that a country should target. A' *systematic preliminary assessment*' of possible sectors to be considered during the TNA is considered good practice (UNFCCC, 2007).

The current draft UNDP TNA Handbook (2010) develops a list of prioritized sectors in three main stages at a national level:

Step 1: Initial identification of relevant sectors based on either IPCC GHG characterization (for mitigation) or sectors that provide the most potential for effective adaptation based on existing vulnerability assessments (VA) or a National Adaptation Program of Action (NAPA). It is important to note that sector definitions are preferably in line with domestic standards of definition. This would be important, particularly in enabling direct support from industry associations or relevant government functions, as well as allowing appropriate access to existing statistics and data.

Step 2: Assess sectors in terms of sustainable mitigation through examination of GHG inventory data, future emissions trends and new technologies, and assess adaptation priorities through stakeholder discussion and characterization of the impacts on sustainable development from each sector.

Step 3: Finalize a list of prioritized (sub)sectors according to their maximum mitigation and adaptation benefits using simple ranking matrices with justification of scores.

However, as touched upon in Chapter 1.2, the vast extent of China, the diverse mix of advanced and more rudimentary technologies across provinces, the wide range of socio-economic conditions and the large variations in climate are some of the factors that combine to make a 'one size fits all' TNA approach extremely challenging there. Moreover, when looking at the lessons drawn from successfully conducted TNAs in the past then it is suggested that not more than two to three sectors be prioritized (UNFCCC, 2006; 2007; 2009). The strict adoption of the UNDP TNA Handbook approach in China, with a very limited number of sectors chosen nationally, is unlikely to capture the diversity of technologies within the country nor the differing technology needs across the nation. In addition, the available budget of the China TNA is significantly higher than of any such exercise carried out previously. For these reasons, for the planned China TNA, a coverage of 10-12 sectors (covering both mitigation and adaptation) might be feasible.

In the following, some possible approaches for sector prioritization are discussed here as this is vital step in the overall TNA framework and can have an impact on the methodology that is most appropriate in later stages of the process. The choice of how to structure a China TNA has direct implications on the arrangement of the TNA project teams and stakeholder groups. Therefore as such this section effectively deals also with a potential overall structure of the China TNA. Each of the following three potential approaches attempts to provide more detail than the current draft UNDP TNA Handbook (2010) methodology as well as offering more regional input into the decision making process. The term region is used loosely to describe provinces, autonomous regions and municipalities that are grouped together on the basis of broad alignment in their socio-economic development, dominant sectors and technology mix. Some form of grouping/aggregation of province level areas is felt to be necessary as the consideration of the more than 30 provincial areas individually would be prohibitive in terms to forming stakeholder groups and retaining cohesion across the TNA process.

4.1 National Approach with National Sector Selection

The first approach described here considers a top down strategy with a national TNA structure and nationally prioritized sectors to guide the TNA process (see Figure 4.1). The number of sectors that are chosen at the national level would be considerably higher than in previous TNA studies due to the factors discussed above. It is anticipated that in the order of 10 to 12 sectors would be chosen nationally, with an aggregation one level below the top sectoral descriptors (i.e. 'steel industry' as opposed to industry in general). Regional input is provided in the form of stakeholders from those regions that are considered to have the most relevance for any particular sector. The high-level steps described below help to clarify this concept.

- National TNA coordinating body formed.
- Short term national stakeholder group created to inform the sector prioritization.
- 10 to 12 sectors identified based on national priorities and national mitigation and adaptation potential.

- Individual TNA stakeholder groups, or tracks, are formed for each of the identified priority sectors[2]. There would be some overlap in members from the National TNA coordinating body and government institutions but the rest of the stakeholders are chosen based on expertise and relevance. In particular each of the regions is considered on a case by case basis to determine the relevance of the sector in that geographic area. Stakeholders are then gathered from regions that are considered as being critical in terms of technology needs within each particular sector.
- Technologies are then prioritized within those sectors at a national level based on national identified needs.

Figure 4.1 *National approach with national selection*

Pros and Cons:

- Gives a national focus to the TNA with a more streamlined set of priority technologies at the end of the process. This is likely to be more amenable to forming effective national policy.
- Suits some sectors such as electricity generation which may have a similar set of technology demands across the country.
- However whether 10-12 national sectors would be sufficient to adequately capture the technology needs of China is open to debate.
- Moreover the regions may feel alienated from the process if it is conducted at a national level. More local traction may be reached through an approach that takes provincial/regional needs into account more.

4.2 Regional Approach with National Sector Selection

The second approach considers a bottom-up regional technology prioritization but uses a national set of prioritized sectors to guide the TNA process (see Figure 4.2). The number of sectors that are chosen at the national level would be similar to the top down TNA described above; i.e. in the order of 10 to 12, with an aggregation one level below the top sectoral descriptors (i.e. 'steel industry' as opposed to industry in general). Although the sectors are determined at a na-

[2] Separate groups are chosen due to the likely scale of each sector across the whole of China and the practical difficulties of considering more than a few sectors within a single stakeholder group due to technology familiarisation requirements.

tional level, each region would form a number of TNA teams depending on which of those sectors were felt to be relevant within the region. These regional teams then carry out the TNA process with a focus on identifying technology needs within each sector that are a priority for their own particular region. The high-level steps described below help to clarify this concept.

- National TNA coordinating body formed.
- Short term national stakeholder group created to inform the sector prioritization.
- 10 to12 sectors identified based on national priorities and national mitigation and adaptation potential.
- Within each region individual TNA stakeholder groups, or tracks, are formed for each of the identified priority sectors that are deemed to be relevant within a region. The criteria for selecting stakeholders would be similar to the national team approach previously described but with a focus on regional representation.
- The regional stakeholders select priority sectors from the national list.
- Technologies are then prioritized within those sectors at a regional level based on regional identified needs.

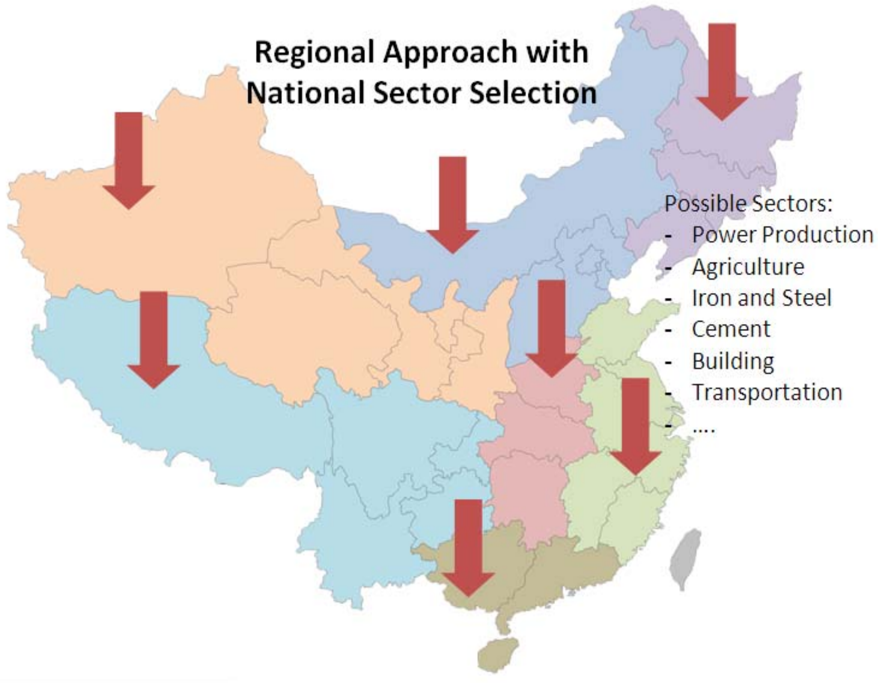


Figure 4.2 *National approach with national sector selection*

Pros and Cons:

- Retains some aspect of national focus within the TNA by maintaining a common set of priority sectors across the country.
- Suits sectors that show a large diversity in technology levels across regions; each region can prioritize the particular technologies that most suit their level of development/capacity.
- This approach would allow the idea of intra-national and trans-national technology transfer barriers to be explored in subsequent steps of the TNA. In some regions technology needs may be largely met through domestically available technologies, but in more advanced areas there might be a larger focus on international transfer.
- The idea of replicating the TNA process for 10-12 sectors across a number of regions raises serious questions on cost and complexity.
- There is a possibility that some sectors will be largely irrelevant for certain regions and that key local sectors may not be included during the national sector prioritization. This possibility is addressed in the final approach below.

4.3 Regional Approach with Regional Sector Selection

The final approach allows regions to select their own priority sectors within which they would conduct a technology prioritization (see Figure 4.3). It is anticipated that the number of sectors that would be chosen within each region would be significantly less than the 10-12 selected in the national approaches described above and also that the number of priority sectors in each region may differ depending on the diversity of economic activity taking place there. A possible structure is described below:

- National TNA coordinating body formed.
- Regional stakeholder groups are created to inform the regional sector prioritization.
- Less than 10 sectors are identified based on regional priorities, mitigation and adaptation potential. It could be 2 to 3 sectors only.
- Regional stakeholder groups conduct the technology prioritization with team members drawn from regional bodies but with some representation from the national level as well.

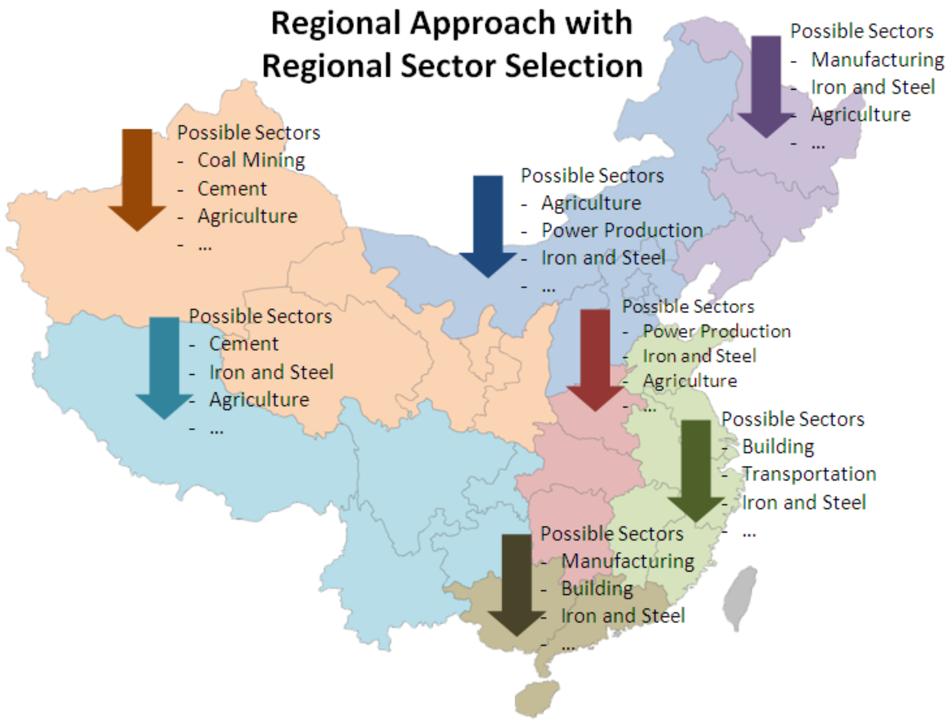
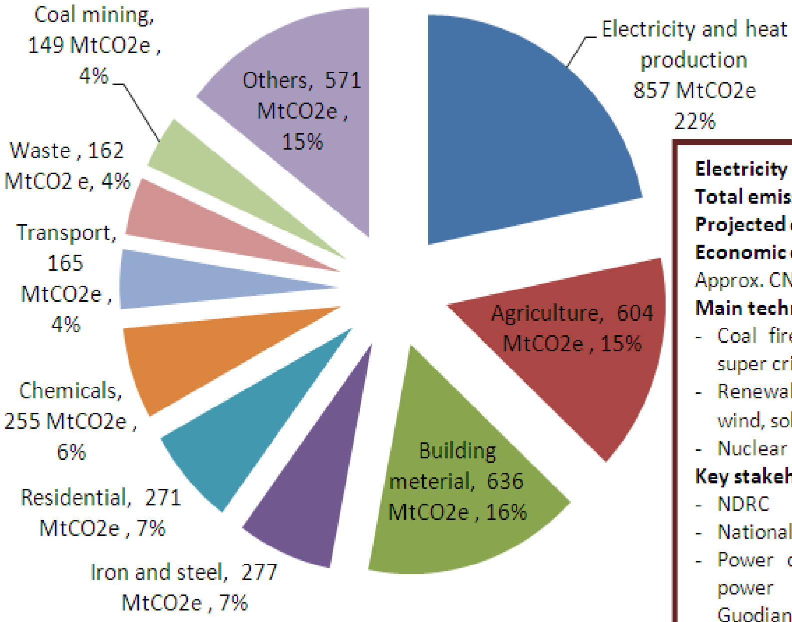


Figure 4.3 *Regional approach with regional sector selection*

Pros and Cons:

- The most flexible approach for different regions and the most likely to identify relevant regional technology needs in the appropriate locally applicable sectors.
- Provides a strong starting point for provincial governmental policy within the framework of national targets.
- The idea of replicating the TNA process for a significant number of sectors across each region raises serious questions on cost and complexity.
- A large number of differing prioritized technologies across the regions may prove ineffective in fostering technology transfer as key technologies are more difficult to target (there are effectively many more 'key' technologies when using this approach).

Figure 4.4 shows how sectors in China could be prioritized based on its GHG emissions under a national approach. Other key characteristics of the sector such as GDP contribution, industry growth, key technologies within the sector, and projected emissions should also be gathered to provide sufficient information for the TNA coordinating body and stakeholder groups. Due to a strong division of responsibilities between different government departments, cross-sectoral efforts can be more time-consuming and difficult than activities focusing on one sector. Therefore, it may make sense to have sector definitions in line with existing practices and official sector definitions, to enable direct support from existing data resources and government or industry bodies.



Electricity and Heat Production (22%)
Total emissions: 857 MtCO2e
Projected emissions (2004): 2,398 MtCO2e
Economic contribution (Value-added):
Approx. CNY 250 billion
Main technologies :
- Coal fired thermal power plants (ultra-super critical, IGCC, etc)
- Renewable Energy (hydropower, biomass, wind, solar PV)
- Nuclear Power

Key stakeholders:
- NDRC
- National Energy Agency
- Power companies (dominated by big 5 power companies: Datang, Huadian, Guodian, Huaneng, CPI)

Figure 4.4 *GHG emissions profile of China*[3]

[3] Data in the Figure 4.4 example is obtained from China's 1994 national GHG inventory published in 2007; sector projection and value added data are obtained from WRI CAIT and calculated from published national statistics respectively.

Box 1: *Identifying stakeholders in China*

Identifying Stakeholders in China

Stakeholder consultation is crucial in every step of the TNA. There are at least 5 stakeholder groups that have to be engaged to have sufficient coverage for each sector.

- ***Regulators***

The government organization that is responsible for overseeing the development of a sector is not only able to provide policy directions, but also an important source of information. In a heavily regulated market such as China, government entities such as the country's National Development and Reform Committee (NDRC) and local DRCs, Ministry of Industry and Information Technology (MIIT), and Ministry of Housing and Urban-Rural Development (MOHURD) have the most access to industry data and information. Pricing control and policies (taxes, tariffs, etc.) related to the transfer and use of technology is also typically overseen by NDRC and local DRCs or by government-led price regulating bodies.

- ***Industry and Trade Associations***

In China, there are numerous industry associations whose members come from either private or state-owned enterprises which are representative of the sector. An important process in identifying appropriate industry associations is to evaluate their expertise, their willingness to collaborate, their reputation, and their sphere of influence. To evaluate these factors, consultation with the highest ranking supervisory body of the relevant sector would be a recommended first step. In China the supervisory bodies to consult, depending on the sector ,would be NDRC, Ministry of Transport, MOHURD, etc.

- ***Technology Providers***

These include organizations involved in the R&D, manufacturing, import and sale of technologies for mitigation or adaptation**.** Stakeholders in this category include Chinese institutions that provide technical support to both government and industry such as universities, R&D departments of private enterprises, public think tanks, and private consultancy firms.

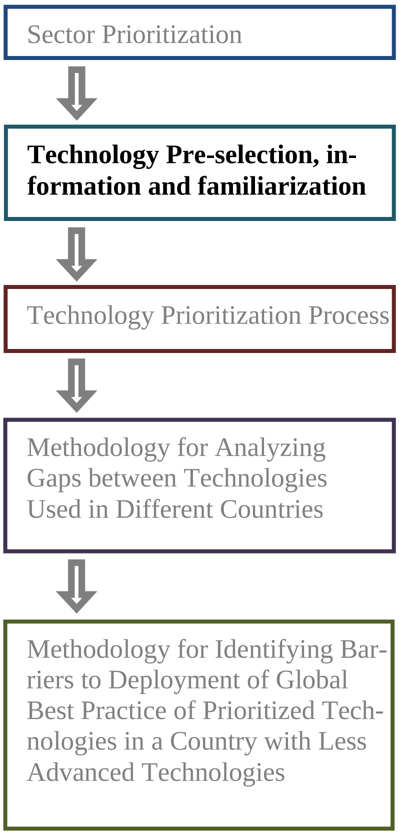
- ***Finance community***

The finance community will likely provide the majority of capital required for project development and technology implementation. In China, this group includes the Ministry of Finance, private equity funds, multilateral and bilateral funding from public institutions (World Bank, UNIDO, IMF, etc), and private funders both Chinese and international (individuals, foundations, etc).

- ***Other stakeholder***

Other relevant stakeholders include local and international NGOs involved with the promotion of environmental and social objectives, consumer groups, media, etc.

5. Technology pre-selection, information and familiarization



- Technology pre-selection is a crucial steps as it may predetermine the outcome of the prioritization.
- Applying only the approach suggested in the current UNDP TNA handbook may not be suitable for China. Possibility of involving sector experts to identify most important current and future technologies, supplemented by sectoral consultants.
- Lack of information regarding the specified technologies is cited as a key challenge in previous TNAs. Stakeholders tend to favor technologies they are familiar with or have heard about.
- Technology factsheets to use as a basis for information collection and technology familiarization.
- Where practical, issues covered in the technology factsheet should already correspond to the criteria used later for the technology prioritization.
- Filling out comprehensive technology factsheets is a time and resource intensive process. Two stage approach suggested.
- Potential information sources: existing technology databases and technology specific publications (e.g. by the IEA) for global parameters, for China-specific information, information more readily available for high-energy intensive sectors.

5.1 Technology pre-selection

Once a number of sectors or subsectors within the area of interest of the TNA have been selected and prioritized there is a need to determine what technology choices are available, both nationally and internationally for potential transfer. The resulting process of selecting and developing a list of adaptation and mitigation technologies is a vital step in performing a TNA in any country. A future focused and progressive national technology prioritization can only occur once all the appropriate low carbon and adaptation technologies have been identified, as it is this set of available technologies that forms the basis of all future activities. Should a technology be overlooked or omitted at this early stage then the nature of the TNA methodology makes it unlikely that the particular technology would be considered until a subsequent round of assessment took place at some time in the future.

5.1.1 Technology pre-selection - TNA Handbook

The UNDP TNA Handbook recommends that the *TNAssess* software that complements the handbook be used to provide a starting list of technologies. TNAssess is planned to contain a pre-defined list of technologies linked to the ClimateTechWiki website, which will offer generic descriptions of these technologies. This list[4] is relatively thorough, but may still lack some of the detail of interest for the China TNA. As an example, the section on industrial efficiency

[4] As given in the UNDP TNA Handbook Annex 5-2.

simply notes 'Energy saving in the chemical industry' as a technology rather than giving a more detailed breakdown of technology options within this broad topic.

5.1.2 Technology pre-selection - possible elements of methodology

For the China TNA, the technology topics proposed by *TNAssess* within each sector could, on a case by case basis, be reviewed with appropriate sector specific experts to determine which technology topics should be broken down into more specific technologies or where new technologies should be added to augment the existing list. This is a task that is unlikely to benefit from the input of the wider stakeholder group. It may be coordinated for each of the sectors by the national TNA coordinating body that oversees the entire TNA process. In any case, one has to be aware, that the process of defining priority technologies is typically highly dependent on the body of knowledge accumulated within the stakeholder group.

Within the selected sectors, the current UNDP TNA Handbook recommends to use a list of clean technologies which is as comprehensive as possible as a basis for the technology prioritization process. However, it may be worth considering to reduce the number of technologies to be considered in the China TNA to limit the efforts needed for gathering detailed information on the technologies. When pre-selecting technologies in specific sectors, it is suggested to make sure that technologies prioritized for similar purposes, e.g. for China's energy efficiency improvement programs (see Chapter 5.2.3) are included in the list to be considered.

Much of the available literature concerning technology identification and pre-selection is focused on mitigation related actions. The development of a list of adaptation technologies is a less well defined task within the UNDP TNA Handbook. A list is provided in the handbook as a starting point for discussions. However it is noted there that the development of a comprehensive list is very difficult due to the difficulty in distinguishing adaptation and sustainable development technologies from one another, the relatively early stage of development of some adaptation technologies and the importance of social factors in many adaptation activities rather than technology per se. The dominant factors in determining such a list will be national development priorities and local climactic vulnerabilities which implies that the resulting technology list will necessarily be specific to a particular country or region. As for mitigation actions the involvement of local experts and stakeholders could be used to expand the UNDP TNA Handbook list of technologies as appropriate.

It is understood from the draft planning of the China TNA, that the resulting methodology for technology identification should be an ongoing or iterative process. Therefore it may be sensible to maintain a list of clean technologies relevant to China at a government body or university in an institutional framework that permits ongoing updating of this list with best practice / state of the art technologies

Previous TNA's have often been limited to more traditional or existing technologies (ENTTRANS, 2008) which could make sense for a less developed country; however for China there may be a desire to capture technologies that might be available only in the medium to long term, as well as cutting edge technology developments, However, this is a difficult task, which may not be feasible for a long list of technologies.

5.2 Technology information and familiarization

As a result of the technology pre-selection, a (long) list of technologies with potential mitigation or adaptation benefits is created for each (sub)sector. The typically open and discussion based format of the prioritization process demands that each of the stakeholders has a suitable baseline level of knowledge regarding each of the technologies. This process ogver informing the stakeholders of, inter alia, the opportunities, risks, costs and level of development of specific technologies is called technology familiarization within the UNDP TNA Handbook. This is discussed further in the following section.

5.2.1 Technology information and familiarization - Previous TNA Experience

In previously conducted TNAs very little information is provided about the methodologies used to collate information on technologies and disseminate that within the stakeholder groups. However observations of the overall TNA process suggest that more could have been done during these past TNAs to ensure that stakeholders were suitably familiar with the technologies that were to be prioritized. Lack of information regarding the specified technologies is cited as a key issue in prioritization during previous TNA's, particularly in regards to technology costs (UNFCCC, 2006; 2007; 2009). Stakeholders were also found to be more likely to favor technologies that they are familiar with or that are already well developed; *"the usually recommended approach for assessing technology needs in a (developing) country inadvertently anchors a TNA in existing technologies and will always look to the past"* (ENTTRANS, 2008).

5.2.2 Technology information and familiarization - TNA Handbook

The UNDP TNA Handbook suggests that a technology familiarization process take place after sector prioritization. A 'technology champion' is tasked to find information for the stakeholder group from a range of sources but little guidance is provided on which aspects are considered important for stakeholders to be familiar with. This may lead to aspects related to technology innovation being overlooked during this largely informal familiarization process, Such forward looking aspects are then unlikely to be captured in subsequent discussions and recommendations.

The UNDP TNA Handbook also introduces the idea of technology 'factsheets' that are used to summarize the information that has been collated for a particular technology. These factsheets are either created after the technology prioritization as a kind of summary document, or earlier in the TNA process for technology familiarization. The current draft TNA Handbook (2010) gives examples of 5 to 7 page documents.

5.2.3 Information gathering - possible elements of methodology

It may indeed be useful to put together technology factsheets and make them available (if necessary translated) before the technology prioritization process takes place. Then, a program of technology familiarization could be conducted with the country stakeholders in accordance with the UNDP TNA Handbook; ideally the factsheets would form the basis for this familiarization. Even if a regional approach is adopted, it may make sense to create one set of national technology factsheets, in order to give common and accurate baseline levels of information to regional stakeholder groups. Factsheets should ideally use a brief, fact focused writing style (if possible quantitative) with specific focused headings. Table 5.1 shows a generic proposal template for a mitigation fact sheet, annex 2 gives a concrete example fact sheet for the wind industry in China, and annex 3 lists two technology descriptions from the ClimateTechWiki database which could form the basis of a more detailed factsheet.

Where practical there is significant added value, if factsheet categories correspond to the criteria used for the eventual technology prioritization (whether this is with MCDA or some alternative approach). It is therefore recommended to define the criteria before finalizing the technology factsheets.

Putting together a comprehensive technology factsheet as described above is time and resource intensive. For efficiency reasons, it would be possible to create more basic TNA factsheets to support prioritization. The factsheets for prioritized technologies could then be in detail and more fully quantified when planning the implementation of technology transfer actions. Detailed market aspects and detailed cost data, may for example not be needed for the prioritization process.

5.2.4 Mitigation Technology Factsheet - Proposal

Factsheets could be created by a smaller group of specialists and experts, potentially moderated by representatives from the TNA coordinating body. For global parameters existing information from clean technology databases could form the basis of the factsheet. The web based database ClimateTechWiki[5] is for example being specifically developed to provide generic information on clean technologies for Technology Needs Assessments. Other relevant websites include for example ClimateLab[6], information provided by the Office of Energy Efficiency and Renewable Energy (EERE) of the US Department of Energy[7] or GTZ Energypedia[8]. In addition, publications on technology development, e.g. the IEA energy technology roadmaps[9], or industry publications could be useful sources of information.

5 http://climatetechwiki.org/
6 http://climatelab.org
7 http://www.eere.energy.gov/
8 http://energypedia.info/index.php?title=Special:UserLogin
9 http://www.iea.org/subjectqueries/keyresult.asp?KEYWORD_ID=4156

Table 5.1 *Generic template for a mitigation factsheet*

1. **Name & sector**
2. **Technology specific**
   - Technology description (including how it works, state of technological development, and expected future developments).
   - Feasibility of the technology and operational necessities Technical / operational / regulatory requirements.[10]
   - Market penetration (global & local), today and market penetration development potential.[11]
3. **Technology impacts**
   - GHG emissions (emissions per output in absolute terms and when compared to usual alternatives).
   - Development benefits (and negative impacts if applicable) (e.g. employment generation, food security, gender equity etc).
   - Environmental benefits (and risk) (e.g. reduction of air pollution, water resource protection etc).
4. **Costs**
   - Capital costs.
   - Operation and maintenance costs including fuel costs.
   - (if available) expected internal rate of return / payback period when technology is implemented in today's market environment.
5. **Market aspects**[12]
   - Current manufacturers globally.
   - Current price range.
   - Ownership of IPR.
   - Current Chinese manufacturers and Chinese companies with a potential interest in the technology.

For China specific information, the following could be helpful: statistics data from national and local statistics bureau, aggregated data on energy efficiency from relevant local and central government organizations, existing publications and statistics data from key industry associations, (e.g. China Electric Power Yearbook, China Cement Almanac released by the China Cement Association, and statistics data from China Electricity Council, etc).

It would be useful if the national TNA coordinator identified relevant Chinese institutions that have access to high quality primary data. As part of this identification process, the following key information sources could be considered:

1. Government sources of key information on technology: During China's 11th Five Year Plan, the central government defined different roles and responsibilities for each organization tasked to help the country meet its energy and pollution abatement targets at both the national and local level. In most instances, local and national energy conservation bureaus and environment protection bureaus are the main aggregators of primary data on China's most energy intensive industries (e.g. heat and power generation, iron and steel sector, cement sector, etc) and the building sector for certain regions. Meanwhile, data relevant to the GHG performance of buildings and the transportation sectors can most likely be found within the

10 Information that gives an understanding of the conditions under which the technology functions, i.e. resource requirements for renewable energies, climatic requirements, need for a specific regulatory framework (e.g. on CCS), for social acceptance, for trained engineers for maintenance etc.

11 Projections for future market development are inherently subjective. Potential sources of information could be IEA roadmaps or industry projections. Such information can be important to get an understanding of the expected global importance of the technology over the next 20-30 years.

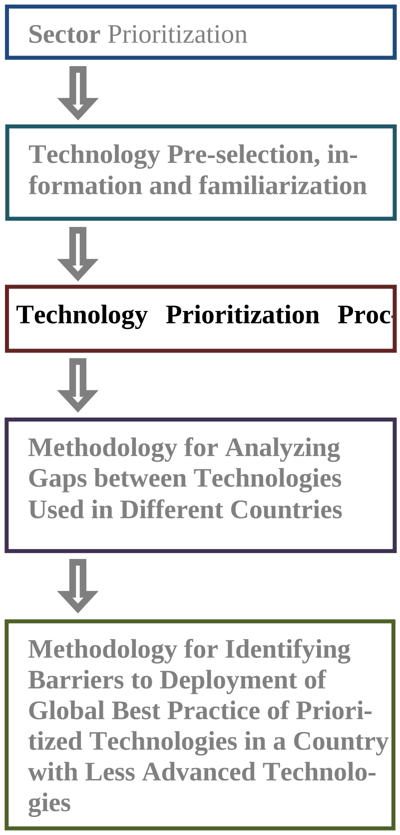
12 Market aspects are important, especially when it comes to supporting local manufacturing capacity, and to promoting innovation. However, this information is more difficult to gather, and most probably more expensive, if requested from a consultant. Gathering this information could potentially be delayed.

relevant departments of the Ministry of Housing and Urban-Rural Development (MOHURD) at the central level and the Construction Committees/Bureaus at the local level. Building research institutes and universities are other potential sources of primary data in these sectors.

2. Industry associations: In China, industry associations are often a key source of information for specific energy intensive sectors (e.g. China Cement Association). However, it is important to distinguish which industry associations have the most clout in terms of the expertise of its members and their access to high quality, primary data.

6. Technology Prioritization Process

- There are a number of possible approaches, each with its own benefits and limitations, for prioritizing technologies, e.g. different forms of multi-criteria decision analysis, marginal abatement cost curves, SWOT analysis and cost-benefit analysis. based on numerous different assessment criteria as is required by a TNA.
- Previous TNAs have used an MCDA approach as it allows for considering trade-offs between multiple and conflicting objectives.
- A simple linear additive MCDA approach, as recommended in the UNDP TNA Handbook, undertaken in stakeholder workshops could be an appropriate methodology for the China TNA as well, potentially supplemented by a cost-benefit analysis or a SWOT analysis.
- The choice of the stakeholders determined the outcome of the prioritization process.
- MCDA should only be used to guide the decision making process. The choice of a moderator is crucial for the quality of the process.
- TNAssess might be the most obvious choice for an MCDA software.



6.1 Technology Prioritization Process - previous experiences

In past TNAs the methods used to prioritize technology needs included multi-criteria decision analysis (MCDA), the analytical hierarchy process, cost-benefit and risk-benefit analyses, use of optimization models, and questionnaire surveys, interviews and workshops with stakeholders. Many Parties described in detail the methodologies used, but these methods were not always applied consistently. Several Parties provided only a list of technological options without details of how and why these were selected. The TNA reports suggest that in the majority of cases, the tools are used to help in the decision-making process rather than drive it (UNFCCC, 2007)

ENTTRANS (2008) list some problems encountered in performing the technology prioritization during their ESNAs, including:

- Awareness - Lack of awareness of technologies, their state of development and a preference for technologies with they were familiar with.
- Perception of costs - believe that new technologies are necessarily more expensive.
- Historic experience - previous negative experiences through poorly implemented projects meant that those technologies were give low rankings in this subsequent study.
- Embedded bias - people would give a higher preference to those technologies that fitted with their background in industry or government. “Organisations operate in embedded socio-technical networks and tend to re-invest in established competences: disruptive technologies (e.g. renewable energy technologies) rarely make sense to incumbents so their development is left to outsider organisations” (Winskel, 2006).
- Cultural aspects - the technology should be appropriate for local use and customs.

- Previous China TNA (1998) used questions posted/emailed to experts following the methodology of the Analytical Hierarchy Process (AHP) with an equal weighting across criterion (UNFCCC, 2007). “Serious doubts have been raised about the theoretical foundations of the AHP and about some of its properties” (DCLG, 2009).

According to UNFCCC (2007), *“the experiences of Parties suggest there is no other activity in the TNA process where stakeholder involvement is more important”*. This statement seems to be confirmed by the outcomes of the previous TNAs conducted in China, i.e. the ENTTRANS Energy Service Needs Assessment (ESNA) and the Expert Group on Technology Transfer (EGTT) TNA, which differ significantly and involved different stakeholder groups. The top identified technologies are listed for comparison (ENTTRANS, 2008) in Table 1. The EGTT TNA prioritizes large-scale electricity supply options, whereas small-scale options such as energy saving lamps also form part of the top 5 technologies of the ENTTRANS prioritization. However, there was also a 9-10 year time interval between the 1998 EGTT TNA and the 2007/08 ENTTRANS process.

Table 6.1 *Top prioritized technologies from different China TNA approaches*

EGTT TNA Approach	ENTTRANS ESNA (Yunnan)	ENTTRANS ESNA (Shandong)
1. Circulating Fluidised Bed Combustion (CFBC)	1. Energy saving lamps	1. Clean-coal for large-scale power supply
2. High Efficiency Motor	2. Solar coolers	2. Hydropower through dams
3. Boiler (increasing efficiency)	3. Clean-coal for large-scale power supply	3. Energy saving lamps
4. Wind power	4. Cement industry energy conservation	4. Cement industry energy conservation
5. Coal Bed Methane power generation	5. Hydropower through dams	5. Solar coolers

6.2 Technology Prioritization - TNA Handbook methodology

The current draft UNDP TNA Handbook (UNDP, 2010) suggests the following steps for prioritizing technologies:

- *“Assessing technologies through multi-criteria decision analysis*
  - *Determine assessment framework including assessment criteria*
  - *Conduct assessments on technologies based on their:*
    - *Contribution to development goals*
    - *Potential of GHG emission reduction or vulnerability reduction*
    - *Costs and benefits*
  - *Produce assessment spreadsheets with overall weighted scoring for each technology. In this process weights are assigned to the criteria above as well as to country specific sub-criteria.*
- *Making final decisions*
  - *Review assessment results*
  - *Conduct sensitivity analysis on assessment results including discussing decisions behind*
  - *weighting*
  - *Decide prioritization of technologies for sectors”*

The handbook suggests an MCDA approach based on a simple linear additive model (see chapter 6.3). Once the 2010 version of the UNDP TNA handbook is available, it will come with an excel-based software tool, called TNAssess, that can be used by countries in the MCDA process (see Chapter 6.4).

6.3 Technology Prioritization - possible elements of a methodology

- There are a number of possible approaches, each with its own benefits and limitations, for prioritizing technologies, e.g. different forms of multi-criteria decision analysis, marginal abatement cost curves, SWOT analysis and cost-benefit analysis. based on numerous different assessment criteria as is required by a TNA.
- Previous TNAs have used an MCDA approach as it allows for considering trade-offs between multiple and conflicting objectives.
- A simple linear additive MCDA approach, as recommended in the UNDP TNA Handbook, undertaken in stakeholder workshops could be an appropriate methodology for the China TNA as well, potentially supplemented by a cost-benefit analysis or a SWOT analysis.
- The choice of the stakeholders determined the outcome of the prioritization process.
- MCDA should only be used to guide the decision making process. The choice of a moderator is crucial for the quality of the process.
- TNAssess might be the most obvious choice for an MCDA software.

This chapter starts with some concrete considerations on the methodological approach for technology prioritization within the China TNA, before giving a more general overview over available methods.

As explained above, previous TNAs and the current UNDP TNA handbook (2010) rely on a multi-criteria decision analysis process for the prioritization of technologies. For a number of reasons, this could be a valuable approach for the China TNA as well: MCDA aims at formalizing and structuring the human decision making process. In contrast to other decision making tools, it allows for considering trade-offs between a number of different and potentially conflicting objectives and for comparing quantitative versus qualitative criteria with high uncertainties. In addition, MCDA can be used to support decision making in a group.

If using MCDA, there is added value in undertaking the technology prioritization process with a stakeholder group in the form of workshops. Participation in the decision making process, increases the feeling of ‘ownership’ of the outcome for the involved persons, and may contribute to a commitment for potential follow-up actions. Some MCDA tools allow for the set-up of virtual conferences aided by interactive tools. But given that the decision making process involves complex considerations and to a certain extent value judgment, the personal interactions of a workshop may be more favourable.

The selection of stakeholders to participate in the process is crucial. Involving different groups of stakeholders may for example have been one of the reasons why two of the previous China TNA exercises resulted in very different choices of technologies (see Section 6.1). If feasible, it may be good to include decision makers from the public and potentially private sector into the technology prioritization process, who will later be involved in subsequent steps of implementing actions for technology transfer and deployment. Some considerations for choosing relevant stakeholders in the Chinese context are given in Box 1.

In any case, it is recommended to use the MCDA approach only as a way to guide the decision making process and structure an informed discussion (UNDP, 2009). Any results provided by the MCDA model used should be critically reviewed to gain an understanding of why these results were reached, instead of simply relying on the output of the MCDA process (UNDP, 2009). To guide and support this process in a constructive manner, the role of the moderator is crucial. MCDA approaches and tools are not self-explanatory. There is a risk of losing the attention of participants or distracting from the real discussion on technology choices due to ‘technical questions' about the MCDA tool and the process of weighing criteria. In addition, trust in the outcome of the technology prioritization process is at risk, if participants feel that the outcome is dictated by an interactive tool. It might therefore be beneficial if the person(s) moderating a technology prioritization workshop based on MCDA have practical experience in applying such a process, preferably in China itself. They should be familiar enough with the MCDA tool used to be able to focus the discussion on the technology choices, using the MCDA tool in seemingly casual manner.

For the China TNA, an MCDA approach could be complemented with other tools, e.g. with a partial cost-benefit analysis for a number of the most easily monetized criteria, such as mitigation cost, employment gains and energy savings. In this manner the robustness of an MCDA could be improved by providing impartial quantitative measures of performance against key economic criteria. A SWOT analysis could be used to complement the MCDA for assessing market development opportunities and in a later stage for identifying and overcoming barriers to deployment.

Overview over some decision making tools potentially relevant for a TNA process
The following gives a more theoretical overview over the available methodological approaches mentioned above. Within the field of decision making theory there is a long history surrounding problems of selection and prioritization of options against a number of diverse competing criteria. Broadly speaking there two types of approaches: i) explicitly monetary based techniques that attempt to assess the total cost or cost effectiveness of various options or ii) multi-criteria decision methodologies which attempt to prioritize/choose options on the basis a number of criteria and which usually internalize monetary considerations within the decision process. Table 6.2 lists some advantages and disadvantages of potential methods for the technology prioritization process. A detailed description of each option follows the table.

Table 6.2 *Advantages and disadvantages of potential approaches for technology prioritization*

Method	Advantages	Disadvantages
MCDA Linear Additive Models	- Easy communication.	- Requires that criteria are independent of one another. - Does not consider the uncertainty in criteria ratings.
MCDA Utility Theory	- Considers uncertainty in criteria ratings. - Can be designed to consider interactions between criteria.	- In its general form it is complex and time consuming; requiring input from specialists in MCDA theory.
MCDA Analytical Hierarchy Process	- Considers uncertainty in criteria ratings. - Can be designed to consider interactions between criteria.	- In its general form it is complex and time consuming; requiring input from specialists in MCDA theory.
MCDA Outranking	- Allows for incompatibility of options; i.e. they cannot be ranked relative to each other. - Mirrors the decision making process associated with public bodies.	- Requires that criteria are independent of one another. - Does not consider the uncertainty in criteria ratings. - Subjective decisions on what constitutes outranking and thresholds. - More suited to selected a favoured option, not prioritization/ranking.
MAC curve (cost effectiveness analysis)	- Easy communication.	- Optimizes for GHG emissions and costs only. - Not forward looking, usually does not consider future technologies.
SWOT[13]	- Relatively straightforward. - Focused on market development.	- No formal weighting or rating of options. - Interpretation of the results can be subjective. - Rating of criteria is typically based on largely qualitative information.

Source: UNDP TNA Handbook (2010), author's judgment.

6.3.1 Multi-criteria decision analysis (MCDA)

MCDA is a broad term that refers to a number of techniques and theories that can be used to either identify a preferred option, rank options or simply distinguish acceptable and unacceptable outcomes. In its broadest sense, MCDA first involves the selection of a number of criteria against which the competing options will be assessed. By scoring or rating each of the options against each of the criteria, which may or may not be weighted, an overall picture of which options are strong in each area of assessment begins to emerge. Typically the criteria sub-scores for each option are summed to identify the favoured options. However it is noted in the UNDP TNA Handbook (2010) that this aggregation of sub-scores into a total for each option may not be sufficient to prioritize technologies as the underlying factors can be obscured in such a process. (UNDP, 2009).

There are many MCDA techniques described in literature due to the many different types of decisions and surrounding circumstances. Considered below is a broad subset of the main techniques that are in frequent use and that are oriented towards the kind of decisions that have been

[13] Strengths, weaknesses, opportunities, threats.

made by public sector bodies which could reasonably be expected to be similar to the technology prioritization process required from a TNA.

Linear Additive Models
Perhaps the simplest and most common form of MCDA is the linear additive model. This model is, in itself, a grouping of different methodologies which share some common traits. In general the linear additive model requires that decision criteria are, or can be reasonably assumed to be, independent of each other. Uncertainty is also not formally built into the linear additive model. Although these assumptions may not strictly be applicable to all criteria that may be used in a TNA, such simplifying statements are likely to be necessary to conduct the TNA in a timely and cost effective manner.

The linear model is premised on the basic description of the core MCDA approach described before and provides a simple approach for how an option's sub-scores for each of the criteria can be combined into an overall total score. This is achieved by multiplying the sub-scores for each criterion by the respective weight of that criterion, and then adding all those weighted scores.

Linear models have a long history of successful use by decision-makers and public bodies working on a range of issues (DCLG, 2009). Most MCDA approaches use some form of this additive model, and in its basic form it is the basis of the MCDA model used in the UNDP TNA Handbook (2010).

Multi-attribute Utility Theory
A least in regards to the theoretical treatment of the criteria and their ranking, the MCDA approach that comes closest to universal acceptance is based on multi-attribute utility theory (DCLG, 2009). This form of MCDA formally takes uncertainty into account and also allows criteria to interact with each other such that it does not assume the mutual independence of preferences. While these factors can improve the robustness of an MCDA process they also make the methodology significantly more demanding in terms of both resources (particularly in terms of the expertise required to successfully facilitate such an approach) and technical data input.

It is likely that a detailed multi-attribute utility theory approach would not be the most appropriate methodological choice for technology prioritization in China given the expected large number of competing options to be assessed and the significant number of criteria upon which they will be ranked.

Analytical Hierarchy Process (AHP)
The Analytic Hierarchy Process (AHP) is effectively a form of linear additive model, but with an important characteristic in the way it determines criteria scores and weights, i.e. by pair-wise comparisons between criteria and between options. The decision makers are asked a series of questions, each of which asks them to compare how important one particular criterion/option is relative to another.

While the approach has been used in a number relevant applications, including in a simplified form within the initial TNA conducted in China (UNFCCC, 2007), doubts have been raised about the theoretical foundations of the AHP. In particular, the rank reversal phenomenon; the possibility that when a new option is added into the decision making process, the previous ranking of two other options, not related in any way to the new one, can be reversed; an outcome that is inconsistent with logical decision making theory (DCLG, 2009).

Outranking Methods
MCDA approaches based on outranking methods are relatively new and have been used to a limited extent in Europe. In any MCDA process it is sometimes possible to find options that are effectively 'dominated', i.e. they perform worse that the other options on a number of criteria

and perform no better than the other options on the remaining criteria. In these instances the 'outranked' option could safely be excluded from further analysis. The outranking methodology takes this approach a step further to create a number of thresholds and rules that allow decision makers to slowly reduce the number of options by identifying those that are outranked in some sense. The approach is appealing in the way it mirrors some aspects of a typical decision makers approach in the public sector where more weight is given to some aspects of a choice than others. However a significant concern with the approach is that it is dependent on somewhat arbitrary definitions of what constitutes outranking and how the threshold parameters are set and manipulated (DCLG, 2009); leaving it open to a relatively high level of subjectivity throughout the process.

6.3.2 Marginal Abatement Cost (MAC) curves

One of the simpler economic approaches to decision making in the field of climate change is the marginal abatement cost (MAC) curve. A MAC curve provides a visual representation of GHG abatement opportunities by plotting each mitigation option against both the marginal cost per ton of CO_2 abated for that option and the total mitigation potential associated with the option. By arranging the mitigation options from least costly to most costly a curve is developed that shows the level of possible abatement at any particular marginal cost. For prioritizing mitigation options the MAC curve is approximately analogous to a traditional cost effectiveness analysis which compares competing options on the basis of their impact for a given expenditure.

While MAC curves are appealing in their simplicity and their ability to communicate mitigation potentials, particularly cost positive ones, they have limited value in the TNA process, due to their focus on abatement potential and cost. Additionally, MAC curves are typically developed for a set of existing technologies for which the costs are better understood, whereas a TNA process is also interested in technologies that become available in the medium to long term. Furthermore MAC curves cannot account for technologies related to adaptation (UNDP, 2010).

6.3.3 Cost-Benefit Analysis

The concept of cost-benefit analysis (CBA) has been in use for a significant period of time and is regularly used by government bodies around the world in making decisions relating to infrastructure investments and / or the environment as well as being a standard tool for private firms when comparing market opportunities. For each option being considered, CBA attempts to value the expected outcomes. To do this, it requires that the advantages (benefits) and disadvantages (costs) associated with a particular project or policy are quantified in terms of monetary values, for each of the decision criteria. It is then possible to determine the overall theoretical cost or benefit for each option (though it should be noted that this is not equivalent to an expected net cash flow as many of the criteria may be quantifiable yet are not financially realizable to the investor).

Cost-benefit analysis is attractive to policy makers as 1) it considers the impact on all members of the society who have been included in the scope; 2) it values impacts in terms of a single, familiar measurement scale, i.e. money; 3) it uses established methods of measurement, where available, to determine how people value their preferences which implies a fair balanced decision process (DCLG, 2009).

The limitation of CBA chiefly lies in the difficulty of assigning explicit costs and benefit values. Some of the environmental aspects of the various options may be estimated using economic theories of valuation based on willingness-to-pay or to accept; however for many of the criteria typically associated with a TNA it will not be possible or practical (in regards to time and cost) to quantify the options in terms of economic impact.

As discussed above, a CBA could complement an MCDA approach for technology prioritization in a TNA.

6.3.4 SWOT

A strength, weakness, opportunity, threat (SWOT) analysis has been historically used by firms in order to match market opportunities to their company's strengths. However it could also be used to assist in finding the best match between external technology options (and their associated opportunities and threats) and internal national capabilities (strengths and weaknesses). Should this approach be adopted for a TNA, a country could first make a list of all the internal national factors that play a role in technology development and transfer and decide whether these are strengths or weaknesses and to what extent. Likewise, a similar analysis would be performed for external factors for a particular technology to determine what opportunities and threats were posed by that technology. From this a SWOT analysis for each technology option would be developed that could be used to study market development barriers and opportunities. The weakness in a SWOT lies in its relatively informal framework of criteria development and ranking and the difficulty in comparing one SWOT analysis to another. In this sense it is of limited value to a TNA process in the prioritization phase however it could provide value in the analysis of barriers later on.

6.4 MCDA Software

If an MCDA approach is to be used for a TNA, it is very likely that a software package is needed in order to facilitate the process. A wide variety of tools and software packages for Multi-Criteria Decision Analysis are available on a commercial or free-ware basis. The following documents give a good overview over existing solutions: 'Software to support MCA' by van Herwijnen (2006) and 'Decision Analysis Software Survey' by OR/MS Today (2008).

TNAssess, which is being developed to support the current UNDP TNA handbook (2010) might be the most obvious software tool for use in the China TNA process. TNAssess is developed explicitly for the use in TNAs and it's relatively simple to use based on a simple linear additive model and on excel-spreadsheets. The tool is currently still under development. It is expected to be available in October 2010[14]. A disadvantage may be the fact that to date, there seems to be limited practical experience with TNAssess, as it has not yet been used in a formal TNA process.

In general, an MCDA tool to be used in the China TNA should be fit for use in a participatory, multi-stakeholder setting, allow for an assessment based on qualitative criteria, and it should be easy and straightforward to use in order not to distract from the discussion on technology choices. Commercially available MCDA support tools include Hiview[15]and Logical sions[16]. However, choosing experienced moderators to facilitate the technology prioritization process may be the more important choice than the software package itself, and the choice of the moderator may determine the choice for the technical tool.

14 See http://portal.climatetechwiki.org/.
15 See http://www.catalyze.co.uk/?id=230.
16 See http://www.logicaldecisions.com.

6.5 Criteria Selection

- Criteria selection is a crucial step, as it is expected that the outcome of the technology prioritization process will be relatively sensitive to the criteria selected.
- Therefore criteria selection is a key decision to be taken by the TNA team and the experts and national decision makers involved in the TNA process.
- The information suggested in the technology factsheet gives some guidance for criteria, as do the criteria that have been commonly used in previous TNAs and the CTF investment criteria.
- Information collection about how a technology rates according to the criteria can be combined with information collection for the technology factsheets.

6.5.1 Criteria Selection in the current TNA handbook

The current UNDP TNA Handbook (2009) suggests a number of broad objectives according to which a technology is expected to be judged, namely:

- *"to maximize . the resilience of the sector against climate change*
- *to minimize any GHG emissions,*
- *to maximize development priority benefits in terms of environmental, social and economic benefits & minimize adverse impacts due to the measure"*.

Based on these objectives, three set of criteria are defined, i.e.

- *"Contribution to the country's development priorities, in terms of environmental improvement, social improvement and economic improvement*
- *GHG emission reduction potential of the technology (for mitigation) or reduction of vulnerability to climate change of the technology (for adaptation)*
- *Performance of technology in terms of costs and profitability"*.

In addition, there is a possibility to define additional criteria if appropriate. TNAssess allows for including up to 5 additional criteria.

6.5.2 Criteria Selection - options for a methodology

It is expected that the outcome of the technology prioritization process will be relatively sensitive to the criteria selected. And the choice of criteria already reflects the objectives of the stakeholders involved. Therefore criteria selection is one of the key decisions that need to be taken by the TNA team and the experts and national decision makers involved in the TNA process. It is good practice to align the criteria with general development goals of the country, but also more specifically with sectoral targets and/or regional plans.

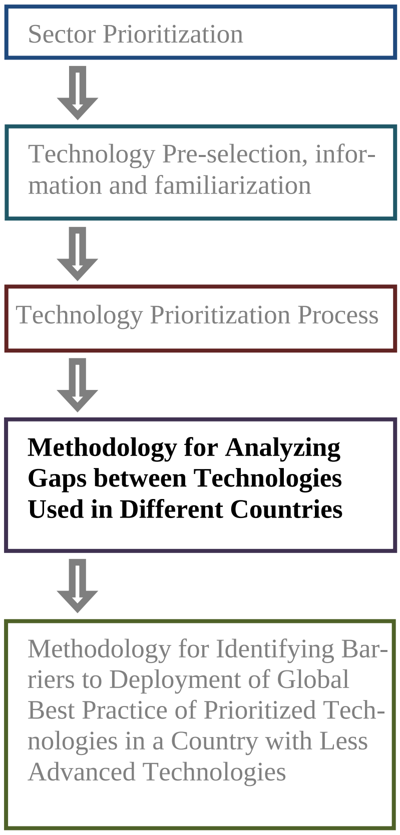
This study can only give an indication of potential criteria that could be used.

- The information suggested in the technology factsheet in Chapter 5.2.4 gives some guidance for potential criteria. It may be useful to already target the information collection process for the technology familiarization step towards also collecting information needed for assessing the technologies according to the criteria used.
- Annex 4 lists the criteria that have been commonly used in previous TNAs. This could inform the criteria selection process for the China TNA.
- Annex 5 lists the criteria used for prioritizing investments for the GEF Clean Technology Fund (see Chapter 2.4). These are mostly relatively similar to the information suggested in the technology factsheet above.

Chapter 5.2.3 suggest a range of sources, by which information could be gathered on how each of the technologies rates according the parameters determined above.

7. Analyzing Gaps between Technology Use in Different Countries

- Analyzing technology gaps is not a straightforward process as it highly depends on the definition of what constitutes the gap.
- However, gap analysis may be valuable in identifying technology transfer strategies.
- Three approaches to gap analysis are described, i.e.
  - Best practice
  - Benchmarking
  - Expert Assessment



Depending on the specific aim of the TNA, there may be a demand for insight in the gap between technology use in the country of the TNA versus global best-practice or global average. This chapter focuses on determining the existing technology gap. However, analyzing a technology gap is not a straightforward process as it strongly depends on how the gap is defined. It can for example be defined as the technological difference between the current state of technology in the TNA country versus developed country standards or current or future advanced technology worldwide or versus the most advanced technology used in the country itself. Also the current state of technology in the TNA country may be defined differently, e.g. as the most advanced technology available locally or as average technology-used.

In spite of these difficulties in definition, mapping out the technology gap may serve to create a clearer understanding of the steps that need to be taken in order to close the gap. Thus, technology gap analysis can be important for formulating technology transfer strategies after the TNA is completed.

The TNA handbook offers no guidance on technology gap analysis, but several methodologies can be employed to map the technology gap in different sectors. In practice, different methodologies might be used for different sectors and technologies, depending on data availability and knowledge of the stakeholders involved.

7.1 What is a best practice

Best practices represent the best standard for an industry in deploying low-carbon technology. Best-practices can be geographically defined. For the purpose of a TNA it may make sense to consider global best-practices in order to identify the international technology transfer potential. Best practices focus on currently existing and implemented technologies, but do not capture early stage or potential future technologies. Furthermore, in most cases, best-practices capture mostly cost-effective technologies, or at least technologies that are reasonably affordable. Otherwise, the technology simply wouldn't be implemented. Cost-effectiveness may simply be the result of the cost of the technology or it might be created by favourable regulation and subsidies. Understanding what drives the implementation of a best practice (subsidies, regulation or basic cost and market drivers) is important for informing discussions on how to overcome barriers to the implementation of best practices.

7.2 Methodology to determine gaps

Determining technology gaps between industry practices in one country and another can be very difficult to achieve. The main reason for this is that similar industry in two different geographical locations are often not comparable. GHG performance of an industry is not only influenced by technology related issues, but also by other aspects such as different access to energy resources and raw materials, different market demand, different industry standards, as well as statistical boundaries.

Given the situation described above, it is important to keep in mind that the purpose of technology gaps analysis is to enable technology transfer that increases the sector's overall mitigation or adaptation performance compared to its historical condition as a baseline (as it provides a valid comparison within the same context) or to best practices in a comparable context. Due to this reason, a valid technology gaps analysis requires two basic steps.

Step1: A thorough analysis of the local context of the sector needs to be conducted to get a clear understanding of whether a technology gap actually exists. Local conditions such as market demand and resource availability for raw materials and energy supply are the main factors that need to be considered. This step of the analysis would result in filtering out technologies that are not feasible for implementation, and identifying real (or 'corrected') technology gaps.

Step 2: Analysis of technology gaps related to their technical performance, economic feasibility, environmental performance, and social benefits/disadvantages.

In the following, three approached are introduced which follow the above steps and can be implemented selectively for different sectors depending on the complexity of the sector, data availability, and knowledge level of stakeholders.

7.2.1 Best practice

The process of identifying best-practices on low-carbon technology is relatively well established in many industries in different countries around the world. For example, for many sectors energy efficiency best practice manuals have been established as part of government programs to incentivize industry to adopt these best practices. Examples are the EnergyStar Guides of the U.S. Department of Energy and similar guidelines developed by national agencies focusing on energy and the environment such as in the Netherlands (SenterNovem), Denmark (Danish Energy Agency) and France (Ademe), etc. Similar best practice guidebooks are often also developed by national and international industry associations. Such best practice guidebooks are potentially very useful in clearly identifying technology gaps in certain sectors.

Developing best practice guidebooks can be an elaborate process, as it requires industry and energy experts to review a broad field of practice and compile what can be considered a best practice. However, existing studies and guidebooks on best-practices can be used to inform the gap analysis in specific sectors.

7.2.2 Benchmarking

Benchmarking is a process whereby a company or group of companies assess their performance relative to their peers in the sector based on a set of preselected performance indicators. Energy efficiency benchmarking has been used as a mechanism to assess company's relative performance on energy efficiency under various voluntary and regulatory programs aimed at improving the energy efficiency of industry sectors. Benchmarking can be done relative to the industry average or industry top performers, but energy efficiency benchmarking usually refers to the best performers. In China voluntary energy benchmarking programs have been set up by the government in key energy consuming sectors.

Despite its apparent simplicity by relying on only one or few indicators, benchmarking is a very complicated process that requires specialized knowledge regarding the industry, its processes and energy consumption. Under benchmarking different companies in different locations with different processes may be compared. However, adjustments often need to be made to account for differences in processes and company circumstances to see whether a technology gap actually exists. For example, consider two steel plants with different product mixes but both with all best practices implemented. Their energy consumption is likely to be significantly different. If we benchmark them on energy consumption per unit of product one plant will look better than the other. However, this does not necessary point to a technology gap as both plants have implemented best practices.

While comparing benchmark indicators among plants is complicated, there are a number of benchmarking tools available for different sectors. An example is the BEST tool developed by the Lawrence Berkeley Laboratory of the US to benchmark performance of individual plants in the cement sector relative to national and international average and best performance.

At a country or regional level, benchmarking may help to establish the size of the technology gap. For example, it can indicate that average energy consumption per unit of cement is X in China versus Y in developed countries. This points to the fact that there is a technology gap and that the benefits of closing the gap are defined by the difference between X and Y. Such an analysis, however, does not automatically generate a picture of what the gap consists of. A more detailed analysis on industry practices provided by experts and best-practice studies may therefore be necessary to provide the whole picture.

7.2.3 Expert assessment

Assessing the technology gap may also be done through expert assessment. A group of industry and energy or low-carbon technology experts can be brought together to discuss and draw conclusions on how big the technology gap on specific technologies is and what constitutes the technology gap. The benchmarking and best practice studies described above can be used as input for this group.

A key advantage of using expert assessment is that it allows a more dynamic view on how the technology gap might evolve in the future. Benchmarking and best practices studies predominantly present a static situation. Experts can incorporate their knowledge on key industry and technology developments in the gap analysis, thus also taking into account the gap to emerging and future technologies.

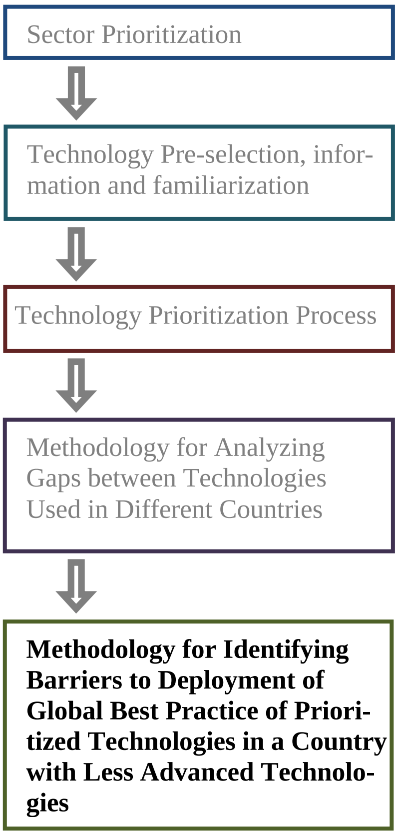
Expert assessment can also be used to develop technology roadmaps. Technology roadmaps are used in government and the private sector to chart a clear step-wise and time-bound path for developing a technology to a certain standard, maturity or market deployment. Technology roadmaps start from a consensus on the goal of the roadmap, for example achieve domestic design and manufacturing capacity to produce 5MW offshore wind turbines. Then a group of experts researches how to achieve the goal from the current status. This implies a detailed analysis of the status quo of the industry, as well as an analysis of the key capacities that need to be created, technologies that are needed and barriers that need to be removed. In the case of technology roadmaps the technology gap is defined relative to an ambition, not to a practice or standard elsewhere in the world. The ambition level might be well beyond current technology available or being applied in the world.

The advantages in technology road maps lie in their ability to define the technology gap and chart a path to closing the gap such that a coherent set of prioritized technology and capacity development steps are created that work towards a common goal. Prioritization of actions is therefore driven by the overall goal. The goal itself can result from the technology prioritization. Taking again the example of offshore wind, the technology priority may be to develop offshore wind turbine design, manufacturing and installation capacity. The specific goal, taking into account expected developments in turbine generating capacity for offshore turbines worldwide, could be to achieve domestic design and manufacturing capacity to produce 5MW offshore wind turbines by 2015. Consequently a group of experts can analyze the capacities, technologies and next steps needed to achieve this goal.

An advantage of technology roadmaps is that they look beyond the current status of technology to future technology needs. Therefore, recommendations on technology transfer that result from such a roadmap are clearly future oriented and support meeting a technology need that is likely to remain over an longer period of time.

Technology ‘roadmapping’, however, does require a lot of expert input and analysis and it is not likely that it can be carried out for a large number of technologies. For key prioritized technologies, however, technology roadmapping might offer a more detailed and future oriented picture of the technology gap and a clear structure for closing the gap.

8. Identifying Barriers to Deployment of Global Best Practice of Prioritized Technologies



- Barrier analysis to be done on the basis of individual prioritized technologies
- Market mapping approach suggested in the current TNA handbook especially well suited for rural environments in developing countries
- More general approach to barrier identification

8.1 Barrier analysis in past TNAs

In past TNAs the process for analyzing barriers varied. In some TNAs barrier analysis was preformed for individual technologies whilst others conducted a sectoral, national or regional analysis. The methodology for barrier analysis is rarely described. Annex II of the second UNFCCC synthesis report (2009) contains a full list of the barriers identified in previous TNAs that could inform the TNA in China.

8.2 Barrier analysis in current TNA Handbook - Market Mapping

The UNDP TNA Handbook (UNDP, 2010) suggests a market mapping approach for barrier identification and removal (see chapter, and Annex 6.1 and 6.2 of the handbook). Market mapping was first suggested by Albu and Griffith (2005) in the context of extending a sustainable livelihoods framework for small-scale poor farmers in developing countries. Resulting barriers are categorized in terms of enabling environment, market chain and support services. Examples of market maps can be found in ENTTRANS (2008) where the approach was first published in relation to TNAs.

8.3 Barrier Analysis - possible elements of a methodology

To identify technology specific barriers it is recommended to perform an analysis of barrier per prioritized technology.

Market mapping seems to be most suitable for a participatory process in a rural, developing country setting, and may therefore be suitable for specific regions / technologies in China. In the following a more general approach is described, that could be applied for a wide range of mitigation and adaptation technologies.

The general approach explained here consists of a combination of expert interviews (face-to-face or telephone interviews) and workshops and literature review for specifying and validating the identified barriers. This set-up is expected to work for mitigation and adaptation technologies and comprises the following steps

1. Decide if barrier analysis should take place on a national or regional level. This may be the same as for technology prioritization process.
2. Identify experts for the technology or sector: these experts may include end-users of the technology, members of industry associations, technology manufacturers, researchers and policy makers.
3. Conduct face-to-face or telephone interviews with the selected experts asking them to identify barriers for wide-spread use of the technology.
4. Validate the identified barriers by.
    a. Literature research: a wide range of literature exists on many adaptation and mitigation technologies, that describes barriers to technology deployment, e.g. peer-reviewed journals, industry publications and 'grey' literature related to climate policy. Barriers described in literature for other countries may inform the process in China. Potential sources are for example CDM methodology documents[17] and a list of barriers identified in previous TNAs (see UNFCCC, 2008, Annex II).
    b. Workshops: after the initial identification of barriers, expert workshops may be used to validate the identified barriers, to rank them according to their importance, and to discuss measures to overcome barriers.

The template in Table 8.1 may help to structure the discussion and to categorize the identified barriers. Identifying the incentive needed to overcome a barrier will help to define the specific barrier more clearly.

[17] In the CDM, barrier analysis may be used in certain situations to prove the additionally of a proposed CDM project. However the CDM does not prescribe a methodology for barrier analysis. It is only suggested to group barriers into the following categories: Investment barrier, Access-to-finance barrier, Technological barrier, Barrier due to prevailing practice, Other barriers such as institutional barriers or limited information, managerial resources, organizational capacity, or capacity to absorb new technologies. (CDM Executive Board, 2008) Some of the CDM methodology documents contain a list of frequently encountered barriers for the respective technologies. CDM methodology documents are available at https://cdm.unfccc.int/methodologies/PAmethodologies/approved.html

Table 8.1 *Template to structure barriers to technology transfer and deployment. Hard barriers mean that there is no use of the technology unless the barrier is removed. Soft barriers prevent a widespread application*

Barrier Type	Examples	Importance (1-5)	Hard or soft barrier	Incentive needed to overcome the barrier
Technology	High risk for failure		S	
Capacity	No trained engineers available for maintenance		s	Train people
	No awareness of technology			Raise awareness
Financial & market	Up-front capital costs too high		S	Financial
	Monopolistic market structure		H	
Behavioral / acceptance				
Organizational / Institutional	No responsible person for energy efficiency in company			Assign mandate
			H	Different law needed
Systemic	Whole manufacturing process is fixed and does not allow for changes		H	
Regulatory / policy related	Law forbids application of the technology			
Other				

9. Conclusions

The preceding chapters reviewed previous TNAs, similar efforts and the current UNDP TNA Handbook and provided recommendations for the China TNA for the following key steps of a TNA process:
- Sector prioritization.
- Technology pre-selection, information, and familiarization.
- Technology prioritization.
- Analyzing gaps between technology use in different countries.
- Identifying barriers to deployment of global best practice of prioritized technologies.

Overall, the analysis shows that experience with previous TNAs can guide the China TNA process only to a limited extend as few TNAs were conducted in large emerging economies. The analysis also shows that for many aspects of the planned China TNA, the latest version of the UNDP TNA handbook (2010) can provide guidance for the methodology applied in China. However, there are several key steps where due to the size, complexity and diversity of China, it may make sense to adapt, change or complement the suggestion of the handbook, for example it is likely that a larger number of sectors will be prioritized.

There are a number of key decisions that need to be taken during the organization of the TNA, including:
- Determining if the sector and technology prioritization process should take place on a regional or national level.
- Determining the stakeholders to be included into the process of prioritizing sectors and technologies, as this choice is likely to influence the outcome of the prioritization. Involving key decision makers in the process will increase their feeling of ownership of the results and their commitment to the outcome including to later steps of implementation of technology transfer actions.
- Finding an experienced moderator for workshops on the technology prioritization process (if a participatory MCDA approach is to be used).

Key choices during the TNA process include:
- The selection of criteria for prioritizing technologies as this will also influence the outcome of the prioritization.
- The approach to measuring the gap in technology use between China and other parts of the world.

It may also useful, if the process for prioritizing technologies including associated steps such as collecting technology information and determining gaps in technology use was to be institutionalized in order to allow for an easy replication of the TNA and to inform national policy making processes.

References

Albu, M. and A. Griffith (2005): *Mapping the market - a framework for rural enterprise development policy and practice.* Practical Action. Available at http://practicalaction.org/docs/ia2/mapping_the_market.pdf

CDM Executive Board (2008): *Methodological tool – 'Combined tool to identify the baseline scenario and demonstrate additionality'* (Version 02.2). Available at https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-02-v2.2.pdf

CTI (2001): *Methods for Climate Change Technology Transfer Needs Assessments and Implementing Activities - Developing and Transition Country Approaches and Experiences.* Available at http://unfccc.int/ttclear/pdf/TNA/CTI/Tech%20Transfer%20Guidelines-12%20_final_.pdf

Department for Communities and Local Government (DCLG) (2009): *Multi-criteria analysis: a manual*. Communities and Local Government Publications, Wetherby, UK. Available at: http://eprints.lse.ac.uk/12761/1/Multi-criteria_Analysis.pdf

ENTTRANS Final Report (2008): *ENTTRANS: The potential of transferring and implementing sustainable energy technologies through the clean development mechanism of the Kyoto Protocol*. FP6 Project, funded by the European Commission (EC-DG Research FP6)

GEF (2008): *The Clean Technology Fund*. Available at http://www.climateinvestmentfunds.org/cif/sites/climateinvestmentfunds.org/files/Clean_Technology_Fund_paper_June_9_final.pdf

Gross, R., W. Dougherty, K. Kumarsingh (2004):*Conducting Technology Needs Assessments for Climate Change*. UNDP, New York, US, 26 pp. Available at http://unfccc.int/ttclear/pdf/TNA/UNDP/TNA%20Handbook_Final%20version.pdf

IPCC (2000): *IPCC Special Report Metholodolgical and Technological Issues in Technology Transfer*.

Ji, Z. et al. (2008): *Preliminary Technology Needs Assessment in the Ten Prioritized Areas for Energy Conservation in China*, EU-China Energy and Environment Programme.

Schellnhuber, H.J. (2009): *Solving the Climate Dilemma: The Budget Approach.* Presentation at UND P NHDR side event at UN FCCC, 15th Conference of the Parties, Copenhagen

Smith, J. (2006): *Overview of technologies for adaptation*. Presentation at the UNFCCC, 2007. Best practices in technology needs assessments, Technical paper, FCCC/TP/2007/3 15 November 2007.

UNEP (2008): *United Nations environment programme assistance to fourteen countries within the framework of the global environment facility expedited financing for (interim) measures for capacity building in priority areas*. Available at http://unfccc.int/ttclear/pdf/TNA/UNEP/UNEP-TNAReports.pdf

UNDP (2008): *Experiences and lessons learned from technology needs assessments (TNAs)* - Report to the Global Environment Facility (GEF). Available at http://unfccc.int/ttclear/pdf/TNA/UNDP/UNDP-TNA-Report.doc

UNDP (2009): *Handbook for Conducting Technology Needs Assessment for Climate Change*. Available at http://unfccc.int/ttclear/pdf/TNAHandbook_9-15-2009.pdf

UNDP (2010): *Handbook for Conducting Technology Needs Assessment for Climate Change* (draft version)

UNDP (2010): *China Human Development Report 2009/10 - China and a Sustainable Future: Towards a Low Carbon Economy and Society*, China Translation and Publishing Corporation, Beijing, China

UNFCCC (2006): *Synthesis report on technology needs identified by Parties not included in Annex I to the Convention*. FCCC/SBSTA/2006/INF.1, Available at http://unfccc.int/resource/docs/2006/sbsta/eng/inf01.pdf

UNFCCC (2007): *Report on the workshop on best practices in conducting technology needs assessments*. FCCC/SBSTA/2007/11. Available at http://unfccc.int/resource/docs/2007/tp/03.pdf

UNFCCC (2009): *Second synthesis report on technology needs identified by Parties not included in Annex I to the Convention*. FCCC/SBSTA/2009/INF.1. Available at http://unfccc.int/resource/docs/2009/sbsta/eng/inf01.pdf

Winskel. M., A. Mcleod, R. Wallace, R. Williams (2006): *Energy Policy and the institutional context: marine energy innovation systems*, Energy Policy, 33, 5, pp. 365-76

WWF (2010): *The 12th five year plan - The Formulation of China's Major Plans and Programs 2008-2010 and onwards*. Available at http://pamlin.net/blog/China%2012th%20FIVE%20year%20plan.pdf

Appendix A Previous TNA related efforts in China

Preliminary Technology Needs Assessment in the Ten Prioritized Areas for Energy Conservation in China, is by far the most comprehensive China technology needs assessment document conducted by Renmin University of China as part of the EU-China Energy and Environment Programme. The work focuses on the key technologies in ten prioritized areas for energy conservation, and prepares and fosters technological information and the methodology for in-depth technology needs assessment. It describes the current situation of the ten prioritized areas and the situation of their related sectors, and further elaborates the technologies needed in this area. The report also analyzed barriers in the prioritized areas in terms of barriers from provider side, receiver side and infrastructure. The ten prioritized energy conservation areas are:

1) Coal-fired Industrial Boilers (Kilns) Retrofit Project.
2) District Co-generation Projects.
3) Residual Heat and Pressure Utilization Project.
4) Petroleum Saving and Substituting Projects.
5) Energy Saving Projects on Electric Motor System.
6) Energy System Optimization Projects.
7) Building Energy-saving Project.
8) Green Lighting Project.
9) Energy-saving Project of Government Organizations.
10) Energy-saving Monitoring and Construction Engineering of Technology Service System.

The report describes the general process and steps of Technology Needs Assessment (TNA) as follows:

1) Establish the TNA management department (institute or organization) and working team.
2) Preliminarily identify those major departments which have abatement potential on account of macro background and their abatement capacity according to the GHGs listing; meanwhile, identify the characteristics of these departments based on the national planning.
3) Map out the criteria of TNA.
4) Further identify the abatement technologies with priority according to the assessment criteria.
5) Identify the R&D and popularization barriers of the abatement technologies and further policy needs, as well as the applied possibility and space.
6) Taxis of the abatement technologies with priority and key departments.
7) Prepare for the integrated assessment report including stakeholder analysis, assessment of technology needs of each department, project proposals and possible fund sources; finally hand in the general report and major findings got by the communication of TNA with institutes or organizations related.
8) Carry out related future work, see whether the assessment fund sources are adequate at the start-up, guarantee the transparency of the process and identify the means of reducing barriers; make some revise of the plan if necessary.

Technology Cooperation Framework - China and *The China Wind Power Study Report*, which are both available on UNFCCC’s website, are two examples of TNA related research.

Technology Cooperation Framework - China was conducted in the following process:

1. A team was established to develop TCF.
2. An interagency consultant team, consisting of experts from relevant ministries and commissions, was established to help selection of technology priorities and provide guidance for the development of the options in the framework.
3. Research work on selecting technology priorities was carried out based on the results of domestic and international cooperative projects on GHG mitigation.
4. A scooping meeting was held to discuss and evaluate the technology priorities.

5. Research was conducted, market barriers and some key technology options to overcome these barriers were identified.
6. This draft report was prepared and reviewed by the framework team.

The process for Screening and Validating Technology Cooperation Priorities is:
First, both international and domestic experts discussed and agreed on the following criteria for identification. The criteria were divided into four categories:
1. Environmental benefits.
2. Economic development.
3. Conditions for technology transfer.
4. Investment.

Second, referring to these criteria, experts supposed the mitigation technologies based on their experiences in different sectors. After summarized, total 19 technologies were proposed, i.e.:
1. High efficiency boilers.
2. Large thermal power generation (300-600 MW).
3. Cogeneration.
4. High efficiency electric motors.
5. Green lighting.
6. Energy saving buildings.
7. Coal-bed methane recovery and utilization.
8. Biomass gasification.
9. Wind energy.
10. Solar thermal heat.
11. Biogas.
12. Waste heat and energy recovery.
13. Village hybrid renewable energy (wind & PV).
14. High efficiency cook stoves.
15. Alternative fuel transportation for urban regions.
16. Small-scale hydropower.
17. Combined cycle natural gas power generation.
18. Central heating.
19. Waste gas recovery.

Third, a matrix involving technologies and the criteria was designed and spread to only domestic experts to ask them making a score of each criterion of each technology. For simplicity, an equal weight here was assigned to each criterion. About 20 experts were involved at the meeting.

Fourth, a comprehensive statistics was conducted, and finally the top five high scored technologies were identified, they were thermal power generation, high efficiency motors, high efficiency boilers, wind energy and coal bed methane recovery.

The report further analyzed situation and barriers in the 19 technologies listed above.

The China Wind Power Study Report gives an overview of worldwide wind power technologies situation, with focus on the technology situation and potential in Chinese wind market. It also illustrates two technology transfer examples: Xinjiang Wind Energy Company - licensing of Jacobs turbines, and State Development Planning Commission ‘Ride the Wind’ program.

Preliminary Technology Needs Assessment in the Ten Prioritized Areas for Energy Conservation in China systematically analyzed the technology needs in China, with complete process of identifying criteria and selecting key technologies. *Technology Cooperation Framework - China* provided more detailed barriers on each specific technology. Both reports listed key technologies, which are compatible with national development plans, however, the technologies are not classified into a structured category. It may lead to missing or duplicate TNA in certain sectors. *The China Wind Power Study Report* provided two examples of how technologies can be transferred and how national and provincial policies help technology transfer.

Appendix B Wind Technology Factsheet

Name and Sector:

Wind Turbines, Renewable Energy Sector

Technology specific

Technology description (including how it works, state of technological development, and expected future developments)

A wind turbine transforms the kinetic energy of the wind into electricity that can be sold to utilities and used by various end-users including residential homes, businesses, commercial developments, etc.

Currently, there are two basic designs of wind electric turbines: vertical-axis or' egg-beater' style, and horizontal-axis (propeller-style) machines. Horizontal-axis wind turbines are the most common today, and constitute nearly all of the 'utility-scale' (100 kilowatts, kW, capacity and larger) turbines in the global market.

Turbine subsystems include:

- a rotor, or blades, which convert the wind's energy into rotational shaft energy;
- a nacelle (enclosure) containing a drive train, usually including a gearbox* and a generator;
- a tower, to support the rotor and drive train; and
- electronic equipment such as controls, electrical cables, ground support equipment, and interconnection equipment.

*Some turbines do not require a gearbox

The electricity generated by a utility-scale wind turbine is normally collected and fed into utility power lines, where it is mixed with electricity from other power plants and then delivered to utility customers.

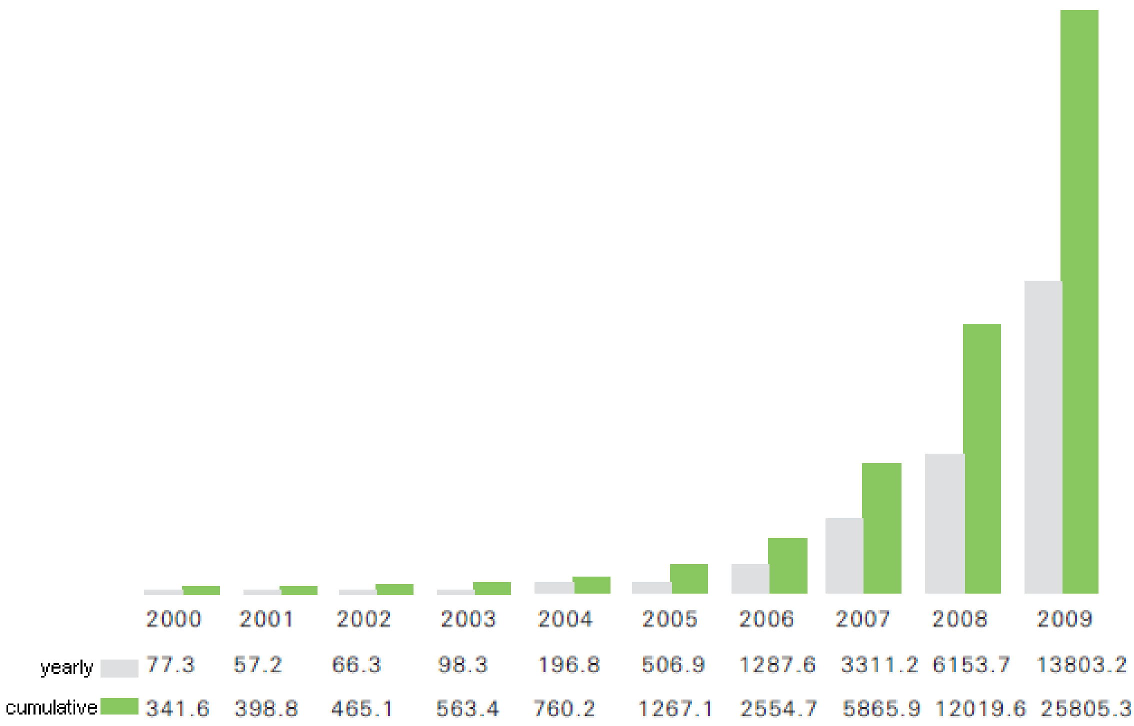
In 2005, about 21.5% of newly installed turbines in China are greater than 1MW. It increased to 86.86% in 2009. Among all the turbines greater than 1MW installed in China in 2009, the 1.5MW turbines are the most commonly used ones. They accounts for 73.8% of the total newly install turbines.

Technical / operational / regulatory requirements

Currently, wind turbine manufacturers in China follow 54 standards, including 22 Chinese national standards (GB), three Chinese Power Standards (DL/T), 15 Chinese Mechanical Standards (JB/T), 11 International Electrotechnical Commission (IEC) Standards and three others. The standards cover comprehensive aspects of wind turbine design and manufacturing, such as: methodology to assess wind resources, test method and technical conditions of generating system, safety requirements, maintenance and operation, noise measurement and wind turbine certification.

Market penetration (global & local), today and market penetration development potential

As of the end of 2009, cumulative installed capacity in China (not including Taiwan) reached 25.8GW, with 13.8GW installed in 2009. Wind power accounted for about 0.75% of total power generated in China in 2009. On the other hand, the official target of Chinese government is to have non-hydro renewables (mainly wind) account for 1% of generation by 2010 and 3% by 2020, which will be 30GW by 2020. The following chart shows the capacity (MW) installed every year from 2000 to 2009[2] .



China Wind Installed Capacity 2000-2009

The following chart provides the provincial distribution of installed capacity in China[2] .

Cumulative installed capacity of each province in China (MW)

Technology impacts

GHG reductions compared to current practices and absolute GHG emissions (mitigation)

Wind turbines are extremely effective at reducing emissions of carbon dioxide (CO_2), the leading greenhouse gas.

A single 750-kilowatt (kW) wind turbine, typical of those now being installed in power plants around the world, produces roughly 2 million kilowatt-hours (kWh) of electricity annually.

Based on China's average emission factor for electricity from the grid, 0.85 tCO2 emissions from each MWh electricity generated, a single 750kW wind turbine can help reduce GHG emission of 1.7 tCO2 per year.

Environmental benefits (and risk) (e.g. reduction of air pollution, water resource protection etc)

The most important burdens derived from the production and uses of energy are:

- Greenhouse gases;
- Particles and other pollutants released into the atmosphere;
- Liquid wastes discharges on water and/or soil; and
- Solid wastes

Fossil fuel energies exhaust natural resources and are mostly responsible for environmental impacts, while renewable energies in general, and wind energy in particular, produce significantly lower environmental impacts than conventional energies.

On the other hand, wind energy also has some minor negative environmental impacts, for instance, for on-shore wind farms, the impacts are: visual impact, noise impacts, land use, impacts on birds, electromagnetic interferences and constraints on natural reserve areas.

Costs

While cost of a wind energy project is dominated by the cost of the wind turbine itself, there are some other costs such as foundation, electric installation, grid connection, control systems, consultancy, land, financial costs, road and also operation and maintenance costs

Take a 49.5 MW wind projects in Inner Mongolia for example, the total investment is about CNY 500 million, within which, the cost of turbines is about CNY 250 million, given that the turbine price is about CNY 5000/kW. The annual maintenance cost, according to the feasibility report developed by Inner Mongolia Institute of Electricity Power Survey and Design, is about CNY 80/MWh.

Market aspects

Current leading turbine manufacturers globally:

- Vestas (Denmark)
- Enercon (Germany)
- Gamesa (Spain)
- GE Energy (Germany / United States)
- Siemens (Denmark / Germany)
- Suzlon (India)
- Nordex (Germany)
- Acciona (Spain)
- REpower (Germany)
- Goldwind (China)

Current price range:

China will be divided into four wind resource regions based on resources and construction conditions, the benchmarking feed-in tariff of wind projects will be RMB 0.51/kWh, RMB 0.54/kWh, RMB 0.58/kWh, RMB 0.61/kWh, and projects straddling two price regions can adopt the high feed-in tariff. Starting 1 Aug 2009, all new on-shore wind projects will be granted the fixed tariffs. Feed-in tariffs for off-shore projects will be different and have yet to be determined. The distribution of tariffs is very much aligned with distribution of resources.

Ownership of IPR:

The manufacturers currently operating in China can be categorized into the following groups, according to the way the acquire the IPR:

- Subsidies of foreign manufacturers,
- Purchase IPR from other companies, universities, research institutes, or build joint venture with them.
- Develop their own R&D department.
- Acquire companies with IPR, for example: Goldwind acquired 70% of German turbine maker Vensys Energy AG, to manufacture large-scale turbines.

Manufacturer's installed capacity in China and their market share[2] :

Turbine Size (MW)	Manufacturer	Cumulative installed capacity (MW)	Market share
>1000	Huarui	5652	21.9%
	Goldwind	5351.05	20.7%
	Dongfang Turbine	3328.5	12.9%
	Vestas	2011.5	7.8%
	Gamesa	1828.75	7.1%
500-1000	GE	957	3.7%
	Mingyang Electric	895.5	3.5%
	United Power	792	3.1%
	Suzlon	605.25	2.3%
	Windey	594	2.3%
	XEMC	582	2.3%
100-500	Shanghai Electric	475.5	1.8%
	Nordex	467.6	1.8%
	Nantong CASC Wanyuan	249	1.0%
	Repower	200	0.8%
	Beizhong	198	0.8%
	China Creative Wind Energy	196.5	0.8%
	NEG-Micon	151.95	0.6%
	Vista	150	0.6%
	Xinyu	135	0.5%
	Hewind	133.44	0.5%
	CSR Times Electric	130.35	0.5%
Others		720.41	2.8%
Total		25805.3	100.0%

Leading Project developers in China and their market shares[2] :

Turbine Size (MW)	Project Developer	Installed capacity in2009 (MW)	Market share
>1000	Guodian	2600.4	18.8%
	Datang	1739.85	12.6%
	Huaneng	1644.75	11.9%
	Huadian	1230.05	8.9%
500-1000	Guangdong Nuclear	854.45	6.2%
	Beijing Energy Investment	797.5	5.8%
	Guohua	590.25	4.3%
100-500	CECIC	400.25	2.9%
	China Power Investment	319.67	2.3%
	China Resources	309.75	2.2%
	Tianrun	309.75	2.2%
	China Wind Power	295.5	2.1%
	Hebei Construction	160.4	1.2%
	SDIC	151.5	1.1%
	CWE	148.5	1.1%
	Ningxia Electric Power	143.5	1.0%
	Fujian Investment & Development	130	0.9%
	Shenzhen Energy	129	0.9%
	Luneng	102.25	0.7%
	Honiton Energy	100	0.7%
Others		1645.89	11.9%
Total		13803.21	100.0%

References:

[1] China Wind Market: Project Developer Tracker, Volume 4, Azure International
[2] Chinese Wind Energy Association
[3] American Wind Energy Association
[4] www.wind-energy-the-facts.org

Appendix C Generic technology fact sheet from ClimateTechWiki: Wave energy[18]

Table of Contents

Marine renewables, also known as ocean energy, refers to a broad range of technologies that extract energy from the ocean; this energy can be in the form of ocean waves, tidal movements or thermal gradients. Marine renewables are, in general, at a relatively early stage in their development and, as such, the methods of converting these potential energy sources into useful electrical power are still highly diversified, with many technologies competing for commercial viability.

Wave energy plants use either nearshore or offshore ocean waves and can be so-called attenuators, point absorbers, surge converters, oscillating water columns, overtopping devices and submerged pressure differential. Several prototypes or pre-commercial demonstrators (up to 750kW capacity per device) have been deployed around the world and a number of larger-scale projects are under development but these larger projects generally depend on further cost reductions to be viable

1. Introduction:

Wave energy converters (WECs) capture the energy found in ocean surface waves. These waves result from the action of wind blowing over long stretches (or fetches) of open ocean surface. Like wind power the availability of wave power is variable and will depend on the prevailing wave conditions at any particular time, sometimes producing maximum power and sometime producing none. The predictability of waves is slightly better than wind forecasting as the incoming swell heights can be measured by buoys or satellites far from the coast meaning that reasonable forecasts of wave conditions can be made up to 5 days in advance. Although waves are created by winds, these inducing winds occur at distant locations. By the time the waves reach the coast for power generation there is not necessarily any correlation between the amount of local wind on a particular day and the energy in the waves in the same region. There are a number of different approaches as to how the power in these waves is converted into useful work and at this stage of development there are many competing designs of WEC. The European Wave Energy Centre (EMEC, 2010) defines 6 main categories of WEC plus a seventh 'catch-all' category for designs that cannot be classified as belonging to one of the 6 main types.

[18] Source: ECN, 2010 available at www.climatetechwiki.org

Attenuator

This is a device that floats on the surface of the waves and extracts energy in parallel to the direction of the wave front by changing shape along its length. These types of devices are typically deployed in deeper water using a number of catenary mooring lines fixed to points on the ocean floor. The wave power is usually converted to electricity in the device using hydraulics and induction generators. Pelamis (PWP, 2010) is the most well known example of an attenuator type WEC.

Point Absorber

Point absorbers also float on the ocean surface but are typically axisymmetrical and absorb energy in all directions through their vertical movements. These types of devices are seen to have multiple competing designs for the power conversion / power take-off (PTO) including remote (at sea) direct conversion with linear generators or onshore conversion using high pressure water and hydroelectric equipment. Power Buoy (OPT, 2010) and Wave Bob (WaveBob Ltd, 2010) are prominent devices that use the point absorber principle.

Oscillating Wave Surge Converter

As waves approach the shore, the shallower water causes them to shoal; elongating the previously circular motion of the water particles. WECs in this category extract the energy from this surging motion using either a linear or rotational oscillator. The nature of surging waves means that devices of this type need to be deployed in shallow water depths, typically with a solid foundation. Oyster (APL, 2010) is the most well recognised device of this type.

Oscillating Water Column

Oscillating water column (OWC) devices use the semi-submerged volume of air open to the sea to extract energy. As the waves pass the device the air in the device is compressed and decompressed; the resulting out or in rushing air is passed through a turbine that is designed to operate in the same direction, irrespective of the flow direction. Devices of this kind may be mounted on the shoreline or breakwaters but they have also been demonstrated in deeper water. Limpet (VHW, 2010) and Oceanlinx (2010) are examples of onshore and offshore OWC devices respectively.

Overtopping Device

This type of device uses the height of a wave to fill a reservoir by spilling over a barrier and the water in the reservoir is drained back to the sea level through conventional low-head turbines. An overtopping device may use physical reflectors to concentrate the wave energy. There are limited devices of this type, with Wave Dragon (2005) being the most well known.

Submerged pressure differential

These devices are typically located in the nearshore region and mounted to the seabed. The waves cause the sea level to rise and fall over the device, inducing a pressure differential. The alternating pressure difference can then be used to create motion and generate electricity, typically by pumping high pressure fluid. The Archimedes Waveswing (AWSOE, 2010) and CETO (Carnegie, 2010) devices use this principle of operation.

Other

There are a small number of devices that do not fit into the above categories including turbines that are directly turned by the waves (Ecofys, 2002), flexible tubes that bulge (Checkmate, 2010) and devices using electroactive polymers to convert the wave energy into electricity (SRI, 2008).

2. Feasibility of technology and operational necessities:

Resource

The primary factor that will determine the suitability of a country or site for wave power is the level of wave resource found there. Wave power at a location is normally expressed in units of the average kilowatts per metre of incident wave front over a year, or kW/m. Thus at a sight with an average wave resource of 20kW/m the average amount of power that could be converted by a 10 metre wide device is in the order of 200kW, assuming 100 percent of the energy is captured (although devices will capture less than this in practice). The momentary power production can be significantly higher during periods of larger waves however the yearly average resource at a site gives a good measure of the suitability of a site assuming the selected device characteristics are known. Given the wide range of device types and the conditions they require it is not possible to endorse a certain threshold that makes any single site suitable, instead the overall economic picture must be considered.

The best wave climates, with annual average offshore power levels between 20-70 kW/m of wave front or higher, are found in the temperate zones at 30 to 60 degrees latitude in countries such as Chile, Canada, UK, Ireland, Australia, New Zealand, USA, and Portugal amongst others. The size and nature of the wave resource also changes depending on the water depth; as waves progress to shallower depths they lose energy due to wave breaking and bottom friction effects. While this causes lower gross energy levels in the nearshore, the associated 'filtering out' of extreme storm events can potentially compensate for the decreased energy levels (Folley & Whittaker, 2009).

When selecting a final site for deployment the wave resource at that particular location will typically be modelled using historical wind/swell data to give the expected performance over time (and thus economic performance) and this modelling may be supplemented by direct measurements of wave heights and periods using some form of deployed buoy or probe.

Location

Being situated in the ocean, and typically being deployed on or near the surface, WECs must compete for space with more traditional stakeholders such as shipping/transport vessels, fisheries, recreation areas and zones reserved for environmental conservation. The nature of the wave power intensity means that large installations, on the multi-mega watt scale, may require many hundreds of metres of length in which to be deployed, if not kilometres for utility scale installations. Depending on the nature of the device this may be offshore where interactions are generally limited to ocean going vessels, or closer to the nearshore where additional concerned parties must be considered.

Technical Requirements

The installation and maintenance of WECs typically involves a large proportion of offshore activities. During the installation phase this may involve large specialised vessels for the transport and lifting of devices. However more and more device developers are attempting to simplify installation procedures to reduce or remove the need for costly specialised craft; this can be done in a number of ways and depends on the specific device being considered. However all installation approaches must face the same issue of survivability in extreme sea states. By their very nature WECs are deployed in some of the most hostile ocean conditions making it a significant challenge to secure the device in a cost effective manor.

There is also a large diversification in the maintenance philosophies adopted across the range of devices, with some designs requiring offshore maintenance, some using a 'tow-to-shore' strategy and others placing much of their power conversion equipment onshore to decrease the maintenance burden. These activities require skilled offshore workers and vessels as well as the appropriate onshore technical support. Both the installation and maintenance of WECs can be very large cost drivers in the lifetime cost of a device and should be considered carefully when comparing designs.

Legal/Regulatory

While the regulatory framework for the development and consenting of onshore wind farms (and to a certain extent offshore wind in many countries) is generally well developed, the small number of deployments of WECs means that in most countries the process for obtaining seabed leases and the necessary permits would be considered as ad hoc. It is generally necessary to arrange the following broad set of agreements

- A seabed lease for the area of interest for deployment from the relevant government body that controls that region of the ocean
- Possibly an onshore lease for the area of land that is required for the cable/pipeline landing and onshore substation
- Appropriate environmental permits by conducting an environmental impact assessment (EIA) that can take between 1-2 years depending on the level of baseline data demanded by the permitting authority

- Grid connection agreement / power purchase agreement with the relevant body to ensure distribution and a market for the resulting electricity.

Social Acceptance

The experience with public acceptability in relation to marine energy has so far been very limited. The comparatively benign and non-obtrusive (they are typically deployed far from shore and protrude a limited distance above the sea surface) nature of WECs give them a relatively high level of social acceptance. The main stakeholders that must be considered are other impacted ocean users and environmental groups.

3. Status of the technology and its future market potential:

Wave energy is in the demonstration phase of technology development. Without any major evidence to the contrary it is reasonable to say that there are no commercially viable WECs in operation anywhere in the world. However it should be said that a significant number of full scale prototypes have been deployed across a number of countries; certainly all of the companies listed above have full-size or scaled prototypes deployed in representative ocean conditions.

The large number of designs remains highly diversified with more than 100 different developers listed on the EMEC (2010) database alone. The state of development could roughly be compared to the early years of the wind industry when there were a number of competing technologies until the 3 bladed horizontal axis wind turbine came to dominate the market. That is not to say that will be a clear cut 'winner' in the wave power market however it is certain that the current level of diversification cannot be sustained and future cost reductions will require the mass production and refinement of a much smaller subset of the currently promoted designs.

To the best of the author's knowledge there have been no major wave power projects deployed in developing countries at this stage.

Global resource levels are estimated to be very large, however much of this is considered unexploitable due to geographic, grid or environmental constraints. The total global exploitable resource has been roughly estimated as being in excess of 2TW, two million megawatts (WEC, 1993); however more detailed resource maps are available for many countries and these will often distinguish between deeper water and nearshore resource levels.

The IEA (2009) forecast only a small share of global power generation will be taken by marine renewables in 2050; less than 50GW. However forecasts in specific countries are often more aggressive; for example in the UK between 2 and 5 GW of installed capacity is being proposed in 2020 (UKERC, 2008; Carbon Trust, 2006).

4. Contribution of the technology to protection of the environment:

There is limited information available on the local impacts of WECs on the environment. The small number of projects, limited deployment times and small scale of these projects means that there is still a reasonable degree of uncertainty about the long term impacts of large scale deployments; however it should be noted that at this time all the available data points to WECs as being relatively benign devices that have minimal environmental impact. Only during the course of further development, through more environmental impact assessment studies and larger constructions will the wave energy community be able to gain a firmer idea of any potential impacts on marine and bird life due to possible noise, motion or wave shadow effects.

5. Climate:

WECs directly contribute to climate change mitigation by providing a completely renewable energy source free of GHG emissions (beyond the initial GHG gases associated with production and installation that could be expected to be offset in similarly small time frames as wind turbines due to the broadly comparable device sizes and capacity factors). However, as discussed in the following section on marine energy economics, the total installed capacity will very likely remain small for wave energy technologies meaning that their overall contribution to mitigation with the next decades will be relatively small.

6. Financial requirements and costs:

As marine renewables are still largely at the R&D and demonstration phase, with a corresponding lack of commercial devices, it is very difficult to accurately estimate costs. The IEA (2009) put lifetime delivered energy costs of marine renewables at USD 150/MWh to 300/MWh across the range of technologies (minus tidal barrage), generally well outside the range of current electricity revenues even when current carbon finance incentives (available in certain countries) are considered. They estimate that costs will need to reduce to between a third and a quarter of their current levels to be feasible without significant support.

For wave technologies the challenge comes from the difficult installation environment posed by the open ocean and the relatively limited but costly offshore maintenance strategies required; however these are not insurmountable barriers.

Uncertainties about the costs and technical performance of marine energy technologies must be overcome before significant commercial investment can be attracted. Large-scale prototype/demonstration schemes can help in this respect to inform investors regarding the key issues of reliability, efficiency, reparability.

The issues mentioned above do not make marine renewables undesirable; in fact many countries have been supporting research programmes and private sector development. The incentive for such support is the potential for ocean energy to provide a new set of industries and jobs in early adopting countries as well as providing an alternate source of energy security and a diversification of the energy supply to reduce the intermittency associated with the dominance of a single type of renewable.

7. References

Aquamarine Power Ltd (APL), 2010. Oyster Wave Power Technology, available at: www.aquamarinepower.com, last accessed: 07/05/2010
AWS Ocean Energy (AWSOE), 2010. Archimedes Waveswing, available at: www.awsocean.com, last accessed: 07/05/2010
Boud, R. & Thorpe, T. 2003. Wavenet - Section D Financing and Economics, available at: www.wave-energy.net/Library/, last accessed: 07/05/2010
Carbon Trust, 2006. Future Marine Energy, available at: www.carbontrust.co.uk/Publications/pages/PublicationDetail.aspx?id=CTC601, last accessed: 07/05/2010
Carnegie, 2009. What is CETO? available from: www.carnegiewave.com, last accessed: 07/05/2010
Checkmate, 2010. Checkmate Seaenergy - Anaconda, available at: www.checkmateuk.com/seaenergy/, last accessed: 07/05/2010
Ecofys, 2002. Wave Rotor, available at: www.ecofys.com/com/news/pressreleases2002/pressrelease02aug2002.htm, last accessed: 07/05/2010
European Marine Energy Centre (EMEC), 2010. available at: www.emec.org.uk, last accessed: 07/05/2010
Folley, M. and Whittaker, T.J.T. 2009, Analysis of the nearshore wave energy resource, Renewable Energy, vol. 34, no. 7, pp. 1709-1715
IEA 2008. Energy Technology Perspectives 2008. Scenarios & Strategies to 2050. Paris, France
Oceanlinx, 2010. How it works - Oceanlinx, available at: www.oceanlinx.com, last accessed: 07/05/2010
Pelamis Wave Power Ltd (PWP), 2010. The Pelamis Wave Energy Converter, available at: www.pelamiswave.com, last accessed: 07/05/2010
SRI, 2008. SRI Demonstrates Ocean Wave-Powered Generator off California Coast, available at: www.sri.com/news/releases/120808.html, last accessed: 07/05/2010
UKERC, 2008. Marine (Wave and Tidal Current) Renewable Energy Technology Roadmap, available at: ukerc.rl.ac.uk/Roadmaps/Marine/Tech_roadmap_summary%20HJMWMM.pdf, last accessed: 07/05/2010
Voith Hydro Wavegen (VHW), 2010. Land Installed Marine Powered Energy Transformer, available at: www.wavegen.com, last accessed: 07/05/2010
Wave Dragon ApS, 2005. Technology - Wave Dragon, available at: www.wavedragon.net, last accessed: 07/05/2010
WEC, 1993. Renewable Energy Resources: Opportunities and Constraints 1990-2020, World Energy Council, London.

Appendix D Commonly used criteria for prioritizing technology needs in previous TNAs

	Development benefits										Climate change			Market					Environmental protection					
Country	Employment generation	Wealth creation	Utilization of local resources	Rational utilization of resources	Improvement in health and quality of life	Food security	Capacity-building	Environmental sustainability	Gender equality	Socio-economic importance	Greenhouse gas reduction potential	Preservation of sinks	Potential for adaptation	Investment costs	Maintenance costs	Lifetime of the investment	Possibilities for replication	Social acceptance	Minimum impact on the environment	Pollution reduction	Recovery of water resources	Potential for reuse and recycling	Total	Per cent of Parties
Albania	●	●	●	●	●			●	●	●	●			●				●	●				12	55
Azerbaijan				●						●	●			●				●	●				6	27
Bhutan				●	●	●					●		●						●				6	27
Botswana	●	●	●		●	●	●		●		●					●	●		●	●			12	55
Burundi	●		●	●							●			●				●	●				7	32
China	●	●	●	●							●			●		●	●			●			9	41
Comoros		●			●	●		●			●									●			2	9
Democratic Republic of the Congo	●		●				●			●	●	●	●	●	●	●	●	●	●				13	59
Dominica					●	●	●			●													4	18
Dominican Republic			●	●						●	●								●	●			6	27
Ecuador											●												1	5
Ethiopia		●			●					●	●			●									5	23
Georgia											●			●		●							3	14
Ghana	●		●	●						●	●			●				●	●				8	36
Guinea							●				●		●										3	14
Guyana							●						●										2	9
Haiti				●						●									●				3	14
Indonesia			●	●						●	●			●				●	●				7	32
Islamic Republic of Iran		●	●		●	●				●													5	23
Jamaica	●							●		●				●					●				5	23
Kenya	●			●						●	●			●									5	23
Lebanon		●	●						●	●	●	●	●	●		●	●	●					11	50
Lesotho	●			●						●	●			●				●					6	27
Malawi			●	●						●	●			●				●	●				7	32
Malta	●		●				●	●			●	●	●	●		●	●	●	●				12	55
Mauritius			●	●						●	●								●				5	23
Peru	●	●			●		●	●		●			●						●				8	36
Republic of Moldova										●	●			●					●				4	18
Namibia	●	●			●		●	●	●				●			●						●	9	41
Niger					●		●			●													3	14
Niue			●							●	●			●									4	18
Paraguay											●							●					2	9
Saint Lucia	●	●			●		●	●					●						●				7	32
Samoa							●					●	●										3	14
Sri Lanka												●	●								●		3	14
Tajikistan			●	●						●	●			●					●				6	27
Thailand						●															●	●	3	14
Togo					●	●					●								●				4	18
Turkmenistan								●		●	●			●				●	●	●			7	32
United Republic of Tanzania								●			●		●	●					●				4	18
Uganda	●	●			●	●	●	●	●	●	●	●											10	45
Uzbekistan											●			●	●								3	14
Viet Nam			●	●						●	●			●					●				6	27
Zimbabwe	●		●							●	●			●									5	23
Total	15	11	17	15	13	8	12	10	5	25	32	6	12	23	2	7	5	12	22	5	2	2		
Per cent	38	28	43	38	32.5	20	30	25	13	63	80	15	30	58	5	18	13	30	55	13	5	5		

Source: UNFCCC, 2009, p. 49.

Appendix E CTF Investment Criteria

Potential for Long-Term GHG Emissions Savings

(i) Cumulative emissions reductions[12], or avoided, from the investment and per unit cost

(ii) Reductions in carbon intensity

(iii) Scalability and replicability of low carbon investments, given carbon intensity of GDP and electricity generation, economic growth rates and sector expansion plans

(iv) Significant opportunity for reducing growth in GHG emissions.

Demonstration Potential: Accelerate deployment, diffusion and transfer of low carbon technologies, consistent with the objectives of the CTF, at the following scale:

(i) thematic programs and large-scale projects;

(ii) sector or sub-sector in a given country;

(iii) sub-nationally, by focusing activity on a particular province/state/municipality;

(iv) regionally, particularly where regional cooperation is required;

(v) through the private sector, or public-private partnerships.

Development Impact

(i) Poverty alleviation, fuel savings, efficiency gains, air and water quality, energy security and access, economies of scale, economy-wide impact, local industrial development potential, and environmental co-benefits.

Implementation Potential:

(i) Technology development/commercialization status, and policies and capacity to support technology adoption are present or can be developed in the short term

(ii) Minimum level of macroeconomic stability and stable budget management

(iii) Commitment to an enabling policy and regulatory environment, including planning commitment and expenditure framework in the sector or sub-sector

(iv) Incentives for leveraging private sector financing

(v) Institutional arrangements for implementation of policies

Source: GEF, 2008, p.19.