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Overcoming Barriers to the Transfer and Diffusion of Climate Technologies

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Second Edition

UNEP DTU PARTNERSHIP

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Contents

Abbreviations

CEIT	Country with Economy in Transition
CHP	Combined Heat and Power Production Plant
CTI	Climate Technology Initiative
DCED	Donor Committee for Enterprise Development
EGTT	Expert Group on Technology Transfer
EIT	Economies In Transition
FDI	Foreign Direct Investment
GATT	General Agreement on Tariffs and Trade, negotiated during the UN Conference on Trade and Employment
GEF	Global Environment Facility
GHG	Green House Gas
ICTSD	International Centre for Trade and Sustainable Development
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
IPR	Intellectual Property Rights
LDC	Least Developed Country
MDG	Millenium Development Goals
NAMA	Nationally Appropriate Mitigation Actions
NAPA	National Adaptation Programme of Action
NC	National Communication
O&M	Operation and Maintenance
PMCA	Participatory Market Chain Approach

PPA	Power Purchase Agreement
PV	Solar Photovoltaic System (Generating Electricity)
RE	Renewable Energy
R-PP	Readiness Preparation Proposal
SBSTA	Subsidiary Body for Scientific and Technological Advice
SME	Small Medium-sized Enterprises
TAP	Technology Action Plans
TNA	Technology Needs Assessment
TRIP	Trade-related Aspects of Intellectual Property (A WTO Agreement)
TTD	Technology Transfer and Diffusion
TT:CLEAR	UNFCCC Technology Information Clearing House
UNEP	United Nations Environment Programme
URC	UNEP Risø Centre
WTO	World Trade Organization

Glossary

Adaptation is short for 'climate change adaptation', meaning adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities (IPCC, 2007). Adaptation is a process, not an outcome.

Adoption. The process by which a technology is selected for use by an individual, an organization or a society.

Barrier. A reason why a target is adversely affected, including any failed or missing countermeasures that could or should have prevented the undesired effect(s).

Capital goods. Machinery and equipment used in the production of other goods, e.g. consumer goods, boilers, motors, steel or pumps. May also be termed 'producer goods'.

Consumer goods. Goods and products specifically intended for the mass market and purchased by (private) consumers.

Diffusion. The process by which a technology is spread or disseminated through various channels over time in a society, where the technology is gradually adopted by more and more members of the society (people, institutions, companies, etc.).

Enabling environment. The set of resources and conditions within which the technology and the target beneficiaries operate. The resources and conditions that are generated by structures and institutions that are beyond the immediate control of the beneficiaries should support and improve the quality and efficacy of the transfer and diffusion of technologies.

Hardware. The tangible aspects of technology, such as equipment and machinery.

Incentive. Cf. 'Measure'.

Innovation. Both the processes of research and development and the commercialization of the technology, including its social acceptance and adoption. However, this guidebook focuses on the later phases of innovation, not technical innovation in the sense of research and development.

Innovation system. All important economic, social, political, organizational and other factors that influence the development, diffusion and use of innovations.

Market/value chain. The chain of economic actors that own and transact a particular product as it moves from primary producer to final consumer.

Market mapping. An analytical framework for understanding market systems and an approach to market development that is both systemic and participatory.

Measure. Any factor (financial or non-financial) that enables or motivates a particular course of action or behavioural change, or is a reason for preferring one choice over the alternatives. Often the word 'incentive' is used synonymously, sometimes with a slightly different interpretation. This guidebook does not distinguish between 'measure' and 'incentive'.[1]

Mitigation. In this guidebook, 'mitigation' is short for 'climate change mitigation', meaning an action to decrease the concentration of greenhouse gasses, either by reducing their sources or by increasing their sinks.

Niche market. A focused, targetable portion of a market, where new technologies can benefit from learning opportunities.

Non-market goods. Goods not traded in a market.

Orgware. The institutional framework, or organisational aspects, involved in the diffusion and uptake of a technology.

Publicly provided goods. A category of technologies characterised by large investments, general public ownership, and production of goods and services available (free or paid) to the public or a large group of persons.

Software. The intangible elements associated with the production and use of the technological hardware. This comprises know-how (e.g. manuals and skills) and experience and practices (e.g. agricultural, management, cooking and behavioural practices).

Stakeholder. A person, group, organization or system that affects or can be affected by an organization's actions.

Technology is a piece of equipment, technique, practical knowledge or skills for performing a particular activity. It is common to distinguish between three different elements of technology: the tangible aspects, such as equipment and products (hardware); the know-how, experience and practices (software) associated with the production and use of the hardware; and the institutional framework, or organisation, involved in the transfer and diffusion of a new piece of equipment or product (orgware).

Technology transfer involves *vertical* technology transfer, which is understood as the movement of technologies from the R&D stage through to commercialisation, and *horizontal* transfer, which involves the spatial relocation or diffusion of technologies across space.

Vulnerability is in this guidebook the short term for 'climate change vulnerability'. Vulnerability is the degree to which a system is susceptible to, and unable to cope with, the adverse effects of climate change, including climate variability and extremes (IPCC, 2007). Vulnerability is a function of the nature, magnitude and rate of climate change and of the variation to which a system is exposed, its sensitivity and its adaptive capacity.

1 Other frequent and very similar phrases are 'policy tools' and 'policy instruments'.

1. Introduction

Objectives and commitments regarding the transfer of technology exist under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. The purpose of the Technology Needs Assessment (TNA) project is to assist participant developing countries to identify and analyse priority technology needs, which can form the basis for a portfolio of projects and programmes to facilitate the transfer of, and access to, climate technologies and know-how through implementation of Article 4.5 of the UNFCCC Convention (http://tech-action.org/).

TNAs are therefore central to the work of the Parties to the Convention on technology transfer and present an opportunity to track an evolving need for new equipment, techniques, practical knowledge and skills, which are necessary to mitigate GHG emissions and/or reduce the vulnerability of social, economic and natural systems to the adverse impacts of climate change.

The TNA project comprises three main components:

1. The identification and prioritization of technologies that can contribute to the mitigation and adaptation goals of the participant countries, while meeting their national sustainable development goals and priorities.
2. The identification of barriers hindering the acquisition and diffusion of prioritized technologies and developing enabling frameworks to overcome the barriers and facilitate the transfer, adoption and diffusion of selected technologies in the participant countries.
3. The development of Technology Action Plans (TAPs) specifying activities (based on the enabling frameworks) at the sectoral and cross-cutting levels to facilitate the transfer, adoption and diffusion of selected technologies in the participant countries.

The aim is to provide practical and operational guidance on how to assess the barriers to identified technologies in the countries concerned, and on how to address and overcome these barriers through different types of measures.

The guidebook feeds into the process of the preparation of TAPs based on the measures that have been identified and prioritized, which is the outcome of undertaking the barrier analysis. Logical consistency and coherence between components two and three should be ensured by establishing clear links between the barriers and the measures identified in the barrier analysis and the subsequent policies and plans to promote the transfer and diffusion of climate technologies in the TAPs. More detailed guidance on the preparation of TAPs, including reporting formats and guidelines, can be found at http://tech-action.org/.

In the first phase of the TNA project (TNA Phase I) (2010-2013), 36 countries developed TNAs. In the second phase (TNA Phase II) (2014-2017), 26 additional countries will develop similar TNAs. The present guidebook has been revised to incorporate the practical experience gathered from the first phase, taking into consideration the insights of the consultants, national stakeholders and TNA project implementing team members involved, and based on experience obtained during consultations in workshops.

While the authors hope that the guidebook may serve a wider audience by addressing barriers to the transfer and diffusion of technologies, including public administrators and development practitioners, the target audience is the TNA National Teams and their consultants. Therefore the guidebook adopts a pragmatic approach, taking into consideration the framework for the TNA project. It addresses the challenges in overcoming barriers to technology transfer and diffusion after a TNA Team has identified, assessed and prioritized technologies for climate change. It is important to stress that the guidebook is intended to be applicable to concrete technologies, not a whole sector (e.g. transport) or technology group (e.g. renewable energy).

As there is no pre-set answer to enhancing technology transfer and diffusion, policy actions need to be tailored to specific contexts and interests. Therefore, the guidebook provides a flexible approach, identifying various options for analysts and decision-makers. It should therefore not be seen as a manual or blueprint for elaborating measures for the transfer and diffusion of technologies.

While acknowledging that most technology transfer and diffusion processes take place without government intervention, usually being driven by commercial incentives and private-sector stakeholders, this guidebook focuses on how governments can accelerate the transfer and diffusion of technologies by applying various policy measures. Government-facilitated technology transfer and diffusion may involve a combination of the processes enumerated below:

1. Identify, assess and prioritize technologies
2. Understand the economic and institutional framework
3. Identify and analyse barriers
4. Identify and implement measures to overcome barriers

While the above list is to some extent a timeline, it should not be interpreted as such too rigidly. Some processes may be conducted in parallel, and the sequence may be altered. Also, although the overall process never stops, it needs to be repeated at regular intervals.

Despite the existence of programmes for the transfer and diffusion of mitigation technologies that governments and development organisations have drawn up during the last three decades, and despite the huge amounts of research on processes leading to the transfer and diffusion of technology, there are still essential deficiencies in the understanding of processes leading to the successful transfer and diffusion of technologies in general. There are numerous examples of the transfer and diffusion of mitigation technologies, but fewer examples for adaptation technologies. The guiding principles for the transfer and diffusion of adaptation technologies are therefore less empirically grounded than for mitigation technologies, in spite of the many initiatives and efforts being undertaken at the local level to adapt to climate change.

Against this background, it has not been possible to produce practical and operational guidance in all its aspects on how to assess the barriers to identified technologies in the countries concerned, or on how to address and overcome these barriers. So, even though the authors have attempted to synthesize pertinent information and present good cases for learning purposes, the guidebook should be considered a living document which should be continuously amended and updated when justified by new insights.

The present guidebook should be seen as an integrated part of the TNA Guidebook Series, the Technology Transfer Perspective Series, and the Climate Techwiki (http://climatetechwiki.org/), all products developed as supporting tools for the TNA project.

The remainder of the guidebook is structured as follows.

Chapter 2 introduces the main concepts to be used in this guidebook. The central concept of technology is defined in the first section, and this is followed by a categorization of technologies according to the goods and services they belong to or contribute to. The guidebook defines four generic categories: consumer goods, capital goods, publicly provided goods and non-market goods. These categories are used throughout the book in order to ease the identification of generic barriers and measures. The chapter continues by defining the concept of an enabling environment, and concludes by conceptualising the transfer and diffusion of technologies.

Chapter 3 provides guiding principles for how barriers to the transfer and diffusion of climate technologies are identified and analysed. After a presentation of how the barrier analysis fits into the overall TNA process, the reader is taken through the following stepwise process: i) identify all possible barriers; ii) screen the gross list of barriers to disregard the less important ones; iii) classify the remaining key barriers into a hierarchy of categories.

Chapter 4 deals with technologies traded in a market place, essentially the technology categories of ‘consumer goods’ and ‘capital goods’, in order to understand properly the particular framework conditions of such technologies. The Chapter presents comparative techno-economic assessments, the value chain framework, the technological innovation system framework and the market mapping framework, all of which can be used as tools to assess the feasibility of different market goods technologies.

Chapter 5 addresses the specific barriers related to the diffusion of non-market technologies, which fall into two categories: publicly provided goods, and other non-market goods. The Chapter identifies the key role of governments as the primary decision-making authorities for and investors in these non-market technologies. A key barrier to these technologies is access to finance, and the decision to undertake such investments requires a political process involving weighing the costs and benefits of different groups against each other. This balancing is often assessed through feasibility studies, cost-benefit analysis and environmental impact assessments. The category of other non-market goods comprises three groups: technologies provided by institutions, the creation of new institutions, and behavioural change. Diffusion of these technologies is mainly financed by donor organisations and NGOs, and the main barriers for starting these projects are access to finance and studies for project preparation.

Chapter 6 describes how the barriers identified in Chapters 3, 4 and 5 can be translated into measures to overcome the barriers. Exact understanding of elements of the barriers and the relationships between them will indicate which measures may be necessary. The chapter is illustrated with examples of how a set of complementary measures may be used to enhance the intended benefits, and how different sets of measures achieving the same goal may have different economic and other impacts. It is therefore recommended to carry out a cost-benefit analysis of various sets of measures and to discuss the latter at the highest political level before selecting the set of measures to be included in the technology action plan.

Chapter 7 summarizes the general recommendations for the government-facilitated transfer and diffusion of climate technologies. Please note that, although the process is presented as linear, it may be advisable to do some iterations (feedback loops) by returning to previous steps and possibly making amendments. As an example, while assessing and developing the measures to overcome barriers, it may be useful to have a second look at the screened list of barriers and reconsider whether some barriers that were removed from the gross list during the screening process should be included again, due to increased insight.

Photo credit: Barefoot Photographers of Tilonia

2. Understanding Technology

2.1 The technology concept

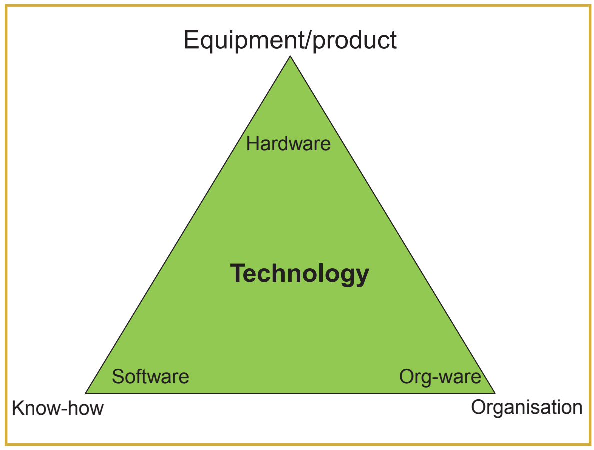
This guidebook makes use of the following definitions:

Technology is 'a piece of equipment, technique, practical knowledge or skills for performing a particular activity' (IPCC, 2000). It is common to distinguish between three different components of technology (Ramanathan, 1994; Sharif, 1994; Müller, 2003):

- the tangible component, such as equipment and products – hardware.
- the processes associated with the production and use of the hardware. This comprises know-how (e.g. manuals and skills) and experience and practices (e.g. agricultural, management, cooking and behavioural practices) – software.
- the institutional framework, or organisation, involved in the adoption and diffusion process of a technology – orgware.

These three components are all part of a specific technology, but the relative importance of each component may vary from one technology to another (Metcalfe, 1995). This can be visualised as a triangle in which the corners constitute each of the components, namely hardware, orgware and software:

Figure 2.1: Components of technology.



To illustrate how the three components are embedded in a specific mitigation technology, the example of solar home systems (SHS) can serve as illustration. The hardware component of SHS comprises the physical equipment needed to construct a functioning system that can provide electricity to households. This includes the solar panels and the balance of systems components, such as the wiring, switches, mounting systems, inverters, battery bank and chargers. The software component involves the technical (engineering-based) know-how needed to design and install the systems and the knowledge of users needed to operate and maintain them. Some of this knowledge may be in a tacit (person-embodied) form, and some may be codified in patents and design specifications (Rosenberg, 1982). The orgware component relates to ownership of the system and to how the use, repair and maintenance of the system is organised. Systems can be owned by the user, in which case repair and maintenance are normally the responsibility of the user. It can also be owned by an Energy Service Company (ESCO), in which case the user pays a fee for service, and the company is responsible for repair and maintenance.

The example of (nation-wide) early-warning systems for flooding provides an illustration of an adaptation technology that includes the three technology components. The hardware component includes the sensor equipment, telecommunication systems, computer programs and calculation models needed to collect, transmit, filter and analyse the relevant data effectively. The software component provides the knowledge and expertise needed to handle these large datasets and control systems, as well as the combination of multiple, complex analytical processes. The orgware component comprises the institutional set-up and decision support system enabling effective collaboration between different actors and organisations to respond swiftly to emerging threats.

Some technologies may have a higher share of the software and orgware components compared to the hardware component. In the case of the introduction of a new farming system technology, such as new crop-rotation schemes, for example, the importance of the hardware component (machinery and equipment) may be much lower compared to the necessary know-how, practical experience, organisational routines and farm-management practices needed (Trærup and Christiansen, 2015).

Another example is drip irrigation. The hardware component in this case comprises already well-known hardware components, such as plastic tubes and water pumps. The knowledge of how to design the tube systems, how to determine the size of holes and the spaces between holes in the tubes and how to obtain the appropriate water pressure is on the other hand essential for the proper functioning of the system. Likewise, the use of drip irrigation requires a certain organisation which can handle access to water sources, install the system, maintain the system and in some cases even move systems between fields.

These examples illustrate how all three components, hardware, software and orgware, are to varying degrees components of, and embedded in, the concept of technology. In the literature on adaptation technologies there are many examples of how the technology concept has been deflated, mainly driven by a bottom-up approach, according to which various development actors have tended to incorporate their own 'needs' or 'products' into the concept (Sharma and Moehner, 2011). A prominent example is that capacity-building is often included as a technology (Trindade et al., 2000).

In this guidebook, we do not consider it appropriate to include capacity-building as a technology It is a measure to acquire know-how rather than know-how itself. Capacity-building can be an important measure to diffuse technologies (including knowhow), but it needs a subject, it is not an end in itself. Including capacity-building as a technology would therefore not only be problematic from a definition point of view, but would also create confusion between measures and technologies.

Even considering pure orgware and pure software as technologies may create some confusion between the means to diffuse technologies and the technologies per se. These issues will be elaborated on further in Section 5.3, dealing with barriers to other non-market technologies. Experience from the first phase of the TNA project shows that the confusion between technologies and the means to diffuse them is most prominent within the adaptation community. We have therefore especially elaborated on the nature of adaptation technologies in Annex D. For further discussion, see also Nygaard and Hansen (2015).

2.2 Technology categories and market characteristics

IPCC (2000) distinguishes between technologies that are transferred and diffused by governments, the private sector (the market) and communities (such as NGOs and donors). We take this threefold categorisation of technology further in this guidebook by considering the transfer and diffusion of technologies under different market conditions, which means that the barriers to their transfer and diffusion are intrinsically linked to market characteristics.

To facilitate the barrier analysis, we find it useful to categorize technologies according to the types of goods and services they belong to or contribute to, as the different types of goods and services have distinct market characteristics. For the purposes of this guidebook, the following four generic categories will be used as a framework for characterizing technologies according to their relationship to the market:[2]

a) Market goods:
   - consumer goods
   - capital goods

b) Non-market goods:
   - publicly provided goods
   - other non-market goods

In this way, technologies are not categorized according to their technical properties, but according to both the types of goods and services they belong to or contribute to, and the markets or non-markets in which they are transferred and diffused. As illustrated in the examples below, the categories overlap and should be seen as placed on a continuum from pure market to non-market conditions. The four categories draw loosely upon concepts from within conventional economic theory and insights from innovation system studies (Lundvall et al., 2009).

The concepts of 'consumer goods' and 'capital goods' are well-known within economics and have been used here in a relatively straightforward manner (Welch and Welch, 2012). Technologies in the 'consumer goods' category are diffused in a mass market with large supply chains and a high number of customers, including households, businesses and institutions. Technologies in the 'capital goods' category are intended for a restricted national market with only a few buyers, such as industry and utilities, and only a few national suppliers of the technology in question.

The concept of 'publicly provided goods' denotes technologies that are procured and diffused by public entities to a large population of users and beneficiaries. Technologies in this category are therefore also traded in a market place, but the market is often not very liquid, as the public entities purchase their goods through a tendering process, which may be restricted to a limited number of invited national and international construction companies and technology suppliers. The concept of 'publicly provided goods' should not be confused with the concept of 'public goods', which in conventional economics denotes non-excludable and non-rivalrous goods (such as sunlight).

Technologies in the category of 'other non-market goods' are similar to publicly provided goods, but while the hardware dimension is high in the publicly provided goods category, non-market goods are dominated by the software and orgware dimensions of technology. Within this category, a distinction is made between technologies that are provided by institutions (such as early warning systems for drought) and the establishment of new institutions (such as microfinance institutions and seed banks).

It is reasonable to expect that there are common features within each category as to which barriers predominate and how these particular barriers need to be addressed. It may, therefore, be instructive to distinguish the different types of goods when experience of barrier removal for one technology informs barrier removal for other technologies. Table 2.1 below provides details of the technologies that fall under each of the four categories:

2 In order to keep the names of the categories short, the term 'goods' embraces what are usually referred to as goods and services.

Table 2.1. Technology categories and their market characteristics

Category	Description	Market characteristics	Technology examples
Consumer goods	Goods specifically intended for the mass market; households, businesses and institutions.	• a high number of potential consumers • interaction with existing markets and requiring distribution, maintenance and installer networks in the supply chain • large and complicated supply chains with many actors, including producers, assemblers, importers, wholesalers, retailers and end consumers • barriers may exist in all steps in the supply chain • demand depends on consumer awareness and preferences and on commercial marketing and promotional efforts	• Solar home systems, CFLs, energy-efficient air conditioners, drip irrigation tubes, seeds for drought-resistant crops.
Capital goods	Machinery and equipment used in the production of goods, e.g. consumer goods or electricity.	• a limited number of potential sites/consumers • relatively large capital investment • simpler market chain, i.e. few or no existing technology providers • demand is profit-driven and depends on demand for the products the capital goods are used to make	• Utility technologies, such as biomass plants, small-scale hydropower plants, or technological parts thereof. Could also be machinery used in agriculture, and technologies used in industrial processes.
Publicly provided goods	Technologies in this category are often (although not always) publicly owned, and production of goods and services are available (free or paid) to the public or to a large group of persons.	• very few sites • large investment, government/donor funding • public ownership or ownership by large companies • simple market chain; technology procured through national or international tenders. • investments in large-scale technologies tend to be decided at the government level and heavily dependent on existing infrastructure and policies.	• Sea dykes, infrastructure (roads and bridges, sewage systems), mass transport systems (metros).
Other non-market goods	Non-tradable technologies transferred and diffused under non-market conditions, whether by governments, public or non-profit institutions, international donors or NGOs.	• technologies are not transferred as part of a market but within a public non-commercial domain. • serves overall political objectives, such as energy saving and poverty alleviation • donor or government funding	• Early warning systems for drought, seasonal forecast of rain for optimal planting, microfinance institutions, seed banks, energy saving by behavioural change.

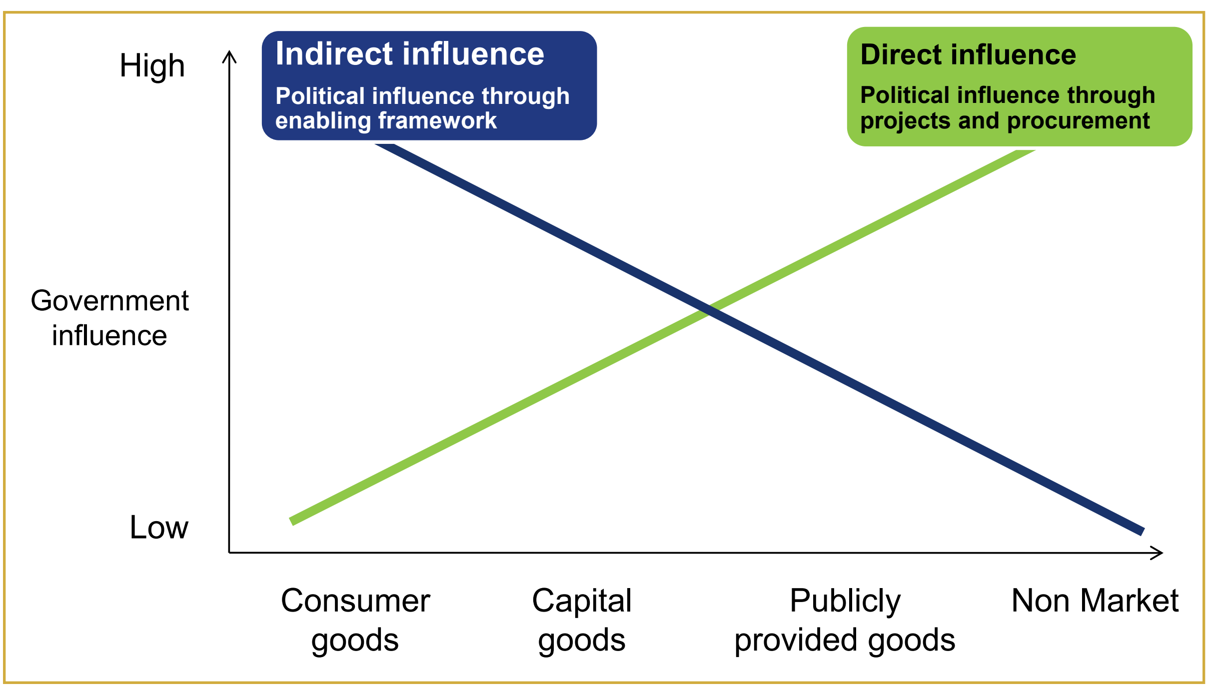
The transfer and diffusion of technologies within each of the four categories are influenced by policy through different mechanisms. The diffusion of consumer goods and capital goods is predominantly influenced *indirectly* by politically changed market conditions, while the diffusion of publicly provided goods and non-market goods is influenced *directly* though political decisions taken by governments and public entities regarding the implementation of specific projects.

This means that the scope for government interventions to promote a particular consumer goods technology is related to the broad enabling framework conditions. Interventions to remove barriers to consumers goods are therefore indirect, for example, in the form of awareness-raising and educational programs, improving general product-quality requirements, creating more favourable import tax and duty regulations, provision of support for private businesses in the supply chain and subsidy programs for specific product groups (such as efficient light bulbs). At the other end of the spectrum, the scope exists for direct government interventions through targeted projects and programmes to promote particular non-market good technologies, such as the establishment of new institutions. This relationship is illustrated in Figure 2.2 below:

2.3 Enabling environment

A central concept in the present guidebook is the 'enabling environment', which is used interchangeably with the notion of an 'enabling framework' throughout the text. The enabling environment denotes the entire range of institutional, regulatory and political framework conditions that are conducive to promoting and facilitating the transfer and diffusion of technologies (IPCC, 2000). This includes the country-specific circumstances that encompass existing market and technological conditions, institutions, resources and practices, which can be subject to changes in response to government actions. Enabling environment conditions may target both technology supply-side and demand-side aspects of the transfer and diffusion of technologies.

Figure 2.2.: Schematic illustration of the level of direct and indirect political influence with respect to the four categories of technology. The categories overlap and should be seen as examples on a continuum from pure market to non-market.



A number of elements of political influence in combination may be distinguished as comprising the notion of a larger enabling environment. These elements can be categorised as shown in Table 2.2 below, which depicts the main areas that governments can influence in order to modify the framework conditions to promote technology transfer and diffusion. Although there are equally important circumstances pertaining to the enabling environment of the technology originator country, the main focus in the present guidebook is the enabling environment of the host (or technology recipient) country.

In this context, it should be noted that an enabling framework normally relates to the national level, but that special elements of an enabling framework (e.g. regulations or subsidies) could be defined for a specific region of the country. The focus of the enabling framework may comprise a group of technologies (e.g. renewable energy) or a specific technology, such as wind turbines.

Table 2.2. Elements of enabling environments for the transfer and diffusion of technologies

Enabling environment elements	Relevant government policies (examples of areas of influence)	Barriers addressed (examples)
National macroeconomic conditions	• Trade policies and laws • Tax, subsidies, and tariff regime policies • Regulation of financial sector institutions • Public investment policies • Commercial law and practices	• High cost of capital and interest rates • High inflation rate and high price fluctuations • Balance of payment problems • High import duties • Unstable currency and uncertain exchange rates
Human, organisational, and institutional capacity	• Capacity-building programmes of governmental agencies and institutions • Initiatives to enhance efficiency in government procedures and processes • Promotion of industry associations, networks, organisations and alliances	• Human resource-constrained legal entities • Ineffective coordination between governmental agencies • Prevailing culture of the disengagement of civil society in public affairs • Under-specialised governmental agencies
Research and technological capacity	• Technical standards, certification, and codes • Publicly funded research and development and training programmes • Support for testing and demonstration facilities (including training programs) • Monitoring capacity enhancement programmes • Property rights regimes policies	• Few technology nurturing sites • Limited capacity to install, implement, operate and maintain technology • Insufficient specialised expertise in technology, practice, or organisational system • Low technology and product quality

Enabling environment elements	Relevant government policies (examples of areas of influence)	Barriers addressed (examples)
Social and cultural	• Information dissemination, outreach and awareness-raising campaigns • Targeted assistance to support early adopters and technology front-runners • Promotion of public–private partnerships • Education policies	• Limited awareness, trust in, or acceptance of the suitability/ reliability of the technology • Aesthetic considerations by users of technology (e.g. products lack appeal) • Community resistance to technology or practice • Tradition, social esteem, pride, comfort and religious belief discouraging adoption of technology

Sources: Painuly (2001), Painuly and Fenhann (2002), Beck and Martinot (2004) and Philibert (2006).

It should be noted that the importance and relevance of specific elements of an enabling environment depends on the type of technology. Social and cultural elements might, for example, be more important for technologies that are mainly used in rural areas than for technologies that are mainly used in urban areas.

2.4 Transfer and diffusion of technologies

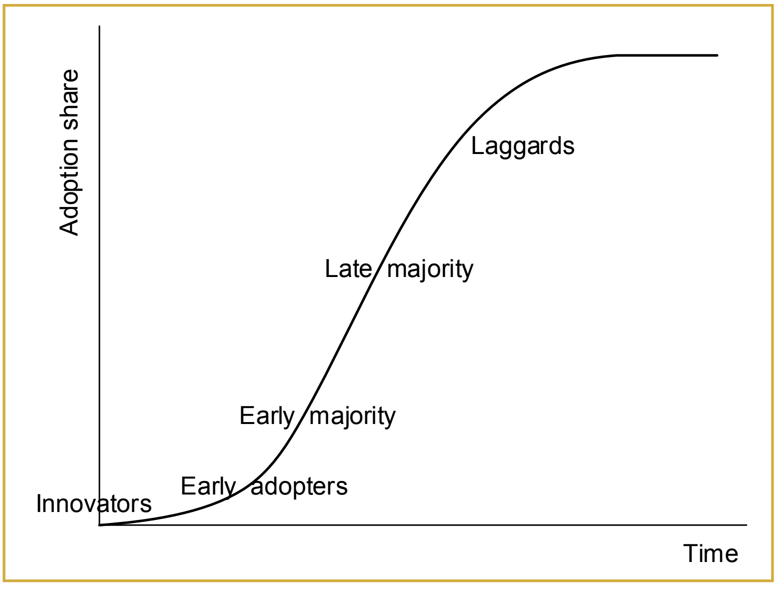
This guidebook understands the transfer and diffusion of climate technologies as the exchange of the technical artefacts (hardware), knowledge (software) and organisational elements (orgware), both across and within countries (Bell, 1990; Wei, 1995; Levin, 1997). This understanding follows the definition of technology transfer by the IPCC (2000) as 'a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders [which] encompasses [the] diffusion of technologies and technology cooperation across and within countries'. Further, this guidebook understands the transfer and diffusion of climate technologies as involving reciprocal exchange among recipients and transmitters rather than a unidirectional flow.

Following Ockwell et al. (2008), a distinction is also made between vertical and horizontal technology transfer. While vertical technology transfer involves the movement of technologies from the R&D stage through to commercialization, horizontal transfer involves the spatial relocation or diffusion of technologies across space. In some cases, these two processes may be linked when a technology is undergoing commercialization in parallel with the spread of the technology across borders or within a country, which allows testing and demonstration to take place. Here, it should be mentioned that technologies at the later stage of the innovation cycle, that is, commercially mature technologies or well-proven practices, are the main focus of the present guidebook.

Adoption

The transfer and diffusion of technologies generally follow an S-shaped curve, as a technology is gradually adopted by more and more members of the society over time (people, institutions, companies etc.). Figure 2.3 illustrates how technology adopters (users and consumers) are classified into four categories along this curve: early adopters (first to adopt), early majority, late majority and laggards (last to adopt) according to the time of

Figure 2.3. The S curve of technology diffusion (Rogers, 1962).



adoption since the technology was first introduced (Rogers, 1962).[3]

It should be noted that the time-scale involved to progress through these stages is often of decades rather than years, as the transfer and diffusion of a new technology is a long, uncertain and complicated process. Some technologies, such as mobile phones in developing countries, have moved through these stages within a relatively short timeframe of, for example, the twenty years from 1995-2015, while others, such as solar PV, are still only being used by early adopters, although the first systems were installed in the mid-1980s, about thirty years ago (Hansen et al., 2015).

Niche markets

The early stage of technology diffusion may take place in protected niche markets, where the reliability, practicality and financial feasibility of the technology are demonstrated through gradual learning and experimentation with the technology, user preferences and regulatory conditions. In the context of technology transfer and diffusion, a niche market is a segment in which a technology that may generally be considered too costly or too risky may be favourable for several users or customers due to the specific characteristics of the market, for example, limited to a geographical area or a group of consumers. Theories of niche markets can be found in the strategic niche-management literature, which has focused on analysing the conditions under which niche-market technologies may be scaled up to increase the range of dissemination (Raven, 2005; Schot and Geels, 2008).

An example of an upscaling process for a niche-market technology is the installation of solar PV systems in remote rural settings and on islands, where other energy supply options are extraordinarily expensive, or where there are customers with a high level of willingness to pay, such as rural dispensaries (for vaccine cooling) and telecommunications (Jolly et al., 2012). The initial introduction of PV systems in such niche markets will demonstrate the technology, activate local entrepreneurs and increase learning in government agencies, institutions and NGOs, thereby paving the way for the development of measures to ease

3 A distinction is sometimes made between adoption and absorption, where adoption involves the mere usage of the technology, while absorption reflects the sustainability and efficacy of usage. In this guidebook the term 'adoption' covers both meaning

a more extensive introduction of the technology (Ghosh et al., 2006).

Although the concept of the niche market has been developed for a market context, it may also be applied to non-market goods. One example of this is when micro-credit institutions are initially introduced in specific communities, where the chances of success are greater than in communities in general. This allows the micro-credit institutions to improve their performance and the quality of their services in a 'protected' environment, before the technology is extended to other communities where the chances of success are lower.

Prime movers

Since the introduction of a new technology usually involves the reduction of the market for an incumbent technology, actors can be expected to try to obstruct the development of the new technology, for example, in the political arena. Hence, strong actors, or groups of actors, who can promote the new technology are important. These champions or 'prime movers' are powerful technology developers or powerful users of specific technologies. They perform four important tasks in promoting the new technology: raise awareness, undertake investments, provide legitimacy and diffuse the new technology (Jacobsson and Johnson, 2000).

The role of a prime mover may be played not only by individual actors, but also by a constellation of actors if a number of actors share an interest in the production or use of a new technology. The prime movers of small-scale and decentralised renewable technologies might be clusters of smaller firms organised in new networks, which may be specific to each renewable energy technology. The key issue is to understand how to support the emergence and sustained existence of such champions and 'prime movers' (Jacobsson and Johnson, 2000).

Photo credit: Gerrit de Boorder

3. General methods for identifying and analysing barriers

This chapter provides guiding principles for the identification and analysis of barriers to the transfer and diffusion of climate technologies (both market goods and non-market goods) in order to establish a sufficient basis for developing measures to overcome them.

Identifying barriers can be understood as tracing the reasons that are obstructing the transfer and diffusion of technologies (Painuly, 2001). This includes the identification of any failed or missing measures that could have sustained the diffusion. The primary task is to understand the nature of the individual barriers and the relations between barriers, determine which barriers are important, and identify barriers that are easier to remove. Barriers that are beyond the control of a single country (e.g. global oil prices or EU trade barriers) will be acknowledged and taken into account, but they should not be subject to further analysis, as they are not amenable to any policy action by the country concerned.

A thorough understanding of the barriers to the transfer and diffusion of climate technologies is the key to designing the appropriate portfolio of measures to overcome them. Barrier analysis is not an exact science, and a thorough understanding of the barriers may often be achieved by applying different approaches, or by combining the most appropriate elements of various approaches, as described in this chapter.

Main steps in identifying and analysing barriers and in developing measures to overcome them:

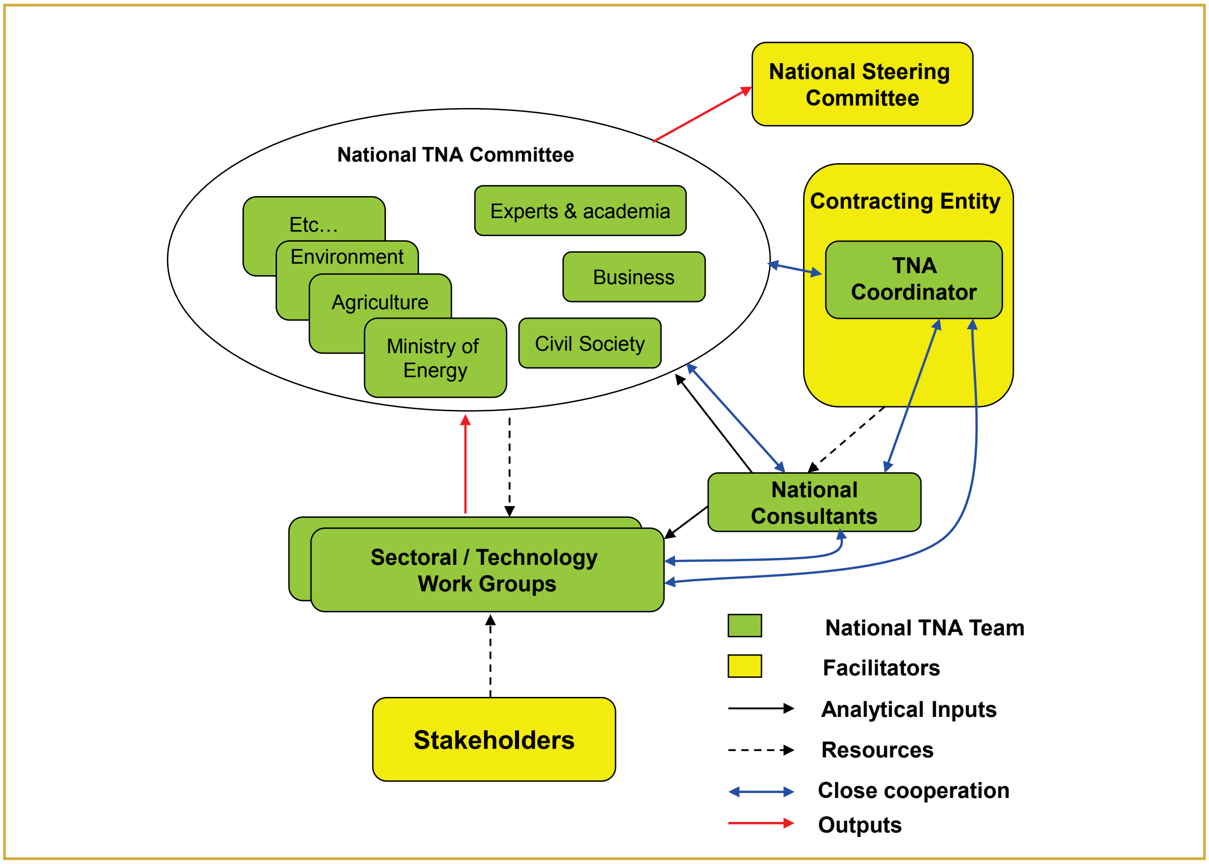
1. Organize the process; Section 3.1
2. Identify all possible barriers through literature survey, interviews and/or workshop brainstorms; Section 3.2
3. Screen the gross list of barriers to select the most essential ones; Section 3.3
4. Classify the selected essential barriers into a hierarchy of categories; Section 3.4
5. Develop measures to overcome barriers by translating barriers into solutions; Section 4.1
6. Assess the costs and benefits of measures to determine whether they comply with policy objectives; Section 4.2
7. Select a set of complementary measures to include in programmes; Section 4.3

3.1 Organising the process

A common institutional arrangement for a TNA project is described in 'Organising the National TNA Process: An Explanatory Note'.[4] The proposed institutional arrangement is illustrated in Figure 3.1.

4 http://www.tech-action.org/Guidebooks/OrganizingNationalTNAprocess.pdf

Figure 3.1. TNA project: institutional arrangements.



In the TNA project, barrier identification and analysis should be conducted for a few selected technologies for each sector (approximately four to eight mitigation technologies and four to eight adaptation technologies across different sectors). In most cases, these technologies have been selected by the sectoral working group through a multi-criteria analysis facilitated by the national consultant. The sectoral working group constituted by the TNA committee may include representatives from government departments with responsibility for policy formulation and regulation, private- and public-sector industries, electric utilities and regulators, technology suppliers, finance, technology end-users (e.g. households, small business, farmers, technology experts from universities and consultants) and others (international organizations, donors).

Identifying barriers and the measures to overcome them constitutes another phase of the project, in which the consultant may again work in close cooperation with the sectoral working groups. In some cases, the consultant and the TNA team may decide to form specific technology groups, consisting of representatives from the sectoral working groups and additional members with specific knowledge of the technologies in question. In order to build up trust and continuity, it is important that the groups remain the same throughout the process, from barrier analysis to identification to proposing measures for the action plan.

Generally some form of participatory approach and stakeholder consultation is recommended to strengthen the understanding and identification of pertinent barriers and to improve the appropriateness of barrier removal measures. In some cases, workshops within the technology working group may be the preferred option, but other forms of stakeholder consultation can be relevant as well, depending on the tradition and culture of the country. This may include written feedback, bilateral discussions between consultants and main decision-makers, and the use of questionnaires, all of which may be combined with stakeholder workshops.

The TNA Committee needs to consider carefully the usefulness of workshops as the preferred method for organising the process of identifying barriers and measures. The number of stakeholders may be too large, or several of the key stakeholders may be high-level people (like permanent secretaries), who cannot or will not take one or two days out of their busy schedules. Under such circumstances, the risk is that the workshop outcome may become biased, incomprehensive or inconclusive. To support the Committee in obtaining a balanced position on the issue of participation, Cooke (2001) may be consulted. For more information on participatory processes, including workshops facilitation, see Chambers (2005) and Rocheleau (1995).

3.2 Identification of barriers

An initial step in the process is to conduct a desk study of policy papers and other pertinent documents to identify the primary reasons why the technology is not currently in widespread use, and why neither the private nor public sectors have invested significantly in it. In particular, proper economic assessments of the selected technologies should be included in the desk study, but possibly also other relevant assessments, for example, of environmental impact and institutional capacity.

Most such information is likely to be available already, either from the technology selection process or from other studies, and the information may add essential value to understanding the significance of individual barriers. The TNA consultant carries out the desk study, which should preferably be supplemented by interviews with experts and stakeholders.

8. For this purpose, barriers can be categorized in various ways. Typical categories are: **Economic and financial:** high cost of capital, investment in technology considered risky (e.g. due to few prior local reference examples), low expected rate on return
9. **Market conditions:** few local suppliers of auxiliary goods and services, uneven playing field (e.g. due to subsidies on competing technologies), market control by industry incumbents
10. **Legal and regulatory:** technology opposing incumbent actors (such as utilities), insufficient legal framework, highly controlled sector, conflicts of interest, political instability, bureaucracy, rent-seeking behaviour
11. **Network:** weak connectivity between actors, incumbent networks being favoured, limited distribution networks
12. **Institutional and organisational capacity:** few professional institutions, limited institutional capacity, limited management and organisational skills
13. **Human skills:** unskilled technical personnel and inadequate training
14. **Social, cultural and behavioural:** consumer preferences and social biases, traditions, dispersed settlements
15. **Information and awareness:** inadequate information, missing feedback, lack of awareness
16. **Technical:** poor technology quality/performance, few local reference examples
17. **Other:** environmental impacts, physical infrastructure conditions

For market-goods technologies (consumer goods and capital goods), which are expected to be diffused in large numbers under market conditions, the market-mapping technique may be used to identify market barriers more systematically (Albu and Griffith, 2005, 2006). The technological innovation system (TIS) perspective can also be helpful to identify barriers within these domains, particularly the so-called functional approach, which conceptualizes seven key functions that, depending on their strength, may impede or encourage the development and diffusion of a new technology (Hekkert et al., 2007; Bergek et al., 2008; Tigabu et al., 2015). A more detailed description of the market mapping technique and the TIS perspective will be presented in Chapter 4.

For non-market goods technologies (publicly provided goods and other non-market goods), such as coastal protection and large-scale hydropower, barriers may be identified with the support of a cost-benefit analysis of the social and environmental costs of technologies, which will be described in further detail in Chapter 5.

Some barriers are common to most countries, but they should be carefully analysed according to the national context. Furthermore, barriers may differ according to 'who' is transferring and/or diffusing the technology. The interests and perspectives of small local diffusers are often quite different from those of a large foreign company that is looking to expand its market in a developing country. Therefore, the actual and conceived barriers can also be very different for the two types of stakeholder. Thus, depending on the resources available for the barrier analysis, a thorough stakeholder analysis can add much value to the exercise.

3.3 Screening barriers

Barrier identification (Section 3.2) results in a long list of barriers gleaned from various documents, interviews and/or the open-minded and non-selective recording of all ideas suggested by workshop participants.

When all the conceivable barriers have been identified, they need to be screened according to their significance. Workshop participants may now argue for and against the listed barriers to reach agreement by consensus or majority. Most important is to identify the essential barriers – that is, the barriers which definitely need to be addressed for technology transfer and diffusion to occur – as well as the non-essential barriers that are to be discarded and subsequently ignored. A simple screening may sort the long list of barriers into key and non-key barriers, thus keeping the focus on the objective, namely the transfer and diffusion of a given technology.

Alternatively, the barriers can be screened through voting. All barriers are entered in random order, and each workshop participant is asked to give each barrier a mark, for example, from 1 to 5, according to how important the barrier is from the participant's own perspective. The barriers are then ranked after adding up all the marks. Prior to the voting, the workshop participants may decide to delete, for example, the bottom third of the ranked barrier list.

Later in the process, when a more comprehensive understanding has been obtained, it may be useful to check the list of non-key barriers and assess whether some of them should be re-classified as key barriers.

It may be useful to apply more screening categories such as killer (non-starter), crucial, important, less important, insignificant (easy starter). Changing WTO regulations is an example of a non-starter, since it is an extremely cumbersome and long-term challenge, if not impossible from the perspective of a single government.

Barriers may also be sorted according to who has the power to do something about it and who is driving change: e.g. the national government, local authorities or power utilities. However, this can wait until the measures to overcome barriers have been developed (cf. Chapter 6).

3.4 Decomposition

An initial analysis of the barriers that remain after screening can be conducted by discussing whether some barriers are actually composed of some of the other barriers, or whether one barrier is just a more concrete formulation of an overall barrier category.

Painuly (2001) has suggested decomposing barriers at four different levels:

1. broad categories of barriers (e.g. economic and financial)
2. barriers within a category (e.g. high cost of capital)
3. elements of barriers (e.g. high interest rate)
4. dimensions of barrier elements (e.g. an interest rate of 15% per annum for households)

Level 1 may have been done already by the TNA consultant as part of the preparation for the barrier identification; cf. section 3.2.

Example of screening of barriers: mini-hydropower plants

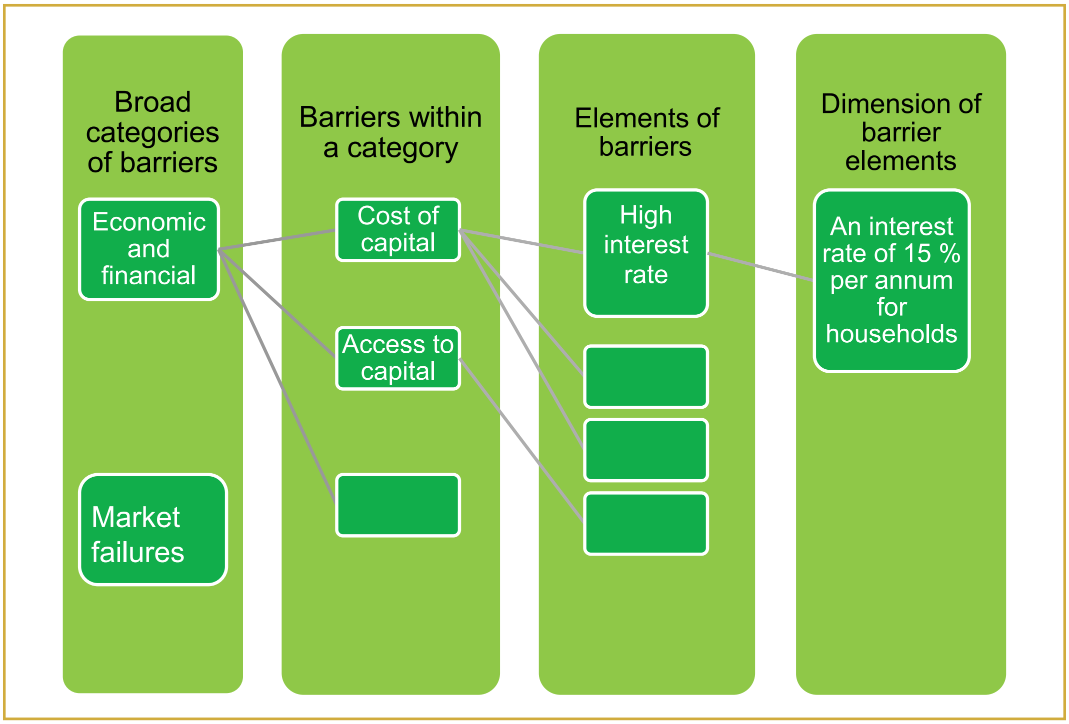
A number of barriers to the further development of mini-hydropower have been identified, e.g. through workshop brainstorming. In random order, the barriers are (numbers are for reference only):

1. Inadequate access to financial resources
2. High cost of capital
3. No comprehensive and strategic energy policy
4. Insufficient institutional framework
5. Insufficient capacity in Ministry of Energy
6. Energy needs of rural population not addressed
7. Insufficient skilled manpower for O&M
8. Disincentives to foreign investment
9. Rivers running dry for some months in the year
10. Low electricity tariff
11. Theft of spare parts
12. Lack of rural development policy
13. Lack of forestry policy
14. Monopolistic utility
15. Discrimination against independent power producers
16. Conflicting legislation

Having completed the barrier identification, participants are now invited to argue the relevance of each proposed barrier. After some discussion, consensus is reached that barriers 3, 12, and 13 may be removed from the list because 'lack of policy' is not a relevant barrier in this context. This is first because the current exercise is to propose the elements of a policy, and secondly because using 'lack of' should be avoided as it prescribes the measure, namely what is missing, rather than the underlying barrier to be addressed. Thus the original list of 16 barriers has been reduced to 13 barriers.

Another member argues that 'insufficient institutional framework' should be more precise. She wants to know which problem the institutional framework should address. The proposer explains that it is difficult to provide 'technical and economic' support to small communities being in charge of the mini-hydro plants. Insufficient institutional framework is therefore substituted by 'Difficulties in providing technical and economic support to small communities'.

Figure 3.2. Decomposition of barriers: an example.



To conclude whether a barrier or a barrier category is relevant or not, the presence of at least one of its components at a lower level is necessary. Otherwise, the barrier may be more imaginary than real. Thus, this exercise may lead to further removals of barriers from the list that remains from the screening process. Figure 3.2 illustrates decomposition of barriers for a technology.

One advantage of decomposing a barrier is that it clarifies the reasons why a barrier exists and makes it easier for stakeholders to comprehend its significance. Another advantage is that appropriate measures to overcome a barrier may be identified more easily when there is a more exact and detailed description of the barrier.

The summaries of proper financial and other assessments of the selected technologies made available by the consultant before the barrier identification process (cf. section 3.2) are also of great value for the decomposition process. As an example, a feasibility analysis usually illustrates the cost of capital, and in particular why the cost may be considered too high for potential investors. Thus decomposing the barrier 'Cost of capital' into its barrier elements and further into their dimensions may be easily deduced from the feasibility report. Two specific tools may be useful in assisting in the analysis of the decomposition of barriers: the root cause analysis, and the logical problem analysis (LPA), both of which are described in further detail in Annex A.

3.5 Summary

This chapter has provided guiding principles for how barriers to the transfer and diffusion of climate technologies can be identified and analysed using a stepwise process. The description comprises how to organise the process, how to identify all possible barriers, how to screen and select the most important barriers, and how to decompose the barriers and make them more specific by establishing a hierarchy of barriers. The next chapter will supplement this general description of barrier analysis with specific guidance for technologies transferred and diffused on market conditions, while Chapter 5, will provide specific guidance for non-market technologies.

Photo credit: GERES Groupe Energies Renouvelables, Environnement et Solidarites

4. Barrier analysis for market goods

This chapter deals specifically with barrier analysis for technologies that are traded in a market place, essentially the technology categories of 'consumer goods' and 'capital goods', in order to understand properly the particular framework conditions of such technologies. With reference to Chapter 2, consumer goods are specifically intended for the mass market, while capital goods are machinery and equipment used in the production of other goods, e.g. consumer goods or electricity. Common to market-goods technologies is that the diffusion of technology is contingent on a well-functioning market. The chapter should be seen as a supplement to the general description of barrier analysis in Chapter 3, and it will also support that analysis and prepare the subsequent steps concerning the measures to be adopted for barrier removal dealt with in Chapter 6.

Assessing the market potential for new technologies and the means for market penetration is a well-established discipline, which is seen in various variations, including in the business and management literature with regard to the introduction of new products in different markets. Most market assessments focus on the heart of the market – demand, supply and transactions – pinpointing demand-side weaknesses, supply-side weaknesses and market opportunities, and often leading to the formulation of a marketing plan. Experienced consultants with expertise in market analysis are available, and such consultants could be asked to assist the TNA Team in assessing the potential for the diffusion of priority technologies.

4.1 Economic assessments

The competiveness of a new technology compared to existing (incumbent) technologies is in general one of the most important barriers to the market-based diffusion of a new technology. It is therefore essential to conduct a solid economic analysis of the actual and the future competiveness of the technology compared to incumbent technologies on the market, which produces the same product or provides the same or a similar service. This economic analysis should ideally be conducted as a cost-benefit analysis, which includes indirect costs, such as the costs of environmental impacts, and benefits such as employment effects. However, addressing strictly the barriers to the diffusion of a specific technology, as in this case, it is most important to compare the costs of goods and services provided by the new technology compared to those of incumbent technologies (the baseline).

This type of economic assessment is often carried out by analysing the investment needs in a new technology and conducting a 'standard' economic feasibility analysis, including the annual revenues from selling the product or service (e.g. electricity, water, seeds, grain) and subtracting the annual costs (capital cost, operation and maintenance costs and reinvestment). Calculation often covers a period of twenty years, and annual gains or losses are actualized by calculating the Net Present Value (NPV) using a discount rate. The technology is competitive when the NPV is positive, and not when it is negative. This type of economic assessment can easily include the impact of a subsidy and the implications of various levels of interest rates on capital. For more details on economic assessment, the reader is advised to consult standard textbooks on the issue or to consult the guidebook on preparing technology transfer projects for financing (UNFCCC, 2006).

Figure 4.1. Economic analysis of a 4 kW roof top solar PV system

Investment (USD)	**7,000**	**Pay back period**	**20**	**Interest rate**	**10.0%**
Electricity price (USD/kWh)	**0.17**	**Production per year (kWh)**	**6,000**	**Efficiency reduction**	**0.70%**
Maintenance	**0.30%**	**Discount rate**	**10.00%**	**Reinvestment**	**2,000**

Year	Annual production (kWh)	Revenue	Mainte-nance	Re-invest-ment	EBITDA*	Principal payment	Interest	Annual result
1	6,000	1,020	- 21		999	- 122	- 700	177
2	5,958	1,013	- 21		992	- 134	- 688	170
3	5,916	1,006	- 21		985	- 148	- 674	163
4	5,875	999	- 21		978	- 163	- 660	156
5	5,834	992	- 21		971	- 179	- 643	149
6	5,793	985	- 21		964	- 197	- 625	142
7	5,752	978	- 21		957	- 217	- 606	135
8	5,712	971	- 21		950	- 238	- 584	128
9	5,672	964	- 21		943	- 262	- 560	121
10	5,632	958	- 21	2,000	- 1,063	- 288	- 534	- 1,886
11	5,593	951	- 21		930	- 317	- 505	108
12	5,554	944	- 21		923	- 349	- 474	101
13	5,515	938	- 21		917	- 384	- 439	94
14	5,476	931	- 21		910	- 422	- 400	88
15	5,438	924	- 21		903	- 464	- 358	81
16	5,400	918	- 21		897	- 511	- 312	75
17	5,362	912	- 21		891	- 562	- 261	68
18	5,325	905	- 21		884	- 618	- 204	62
19	5,287	899	- 21		878	- 680	- 143	56
20	5,250	893	- 21		872	- 747	- 75	49

* EBITDA Earnings before interest, taxes, depreciation and amortization

Key economic results:

Simple payback time (years)	**7.01**
Net present value (NPV)	**352**
Internal rate of return (IRR)	**11%**

Figure 4.1 provides an example of how an economic assessment can be carried out by a simple spreadsheet model. In this example, the price of electricity (the cost of electricity by incumbent technologies) is considered to be the same over the calculation period. In most cases this may change, due to inflation, changes in oil prices or improvements to incumbent technologies, but such changes can be taken into account in the model by making simple modifications.

Instead of evaluating competitiveness with another technology (using the marginal cost of the incumbent technology, in this case diesel-based electricity production), the same model can also be used to evaluate the level of a new feed-in tariff needed to make roof-top solar PV economically feasible. The same spreadsheet model can be used in economic evaluations of, for instance, the introduction of zero-tilling equipment in a farming community.

There are a number of computer-based models and calculation tools to calculate the economic feasibility of new technologies compared to the most relevant competing alternative. In most cases these tools can provide even more advanced financial features. The best known of the simple models for energy systems are RETScreen and HOMER, which are available free of charge on the web. For those who are not already familiar with a specific tool, the TNA project has developed a Excel-based tool called FICAM, which is available on the TNA project webpage. The FICAM tool can be used for technologies from all sectors. For more information about computer tools for economic evaluation and system integration in the energy sector, a review of 37 computer tools is provided in Connolly et al. (2010).

Economic assessments of market-goods technologies should be compared to the most relevant competing alternatives in the particular context. Here it is important to stress that comparative studies should assess competing technologies that can be reasonably compared. The case of solar PV technology can provide an illustration of this.

In many developing countries, solar PV panels provide the basic technology to serve a number of different market segments, from off-grid solar home systems (SHS), to institutions, to large-scale, grid-connected systems, all of which have different competing technologies. In the case of SHS, competing technologies include the use of kerosene lamps for lightning and small generator sets to serve electricity needs in rural households. The competing technologies for utility-scale grid-connected solar power include large-scale diesel, large-scale hydro, coal or gas-fired power plants. The economic assessments should therefore analyse the feasibility of solar PV compared to the specific competing technologies in the different solar PV market segments (Hansen et al., 2015).

In addition to the economic assessment, the technological innovation system (TIS), value chain and market mapping perspectives may be used to analyse the non-economic barriers. These three interrelated perspectives will be described in the following.

4.2 The technological innovation system (TIS) perspective

The TIS perspective is part of a larger literature on innovation systems that takes as its starting point the idea of innovation as a collective activity involving a complex interplay between different actors and organisations involved in the generation and diffusion of technologies (Kim and Nelson, 2000; Lundvall et al., 2009; Lundvall, 2010). According to this literature, technological innovation is therefore not confined to in-house R&D activities within individual enterprises, but takes place through mutual interaction among private firms, government entities, universities and customers in a particular institutional context. Technology development is hence understood as a system comprising interaction among various agents and organisations operating within a given economic and social structure (Edquist, 1997).

Innovation systems can generally be characterized by three basic building blocks that are associated with the development and diffusion of technologies: actors, institutions and networks. Actors may include organizations responsible for education, R&D, industrial activities, and consumers. Institutions are supportive legislation and technology standards. Networks may be in the form of linkages between organizations in research projects and advocacy coalitions.

A TIS is defined as ‘a dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology’ (Carlsson and Stankiewicz, 1991: 94). Although the TIS perspective was originally developed as at least potentially global in scope, it has most often been operationalized within national boundaries (see e.g. Tigabu et al., 2015). The TIS perspective focuses at the same time on the conditions for the supply and (market) demand for the development and diffusion of technologies under the particular institutional circumstances that operate within those national boundaries.

The study of TIS generally proceeds by exploring two main components. The first component involves an analysis of the structural composition of the TIS around a specific technology, which focuses on the actors and organisations involved, such as firms, public agencies and end-users, the networks among these agents, and the formal and informal institutional structures involved, for example, the regulatory, political and cognitive frameworks. The analysis of the structural composition of a TIS typically leads to a detailed mapping of all relevant innovation system actors, networks and institutions involved following a type of scheme shown in Figure 4.2 below.

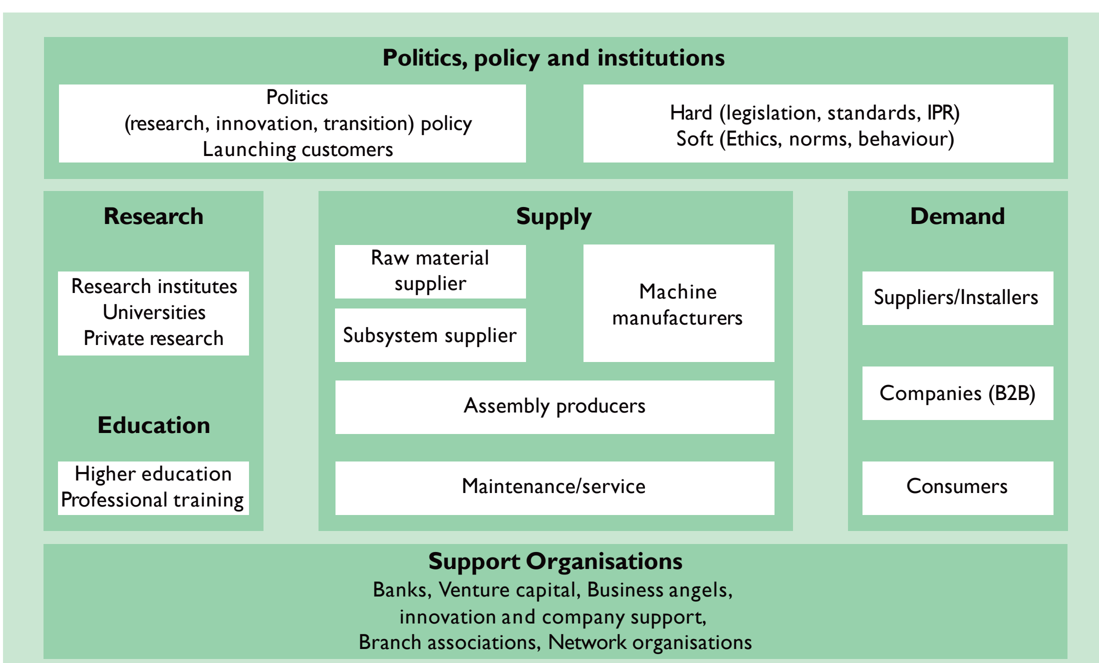
The second component focuses on the overall functioning of the TIS in question, which involves an analysis of the specific functions that, depending on their strength, may impede or encourage the development and diffusion of a new technology. Hekkert et al. (2007) and Bergek et al. (2008) developed a widely used approach to analysing the functionality of innovation systems that specifies seven key functions of particular analytical importance (see Figure 4.3 below). The functional analysis of a TIS should explore in detail the relative strengths and weaknesses of each of these seven functions to promote the development and diffusion of technologies. Different diagnostic tools and indicators can be found in the literature to undertake this assessment (see e.g. Hekkert et al., 2011).

It should be noted that as innovation systems are not static, analysis should include considerations about the dynamics of how the structural composition and the performance of specific functions change over time. Further information about the practical use of the TIS perspective can be found in Hekkert et al. (2007) and Bergek et al. (2008).

4.3 The value chain perspective

As the TIS perspective tends to focus on the national context, the global value chain perspective is often brought in to ensure that international linkages are taken into account in the barrier analysis. The global value chain provides a framework with which to describe the full range of activities required to bring a product or service from conception, through the different phases of production, to delivery to

Figure 4.2. Structure of an innovation system



Source: Hekkert et al. (2011).

Figure 4.3. Functional components of technological innovation systems

Functions	Description
1. Knowledge development and diffusion	The generation of breadth and depth of the knowledge base of the TIS, and the diffusion and combination of knowledge.
2. Influence on the direction of search	The existence of incentives/pressures (and expectations) for actors to enter the TIS, and to direct their activities towards certain parts within the TIS (e.g. technologies, applications or markets).
3. Entrepreneurial experimentation	The probing into new technologies and applications, unfolding a social learning process reducing uncertainty.
4. Market formation	The timing, size and type of markets that have actually been created, including customer demand and user preferences.
5. Legitimation	The extent to which the new technology and its proponents are considered appropriate and desirable by relevant actors in different parts of the TIS to acquire political strength.
6. Resource mobilization	The availability of human resources (e.g. skilled labour), physical resources (e.g. infrastructure, material, etc.), financial resources (e.g. investments, venture capital, subsidies, etc.) and complimentary products and services.
7. Development of positive externalities	The interconnectedness between different parts of the TIS, and between the TIS and the external environment, in fulfilling the other functions.

Source: Adapted from Bergek et al. (2008).

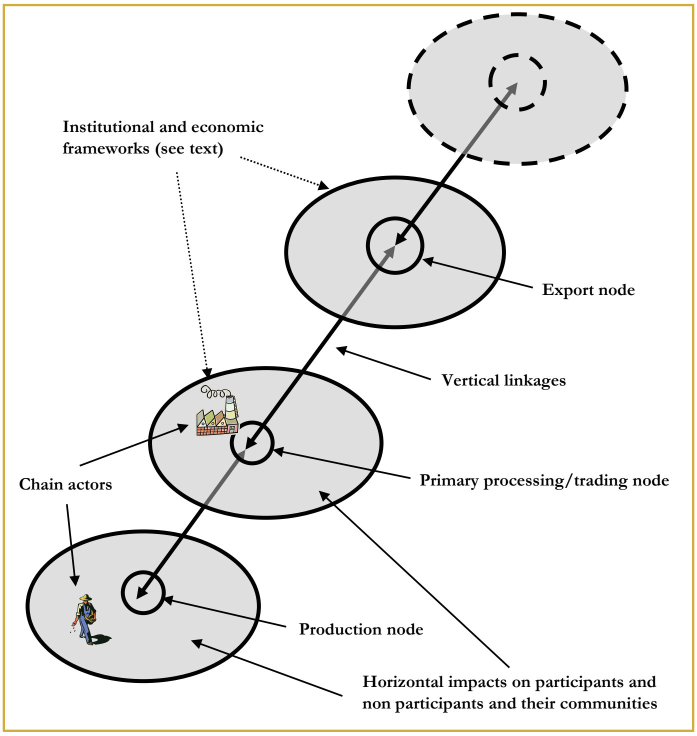
the final consumers and end-users in the market (Kaplinsky and Morris, 2003). By focusing on the overall functioning of the entire range of activities along the value chain, this perspective provides a relevant systemic view of the conditions for the diffusion of market goods technologies.

In analysing the composition and functioning of value chains, four key dimensions are used to describe the actors, institutions and processes linked to particular material flows, transactions and relations pertaining to the specific value chain in question. These comprise (i) the input-output structure; (ii) the geographical scope; (iii) the governance structure; and (iv) the institutional context of the particular value chain or industry (Gereffi and Fernandez-Stark, 2011).

The input-output structure involves a description of the flow of tangible and intangible goods and services channelled through the various segments in the chain ranging from the transformation of raw (input) materials into products to final consumption. This (vertical) flow is typically represented as a set of value-chain boxes connected by arrows mapping the actors and activities in each segment and the value added at different stages in the chain, as shown in Figure 4.4 (Gereffi et al., 2005).

The geographical scope involves a mapping of the physical boundaries of the value-chain activities. These may be confined to a relatively closed, localized production and consumption system, but may also be domestic, regional and/or global in scope where the division of labour and consumption in the chain span a wider geographical scale.

Figure 4.4. Illustration of nodes, actors and institutions and linkages in the value chain approach



Source: Bolwig et al., 2010

The governance structure involves the identification of how the value chain is controlled. This relates to the authority and power relationships that determine how financial, material and human resources are allocated and flow within a chain. These value-chain relations are important, as they influence the overall functioning of the chain and affect the barriers to entry and the prospects for local suppliers from their insertion in specific segments of the chain. Value-chain governance types range from purely market-based transactions to vertically integrated transactions within individual firms.

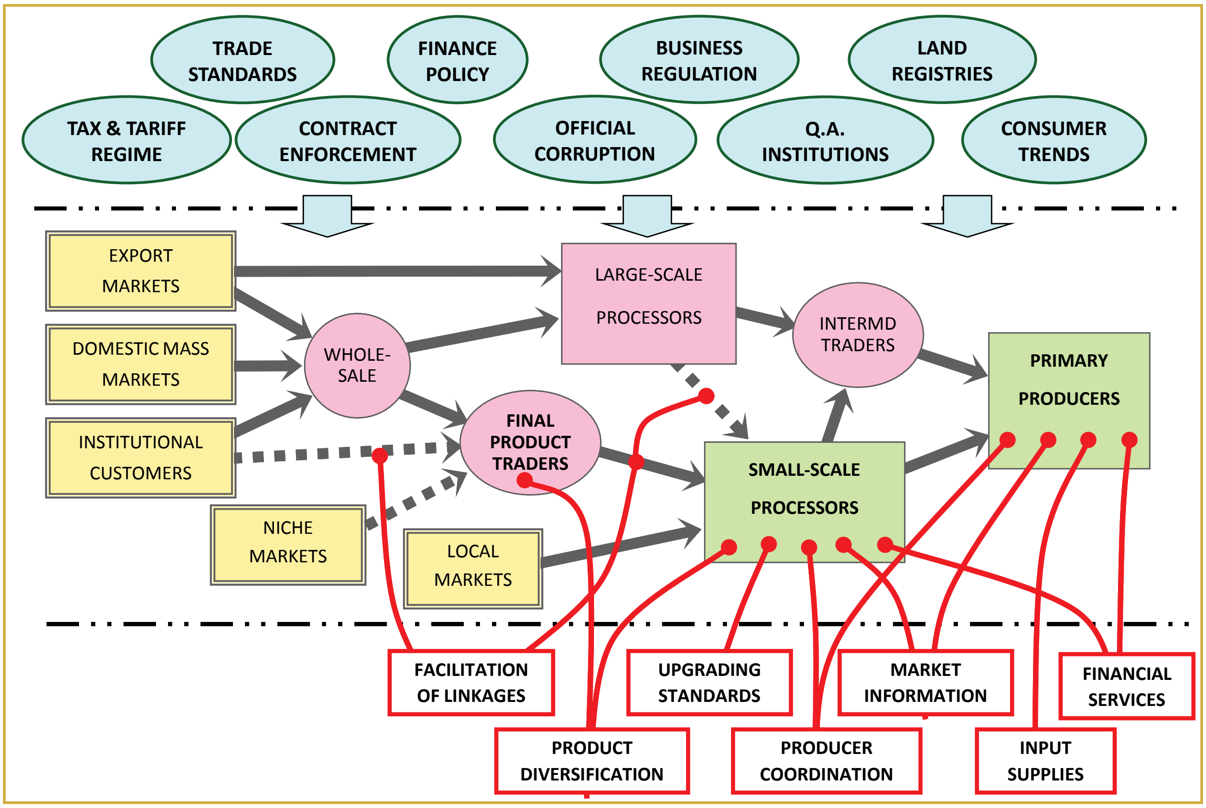
The institutional context relates to the specific local, domestic and global conditions that influence the functioning of value-chain activities. This (horizontal) context refers to the political, regulatory, social and economic conditions around the different nodes and segments along the chain. Macroeconomic conditions on the national scale may, for example, include the availability of key input materials such as labour costs, available infrastructure and access to other resources such as finance, as well as tax systems and labour regulation. The functioning of value chains may also be influenced by international institutional structures, such as multilateral trade agreements and international standards. For further information on how to conduct value-chain analysis, see e.g. Kaplinsky and Morris (2003).

4.4 The market mapping framework

The market mapping technique builds on the TIS approach and the value-chain approach but has been put forward as a more practical and participatory-oriented framework that emphasises stakeholder consultation as a key element in identifying and changing the conditions for value chain functioning.

Market mapping is an analytical framework for understanding market systems and an approach to market development that is both systemic and participatory. The market map is a very useful way to

Figure 4.5. The Market Map complete, a generic schematic



Source: Practical Action, UK.

conceptualize, visually represent and communicate knowledge about the entire commercial and institutional environment in which specific market chains operate. The tool helps to explore who the market actors for a technology are, what support services are available to them and the nature of the enabling business environment (Albu and Griffith, 2005, 2006).

The analysis of market mapping proceeds by exploring three key elements: (i) the enabling business environments; (ii) the market chain; and (iii) the input and service providers. A generic example of these three elements is shown in Figure 4.5. Contrary to convention, the schematic figure shows the flow of income from left to right, with the flow of goods going in the opposite direction.

As can be seen, the three components are separated on the map by the horizontal dot-and-dash lines. The central component is the market chain (the yellow, pink and green boxes in the middle of the map) consisting of the economic actors who produce and transact a particular product as it moves from primary producer to final consumer. The market mapping technique focuses particularly on this element through the direct involvement of market actors in identifying the barriers and measures for value-chain functioning and a participatory and inclusive stakeholder consultation process. This element draws on the wider value-chain framework on the governance of chains, as mentioned above.

The second component, the enabling business environment (the upper blue ovals in the map), is a charting of the critical factors and trends that shape the market-chain environment and operating conditions. Similar to the TIS framework and the value chain framework, this element relates to the local, national institutions, rules and practices of governments, and others as part of the institutional context within which value chains are embedded and operate.

The third component, the input and service providers (the lower white squares in the map), is concerned with mapping the services that support, or could potentially support, the market chain's overall efficiency. This includes the identification of particular service needs and their locations within the market chain in order to understand the opportunities for using and further developing services to improve market-chain efficiency.

The market mapping approach can be very helpful for visualising the complexity of the local innovation system, thus assisting in identifying most non-economic barriers. Its focus on the relation between the market actors, and how the enabling framework can hinder or support the functioning of the market chain is useful in identifying the barriers to and measures for the further diffusion of specific technologies. The market-mapping approach should therefore be seen as a tool which can be used to improve the general barrier analysis for non-economic barriers as described in Chapter 3. Readers are referred to Annex B for a detailed description of the market mapping process and to Annex C for a concrete example of how market mapping can be used in identifying barriers to the diffusion of solar home systems.

4.5 Summary

Chapter 3 provided general guiding principles on how barriers to the transfer and diffusion of climate technologies are identified and analysed. In the present chapter, this general approach has been supplemented in order to provide an in-depth analysis of the barriers to market technologies. The focus in this chapter has been the importance of conducting comparative economic assessments and has been followed by a short description of the technological innovation system perspective, the value-chain perspective and not least the market-mapping approach, which builds on the two other perspectives and which provides a practical tool for identifying barriers to innovation and market development at the national level. The next chapter will focus on barrier analysis for non-market technologies, which are usually diffused through direct government involvement.

Photo credit: Doug Beckers

5. Barrier analysis for non-market goods

This chapter deals with the technology categories of ‘publicly provided goods’ and ‘other non-market goods’ (cf. definitions in section 2.2). The chapter seeks to provide an understanding of the particular framework conditions for such technologies and to illustrate the special nature of barriers related to these categories of technology. The chapter should be seen as an addendum to the general descriptions of how to identify and analyse barriers in Chapter 3, valid for all technologies.

With respect to identifying barriers to the diffusion of non-market technologies, we need to distinguish between the barriers to decisions to procure a technology and the costs and benefits of the technology. This is because, for non-market technologies, it is generally not the user who decides to invest in the technology in question, and consequently we cannot anticipate that the user will actually see a benefit in using the technology after it has been procured. This is backed by the experience that governments and donors that finance non-market technologies have in many cases invested in programmes and in infrastructure that the beneficiaries did not find useful, or in programmes and infrastructure projects that had a number of unintended consequences for other groups in society. More importantly, though, is the fact that costs and benefits for most non-market technologies are not experienced by the same person or entity. On the contrary, the benefits will often be experienced by one group in society, the costs by other groups.

5.1 Social and environmental cost-benefit analysis

As in the case of technologies in the market goods category, it is important to conduct an economic assessment of the competiveness or cost-effectiveness of technologies in the non-market goods category. Since non-market technologies are not traded in the market place and most often financed by public institutions or by donors rather than by users, their competitiveness should in general be understood in a broader social and environmental context.

Socio-environmental cost-benefit analysis can be conducted at various levels ranging, for example, from the individual farmer level to a wider community level, such as a local village, and further to include a regional level analysis, possible in relation to the assessments of large government or donor programs. This will then result in a detailed assessment of whether different technologies are feasible seen from a societal perspective. A number of methods to measure the social and environmental costs and benefits of specific technologies can be found in the environmental economics literature (see e.g. Perman et al., 2003). With this general introduction to non-market goods, we now turn to a specific discussion of ‘publicly provided goods’ and ‘other non-market goods’.

5.2 Publicly provided goods

Publicly provided goods in this context comprise mitigation and adaptation technologies such as large-scale hydropower schemes, sea dykes, flood defences, infrastructure such as roads, bridges, freshwater and sewage systems, and mass transport systems such as metros (see Box 5.1).

Technologies in this category may be traded in a market place like consumer goods and capital goods, as they are purchased by public entities from private constructors and manufacturers. However, the market is often not very liquid, as the public entities purchase their goods through a tendering process, which may be restricted to a limited number of invited national and international construction companies. Large-scale publicly provided goods projects will generally be preceded by thorough analyses such as cost-benefit analyses, feasibility studies and environmental impact assessments, as will be described below.

Barriers to procurement

Whether large-scale infrastructure projects are implemented directly by the government or through a public–private partnership, government and public institutions are always directly involved in taking decisions on their implementation. While a public entity, such as a ministry or a government agency, has the power to take decisions on infrastructure projects, a main barrier to taking decisions might be that the foundation for taking a decision is not available. For project ideas which are in the initial stages, a feasibility analysis might be a solution to overcome the first step in the decision barrier. For projects which are already at feasibility study stage, detailed cost-benefit analysis, environmental impact assessments and financial analysis might be the solution to overcome the next steps in the decision barriers. In developing countries, however, an important barrier is often access to finance. To curb this problem, public-private partnerships have for the last twenty years often been seen as one possible solution, and many examples are to be found, such as private hospitals, private roads, waste-treatment companies and independent power producers (hydro dams), etc. For many adaptation technologies, such as sea dykes, this pathway is difficult to pursue, since it is less clear to the beneficiaries that they need to pay for 'security' against flooding than that they need to pay a private company for electricity or for transport in, for example, a metro. Therefore donor and international finance institutions, such as the IMF and the World Bank, often have an important influence on which projects can be financed and thus procured. In brief, the main barriers to procurement are insufficient information for decision-making purposes and difficult access to finance.

Barriers or necessary political prioritisation of costs and benefits

Projects under the category of publicly provided goods, such as sea dykes, hydropower dams or mass transport systems, are in general projects with implications for a large group of consumers, and even more importantly, they usually have positive impacts for some people, while they have negative impacts on other groups of people. A mass transport system, although generally a least cost option per person per km, may cause traffic congestion during the construction phase and it may even in some cases entail the resettlement of the poor especially. These negative effects are 'cost elements' in the cost-benefit analysis and should of course be minimized.

Regarding benefits, mass transport systems generally benefit the poorer segments of society, those without access to individual transport, but decisions on the location of bus and rail lines will have a huge impact on which poorer groups will benefit and which will not. Also, decisions on tariff structures and the location of bus lines may have the result that rapid public transport excludes the poorer strata in society and ends up being of benefit to the middle class, who can afford it (Rogat et al., 2015). Similarly, hydropower schemes generally provide electricity, which is competitive with fossil fuels and also with renewable energy such as solar PV and wind power. This is to the benefit of the users of electricity, which in most countries are the richest strata in urban areas. Hydropower schemes may also entail irrigation for downstream rural populations and thus contribute to economic development for some of the poorer strata.

However, like the benefits, the costs are also unequally divided both socially and geographically. In some cases, people have to be resettled due to flooding of their agricultural land, while the hydro-dam will increase evaporation levels and reduce downstream water resources to the detriment of other communities or of hydropower dams that are dependent on continuous flows of water. Also dams may reduce mobility for fishermen and for transport, as well as destroying attractive tourist sights and thus reducing income in the tourist sector (WCD, 2000).

Box 5.1. Barriers for publicly provided goods

Mass transport system:

- Stakeholders
  - Government, city council, bus and rail operators, transport associations
  - National NGOs, tourist organisations, environmental organisations
- Benefits
  - Cost per person per km generally lower than other alternatives
  - Increased mobility, transport time savings, social equity benefits, fewer people killed, reduction of noise, air pollution and CO_2
- Costs
  - Traffic congestion during construction
  - Resettlement of poorer people
- Barriers for procurement/investment
  - Few studies of feasibility, costs and benefits
  - Difficult access to finance
  - Short-term interests vs. long-term interests (e.g. related to congestion)
- Who take decisions regarding implementation?
  - Government, city council and external finance institutions
- Barriers to long-term sustainability
  - Inadequate management, finance and business models

Large-scale hydro-power:

- Stakeholders
  - Government, utilities, watershed management organisations, farmers organisations
  - National NGOs, tourist organisations, environmental organisations
- Benefits
  - Cost of electricity generally lower than for fossil fuels, solar, wind and biomass
  - CO_2 emissions reductions, national security of supply, irrigation
- Costs
  - Resettlement of local communities
  - Loss of agricultural land, negative downstream effects
  - Loss of tourist attraction
- Barriers for procurement/investment
  - Few studies of feasibility, costs and benefits
  - Difficult access to finance
  - Resistance by local people and international NGOs
- Who take decisions regarding implementation?
  - Government, utilities and external finance institutions
- Barriers to long-term sustainability
  - Inadequate management, finance and business models

These examples show that a simple barrier analysis is not sufficient for taking decisions on the implementation of these types of projects. Such decisions are highly political, as they will favour some groups in society, while having severely negative economic impacts on other groups, and not least environmental impacts, which are difficult (albeit possible) to evaluate in monetary terms. While in general the social and spatial distribution of costs and benefits should be taken into consideration in cost-benefit analyses and environmental impact assessments, a political choice weighing the costs and benefits of different groups against each other is unavoidable in the end. In this process, political pressure from local people and international NGOs may influence government and international financial institutions, as we have seen in the case of large-scale hydro-power, thus possibly becoming a barrier for procurement as described above.

It might be tempting to see the costs mentioned above, such as the resettlement of people, the flooding of agricultural land, water loss due to evaporation and reduced mobility, as barriers to the diffusion of hydropower. Such an approach is however not very operational, because these are unavoidable costs which cannot be dealt with by simple means. Perceiving these costs as barriers will therefore not be much help in proposing means to overcome the barriers, the exercise undertaken in the next chapter. They should therefore rather be seen as unavoidable costs, which might only be slightly reduced if the right implementation measures are adopted.

Barriers to long-term sustainability

The long-term sustainability of publicly provided services and goods has been a problem in developing countries. The main barriers to a long-term sustainable operation have been non-transparent political involvement in state-owned companies, politically set tariffs, which have not allowed full cost recovery, and non-payment of services delivered to government institutions.

Over the last twenty years, attempts have been made to mitigate these effects through i) the involvement of private-sector operators in public/private partnerships with the state, ii) the part-privatisation of state-owned companies (arms-length principle), and iii) full privatization of state-owned companies.

5.3 Other non-market goods

While projects in the publicly provided goods category are often large in scale, the non-market goods category comprises both small-scale and large-scale projects, and while the hardware element is high in the publicly provided goods category, non-market goods are dominated by the software and orgware components of the technology (cf. the broad definition of technology in section 2.1). Technologies from the category of non-market goods are often financed by donors and public entities and can be divided into three main groups within which technologies share some characteristics in terms of barriers and how to overcome them.

Box 5.2. Barriers for technologies provided by institutions

Technologies provided by institutions

- Early warning systems for drought
- Seasonal forecasts of rain for optimal planting
- New vaccination systems due to climate change
- Introduction of genetic screening for water-borne pathogens

What are the barriers to implementation?

- Few studies of feasibility, costs and benefits
- Difficult access to finance

Who takes decision on implementation?

- Public entities (ministries, government agencies)
- Donors, development banks (in terms of finance)

What are the barriers to long-term sustainability?

- Poor management traditions
- Few national resources for running the service
- Limited qualified personnel

The first group comprises technologies provided by public institutions (see Box 5.2). This group greatly resembles publicly provided goods, but usually they are free of charge. Examples include early warning systems for drought, seasonal forecasts of rain for optimal planting, new vaccination systems and the introduction of genetic screening for water-borne pathogens. Before deciding on implementation, a cost-benefit analysis will be needed to address the issue of relevance (this may have been done as part of the TNA selection process), but if the intervention is considered beneficial, implementing the service is mainly dependent on access to finance and a government decision to implement it. Barriers to its long-term sustainability are poor management skills and traditions, low levels of technical capacity and limited access to required skills and equipment at the institutional level in the countries concerned.

The second group comprises the creation of new institutions with the objective of reducing vulnerability and improving rural livelihoods. Examples are microfinance institutions, forest management groups and village development groups, which are often supported by development actors. These institutions are general-purpose institutions and serve similar roles as institutions earlier described as being central elements in an enabling framework for the diffusion of adaptation as well as mitigation technologies. Since their initial introduction, village development groups have been perceived of and used as a means to transfer technologies in health, agriculture and forestry (Nygaard, 2008). In spite of the risk of confusing the technologies with the means to diffuse them, this group of institutions is included here as technologies. We have done so, because in the literature they often appear as examples of adaptation technologies, alongside an argument that they decrease vulnerability (Sharma and Moehner, 2011).

The creation of new institutions or induced institutional change supported by development actors, such as government agencies, donor agencies and NGOs, has been on the development agenda for the last thirty years. The barriers to such institutions becoming sustainable and actually playing the roles that donors and governments have attributed to them are many. Examples of barriers include capture by local elites, disputes

Box 5.3. Barriers for the creation of new institutions

Institutional change to reduce vulnerability and improve rural livelihoods

- Microfinance institutions
- Forest management groups and village development groups

What are the barriers to implementation?

- Mixed experience with similar interventions
- Funding, decisions by development actors

Who takes decision on implementation?

- Development actors such as government agencies, donor agencies and NGOs

What are the barriers to long-term sustainability?

- Capture by local elites, disputes over external resources, misappropriations of funds, strategies of dependence

What are the measures for improved functionality?

- Better understanding of difficulties in the approach (e.g. donor/recipient relations)
- Better project preparation
- Improved information, better training, better understanding of local needs

Example: local farmer associations involved in adaptation and local development.

1) Practices of adaptation to drought and heavy rainfall in four villages in South Africa and Mozambique have been analysed by Thomas et al. (2005), who shows that, by working together in voluntary associations, villagers have been able to spread the risks of adopting new technologies and to experiment with new crop varieties on their own terms.

   Agricultural projects which utilised local knowledge and had a market base were the most successful. Knowledge transfer from other regions was facilitated through government training.

2) McGray et al. (2007) has reported a number of cases of adaptation from around the world.

3) There is a body of research revealing the difficulties involved in creating long-term sustainable local institutions by donor intervention. Examples in the literature include Nygaard (2010, 2008, 2006), Engberg-Petersen (2002) and Crewe and Harrison (1998).

over external resources, misappropriation of funds and strategies of dependence on continued donor finance (Nygaard, 2008) (see Box 5.3).

Such barriers can be reduced, for example, by improved information and better training, economic support and governance. Better project preparation through rural appraisal techniques may improve the understanding of the complex relationship between donor projects and recipients at the local level, enable the achievement of ownership of technologies by the community, and ensure that lessons learned from past community-based projects are considered, synthesised, assimilated and disseminated.[5]

The third group comprises behavioural change at the individual level. Examples are energy-saving measures, such as turning off lights or air conditioning when they are not needed, changing from individual cars to public transport and bicycles, improved hygiene made necessary due to climate change, use of freely distributed mosquito nets and changing farm practices.

In line with the new institutions mentioned above, and with the risk of confusing the concept of technology and the means to diffuse technologies, behavioural change is included as a technology in this guidebook because it is often mentioned in the technology transfer literature as a technology (Sharma and Moehner, 2011). Including behavioural change as a technology poses problems because behavioural change is an essential means for the diffusion of all technologies, rather than a technology itself. If a farmer shifts from kerosene lamps to solar lamps, he needs to change his behaviour in order to operate the new technology. Similarly, if he changes from using a car to using a bicycle, he needs to change his behaviour. The difference is that moving from a car to a bicycle means moving from a newer and more expensive technology to an older and cheaper technology with less comfort, while the opposite applies in moving from a kerosene lamp to a solar lamp. However, because new technologies are not always the solution to a problem, some practitioners have focused on the aspect of change to existing and even less-advanced technologies and defined this change in behaviour as a 'technology' in itself.

Attempts to change behaviour are often achieved by means of projects or programmes financed by governments and donor organisations. Barriers to the implementation of such projects are in general the need for well-described project proposals and limited finance.

The barriers to actually achieving behavioural changes are both complex, multiple and difficult to overcome. Examples are socially and culturally embedded practices, convenience, tradition, social esteem, pride and religious beliefs (see Box 5.4).

5 For this purpose, it may be useful to apply the approach called Participatory Rural Appraisal or the Framework Tool for Technology Receptivity, developed by SouthSouthNorth (2007).

Box 5.4. Barriers for behavioural change

Behavioural change at the individual level (change of practice)
- Energy-saving measures, such as turning off lights or air conditioning when you are not present
- Changing from individual cars to public transport and bicycles
- Improved hygiene made necessary due to climate change
- Use of mosquito nets, and changing farm practices

What are the barriers to implementation?
- Need for good project proposals
- Low understanding of success factors for this type of project
- Limited funding available from government and development actors

Who takes decision on implementation of projects?
- Development actors such as government agencies, donor agencies and NGOs

What are the barriers to achieving behavioural change?
- Complex, multiple and difficult to overcome
- Culturally embedded practices, convenience, tradition, social esteem, pride, religious beliefs

What are the measures for achieving behavioural change?
- Information and training
- Legal and economic incentives (e.g. traffic regulation, taxes, subsidies)
- New infrastructure (e.g. bicycle lanes)

There are some general measures designed to encourage behavioural change, such as information campaigns and training. Behavioural change may also be facilitated by legal and economic incentives such as traffic regulations, taxes, subsidies or public entities making new infrastructure available, such as bicycle lanes.

5.4 Summary

The present chapter has focused on the specific challenges to the diffusion of non-market technologies, which falls into two categories: publicly provided goods and other non-market goods. Governments usually take decisions on investments in technologies in the category of publicly provided goods. This limits the barriers to taking decisions on the implementation of these technologies to difficulties of access to finance and the low level of information available for establishing a decision base, such as feasibility studies, cost-benefit analyses and environmental impact assessments. It was stressed that it is often different groups of people who bear the cost and enjoy the benefits, respectively, of the introduction of a technology from this category, and that decisions on large infrastructural projects therefore necessarily involve a political process weighing the cost and benefits to different groups against each other.

The main barriers for the long-term sustainable operation of technologies within the category of publicly provided goods has been non-transparent political involvement in state-owned companies, politically set tariffs, which have not allowed full cost recovery, and the non-payment of services delivered to government institutions.

The category of other non-market goods comprises three groups: technologies provided by institutions, the creation of new institutions and behavioural change. The diffusion of these technologies is in general financed and facilitated by development actors, such as donor organisations and NGOs, and the main barriers to starting these projects are access to finance and studies for project preparation. On the other hand, the barriers to successful long-term operation are complex and numerous, including capture by local elites, disputes over external resources, misappropriation of funds and strategies of dependence on continued donor finance.

Photo credit: James Marvin Phelps

6. Measures to overcome barriers

Having established a thorough understanding of the barriers to the transfer and diffusion of technologies, the next step is to analyse how these barriers can be removed or overcome. The guiding principles presented here are valid for both market goods and non-market goods.

In this guidebook, the term 'measure' is used as a general concept for any factor (financial or non-financial) that enables or motivates a particular course of action or behavioural change with the objective of overcoming a barrier. There is therefore a perceived causal and logically consistent link between the barriers that are identified, the measures adopted to circumvent the barriers and the resulting impact of the measures in terms of barrier removal. In the literature, the word 'incentive' is often used synonymously with 'measure', or sometimes with a slightly different interpretation. Accordingly, this guidebook does not distinguish between 'measure' and 'incentive'.

6.1 The process of identifying measures

The first steps in identifying and describing measures would ideally be taken during a facilitated workshop with the group that has been involved in the barrier analysis. During this workshop, various inputs, tools and approaches may be used to identify measures to overcome the identified barriers. These may include the following:

- The TNA consultant's own experience, supplemented by documented experience on policy measures from other countries, would in general be a very important input into this process. The consultant should therefore be well prepared for the workshop. There is considerable sector-specific information available on the web, published by various development institutions, including the World Bank. To provide examples for the present guidebook, the UNEP DTU Partnership has dedicated an issue of the Technology Transfer Perspectives Series (Haselip et al., 2011) to provide case studies of enabling frameworks for renewable energy technologies in various developing countries.[6]
- Measures already touched on during the barrier analysis may be another important input. Although barrier analysis and the identification of measures are in theory distinct processes, practice shows that it is difficult for participants to think of barriers without at the same time thinking of measures or solutions. Although measures are not part of the barrier analysis, it may be practical to take notes, which can be used as input into the identification of measures. This can lead to a discussion among stakeholders of what can be done about barriers.
- In the case of technologies for consumer goods and capital goods, the market mapping tool may have been used to identify barriers. In this case the market mapping tool will also be used for the identification of measures (see Chapter 4).
- In cases where a logical problem analysis has been used to identify barriers, the same tool should be used to move from problems to solutions. This is described in further detail in Annex A.

It may be convenient to address the barriers category by category, using the same categories as those used when identifying the barriers in section 3.2. These could include:

6 Available at http://tech-action.org/

1. Economic and financial measures
2. Measures to address market conditions
3. Legal and regulatory measures
4. Measures to influence network structures
5. Measures to increase institutional and organisational capacity
6. Measures to improve human skills
7. Social, cultural and behavioural measures
8. Measures to increase information and awareness
9. Measures to address technical barriers
10. Other measures

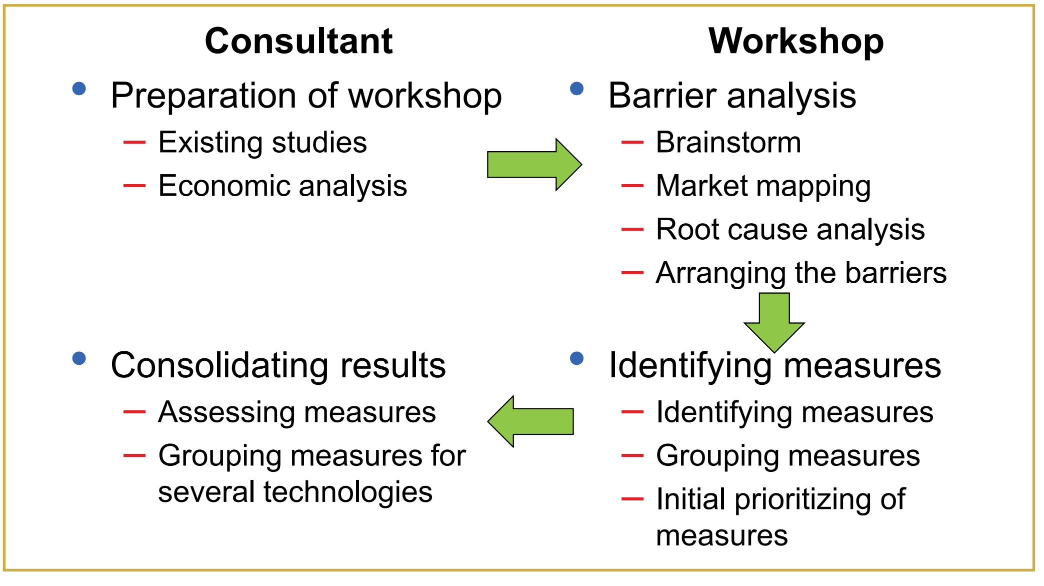
When the measures have been identified and evaluated by the facilitated workshop in, for example, the sectoral workgroup, the consultant needs to go back to the office to assess, prioritize and group the measures and to present them in a report for discussion and approval by the sectoral work group or the TNA committee. The different steps in barrier analysis and the identification of measures are illustrated in Figure 6.1 below.

6.2 Grouping measures and design of programme

Experience shows that, to achieve a significant impact on the diffusion of a specific technology, it is necessary to apply a relatively broad set of complementary measures addressing barriers at various levels. Often measures are classified into two main groups: financial and non-financial measures, as it is of importance to policy-makers which measures can be implemented by legal or other interventions, and which measures need to be financed (nationally or externally). An overview of the financial and non-financial measures that are commonly used in the diffusion of renewable energy is shown in Box 6.1.

Relevant case studies of enabling frameworks for the diffusion of renewable energy technologies in developing countries, such as those illustrated in Haselip et al. (2011), can provide useful input into how such measures can be combined to enhance the effect. Box 6.2 provides a brief description of one of the examples describing measures to enhance the diffusion of solar water heaters in Tunisia. Similar examples may be found for other mitigation technologies.

Figure 6.1. Who is doing what in the process of identifying barriers and measures



Box 6.1. Policy measures most commonly used to promote the diffusion of renewable energy

Financial measures

- Production incentives (e.g. subsidy per produced kWh electricity)
- Standard power purchase agreements (Feed-in-tariffs)
- Investment subsidies
- Loan guarantees
- Set-asides
- Green marketing (e.g. a premium tariff on 'green' electricity)

Non-financial measures

- Market liberalisation (e.g. by allowing competitors to the incumbent fossil-based monopoly)
- Improved infrastructure
- Improved access to the grid
- Obligations to generate or purchase 'green' electricity
- Voluntary agreements
- Competitive concessions (companies competing for a time-limited monopoly to supply a technology in a specific region)
- Government-assisted business development (e.g. by public-private partnership)
- Involving local communities and civil society
- Discouraging alternatives (e.g. environmental taxation of fossil fuels)
- Research, development and demonstration
- Testing and certification
- Information and education

Enabling frameworks for adaptation technologies are described in, for example, a publication available from the international finance cooperation (Stenek et al., 2013), showing that combining measures is also good practice for programmes for the diffusion of adaptation technologies. One example might involve a situation in which a local farming community opposes the introduction of a new technology, such as an unfamiliar cropping technique, because of the (mis)perception that the technology is useless or ineffective in catering to local farming needs. Enabling or supportive elements in terms of information and education should thus be strengthened to overcome the community resistance barrier. This may take the form of awareness-raising campaigns, information dissemination (including site visits, presentations, etc.) and promotional activities.

An example of a combination of a portfolio of complementary measures in a programme for a seasonal weather-forecasting technology in Lesotho is shown in the Box 6.3 below.

Besides the importance of using complementary measures, the literature suggests that financial measures should be simple, transparent and predictable in order to attract investors. The measures in the Tunisian water-heater programme are examples of this. A feed-in tariff for electricity from renewable energy is another example of a simple and transparent financial measure. For feed-in tariffs it is important that there be a predictable decline in tariffs over time, so investors can predict their future incomes.

The transfer and diffusion of technologies is normally a long-term process and thus needs a long-term commitment. Box 6.4 describes the EC-ASEAN Cogen Programme, carried out in three phases from 1991-2004. Unlike most programmes, the first phase of this programme lasted for thirteen years.

Box 6.2. Example of a portfolio of complementary measures

The solar water heater (SWH) programme in Tunisia has combined financial and non-financial measures. The financial incentives comprise:

- A 20% capital cost subsidy, up to TND 100 (USD 72) per square metre (m2), for all new SWH installations.
- The interest rate for bank loans for residential was set as ‘Tunisian money market monthly average rate (TMM) + 1.5%’. Thus, in July 2011, for example, the interest rate charged would have been 4.25% (TMM) + 1.5% = 5.75%.
- The financial support for SWH systems stems from a newly implemented energy efficiency fund or FNME. These incentives are funded by tax revenues from motor vehicle registrations and VAT and custom duties on air-conditioning systems.
- Indirect tax benefits: exemption of SWH systems from VAT and customs duties reduced by 10%.
- Regulatory policy mandating the use of SWHs in new public buildings.

Besides this, a series of supportive accompanying measures were introduced, consisting of quality standards, certification and supplier accreditation schemes, extensive public awareness-raising campaigns, capacity-building for government officials and financiers, and installation training.

The programme has achieved impressive results. By the end of 2008, 80,000 m2 of collector surface had been installed, and a network of 30 suppliers and 733 installation and service professionals established. For more info consult (Ölz, 2011) in Technology Transfer Perspective Series (www.tech-action.org).

Box 6.3. Example of a portfolio of complementary measures

Access to seasonal weather forecasting and climate information is common across most adaptation contexts. Based on her experience of Lesotho, Ziervogel (2009) has pointed out that, although seasonal climate forecast information is useful to some farmers, disseminating the information is a challenge. This is because it is often disseminated in English rather than Sesotho and via a press release that does not have the follow-up support that farmers would like. As a result, they are unable to examine the information in greater depth. This hampers discussion between farmers and experts as to what their information needs are and how the information might be used.

Ziervogel (2009) suggested the following complementary measures to overcome the barriers to a seasonal forecasting programme in Lesotho:

- Information should be disseminated in the local language.
- Timely dissemination of forecasts giving farmers time to make decisions.
- Personnel within the meteorological service, with adequate time dedicated to developing appropriate dissemination strategies, such as radio and print materials. Forecasts are issued nationally via a press release and are expected to ‘filter down’ through the district level to the end-users. This seldom happens effectively due to weak coordination between state institutions, such as the Ministry of Agriculture and the District Agricultural Offices.
- Extension agents should be trained to communicate information effectively to farmers. Also, farmers have indicated a preference for receiving the information from village chiefs at community meetings.
- Follow-up support should be provided to farmers (from agents, input suppliers or other organizations) such as reducing the number of livestock, reducing the density of field crops, or planting more drought-resistant crops.

Based on Clements et al. (2011).

Box 6.4. Case study: the EC-ASEAN Cogen Programme

A long-term agreement was negotiated between the European Union (EU) and the Association of Southeast Asian Nations (ASEAN) dating back to 1980 with the aim of increasing economic cooperation between these regions. Within this overall framework, the EU–ASEAN Cogen Programme was conducted from 1991 to 2004, with the purpose of enhancing the adoption and diffusion of proven biomass cogeneration technologies from Europe into ASEAN countries. As such, the programme provides an appropriate and successful example of an international cooperative initiative with the objective of continuing to increase the adoption of low-carbon technologies in the energy sectors of certain developing countries.

The objective of the EU–ASEAN Cogen Programme was to develop national planning capacities to adopt similar initiatives through the provision of technical assistance to relevant institutions in the process of implementing the programme. It also aimed at facilitating and providing business opportunities for private companies in both regions to engage in technology transfer activities. The programme focused particularly on the implementation of cogeneration technologies in the ASEAN wood and agro-industries, utilizing biomass residues from these industries in order to replace fossil fuels in their energy-consuming processes.

The first phase of the programme (1991–1994) was an identification phase for what was to become Cogen II. It aimed to increase awareness of EU technologies in the ASEAN market and providing information to EU suppliers of the opportunities in ASEAN. The first phase, however, also succeeded in implementing seven demonstration projects.

The second phase (1995–1998) focused on the completion of sixteen full-scale demonstration projects promoting further reference projects. The Cogen coordinating team worked as a business facilitator and thereby laid the basis for an accelerated dissemination of biomass cogeneration technologies in Cogen III through already established company relations.

The purpose of Cogen III (2002–2004) was to secure further deployment and demonstrate the ability to replicate such initiatives in ASEAN. Eight additional projects were implemented, most with a higher capacity than the earlier projects. The training and capacity-building of representatives from private companies and government agencies was a central aspect. To this end, a number of seminars, conferences, matchmaking events, site visits and individual consultations were provided by the Cogen team.

The proposal for programs should also include considerations about the timing of the specific measures under consideration, since the effectiveness of the measures to remove barriers to the diffusion of a technology will depend greatly on whether the technology in question is at the early stage or close to broad-scale market diffusion, or somewhere in between (see Figure 2.3). Whereas in the latter case the supportive instruments should only provide a small push to promote the technology, the measures relevant for early-stage technologies require support for niche experiments and protection against mainstream market selection pressures.

In many cases, in addition to combining different measures into a comprehensive program, it the creation of synergies by including more than one technology in a technology diffusion programme should be considered. To give an example, in a situation where an adaptation technology seeks to accommodate storm risks in a coastal area by building storm shelters, the storm shelters are of little use if the early warning system and communication infrastructure do not exist. In such a case, the technology (storm shelters) is contingent on the technology (early warning system) and on the communication infrastructure. The synergies between the storm shelters and the early warning system and communication infrastructure would therefore contribute significantly to diffusing storm shelters.

6.3 Assessing measures and sets of measures to be included in the Technology Action Plan

At the end of the assessment and grouping process, several competing sets of measures may have been identified, each of them leading to a similar outcome, but with different costs and benefits.

In order to prepare an optimum selection of measures for policy-makers, they should each be assessed in terms of their impacts and their costs. This is a three-step exercise establishing:

1) the effect of each measure and the combination of measures (program)
2) the societal benefit of the programme
3) the cost of the measures included in the program

Effect of the measures

The effect of a measure is the difference between the projected number of systems, installations or equipment being diffused given the measure applied and the projected numbers of systems under a business as usual scenario (baseline). Estimating the effects of individual measures and a combination of measures is usually the most difficult part. For each technology, this requires answering questions such as:

- What is the effect of a subsidy on investment, and how does the effect depend on the size of the subsidy?
- What is the effect of a new low-cost financing scheme, and how does the effect depend on the interest rate?
- What is the effect of a tax exemption?
- What is the effect of an awareness campaign, and how does the effect depend on the size and cost of the campaign?
- What is the effect of a supported networking initiative among equipment producers and suppliers?

To estimate the effect of various economic incentives on market technologies, it is necessary to go back to the barrier analysis (Chapter 4) and use the results of the economic assessment applied in the barrier analysis to assess the level of economic incentives needed to make the technology economically competitive compared to the incumbent technology. However, it is a challenge to estimate how much cheaper a specific technology needs to be to create an increased market demand for the technology (price elasticity).

Societal benefits of measures

When the effects in terms of the increased diffusion of a technology compared to the baseline is established, it is possible to calculate the societal benefits (impacts) of the increased diffusion of the technology, such as the environmental benefits, CO_2 reductions, resource use, employment, fiscal balance, trade balance and other impacts.

Costs of measures

Finally the cost of each measure should be estimated. The cost of a subsidy scheme, a tax exemption scheme or a financing scheme is mainly dependent on the number of installations diffused, and can be calculated by estimating the subsidy element per unit sold. The cost of information campaigns, test centres and institutional support is mainly independent of the numbers of installations diffused and needs to be estimated by evaluating the costs of similar interventions in other sectors.

Example of a cost-benefit analysis of a PV roof-top programme

The cost-benefit analysis of a set of measures (a programme) can be conducted at various levels. Figure 6.2 illustrates the elements in a simple cost-benefit analysis for a roof-top programme for schools and institutions in a fictional country. All figures are for illustrative purposes only.

The example is based on a 4 kW PV roof-top installation at a cost of 7000 USD, including inverter. Projected annual electricity production is 6000 kWh. Economic calculations indicate that existing demand could be strongly increased by introducing a five-year subsidy scheme, with an initial subsidy of 30% being gradually reduced to 10% over five years. Thereafter economies of scale and competition are expected to reduce the costs to a level at which a subsidy is no longer needed. A test centre is established to ensure that only certified panels are subsidized, and a training programme is set up to train technicians in installation and maintenance. The programme will include an awareness programme providing information about the economic benefits to institutions of investing in solar PV, taking into account the subsidy scheme and ensuring quality products. The effect of the programme is estimated to be an increase in systems sold in the first year of 1000 systems. Ten years after programme starts, its annual impact is expected to be 21,000 extra systems sold per year. The direct benefits of the programme is a net employment of 9900 person years in the first ten years and a net CO_2 reduction of 5940 tonnes over the lifetime (twenty years) of the extra systems installed in the first ten years.

The cost of the subsidy is calculated as (systems sold x subsidy per unit). The costs of a test centre, an awareness campaign and technical training are based on assumptions from similar centres, campaigns and training programs. The awareness campaign will be the most expensive in the first year, whereas the technical training will depend on the need for technicians, which will peak in Year 3. The costs of technical training and the test centre will continue for the whole period, while subsidy and awareness campaigns will be phased out after five years. The total programme cost (NPV) over a period of ten years is 86 million USD.

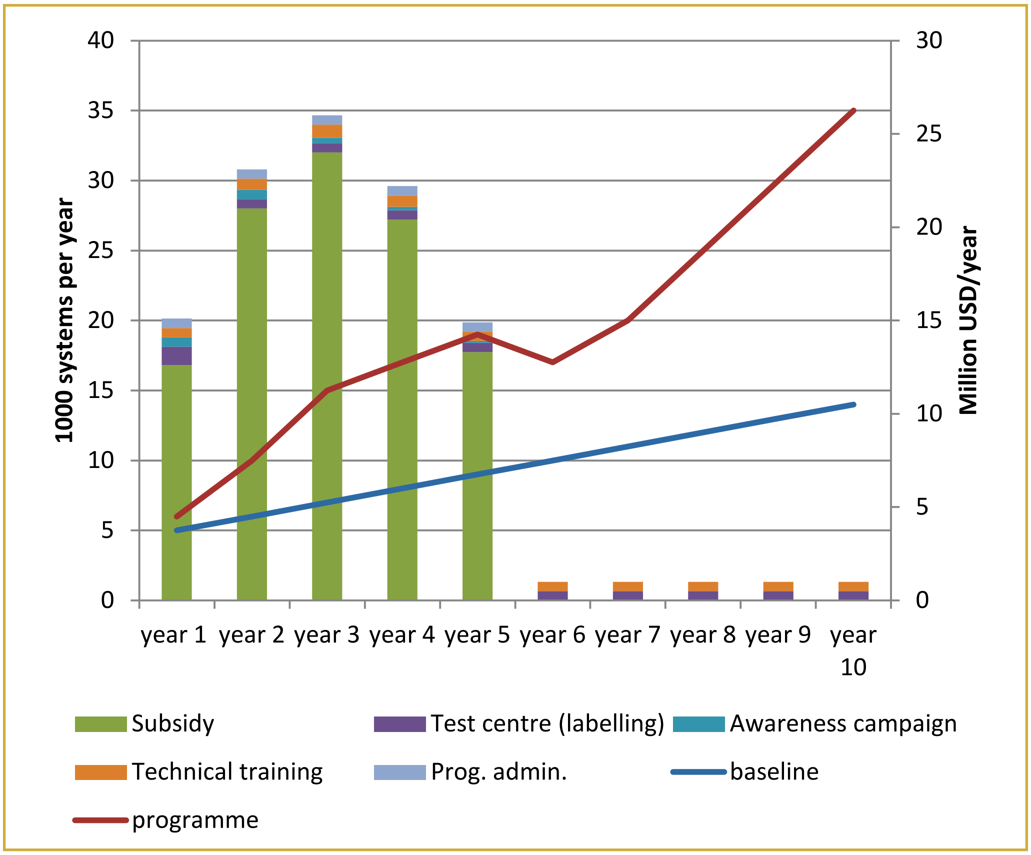
Comparing the costs and benefits for one parameter at a time leads to a CO_2 emissions cost of 14 USD/tonne and a cost of employment of 9900 USD/person year.

Figure 6.2. Fictional example of a cost-benefit analysis for a PV roof-top programme

Text	Unit	Total 10 years	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10
Impact												
Installations/year in baseline	(1000)	95	5	6	7	8	9	10	11	12	13	14
Installations (programme)	(1000)	194	6	10	15	17	19	17	20	25	30	35
Impact - installations/year	(1000)	99	1	4	8	9	10	7	9	13	17	21
Programme costs												
Subsidty per unit	USD		2100	2100	1600	1200	700	0	0	0	0	0
Subsidy	M USD	91.3	12.6	21	24	20.4	13.3	0	0	0	0	0
Test centre (labelling)	M USD	5.5	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Awareness campaign	M USD	1.6	0.5	0.5	0.3	0.2	0.1	0	0	0	0	0
Technical training	M USD	5.4	0.5	0.6	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Prog. admin.	M USD	2.5	0.5	0.5	0.5	0.5	0.5	0	0	0	0	0
Total programme cost (NPV)	M USD	86.0	15.1	23.1	26.0	22.2	14.9	1.0	1.0	1.0	1.0	1.0
Average cost per extra PV system	USD	869	15,100	5,775	3,250	2,467	1,490	143	111	77	59	48
Benefits												
Employment benefits (persons)	persons	9,900	100	400	800	900	1,000	700	900	1,300	1,700	2,100
CO2 reduction total	1000 T	5,940	60	240	480	540	600	420	540	780	1,020	1,260

Cost vs. benefits		
CO2 reduction	14	USD/tons CO2
Employment benefits	8686	USD/workplace/year

Figure 6.3. Graphical presentation of costs and effects in terms of systems sold



In this example, another set of measures might be able to reach the same goal of 35,000 systems being sold after ten years. For example, a financing scheme in combination with an import tax exemption could have been introduced instead of the subsidy, or the training part could be omitted. Also certain types of new public buildings could be obliged to install solar PV when being built. It is therefore recommended to conduct a cost-benefit analysis for at least two different sets of measures to feed into the political process.

The final choice of one set of measures over another is a political question. The proposed sets of measures will therefore have to be discussed, negotiated and agreed upon by relevant stakeholders at the country level so as to be consistent with domestic objectives, and finally to be discussed at the highest level in the ministries involved before selecting the final set of measures to be presented in the Technology Action Plan (TAP). TAPs will also include a detailed plan of action to implement the proposed policy measures and to estimate the need for external assistance to cover additional implementation costs. The plan of action could follow a programmatic approach comprising information about responsibilities and the specific targets and milestones to be achieved in implementing the TAP.

6.4 Summary

The present chapter has described how measures to overcome barriers are identified and combined into sets of measures forming programmes. Examples of such sets of combined measures for various technologies have been presented, and it has been emphasised that different sets of measures should be assessed in terms of the costs and benefits for society as input to prioritization at the political level, before a final set of measures is included in the TAP.

Photo credit: Knut-Erik Helle

7. Overcoming barriers: a brief summary

This guidebook has addressed the process of overcoming barriers to the transfer and diffusion of technologies. Although there is no pre-determined answer to the problem of enhancing technology transfer and diffusion, the present chapter summarizes some general recommendations on how the opportunities for successful technology transfer and diffusion may be enhanced by a systematic and informed approach to overcoming the barriers.

1. For some technologies the challenges may be immense, conceived as next to impossible to overcome. Thus for the purpose of gradually increasing the learning of how to facilitate the actual transfer and diffusion of technologies, it is recommended that the TNA Team begins applying the processes described in this guidebook by focusing on those high-priority technologies that only need modest government intervention to be successfully transferred and diffused, in order to achieve positive experience with the entire process and to avoid frustration from aborted attempts.[7]

2. It is considered appropriate to consider technologies as being placed on a continuum from pure market to non-market conditions, as technologies in both market-goods and non-market goods categories are likely to face similar barriers, and the measures to overcome barriers within these categories are also likely to be similar. The relative scope of governments and donors, and the role of market actors in influencing the transfer and diffusion of technologies changes along the continuum from pure market to non-market conditions.

3. The early stage of the transfer and diffusion of technologies typically occurs through the development of niche markets that may be scaled up over time to reach wider scale implementation. The development of such niche markets depends on the formation of actor networks, conducive learning process and common expectations regarding the technology in question.

4. Barriers can be identified quickly by: i) conducting a desk study of policy papers and other pertinent documents to identify the primary reasons why the technology is not currently in widespread use; ii) supplementing this with expert and stakeholder interviews (either directly or by using questionnaires); and iii) conducting a workshop with key stakeholders (Chapter 3).

5. The next step is to analyse the barriers that have been identified. This can begin by ranking them according to their significance and/or classifying them into a hierarchy of categories.

6. For a technology that is diffused through a market chain, it is suggested that an analytical tool be used to understand properly the market system prior to the analysis of the barriers that are hindering the introduction of the technology into the local market. Financial assessments, the value chain perspective, including the market-mapping technique, and the technological innovation system perspective may be used for both consumer goods and capital goods.

7. While thorough economic assessments are also relevant for non-market technologies, these should focus on assessing the broader social

7 If, for example, a government wishes to promote the diffusion of solar photovoltaic technologies for electricity generation, this will be easier for off-grid solar home systems than grid-connected systems, since the latter may be less feasible economically and also encounter extra challenges in elaborating grid-connection rules and a tariff system.

and environmental impacts, which can provide a detailed understanding of the societal feasibility of specific technologies.

8. The transfer of technologies in the 'publicly provided goods' category may seem simpler than for 'consumer goods' and 'capital goods', mainly because governments have a direct influence over the transfer and diffusion of most publicly provided goods, but only indirect influence over the transfer and diffusion of consumer goods and capital goods, which are market-based (section 5.2). For other non-market goods, it is of particular importance to take adequate account of the technology's recipients (section 5.3).

9. In order to prepare an optimum selection of measures by policy-makers, they should be assessed, that is, their potential benefits should be compared with their potential costs (section 6.3). For policy-makers it is often most important to have a socio-economic assessment, while for the owners and users of the technology a financial assessment will be more relevant. If the result of an assessment shows that it is not feasible or otherwise acceptable to transfer and diffuse a particular technology, it may be necessary to review the identification and prioritisation of technologies and go through the subsequent steps again.

10. In order to achieve a significant impact on the transfer and diffusion of a specific technology, it is necessary to apply a relatively broad set of complementary measures to address the barriers at various levels. This means that measures should be considered from most of the categories listed under identification and grouped into sets of complementary measures.

11. At the end of the assessment and grouping process, several competing sets of measures may have been identified, each of them leading to the same outcome, but with different costs and impacts. The final choice of one set of measures in favour of another is a political question which needs to be discussed at the highest level in the ministries and governmental agencies involved before selecting the final set of measures to be presented in the Technology Action Plan.

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ANNEXES

Annex A. Root Cause Analysis and Logical Problem Analysis

1.1 Root cause analysis

Root cause analysis is a method of reaching a deeper understanding of a problem. By directing corrective measures at the root causes, it is commonly believed that the likelihood of problems recurring will be minimized. However, it is recognized that the complete prevention of recurrence by a single intervention is not always possible. Basically, root cause analysis asks why a problem occurs and continues to ask until the fundamental problem is reached. Often the root problem is also an opportunity, as it also contains information on how to eliminate or reduce it.

1.2 Logical problem analysis

Logical Problem Analysis (LPA) is another tool for analysing causal relations. It is a discussion and analysis technique, which enables a group of stakeholders to approach and delimit a problem area. LPA is a standard systematic design method used by a large number of donors. Since this method is also generally well known among key stakeholders in most developing countries, it facilitates critical assessment both within the stakeholder community and subsequently by potential donors. LPA is part of the Logical Framework Approach or LFA (Norad, 1999; AusAid, 2005). The main aim of the LPA is to arrange observed or alleged problems into a hierarchy of causes and effects as a basis for preparing a concrete and realistic action plan. Each problem is linked to causes and effects, with direct causes below and direct effects above, so that multi-level cause-and-effect paths are created to form a 'tree' known as the problem tree or the causal factor tree.

Figures A.1 and A.2 show simple problem trees. All problems are arranged around a starter problem, that is, a problem considered by the group of stakeholders to be at the heart of the problem area. The starter problem is often a very generic or overriding problem and is usually the first problem that comes to mind when asking the fundamental question, as in Figure A.1: Why do we have so few solar photovoltaic (PV) systems in our country?

The problem tree should include all the barriers identified by the screening process. In the simplified example above, a high import duty is a barrier to imported products and a means to protect local products. The example thus illustrates that a problem for some stakeholders may be a solution for others. Therefore, it is often useful to attach notes to the problem tree to clarify such ambiguities. Also, this problem tree may be expanded to include separate causal streams for imported and local products.

All the identified problems are ordered in a hierarchy of cause-effect relations (strings), with the starter problem in the centre, the direct causes below it and the direct effects above. Each new problem will be linked to causes and effects respectively, so that multi-level cause-effect paths are created to form the problem tree.

The problems situated at the bottom of the tree are called root problems or root barriers. The removal of a root barrier may delete or reduce effect barriers, although not necessarily automatically. For example, removal of the import duty will reduce the barrier of 'high up-front costs', which may or may not be sufficient to make PV systems financially viable in some market segments.

Removal of the 'import duty' plus an essentially lower interest rate should lower the up-front costs, making PV systems financially viable in at least one of the two market segments included in the tree (water pumps and schools). If this is not the case, the tree needs be re-designed, since it should only include barriers which can be overcome.

The major advantages of the LPA are that it:

- ensures that fundamental questions are asked and weaknesses analysed
- brings together in one place all the key elements of a problem
- guides systematic and logical analysis of the inter-related key elements
- highlights linkages between problem elements and external factors

Bearing these advantages in mind as key objectives of the exercise, one should not exaggerate the fine-tuning of details in the problem tree.

1.3 From problems to solutions in Logical Problem Analysis

In cases where Logical Problem Analysis has been used as a tool in the barrier analysis, this tool is also essential in the identification of measures. In practice this is done by reformulating all the problems as positive statements about a future situation in which the problems are solved: for example, the 'pollution of X water source' becomes 'clean X water source', thus becoming an objective. At the same time, the cause-effect relations of the problem tree are converted into measure-result relations.

Figures A.3 and A.4 show a reformulation of the case problem tree into objective trees. The objective tree is a logically organized presentation of objectives. In principle, by implementing

Figure A.1. Simplified example of a problem tree: solar photovoltaic (PV) systems.

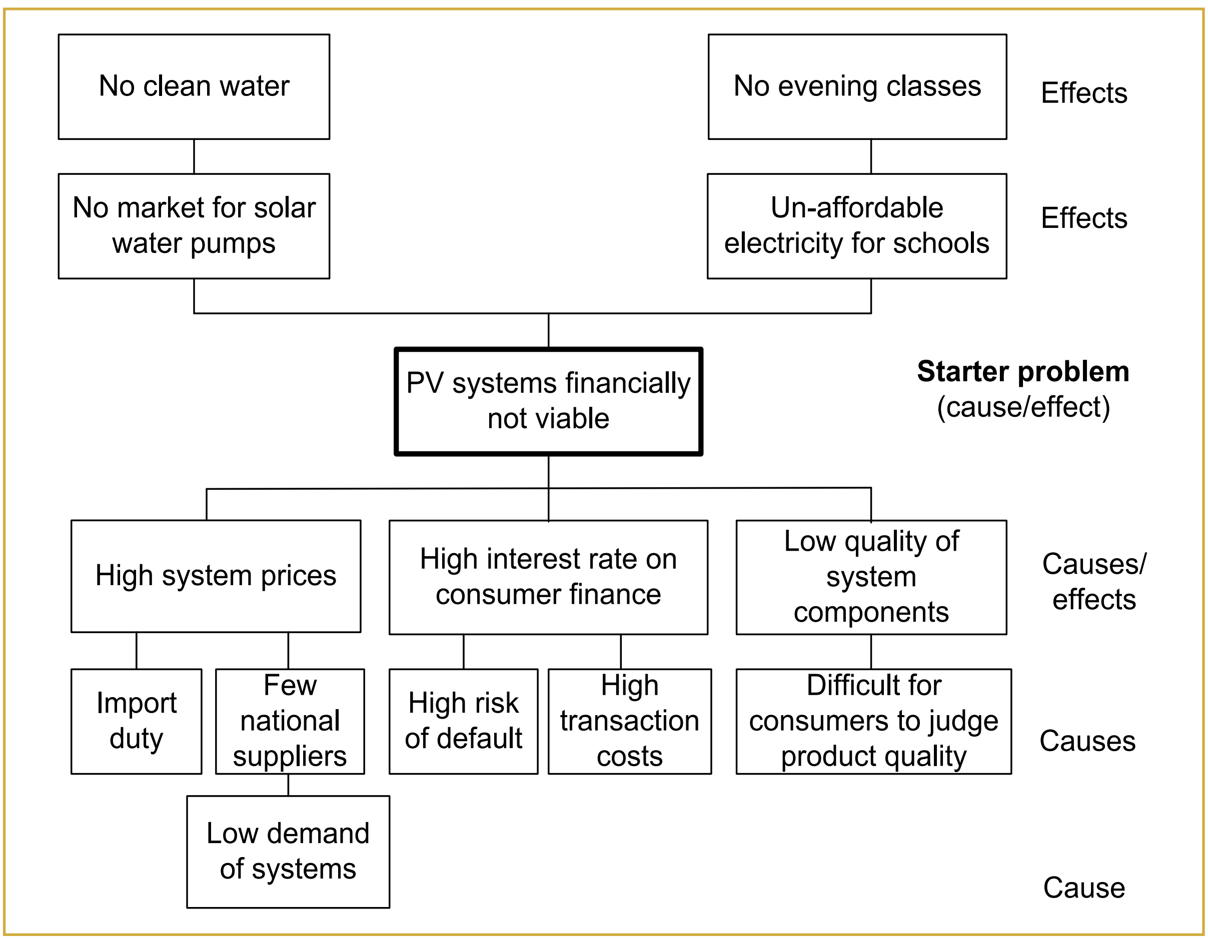
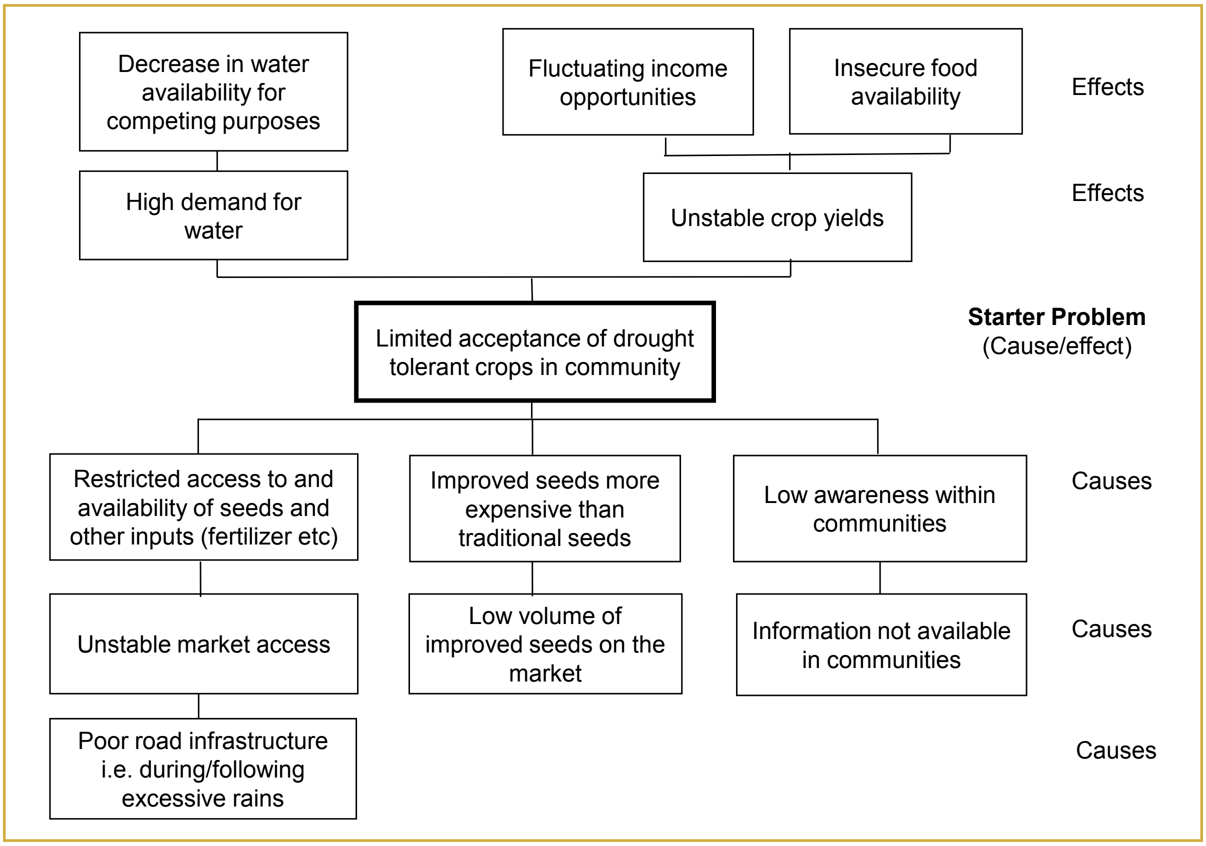


Figure A.2 Simplified example of a problem tree: drought-resistant crops



measures to achieve the objectives at the root of the tree, all the objectives above in the tree should automatically be achieved. However, reality is often more complex than that.

The objective tree is not a reflection of the 'real world', as is the problem tree, but rather an outline of what may be done to solve the problems. Once the objective tree has been established, its measure-result strings can be seen as different approaches or strategies. One such string (see Figure A.1) is:

Acceptable interest rate → Reasonable up-front costs → PV systems financially viable → Affordable electricity for schools → Evening classes possible. Another one is:

Pool of local consultants → Affordable feasibility studies → Low transaction costs → PV systems financially viable → Solar water pumps installed → Clean water for more people.

By overlaying (blacking-out) the strings to reveal one string at a time, each potential strategy can be reviewed, and its operational potentials can be discussed in relation to the interests and ambitions of the stakeholders and the available resources. Against this background, the most feasible strategy or strategies can be selected. This implies that it is not necessary to remove or reduce all the essential barriers. In the example, PV systems may become feasible for water pumping by lowering the transaction costs, although the market for PV water pumping will be further increased by also adding appropriate financial incentives.

It is important to include all objectives (i.e. address all the equivalent barriers) in a given measure-result string, and if it turns out that just one essential barrier in a string cannot be overcome, then that string is not feasible. However, this does not mean that all the activities needed to remove the barriers are needed for successful transfer and diffusion to occur, as there may be other feasible strings.

Figure A.3. Example of an objective tree, a reformulation of the problem tree in Figure A.1.

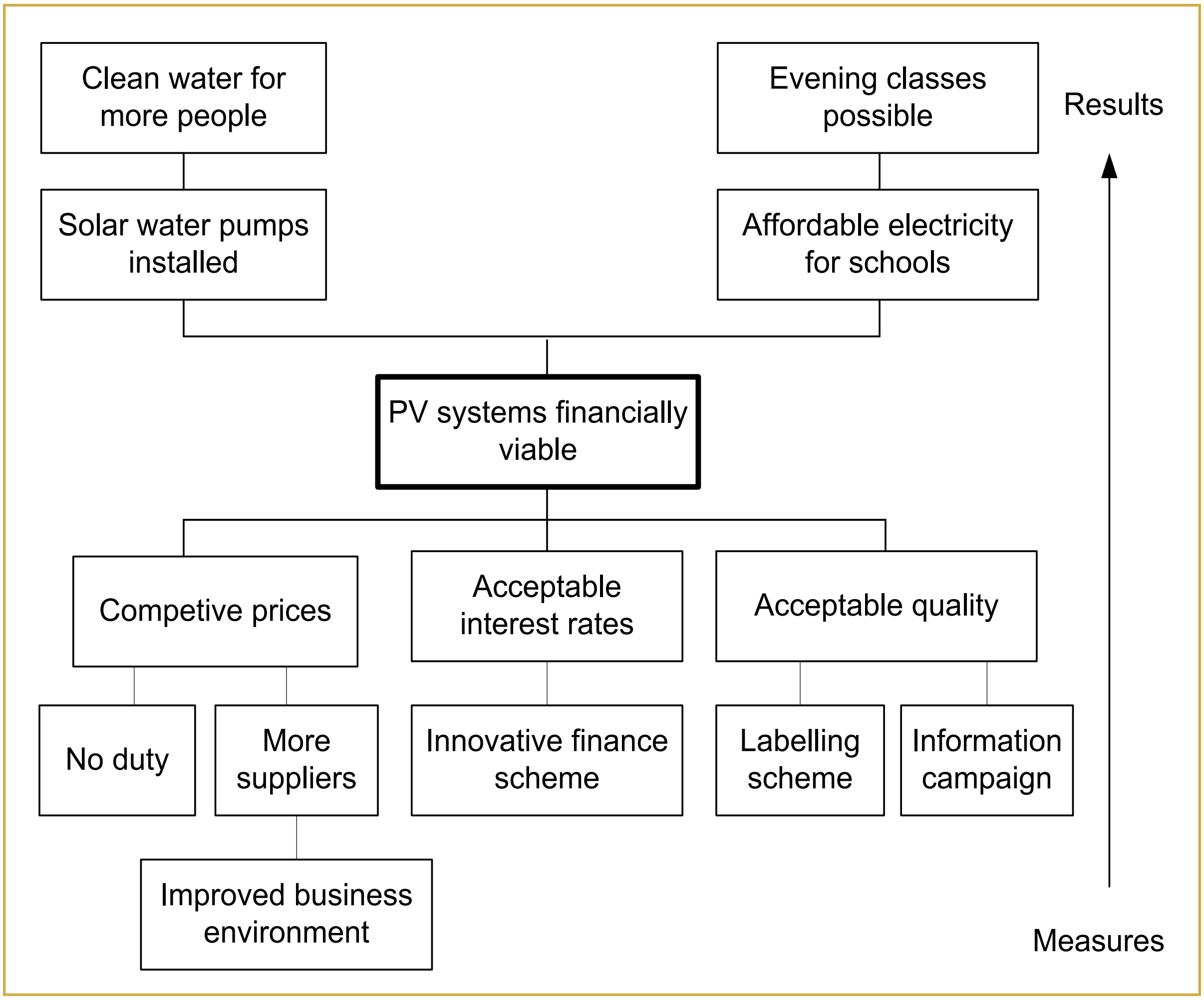
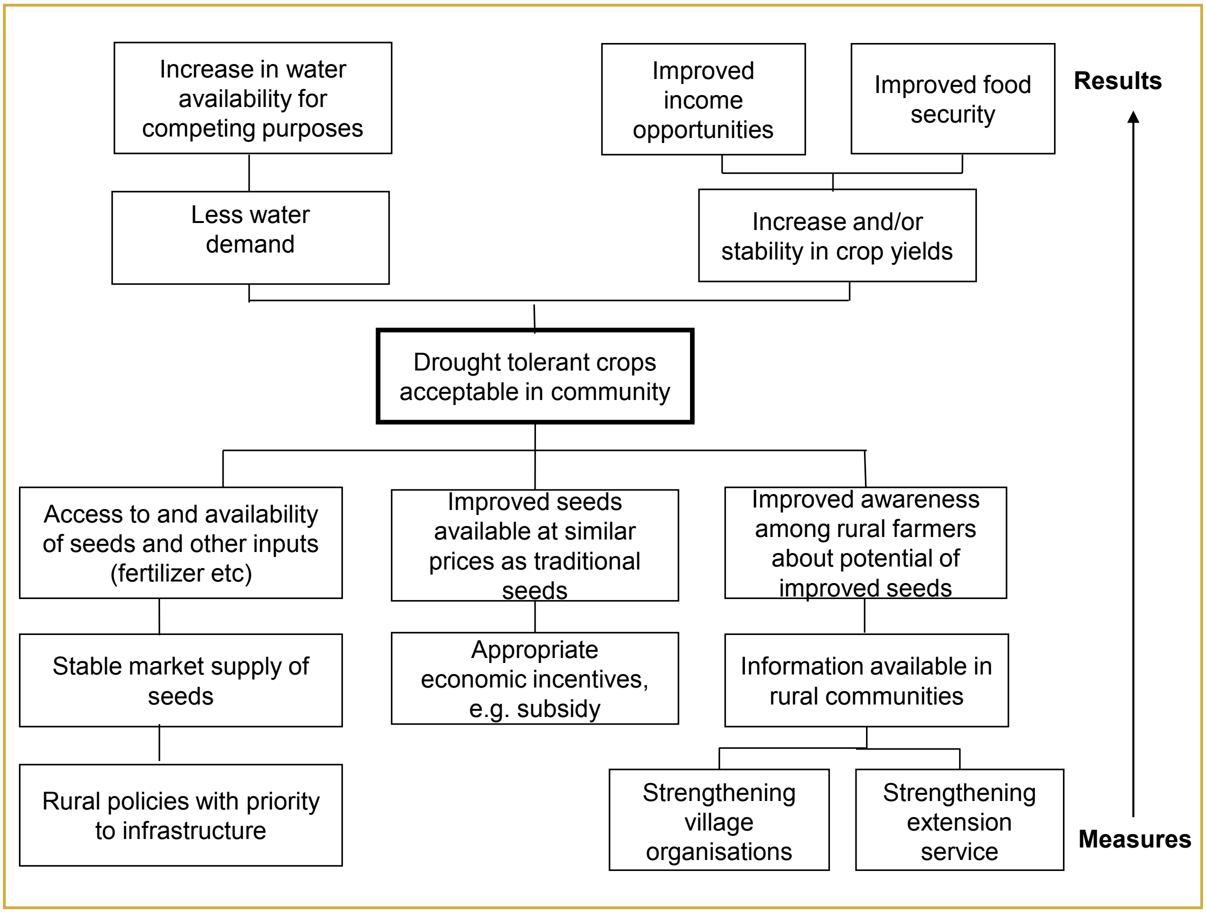


Figure A.4: Example of objective tree for an adaptation technology, a reformulation of the problem tree in Figure A.2



To ensure a transparent selection of strategies, relevant selection criteria must be established. The criteria will vary between different situations, but may be grouped around economic, social and environmental impacts.

Annex B.
The market-mapping process

Overall, the market-mapping exercise can take place in a three-stage process, including:

a. the creation of a preliminary market map
b. a participatory process involving the market players
c. an action phase resulting from the formation of a functioning network of market actors based on the relationships formed and the trust engendered.

Experience of using the market mapping approach is still limited. However, the recommended reference documents (cf. the text box) give examples, based on actual experience, of the operational challenges and solutions. A major challenge is bringing together disparate, competing, mutually suspicious and demanding business people, and motivating them to work for a common goal. Consultants with limited facilitation experience could therefore benefit from teaming up with a skilled facilitator in this part of the process.

1.4 Preliminary market map

A preliminary market map can be helpful as the basis for further discussions, in particular to identify key stakeholders and their interrelations. It may be produced by a facilitating agency such as the TNA consultant using existing literature and information gathered from key informants. If there is a shortage of resources or time, the preliminary market map may be used as a final map, that is, as an alternative to the map produced by the participatory process described below. However, this will, of course, imply a significant loss of the important benefits (see below) of using the participatory approach.

When a preliminary map is produced as a preparatory step to the participatory approach, it is recommended that the map is not shown to the stakeholders, as it may act to trap the participants in a particular model that differs from their own perceptions of the system.

1.5 Participatory market mapping

The participatory market chain approach (PMCA) can facilitate the collaboration that is necessary to improve linkages and efficiencies within the market chain, to lobby effectively on business environment issues and to coordinate activities where producers are numerous but small-scale.

The participatory process requires the market players to:

1. identify tangible incentives to engage busy and sceptical actors in the exercise;
2. form market opportunity groups of representatives through whom a large number of market actors can be represented; and
3. conduct a PMCA to create a market map, while also facilitating efficiency, improving coordination, stimulating innovation and bolstering trust within the market chain.

Participatory market mapping is one of the elements of the participatory approach which this guidebook generally recommends. Specifically for participatory market mapping, Albu and Griffith (2006) have presented some lessons learned and some rules of thumb, which include the following:

- Few entrepreneurs, least of all buyers, are attracted by the idea of attending a ‘development project’ meeting. They may suspect the facilitator’s motives, e.g. fearing pressure to give their suppliers a better price.

Tangible issues or intervention proposals (so-called hooks) that might attract the initial interest of wary actors are therefore absolutely necessary. The preliminary market map can help facilitators identify very specific issues of mutual interest and turn them into proposals that will draw diverse actors into the process.

- Market opportunity groups offer a way to inform and build the confidence of producers, so empowering them to participate on a more equitable basis in both the PMCA workshops and any subsequent negotiated agreements.
- The convening of 'interest forums' has been an important tactic in engaging stakeholders and institutions, which, although outside the market chain, still have an important stake or influence, e.g. service-providers, policy-makers and other moulders of the business environment.
- PMCA workshops are the key events in operationalizing the market map, since they bring together diverse market-chain actors to stimulate interest, bolster trust and facilitate collaboration in relation to linkages, services or the business environment. Typically the workshop involves participants in reflecting and building on the preliminary mapping in a joint effort to establish a common framework of understanding for action.
- Moving from analysis to action: the relationships, knowledge and trust generated are used to effect changes in the business environment and access to services.

Participatory market mapping involves:

1. the identification of market stakeholders;
2. the identification of incentives for engagement by these stakeholders in the technology diffusion process; and
3. meetings with stakeholders to generate a detailed map of the system in which they operate in order to identify opportunities to increase the efficiency of the operation of the market and opportunities for development and co-operation.

An essential outcome of the overall process is the possible creation of a network among the market actors themselves to improve the ground for introducing or generating innovation in products, processes and market access. Thus, market mapping can be an end in itself in bringing market actors together to build trust and in leading to further collaborations outside the purpose of the exercise.

1.6 Identifying and analysing stakeholders

Stakeholders are individuals, groups, institutions and companies that have a stake in something. Stakeholders have an interest in a particular decision, either as individuals or as representatives of a group. This includes those who influence a decision, or can influence it, as well as those affected by it. Stakeholders may thus work for or against the planned changes in a system during all its main phases. It is therefore suggested that a stakeholder analysis is elaborated during the initial phase of the technology transfer process, and that the analysis is reviewed and amended if necessary during consecutive phases.

It is recommended that the stakeholder analysis be conducted by the consultant contracted by the TNA Committee and be presented to the Committee for comments before starting the market mapping process. This is to ensure that an optimum composition of stakeholders is invited to participate in the market mapping exercise. A basic stakeholder analysis includes four main elements:

1. **Identify and list all persons, groups, institutions and companies affected by the problem area or environment.** The 4R's approach (Relationships, Rights, Responsibilities and Revenues) is valuable in helping identify and categorize stakeholders.[1] It may be supplemented with yet another R for risks, including voluntary and involuntary

1 The 4 R's approach developed by IIED (International Institute for Environment and Development). http://www.policy-powertools.org/Tools/Understanding/docs/four_Rs_tool_english.pdf

'risk-takers' and 'risk-bearers', as suggested by the World Bank.[2]

IPCC (2000) and ENTTRANS (2007) recognise a diversity of stakeholders in the process and identify the following key actors:

- technology developers, including research organisations
- technology owners and suppliers
- product buyers and users
- financiers and donors
- market intermediaries, including consultants, NGOs, community groups and trade organisations
- information providers
- government agencies
- educational institutions
- international organisations

Many stakeholders have probably been identified during the preceding technology prioritisation process. However, in dealing with specific market chains for particular technologies, some stakeholder representatives will need to be replaced with stakeholders operating directly in the market chain. For example, a representative from a manufacturers' association should be replaced by representatives from actual traders and manufacturers of solar water heaters if the market chain concerned revolves around solar water heaters. Also, some stakeholders may disturb the actual market-mapping process and should therefore not be invited.

2. **Identify the main interest of each stakeholder in relation to the problem area.** The interest can be economically, politically, personally or geographically delimited. The stakeholder analysis will need to clarify the different interest groups that actively support, oppose or would be affected by the new technology, including: (i) ministries, departments and agencies; (ii) enterprises; (iii) interest groups, such as trade unions; (iv) civil-society organisations and consumer groups; (v) other sub-groups within the general population. It should show the different perspectives of each group, as well as where different perceptions may lead to failures in the required reforms. It should also cover an assessment of how key groups within institutions may affect the policy options being considered for technology diffusion.

3. **Categorize the stakeholders in clusters of related interest and name the clusters.** The linkages in the market map may be useful for this purpose. An important feature of the market map is that it maps the linkages between the stakeholders within the market chain, as well as between market chain participants and service providers. It may thus serve as an important tool to illustrate which types of stakeholder need to be engaged in technology diffusion.

4. **Analyse the significance of stakeholders.** Within each cluster, analyse the significance of stakeholders for the problem area, e.g. interests, fears, strengths, weaknesses and their influence on the problem area and/or how they may be affected by an intended intervention.

Actual and perceived imbalances of power within the market chain can impede the participatory process. Building up trust is therefore important in order to facilitate the open sharing of information and to reduce transaction costs. Albu and Griffith (2005) give valid advice on how to build such trust.

1.7 The market chain

The market chain is a central component of the market map. It maps the economic actors who actually own and transact a particular product as it moves through the market chain from primary producer to final consumer. By better understanding the contribution to the product of each actor in the

2 'Options Assessment Sourcebook', World Bank Report 264/03, July 2003.

chain, the aim is to identify inefficiencies, inequities and losses that can be remedied, or added-value that can be captured. Actors taking legal possession of (parts of) the product should be mapped as part of the market chain, whereas other actors belong to the enabling business environment or the business service providers. An example of a market chain and market chain actors is shown in Figure B1.

A clear objective of the market map approach is to help stakeholders realise mutual benefits by improving the 'systemic efficiency' of the chain. Key to this is helping stakeholders become more aware of functions and processes along the chain that are needed to satisfy more lucrative or reliable markets. Thus, an important aspect of the market mapping technique is the emphasis on the participation of stakeholders in the process of elaborating the market map.

1.8 Enabling environments for market technologies

The second component of the market map is a charting of the critical factors that shape the market-chain environment and operating conditions, but that may be amenable to change. These 'enabling business environment' factors are generated by structures and institutions that are beyond the immediate control of economic actors in the market chain.

The purpose of charting the business environment is to understand the elements that affect the entire market chain and to examine the powers and interests that are driving change. This knowledge can help determine avenues and opportunities for realistic action to improve the enabling environment through concerted lobbying, coordinated campaigns and advocacy.

The enabling business environment can be seen as a subset of the enabling environment described in section 2.3. According to Albu and Griffith (2005), the enabling business environment encompasses the following elements, which are illustrated graphically in Figure B.2:

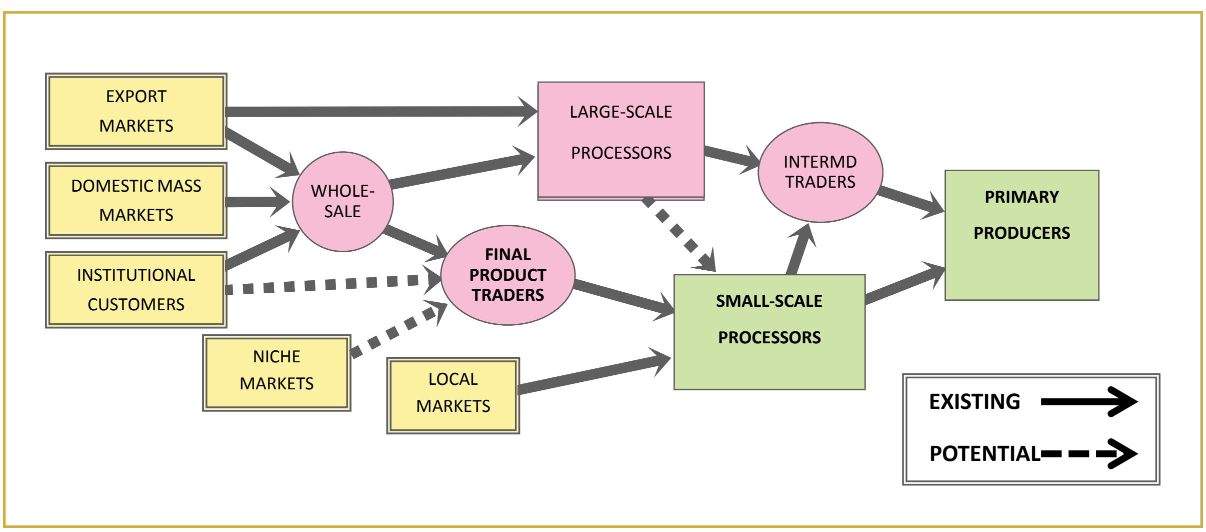
Relating to market demand:

- consumption trends (prices, volumes and quality expectations)
- taxes, subsidies and tariff regimes

Relating to transformation activities, i.e. the costs of doing business:

- infrastructure constraints and investment policies
- transport policies and licensing
- technological development
- trade regime (import/export)

Figure B.1. Market-chain actors and links (a generic schematic). Acknowledgement: Practical Action, UK.



Relating to transaction activities:

- systems of finance
- gender roles in business and finance
- registration of land and property
- legal requirements for contracts
- commercial law and practices
- business licences and regulation
- standards quality control and enforcement

For new entrepreneurs wishing to enter the market with a new technology, major barriers are often the transaction costs and the amount of time needed to obtain approvals from numerous authorities. To reduce this barrier, the government may establish a 'one-stop shop', that is, a single office where the entrepreneur can receive all necessary information and applications, as well as submit applications to the various authorities. Another, not necessarily alternative measure to reduce this barrier is to draw up an investor/project-developer handbook or website, including information on all pertinent requirements and procedures. Valid information on business environments is available at www.businessenvironment.org/dyn/be/besearch.home, run by the Donor Committee for Enterprise Development (DCED).

1.9 Identifying support services

In most effective market chains, the economic actors who form the chain are supported by inputs from other enterprises and support organisations. The third component of the market map is concerned with mapping those services that support, or could potentially support, the market chain's overall efficiency. This includes identifying particular service needs and their locations within the market chain in order to understand the opportunities for using and further developing services to improve market-chain efficiency or equity.

The range of services that can potentially add value is huge and includes the following elements, which are illustrated graphically in Figure B.3:

- input supplies
- market information
- marketing support
- financial services
- legal services (contracting)

Figure B.2. Enabling business environment related to the market chain (a generic schematic). Acknowledgement: Practical Action, UK.

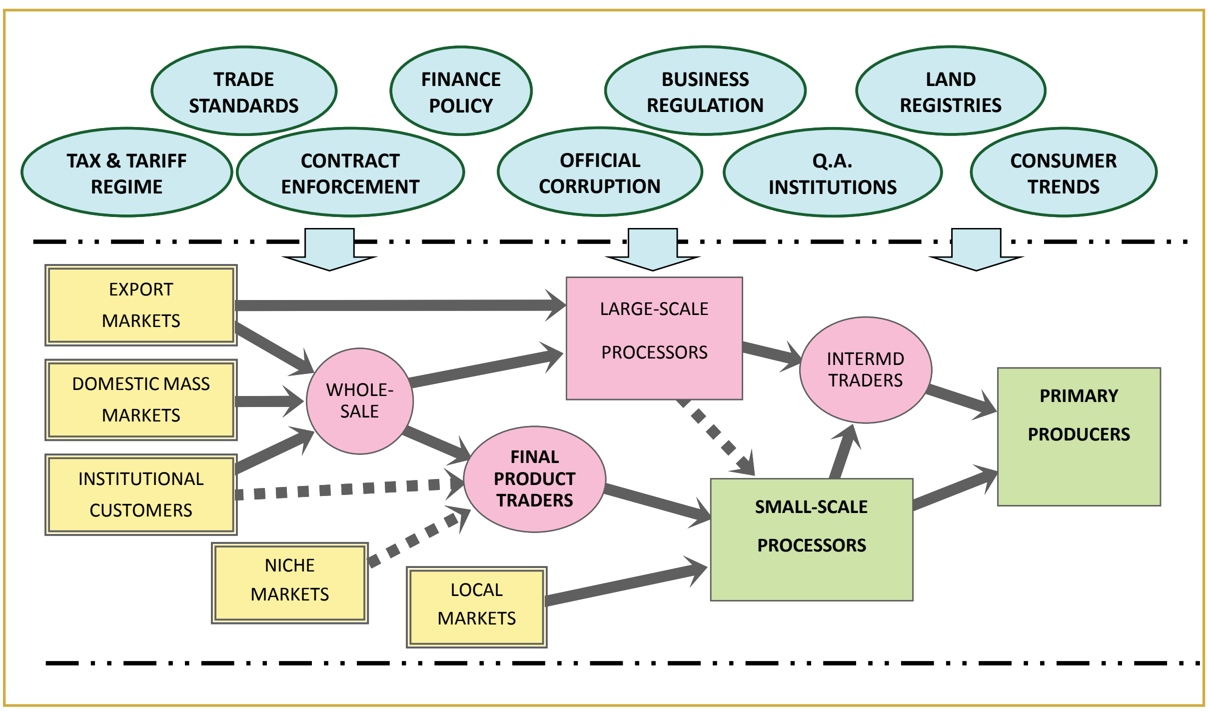
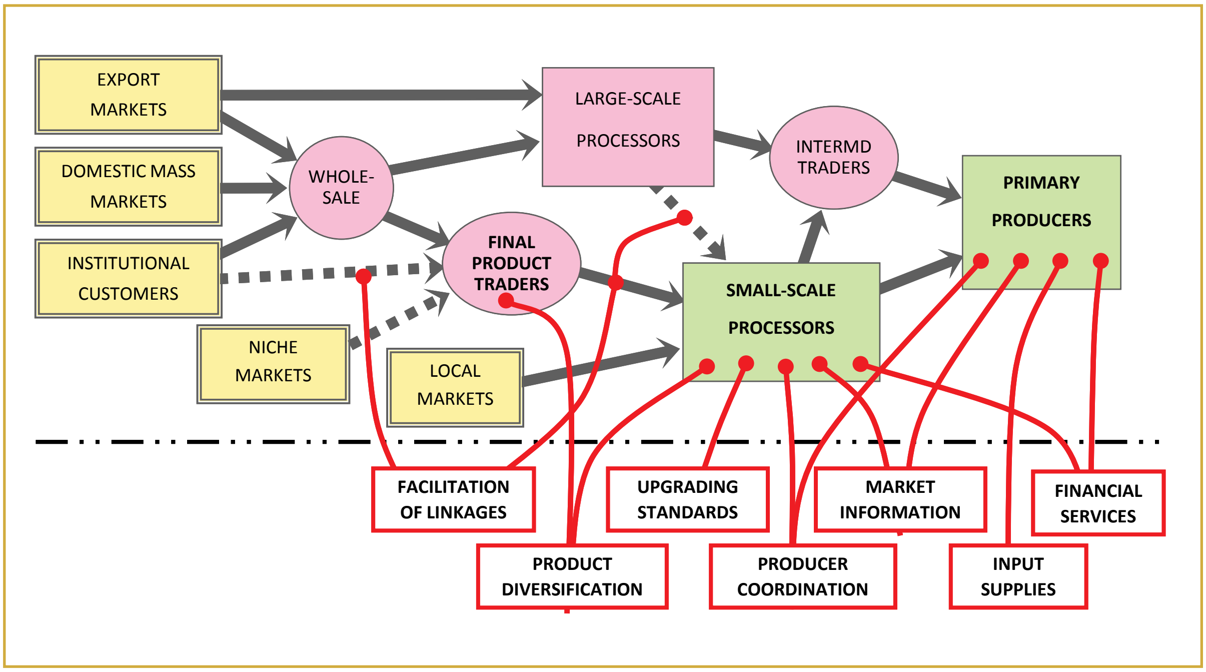


Figure B.3. Extension/business services related to the market chain (a generic schematic). Acknowledgement: Practical Action, UK.



- transport services
- engineering (support for product development and diversification)
- human skills development
- quality assurance (monitoring and accreditation)
- business advice (business-plan and bargaining support)

It is important to recognize that service options are not confined to conventional government extension services and private fee-based services. There are also embedded services, where services are incorporated within a commercial transaction for another product, for example, pest control advice offered to a contract farmer by a trader.

In practice, differentiating between the enabling business environment and the support services is not always clear cut, and different countries or groups may view them differently, so that there may be an overlap between them (cf. ENTTRANS (2007), para. 6.1.2). The most obvious overlapping topics are:

- financial services
- legal services
- professional engineering services; and
- government planning and support, including R&D, codes and standards

For the outcome of the participatory process, it is not overly important whether one function is mapped as part of the enabling business environment or the support services, so there is no need to go through lengthy discussions. It is more important that all essential stakeholders, functions and relations are mapped, and that the map does not become too complex in attempting to achieve scientific accuracy. Valid information on business development services (BDS) is available at www.bdsknowledge.org/, run by the Donor Committee for Enterprise Development (DCED).

Country teams can determine how current and planned government initiatives and donor programmes address barriers (cf. Chapter 4), and then identify possible refinements to these programmes and new initiatives that would help to address these barriers (cf. Chapter 6).

Annex C.
An example of market mapping

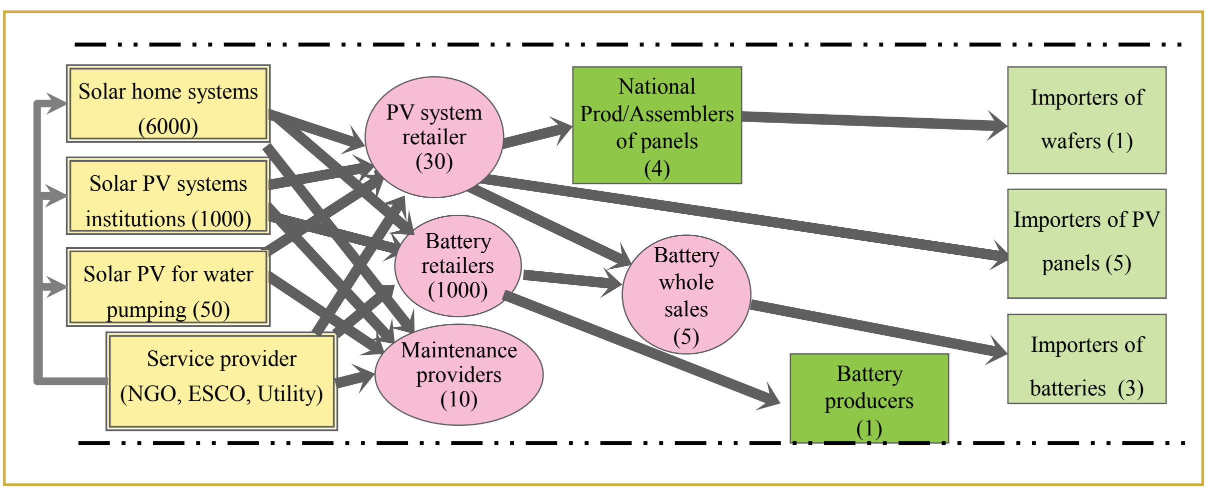
This example of the market mapping of solar PV technology has been drawn up to provide the reader with a more practical understanding of the process of market mapping. The example describes both the result and the group process in which it has been developed. It should be stressed that market mapping can be done in a number of ways, contingent on how the group and the facilitator find it most practical. The following therefore serves as an example rather than as a step–by-step manual. Likewise, the measures suggested in this example are by no means exhaustive and should be used as an inspiration rather than as a blueprint for how to design an enabling framework for the diffusion of solar PV.

Market-chain actors and links

The first step is to map the actors who directly take part in the market chain from consumer to importation or production of the product and to establish the flow of money between them. The market for small-scale PV systems is divided into three different segments: i) solar home systems for individual consumers; ii) solar PV systems for institutions such as schools, health centres and administrative buildings; and iii) solar PV systems for water pumping. Although the products are similar from a technical point of view, each market segment faces different market barriers. Further, in the case of solar PV, a substantial part of the equipment used in the three markets is currently procured by service providers such as utilities, NGOs or energy service companies (ESCOs). These companies constitute a special market segment with special access to funding, although the users may be the same as those described above. Over time it is expected that a larger share of PV systems will be sold directly to consumers, and the four market segments are therefore described separately.

The next level in the market chain comprises the retailers and wholesalers of panels, batteries and whole systems. As these intermediaries are essential in making the market function, there may be important constraints at this level, which can be

Figure C.1. Example of identified market-chain actors for solar PV



addressed. There may, for example, be only one or two actors controlling the market, or there may be a need for a nationwide retailer system. Local production or assembling of batteries and solar panels may in some cases ensure local employment and products at lower costs. In this example there are four such producers. As the production of solar cells (wafers) will normally be produced in large quantities in highly specialised factories, these will in most cases be imported and become parts of the assembled panels. Importers of wafers are shown in the box at the right, along with importers of solar PV panels and importers of batteries.

In order to understand the market structure and the level of competition in the market, it is already important at this stage to collect information on the numbers of consumers within each market segment, the number of retailers, the number of producers and the number of importers. It is possible to make part of the market actor chain more detailed. In the figure above, only imports of wafers are seen as an input to the local production or assembly of panels. In reality there is a need for imports of a number of other parts to be assembled, such as aluminium frames, wires, glass, controllers, etc. The level of market constraints for such items may also be considered by elaborating this chain in the analysis.

It should be remembered that developing the map of market-chain actors is useful in a group discussion because it leads the group through a common understanding of the market and its possible constraints. It is also useful at a later stage in helping visualise these constraints.

Enabling environment

The purpose of charting the enabling environment is to understand the elements that affect the market chain for solar PV and thus to make it possible to examine the powers and interests that drive change. The first step is to map the existing elements of the enabling framework, and the next step is to analyse whether new elements should be added and to what extent existing elements should be improved.

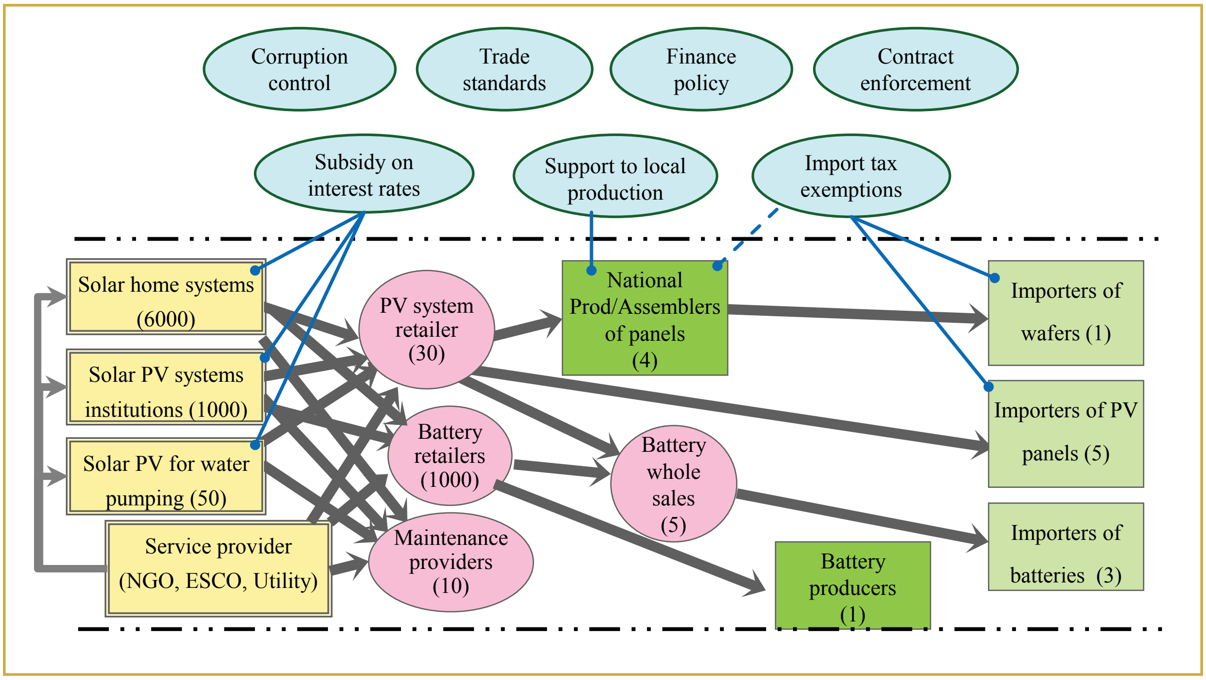
The enabling environment comprises elements of general importance for the market chain, such as the level of corruption control, the certainty of contract enforcement, the stability of financial policy and the enforcement of trading standards. Such general elements, though important, are often difficult to change. Therefore, for the purposes of the present exercise, the most important elements are identifying the existing and potential measures to improve the functionality of the market chain.

In this case, high interest rates on loans are considered to be a main barrier against selling SHS and PV systems to consumers. Programmes to reduce interest rates on loans for solar PV systems have been successful in a number of other countries, so a group member proposes to consider this here. The specific level of subsidy and the modalities need more scrutiny and depend on the structure of the financial sector, including mini- and microfinance institutions, which will be looked at when mapping financial institutions below. For now this option is indicated in the diagram by blue arrows in the market map.

On the other hand, there is already an exemption from import taxes on solar panels and wafers. One problem, however, is that the national assemblers of panels import a number of other parts for the final product, such as aluminium frames, controllers etc., which are not exempt from the 25% import tax. The assemblers therefore face ‘unjust’ competition from the imported panels, which are fully exempted from tax, and they ask for a tax exemption also for the other imported and taxed parts they use in production. Would this be a good solution, or would it, for example, be possible for the government to identify other measures to support local producers? This is indicated by the blue arrows in the figure.

Note that the mapping process should serve as a tool for brainstorming, and at this stage it is important to identify options, but not necessarily to reach a unanimous agreed conclusion.

Figure C.2. Example of identified enabling environment of importance for the PV market chain



Identifying support services

The next step is to identify 'support services' that can facilitate the market chain. These initiatives can be supported by governments and donor programs. At this stage, sources of finance are not considered. Linkages between support services and market actors are illustrated by arrows in red and yellow.

Financial services

For the time being it is difficult for private consumers and government institutions to finance the high up-front costs of SHS (Solar Home Systems) or of PV systems for institutions. In some countries, there are good examples of establishing a loan facility for solar PV installations, where local banks, in cooperation with the retailers and a donor-backed security fund, provide cheap loans for PV systems. This finance facility may also provide preferential loans for investment in local production facilities.

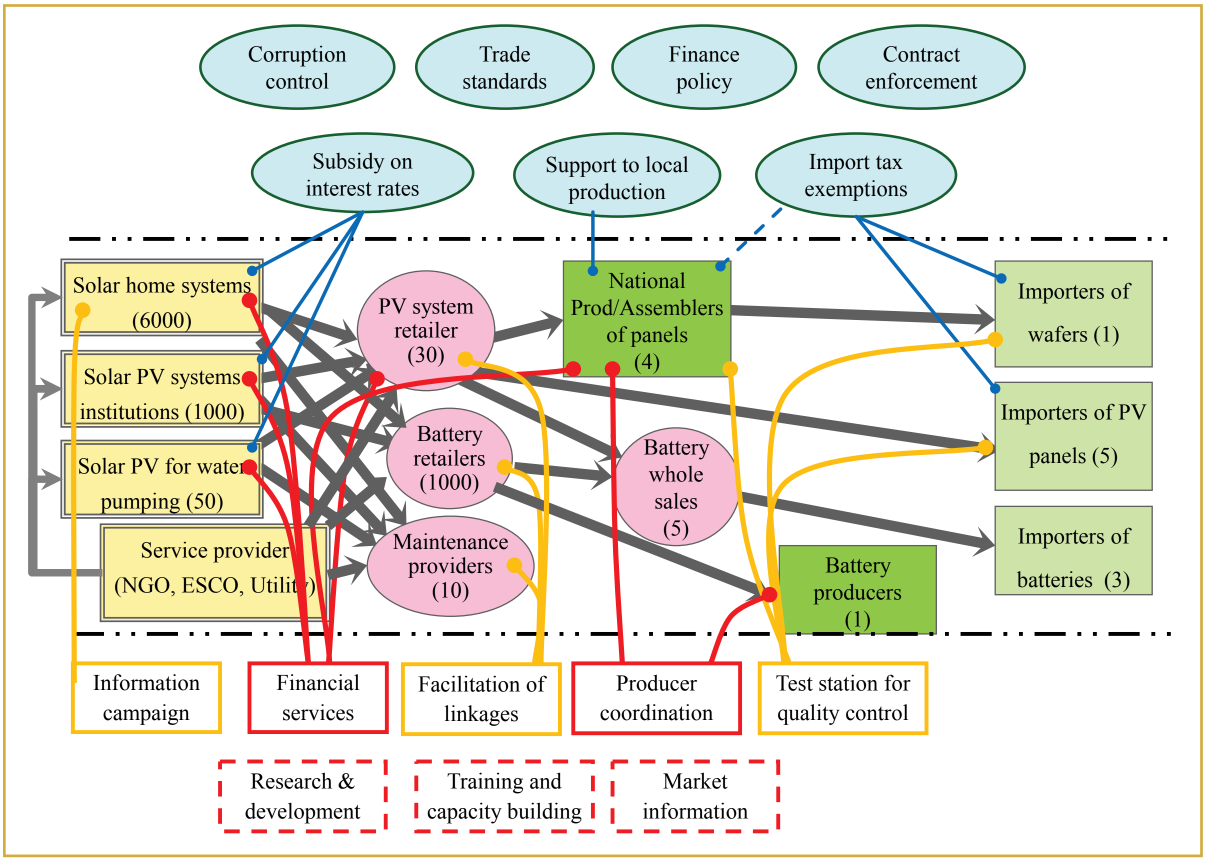
Information campaign

Lack of information for potential customers in rural areas is seen as a major barrier to current sales. It is therefore advisable to establish a general information campaign to inform rural customers about prices, services and the credit facility mentioned above.

Facilitation of linkages

A problem may arise that the retailer system for PV systems and batteries and the maintenance companies do not communicate with each other. As an example, batteries preferred for solar PV systems are not sold through the standard wholesale and retail systems for car batteries, but are imported at a much higher cost by the PV systems retailers. One measure to reduce costs may thus be to encourage or facilitate the three groups to coordinate their products and services in order to reduce costs and thus increase the market to the benefit of all.

Figure C.3. Example of full market map for the solar PV market chain



Producer coordination

Exchanges of information and learning among businesses within the same niche market have proved to be essential for the development of competitive industries. It has been noticed that existing companies in the countries are working very much in isolation. A producer representative has therefore proposed obtaining assistance to establish a producer association, with the objective of addressing the common needs faced by the producers, such as better training of engineers and skilled workers, easier import restrictions, customs facilities etc., as well as establishing cooperation between producers, for example, in negotiating contracts with suppliers of wafers or other items.

Test station for solar panels

Solar panels of poor quality are increasingly being imported into the country, and there is growing concern among all the market-chain actors present that poor quality panels may undermine the reputation of solar panels generally among consumers. To avoid this, a majority of actors proposes establishing a test station for solar panels, to be responsible for a labelling system for solar panels based on a number of parameters, such as efficiency, durability, etc. It could also set some minimum quality standards for the panels to receive a label. At the same time, the test station could serve as a training facility for the technicians and technical specialists that are needed throughout the PV market chain.

Research and development and capacity building

It was also pointed out that there is a need for support to research and development at the national level to ensure that national expertise is available to solve specific problems in the industry, as well as to ensure that engineers and technicians are trained by professionals with up-to-date knowledge on solar PV technology. If the test station mentioned above is linked to the technical university, synergies may result between the test station, research and development, and capacity-building.

Market information

It was also recognised that a general lack of knowledge exists about consumer preferences and the price elasticity of the market, for example, the size of the market contingent on the sales prices of systems. It was therefore suggested that such a study should be supported for the benefit of the whole market chain, as well as a further input to describe the need to reduce further the sales prices on PV systems by other means, such as a targeted investment subsidy for a shorter period of time, in order to push the market to a level where economies of scale over time will reduce costs.

Annex D.
Technologies for climate adaptation

Often discussions regarding the transfer of climate technologies have focused on mitigation technologies, one reason being that many professionals have only a vague idea of what adaptation technologies actually are. In the context of this guidebook, it therefore appears relevant to facilitate a clearer and more concrete understanding of adaptation technologies: what are they, and which particular features necessitate diverging approaches?

Adaptation is defined as adjustments to natural and human systems to reduce their vulnerability to actual or expected climate change effects. Various types of adaptation exist, for example, anticipatory and reactive, private and public, and autonomous and planned. Vulnerability is the degree to which a system is susceptible to, and unable to cope with, the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity.

The vulnerability and capacity of societies to adapt to climate variability and change is determined by a number of different factors, such as income levels, education, institutions, health status, knowledge, and skills and technology, to mention just a few. Consequently, most adaptation measures are carried out as part of larger sectoral or national initiatives involving, for example, planning and policy development, integrated coastal zone management, water resource management, health programmes etc. On the other hand, actions which contribute to adaptive capacity may also be unrelated to climate change concerns, for example, education and poverty reduction. Consequently, the strengthening of adaptive capacity is a precondition for the design and implementation of adaptation strategies, and technology is one among many elements that are commonly scarce in a developing country setting.

Although most initiatives and measures for adaptation to climate change involve some form of technology, adaptation issues are rarely characterized along technology lines. Also, given the blurred boundaries between adaptation and sustainable development, few technologies can be defined as technologies for adaptation per se, with the exception of genetically designed seed varieties and coastal engineering technologies.

A common practice of mitigation has been the transfer of technologies from developed to developing countries. Transfers for adaptation may not follow the same patterns. Climate adaptation is often the continuation of an ongoing process, in which the same techniques for adaptation have been used for generations (for example, building houses on stilts to cope with floods), but face barriers to their further implementation and use. Recognizing that adaptive capacity is highly heterogeneous within a society or locality, much of the current understanding of human adaptation to climate change comes from local-level studies. Such studies can establish broad lessons about the adaptive capacity of individuals and communities, lessons that feed into adaptation planning. In many cases, adaptation technologies already exist to some extent. Examples include addressing the changing climate by storing water in dams so that it can be available during drought periods, or improving seed varieties with traits to improve their tolerance to stress, salinity, drought and extremes of temperature.

The entry point for identifying, prioritizing and implementing adaptation technologies is primarily impact assessments and their inter-linkages with development priorities, where the most vulnerable sectors and regions or communities constitute the basis for adaptation technology assessments. A number of climate-risk screening tools, approaches and exercises have been developed to support efforts to mainstream climate change into development planning, including guidance on the identification, prioritization and implementation of adaptation options. A good overview of existing tools and their applications is provided in Olhoff and Schaer (2010).

A sector categorization is most commonly used when addressing technologies for adaptation, which is why it is the one chosen for the TNA guidance for adaptation. Table D.1 below provides a list of adaptation technologies for different sectors.

Table D.1 illustrates the wide range and multifaceted nature of the available options for adaptation in different sectors. It is also clear from the above that many adaptation technologies are not new and that many have been utilized for generations to cope with climate variability and improve livelihood resilience to socio-economic stresses.

In the adaptation literature, there are examples of adaptation measures which are listed as technologies. This may not be important in some circumstances, but for the approach used in the TNA project, which tries to identify measures for the diffusion of specific technologies, it creates confusion if there is not a clear distinction between measures and technologies. Building codes are seen listed as a technology, although they are a means of diffusing a technology. A building code is not a technology, but it can be one among other measures to diffuse technologies, such as storm-resistant housing, passive-cooled housing and flood-protected housing. If a building code is seen as a technology, it hinders the TNA committee in proposing other measures, such as information dissemination, capacity-building in public construction companies, change of curriculum at engineering schools or even subsidies, which may facilitate the same diffusion of specific housing technologies. Similarly, capacity-building is sometimes listed as a technology, although, as shown above, it is really a measure to diffuse a specific technology.

Other categorizations of technologies for adaptation may, however, be more appropriate in different contexts, for example, according to:

a. When in the adaptation process they are implemented; technology needs for *anticipatory adaptation* may be different from those suitable for *reactive adaptation*.[3]
b. The innovation level of the technology, including: (i) *traditional technologies*, which by definition relate to familiar methods and techniques for coping with climate variability at the community level that have been tested for generations; given their local and historical roots, it is recommended that these be taken into account as much as possible; (ii) *modern technologies*, for example, new crop hybrids and systems of drip irrigation that make better use of limited water; and (iii) *future technologies*, for example, malaria vaccine.
c. The climatic zone in question: tropical, arctic, floodplain, mountains etc.
d. The actors involved: individuals, community organizations, the private sector, local government, international donors etc.

3 Anticipatory adaptation includes measures such as crop and livelihood diversification, seasonal climate forecasting, community-based disaster risk reduction, famine early-warning systems, insurance, water storage and supplementary irrigation. Reactive or ex-post adaptation measures include emergency response, disaster recovery and migration-reactive or ex-post adaptations, for example.

Table D.1. Examples of adaptation technologies for different sectors (authors' compilation based on WTO-UNEP Climate change and trade (2009)

Sector	Adaptation technologies
Agriculture	Systematic observation and seasonal forecasting, early warning systems, crop insurance, drought-resistant crops, crop management, land management, improved water use and availability, including rainwater harvesting, leakage reduction, hydroponic farming, building shelter-belts and wind-breaks to improve the resilience of rangelands, adjustments to planting dates and crop varieties, spatially separated plots for cropping and grazing to diversify exposures,
Water resources and hydrology	Water transfer, water recycling and conservation, water harvesting, increased reservoir capacity, desalination, erection of protection dams against avalanches and increased magnitude of potential debris flows stemming from permafrost thawing, changes in livelihood practices, including changing hunt locations, diversification of hunted species, use of Global Positioning Systems (GPS) technology, encouragement of food sharing.
Coastal zones	Dykes, sea-walls, tidal barriers, detached breakwaters, dune or wetland restoration or creation, beach nourishment, indigenous options such as walls of wood, stone or coconut leaf, mangrove afforestation, early warning and evacuation systems, hazard insurance, practices such as using salt-resistant crops, improved drainage systems, desalination systems.
Health	Vector control, vaccination, impregnated bed nets, health education, greater care with water storage, using appropriate clothing, taking siestas in warm climates, using storm shelters, air conditioning, health education, early warning systems, distribution of bottled water to vulnerable people; operation of a heat information line to answer heat-related questions; availability of emergency medical service vehicles with specially trained staff and medical equipment; disease monitoring and prevention and treatment, access to health services and health alert information.
Infrastructure	Passive cooled housing, storm-resistant housing, flood-secure housing, physical barriers to protect from flooding, minimize paved surfaces and plant trees to moderate urban heat island effects, limit building developments on flood plains or potential mud-slide zones.

This guidebook provides practical and operational guidance on how to assess and overcome barriers facing the transfer and diffusion of technologies for climate change mitigation and adaptation.

The guidebook is designed to support the analysis of specific technologies, rather than pursuing a sectoral (e.g. transport) or technology group (e.g. renewable energy) approach.

Given that there is no single solution to enhancing technology transfer and diffusion policies need be tailored to country-specific context and interests. Therefore, the guidebook presents a flexible approach, identifying various assessment options and tools for analysts and decision makers.

The guidebook has been developed through an experience-based approach during the first phase of the TNA, and has benefitted from feedback from national consultants and workshop participants alongside inputs from UDP staff and external reviewers. It should be noted that this second edition of the guidebook has undergone major changes with respect to structure and content for the benefit of the readers.

The publication is one of several guidebooks produced as part of the GEF-funded Technology Needs assessment (TNA) project, currently being implemented by UNEP and UNEP DTU Partnership in 26 countries across Africa, Asia and Latin America.

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