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Barriers, Opportunities, and Market Potential of Technologies and Practices

Co-ordinating Lead Authors:
JAYANT SATHAYE (USA), DANIEL BOUILLE (ARGENTINA)

Lead Authors:
Dilip Biswas (India), Philippe Crabbe (Canada), Luis Geng (Peru), David Hall† (UK), Hidefumi Imura (Japan), Adam Jaffe (USA), Laurie Michaelis (UK), Grzegorz Peszko (Poland), Aviel Verbruggen (Belgium), Ernst Worrell (Netherlands/USA), F. Yamba (Zambia)

Contributing Authors:
Mauricio Tolmasquim (Brazil), Henry Janzen (Canada)

Review Editors:
Michael Jefferson (UK), R. Sutamihardja (Indonesia)

† Professor David Hall, a close colleague, passed away in August 1999. He inspired us all through his vigorous support for bioenergy, and its just uses in the developing world.

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EXECUTIVE SUMMARY

The transfer of technologies and practices that have the potential to reduce greenhouse gas (GHG) emissions is often hampered by barriers[1] that slow their penetration. The opportunity[2] to mitigate GHG concentrations by removing or modifying barriers to the spread of technology may be viewed within a framework of different potentials for GHG mitigation (*Figure 5.1*). The "market potential" indicates the amount of GHG mitigation that might be achieved under forecast market conditions, with no changes in policy or implementation of measures whose primary purpose is the mitigation of GHGs. The market potential can be close to zero as a result of extreme poverty, absence of markets, and remoteness of communities. The inability of the poor or isolated communities to access modern energy services reflects this situation. Because interventions to address poverty fall outside the immediate scope of this chapter, they receive only limited treatment here despite the intrinsic general importance of the subject.

In addition to the market potential, there is also the economic potential and the socioeconomic potential to be considered. Eliminating imperfections of markets, public policies, and other institutions that inhibit the diffusion of technologies that are (or are projected to be) cost-effective for consumers (evaluated using consumers' private rate of time discounting and prices) without reference to any GHG benefits they may generate would increase GHG mitigation to the level defined as the "economic potential". The "socioeconomic" potential consists of barriers derived from people's individual habits, attitudes and social norms, and vested interests in the diffusion of new technology. This potential represents the level of GHG mitigation that would be achieved if technologies that are cost effective from a societal perspective are implemented.

Finally, some technologies might not be widely used simply because they are too expensive from a societal perspective. This leads to the level of the "technical potential", which can be improved upon by solving scientific and technological problems. Policies to overcome this category of barriers must be aimed at fostering research and development (R&D).

[1] A barrier is any obstacle to reaching a potential that can be overcome by a policy, programme, or measure.

[2] An opportunity is a situation or circumstance to decrease the gap between the market potential of a technology or practice and the economic, socioeconomic, or technological potential.

Technological and social innovation is a complex process of research, experimentation, learning, and development that can contribute to GHG mitigation. Several theories and models have been developed to understand its features, drivers, and implications. New knowledge and human capital may result from R&D spending, through learning by doing, and/or in an evolutionary process. Most innovations require some social or behavioural change on the part of users. Rapidly changing economies, as well as social and institutional structures offer opportunities for locking-in to GHG-mitigative technologies that may lead countries on to sustainable development pathways. The pathways will be influenced by the particular socioeconomic context that reflects prices, financing, international trade, market structure, institutions, the provision of information, and social, cultural and behavioural factors; key elements of which are described below.

Unstable Macroeconomic Conditions
Such conditions increase risk to private investment and finance. Unsound government borrowing and fiscal policy lead to chronic public deficits, reducing the availability of credit to the private sector. Trade barriers that favour inefficient technologies, or prevent access to advanced knowledge and hardware, can slow the diffusion of mitigation options.

Commercial Financing Institutions
These institutions face high risks when developing "green" financial products. Innovative approaches in the private sector to address this and other issues include leasing, environmental and ethical banks, micro-credits or small grants facilities targeted at low income households, environmental funds, energy service companies (ESCOs), and green venture capital.

Distorted or Incomplete Prices
The absence of a market price for certain impacts, such as environmental harm, can constitute a barrier to the diffusion of environmentally beneficial technologies. Distortion of prices arising from taxes, subsidies, or other policy interventions that make resource consumption more or less expensive to consumers can also impede the diffusion of resource-conserving technologies.

Information as a Public Good
Generic information regarding the availability of different kinds of technologies and their performance characteristics has the attributes of a "public good" and hence may be underprovided by the private market.

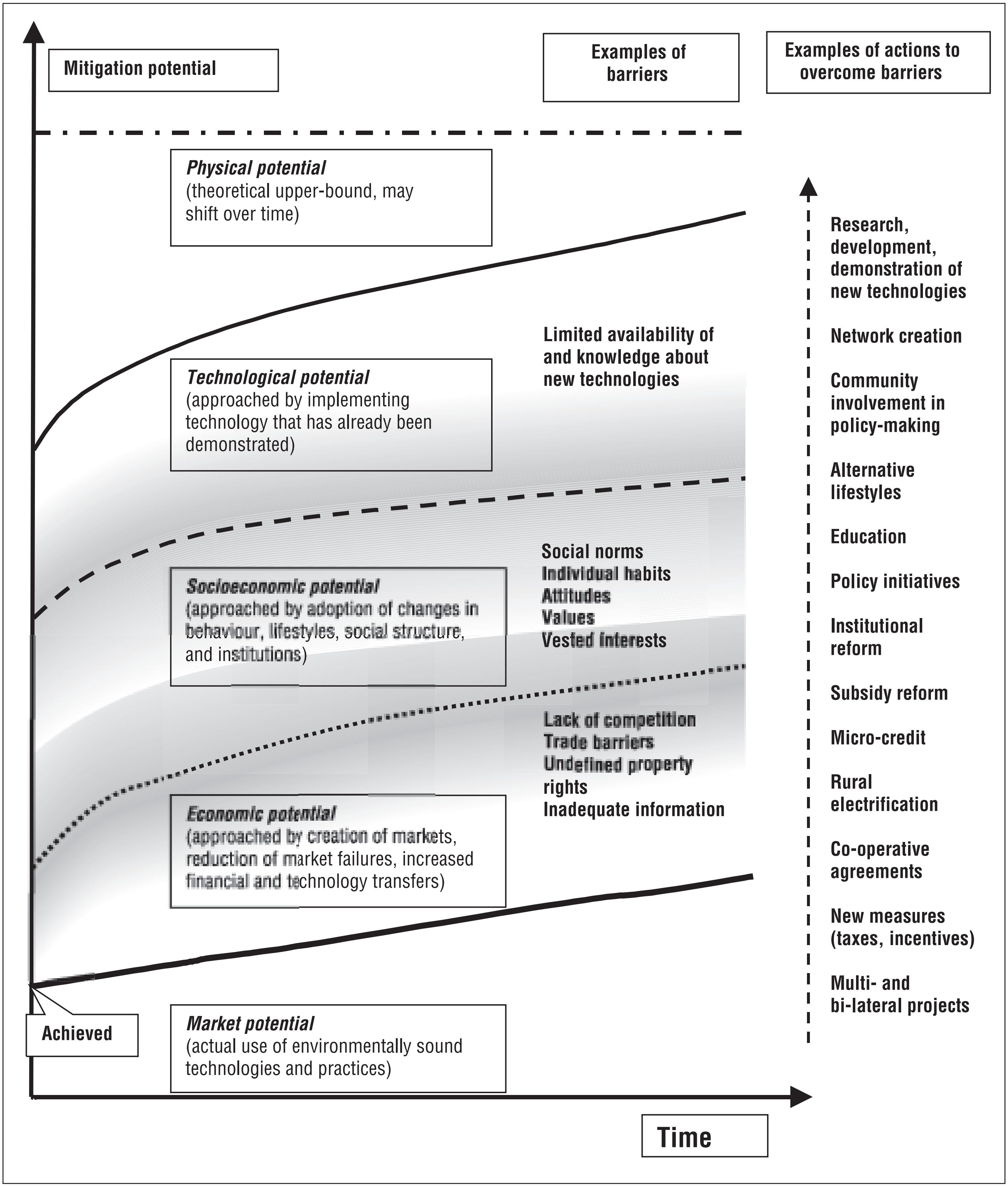

Figure 5.1: *Penetration of Environmentally Sound Technologies: A Conceptual Framework: Various barriers prevent the different potentials from being realized. Opportunities exist to overcome barriers through innovative projects, programmes and financing arrangements. An action can address more than one barrier. Actions may be pursued to address barriers at all levels simultaneously. Their implementation may require public policies, measures and instruments. The socioeconomic potential may lie anywhere in the space between the economic and technological potential.*

Lack of Effective Regulatory Agencies
Many countries have on their books excellent constitutional and legal provisions for environmental protection but the latter are not enforced. However, "informal regulation" under community pressure may substitute for formal regulatory pressure.

Lifestyles, Behaviours, and Consumption Patterns
These have developed within current and historical socio-cultural contexts. Changes in behaviour and lifestyles may result from a number of intertwined processes. Barriers take various forms in association with each of the above processes.

Conventional Policy Development
This type of development is based on a model of human psychology, where people are assumed to be rational welfare-maximizers, that has been widely criticized. Such a model does not explain processes, such as learning, habituation, value formation, or the bounded rationality observed in human choice.

Buildings
The poor in every country are affected far more by barriers in this sector than the rich, because of inadequate access to financing, low literacy rates, adherence to traditional customs, and the need to devote a higher fraction of income to satisfy basic needs, including fuel purchases.

Measures to overcome these barriers that have been implemented include voluntary programmes, building efficiency standards, equipment efficiency standards, state market transformation programmes, financing, government procurement, tax credits, accelerated R&D, and a carbon cap and trade system.

Transport
The low relative cost of fuel, split incentives, a perception that the car is more convenient or economical than alternatives, are some of the barriers that slow the use of mitigation technologies in this sector. The car has also become charged with significance as a means of freedom, mobility and safety, a symbol of personal status and identity, and as one of the most important products in the industrial economy. A combination of policies protecting road transport interests, rather than any single policy, poses the greatest barrier to change.

Industry
Barriers include the high transaction costs for obtaining reliable information, the use of capital for competing investment priorities, high-hurdle rates for energy efficiency investments, lack of skilled personnel for small and medium-sized enterprises (SMEs), and the low relative cost of energy. Information programmes, environmental legislation, and voluntary agreements have been used and tested in developed countries with varying rates of success in reducing barriers.

Energy Supply
The increasing deregulation of energy supply has raised particular concerns. Volatile spot and contract prices, short-term outlook of private investors, and the perceived risks of nuclear and hydropower plants have shifted fuel and technology choice towards natural gas and oil plants, and away from hydro in many countries. Co-generation is hampered by lack of information, the decentralized character of the technology, the hostile attitude of grid operators, the terms of grid connection, and lack of policies that foster long-term planning. Firm public policy and regulatory authority are necessary to install and safeguard harmonized conditions, transparency, and unbundling of the main power supply functions.

Agriculture and Forestry
Adoption of new technology is limited by small farm size, credit constraints, risk aversion, lack of access to information and human capital, inadequate rural infrastructure and tenurial arrangements, and unreliable supply of complementary inputs. Subsidies for critical inputs to agriculture, such as fertilizers, water supply, and electricity and fuels, and to outputs in order to maintain stable agricultural systems and an equitable distribution of wealth distort markets for these products. In relation to climate change mitigation, other issues such as lack of technical capability, lack of credibility about setting project baselines, and monitoring of carbon stocks pose difficult challenges.

Waste Management
The principal barriers to technology transfer include limited financing and institutional capability, jurisdictional complexity, and the need for community involvement. Climate change mitigation projects face further barriers owing to the unfamiliarity with methane (CH_4) capture and potential electricity generation, unwillingness to commit additional human capacity for climate mitigation, and the involvement of diverse institutions at all levels.

Regional Considerations
Changing global patterns provide an opportunity for introducing GHG mitigation technologies and practices that are consistent with development, equity, and sustainability (DES) goals. A culture of energy subsidies, institutional inertia, fragmented capital markets, vested interests, etc., however, presents major barriers to their implementation in the developing countries and those with economies in transition (EIT). Situations in these two groups of countries call for a more careful analysis of trade, institutional, financial, and income barriers and opportunities; distorted prices and information gaps. In the developed countries, other barriers such as the current carbon-intensive lifestyle and consumption patterns, social structures, network externalities, and misplaced incentives offer opportunities for intervention to control the growth of GHG emissions. Lastly, new and used technologies mostly flow from the developed to developing and transitioning countries. A global approach to reducing emissions that targets technology being transferred from developed to developing countries could have a significant impact on future emissions.

5.1 Introduction

Technology transfer comprises a broad set of processes covering the flows of know-how, experience, and equipment for mitigating and adapting to climate change among different stakeholders such as governments, private sector entities, financial institutions, non-governmental organizations (NGOs), and research and/or education institutions (IPCC, 1996; IPCC, 2000b). The term transfer encompasses diffusion of technologies and technology co-operation across and within countries. It comprises the process of learning to understand, utilize, and replicate the technology, including the capacity to choose and adapt it to local conditions, and integrate it with indigenous technologies.

The previous chapters (Chapters 3 and 4) have discussed the characteristics of different technologies and practices, and their potential and costs for the mitigation of climate change. Chapter 3 has identified numerous negative cost or "no regrets" options whose full implementation is prevented by various types of barriers. The focus of this chapter, thus, is on the various barriers that inhibit the process of technology transfer, but not on technology programmes, which are covered in Chapter 3. A "barrier" is any obstacle to reaching a potential that can be overcome by a policy, programme, or measure (*Figure 5.1*). This chapter describes the barriers that lie below the "socioeconomic potential" line in *Figure 5.1*. Barriers to technology transfer may also be viewed as opportunities for intervention by the aforementioned stakeholders so that technologies can reach their full potential. An "opportunity" is thus any situation or circumstance to decrease the gap between the "market potential" of a technology and the economic, socioeconomic, or technical potential. Barriers and opportunities tend to be context-specific, and can change over time and vary across countries. Policies, programmes, and measures may be used to take advantage of the opportunities to help overcome the barriers. The interventions are largely described and assessed in Chapter 6, although some types of interventions at the sectoral level are illustrated in Section 5.4 of this chapter.

Opportunities for climate change mitigation exist both in reducing the intensity of greenhouse gas (GHG) emissions and the level of activities that cause these emissions. Reducing the level of an activity, for instance vehicle travel, need not reduce the services associated with it if a substitute like telecommuting can satisfy the same need. GHG mitigation can thus be achieved without sacrificing consumer welfare. Opportunities for such changes are equally important and need to be actively sought out. The interventions needed for achieving changes in the level of activity, however, can encompass the broad array of macro and micro policies that affect consumers and producers alike. In this chapter, the barriers, opportunities, and sectoral interventions for both the GHG intensity and "activity" changes are discussed. The broader macro-interventions are discussed in Chapter 6.

An element that lies largely unexplored is the connection between poverty and climate change mitigation. A large proportion of the world's population lives in poverty, often outside a cash economy, and does not have access to modern fuels. Even when the poor are part of a cash economy, they are often deprived of access to financial instruments that require collateral. The literature on barriers and opportunities to address their need for fuels, and the consequent GHG emissions, is relatively sparse. In this chapter, the limited material on barriers, opportunities, and interventions associated with the provision of energy services to the poor is reviewed primarily in the sections on finance (Section 5.3.3), energy use in buildings (Section 5.4.1) and agriculture (Section 5.4.5).

Barriers to technology transfer have been described and classified in many different ways. Reddy (1991) classifies barriers by actors, consumers, energy providers, etc.; and others (Hirst and Brown, 1990; Evans, 1991; Hirst, 1992) by the type of barrier, financing, pricing, etc. Technological and social changes offer new opportunities for the diffusion of GHG-mitigative technologies. Rapidly changing economies and institutional and social structures offer opportunities for locking into GHG-mitigative technologies that are likely to grow over the long term. Exploiting opportunities during a period of rapid change is typically easier than in a static environment. For example, the Internet revolution means that many aspects of society and the economy are being reshaped, offering opportunities to build environmental and sustainable development practices into the emerging paradigms. At the more micro-level, the beginning of an investment cycle for power supply systems and house purchase by individuals and families is a period when they are making major purchase decisions. Governments can influence these decisions through various regulations, financial incentives and information at such times to make the new investment less-GHG intensive. Synergies exist between GHG mitigation and other policy goals, e.g., reducing transport air pollution or conserving soils. Measures to address the latter offer opportunities for GHG mitigation also. While the chapter focuses broadly on both barriers and opportunities, Sections 5.3.1 and 5.3.8 specifically review the models of, and experience with, technological and social innovation and the opportunities offered for the diffusion of GHG-mitigative technologies. Synergies too are noted throughout, but particularly so in the sectoral sections 5.4.4 through 5.4.7.

The chapter focuses not only on the energy demand and supply sectors, which have a rich literature in this field, but also on the agriculture, forestry, and waste sectors. In the introductory sections below, a conceptual framework for understanding the role of opportunities and barriers, and a review of the two earlier Intergovernmental Panel on Climate Change (IPCC) reports that have dealt with this topic, namely the Second Assessment Report (SAR) and the Special Report on Technology Transfer (SRTT) are presented. Section 5.3 then discusses the generic opportunities and barriers that apply across all sectors, which is followed by a discussion of the prominent barriers and opportunities in appropriate sectors of the economy.

5.1.1 Summary of the Second Assessment Report – Barriers and Opportunities

The topic of barriers to the market penetration of environmentally sound technologies (ESTs) was treated in Section 1.5.3 ("Market failures and government responses") of the Working Group (WG) III SAR, and also in Chapter 8, Sections 8.2.3 ("Key factors affecting the magnitude of costs: Costs as a function of baselines and policy strategies"), and 8.4.3 ("The top-down vs. bottom-up modelling controversy: Some lessons from the energy field") respectively. The latter sections dealt with the discussion of the differences between top-down and bottom-up modelling when estimating the costs of strategies to reduce or control GHG emissions. The primary question raised in the discussion in the SAR may be summarized as: Given market prices, do firms fail to take advantage of all the energy efficiency opportunities available to them? Thus, a business investment decision, considering private costs, may not undertake all the available efficiency opportunities. Likewise, in the modelling sections, the discussion focused on the existence of the "no regrets" potential. Its existence implies that (1) market and/or institutional failures exist, and (2) cost-effective policies targeted to correct these can be identified and implemented. The SAR notes four categories of market imperfections that explain the above phenomena, and the policies that could be used to address them. A more detailed discussion of these topics is included in other sections of this chapter.

Information Dissemination
Acquiring information is costly, and markets, on their own, do not provide an efficient level of disclosure of information. Governments can amend this by providing information or instituting legislation and/or regulations that requires disclosure of information, e.g., requiring energy performance labels on household appliances (see Section 5.3.7 for further discussion on lack of information as a barrier).

Bureaucratic Structure and Limited Scope of Attention
Economic and organizational theory has emphasized that large organizations are not, in general, run by owners; that the managers, even with best-designed incentives, do not in general maximize the firm's market value; and that among the principal scarce factors within an organization are time and attention. Governments could provide information on energy efficiency that managers could access with ease, which may yield private returns higher than their marginal costs. (See Sections 5.3.5.2 and 5.4.3 for further discussion on barriers and opportunities in the industrial sector.)

Returns to Scale and Network Externalities
Technologies or projects may require large infrastructure or size in order to make them economic. The scale of such a project, e.g., a natural gas-based transportation system, may deter investment, although it may be cost-effective in comparison to a gasoline-based system at some higher future oil price (see Sections 5.3.5 for further discussion on network externalities).

Capital Market Imperfections
Studies of implicit discount rates have shown that households and firms behave as if they use rates substantially above the market rate for long-term government bonds. Firms use discount rates that reflect the riskiness of projects, and, as a result of imperfect information, households and firms often face rationing in capital markets for credit and equity. Economists emphasize that timing, risk, capital constraints, and information or lack thereof should be dealt with separately. A discount rate should reflect investment timing questions, risk should be treated by converting costs and benefits into certainty equivalents, and shadow pricing should address constraints on capital. Lack of information could be addressed through government intervention (see Sections 5.3.3 for further discussion on financing).

5.1.2 Special Report on Technology Transfer – Barriers and Opportunities

This IPCC Special Report was prepared in response to a request made by the UN Framework Convention on Climate Change through its Subsidiary Body for Scientific and Technological Advice (SBSTA) to provide input on the issue of "Development and assessment of methodological and technological aspects of transfer of technology". The focus of the report is on transfer of technology, and it describes actions that governments and other stakeholders can undertake to enhance technology transfer within and between countries. It emphasizes that governments have a key role to play in initiating and facilitating technology transfer, either directly or by creating an enabling environment for the private sector and community involvement.

While the technology transfer process can be complex and intertwined, certain stages can be identified. These include the identification of needs, choice of technology, assessment of conditions of transfer, agreement, and implementation. Evaluation and adjustment to local conditions, and replication are other important stages.

Barriers to the transfer of ESTs arise at each stage of the process. These vary according to the specific context from sector to sector and can manifest themselves differently in developed and developing countries, and in EITs. These barriers range from lack of information; insufficient human capabilities; political and economic barriers, such as lack of capital, high transaction costs, lack of full cost pricing, and trade and policy barriers; institutional and structural barriers; lack of understanding of local needs; business limitations, such as risk aversion in financial institutions; institutional limitations, such as insufficient legal protection; and inadequate environmental codes and standards.

The report further notes that there is no preset answer to enhancing technology transfer. The identification, analysis, and prioritization of barriers should be country based, and actions should be tailored to overcome specific barriers, interests, and influences of specific stakeholders in order to develop effective policy tools.

The thrust of the technology transfer report is on the identification of actions that governments may pursue to overcome barriers that slow or prevent the transfer of technology either within or across countries. This chapter of the TAR (Third Assessment Report) provides an in-depth discussion of the literature on barriers and opportunities, and provides a framework for differentiating between different types of potentials and barriers to technology penetration. The framework also helps in identifying the role of research, development and demonstration phases, and their linkage to the eventual market acceptance of technology. The chapter also discusses the opportunities for technology penetration, but it limits the discussion on policies and measures to sectoral interventions. A discussion of the broader policies and measures is found in Chapter 6.

5.2 Conceptual Framework for Understanding Barriers and Opportunities

The opportunity to mitigate GHG concentrations by removing or modifying barriers to the spread of technology may be viewed as an association between different types or categories of barriers and different concepts of the potential for GHG mitigation (*Figure 5.1*). Each concept of the potential represents a hypothetical projection that might be made today regarding the extent of GHG mitigation over time into the future. The bottom line, labelled "market potential" indicates the amount of GHG mitigation that might be expected to occur under forecast market conditions, with no changes in policy or implementation of measures whose primary purpose is the mitigation of GHGs.

At the other extreme, the "technical potential" describes the maximum amount of GHG mitigation achievable through technology diffusion. This is a hypothetical projection of the extent of GHG mitigation that could be achieved over time if all technically feasible technologies were used in all relevant applications, without regard to their cost or user acceptability.

By definition, it can be said that whatever physical, cultural, institutional, social, or human factors are preventing the progress from the market potential to the technical potential are "barriers" to the mitigation of GHG via technology diffusion. Since, however, the ultimate goal is to understand policy options for mitigation, it is useful to group these barriers in a way that facilitates understanding the kinds of policies that would be necessary to overcome them. As these different categories of barriers are created, there is a corresponding creation of intermediate conceptions of the potential for GHG mitigation. Starting at the bottom, it is possible to imagine addressing barriers (often referred to as "market failures") that relate to markets, public policies and other institutions that inhibit the diffusion of technologies that are (or are projected to be) cost-effective for users without reference to any GHG benefits they may generate. Amelioration of this class of market and institutional imperfections would increase GHG mitigation towards the level that is labelled as the "economic potential". The economic potential represents the level of GHG mitigation that could be achieved if all technologies that are cost-effective from consumers' point of view were implemented. Because economic potential is evaluated from the consumer's point of view, cost-effectiveness would be evaluated using market prices and the private rate of time discounting, and also take into account consumers' preferences regarding the acceptability of the technologies' performance characteristics.[3]

Of course, elimination of all of these market and institutional barriers would not produce technology diffusion at the level of the technical potential. The remaining barriers, which define the gap between economic potential and technical potential, are usefully placed in two groups separated by a socioeconomic potential. The first group consists of barriers derived from people's preferences and other social and cultural barriers to the diffusion of new technology. That is, even if market and institutional barriers are removed, some GHG-mitigating technologies may not be widely used simply because people do not like them, are too poor to afford them, or because existing social and cultural forces operate against their acceptance. If, in addition to overcoming market and institutional barriers, this second group of barriers could be overcome, the "socioeconomic potential" would be achieved. Thus, the socioeconomic potential represents the level of GHG mitigation that would be achieved if all technologies that are cost effective (on the basis of a social rather than a private rate of discount) are implemented, without regard to existing concerns about their performance characteristics, and without regard to social and cultural obstacles to their use.

Finally, even if all market, institutional, social, and cultural barriers were removed, some technologies might not be widely used simply because they are too expensive. That is, the definition of socioeconomic potential includes the requirement that technologies be cost-effective. Elimination of this requirement would therefore allow a progression to the level of "technical potential", the maximum technologically feasible extent of GHG mitigation through technology diffusion.

An issue arises as to how to treat the relative environmental costs of different technologies within this framework. Because the purpose of the exercise is ultimately to identify opportunities for global climate change policies, the technology poten-

[3] The identification of "economic potential" with implementation of technologies that are cost-effective from the consumer's point of view adopts, in effect, the economist's view that economic potential corresponds to the elimination of market failures. Other analysts have used the phrase "economic potential" to incorporate a broader conception, similar to what is dubbed "socioeconomic potential" in this report (Jaffe and Stavins, 1994).

tials are defined without regard to GHG impacts. Costs and benefits associated with other environmental impacts would be part of the cost-effectiveness calculation underlying economic potential only insofar as existing environmental regulations or policies internalize these effects and thereby impose them on consumers. Broader impacts might be ignored by consumers, and hence not enter into the determination of economic potential, but they would be incorporated into a social cost-effectiveness calculation. Thus, to the extent that other environmental benefits make certain technologies socially cost-effective, even if they are not cost-effective from a consumer's point of view, the GHG benefits of diffusion of such technologies would be incorporated in the socioeconomic potential.

The technical potential can be illustrated with reference to the fuel cell as a power source for private vehicles. Current fuel cell technology, making use of hydrogen manufactured from natural gas, can offer GHG emission reductions of around 50%-60% relative to conventional vehicles. This gives some indication of the current technical potential for mitigation. It is imaginable that in the future, fuel cell vehicles using hydrogen or other fuels from non-fossil sources would have even lower GHG emissions, on a full fuel cycle basis (Michaelis, 1997c). Thus, the technical potential of fuel cells for GHG mitigation is significant, and is expected to improve over time, as shown in *Figure 5.1*, through scientific discovery and technological development. However, the Energy Technology Support Unit (ETSU, 1994) notes numerous challenges that would have to be overcome before such vehicles could enter widespread use and offer more substantial emission reductions. In other words, the current market potential is very small at best. The large gap between the market and technical potentials (at the present time) can be understood in terms of specific barriers. Some of these relate to technology performance and cost, while others have to do with fitting non-fossil fuels into the existing infrastructure. The need to improve the cost and performance of the technology would represent barriers separating the technical and socioeconomic potentials. To the extent that the diffusion of cost-effective fuel cells is or will be limited by rigidities in the existing infrastructure, these could be considered barriers separating the economic and socioeconomic potentials for this technology.

The economic potential can be similarly illustrated, for example, with reference to energy conservation opportunities in buildings. Engineering-based analysis in the United States and other countries indicates that measures such as replacing tungsten filament bulbs with compact fluorescent lamps (CFLs), insulating hot water tanks, and introducing more energy-efficient refrigerators, could reduce residential electricity by about 40% and deliver a net saving to consumers (IPCC, 1996). To the extent that achievement of these savings is limited by market and institutional imperfections (such as imperfect information or misplaced incentives), the savings they offer represent the economic potential of these technologies. But even if all of these imperfections were corrected, these technologies would not be used in all possible applications. Some people will not use them because they find them inferior on aesthetic or performance grounds. Other potential users will judge that the high private discount rates they believe are appropriate to this kind of investment render the savings too small to justify the high up-front cost. If, in addition to overcoming market and institutional imperfections, these aspects of consumer preferences were ignored, the socioeconomic potential could then be identified. Finally, even this level of GHG mitigation is smaller than the technical potential, as illustrated in *Figure 5.1*, because many technologies that are available, such as rooftop solar photovoltaic electricity supplies, would not pay for themselves in energy savings even at the social discount rate.

Table 5.1 begins with the baseline level of GHG mitigation that could be achieved without policy intervention (market potential), and then examines in more detail the nature of the barriers and opportunities that are encountered as greater mitigation is pursued, i.e., move towards the technical potential in *Figure 5.1*. Identification of the nature of the barriers and opportunities that separate each of the levels is necessary in order to formulate policy responses to overcome the barriers. The barriers to the achievement of economic potential are market and other institutional failures in the markets for technology, and government policies that distort these markets. These include market failures related to information and capital markets, subsidies for energy use. and trade barriers that inhibit the import of energy-efficient technologies. In principle, policies can be designed to address each of these market or government failures.

Identification of the opportunities to achieve economic potential is important, because removal of these barriers in a cost-effective way would be desirable even if global climate change (GCC) were not a policy concern. That is, if policies can be devised to overcome market and institutional barriers to the use of cost-effective technologies with desirable performance characteristics, consumers would be better off even before any consideration of GCC benefits. The barriers to the achievement of socioeconomic potential include social and cultural constraints, as well as economic forces that cannot be characterized as imperfections of markets or of other institutions. Policies to mitigate the market and institutional imperfections separating market and economic potential constitute "no regrets" policies, i.e., policies that societies would not regret implementing no matter what is learned later about the severity of the GCC problem.

The barriers to the achievement of socioeconomic potential include social and cultural constraints, as well as economic forces that cannot be characterized as imperfections of markets or of other institutions. Other barriers to socioeconomic potential relate to consumer preferences, including attitudes towards uncertainty. Uncertainty about whether estimates of new technologies and cost savings will actually come to pass limits the adoption of new technologies; such hesitation in the face of uncertainty is completely rational given the irreversible nature of many energy-conservation investments (Hassett and

Table 5.1: *Taxonomy of barriers and opportunities*

Source of barrier and/or opportunity	Examples of market and/or institutional imperfections and opportunities[a]	Examples of social & cultural barriers and opportunities
Prices	Missing markets (market creation) Distorted prices (rationalization of prices)	
Financing	Financial market imperfections (sector reform or restructuring of economy) Constraints of official development assistance (ODA) (removing tied aid and/or better targeting of ODA)	Long time and high transaction costs for small projects (pooling of projects)
Trade and environment	Tariffs on imported equipment and restrictive regulations (rationalization of customs tariffs)	
Market structure and functioning		Circumstances requiring rapid payback (fuel subsides) Weaknesses of suppliers in market research (form associations to support market research)
Institutional frameworks	Transactions costs Inadequate property rights (improve land tenure) Misplaced incentives Distorted incentives	Institutional structure and design (restructuring of firms) National policy styles (shifting balance of authority) Lack of effective regulatory agencies (informal regulation)
Information provision	Public goods nature of information (increase public associations) Adoption externality (build demonstration projects)	
Social, cultural, and behavioural norms and aspirations		Inadequate consideration of human motivations and goals in climate mitigation (modify social behaviour) Individual habits (targeted advertising)

a: Remarks in parenthesis indicate opportunities, e.g., missing markets denote an opportunity for the creation of markets.

Metcalf, 1993, 1994). Even putting aside the effects of uncertainty, private decision makers may utilize discount rates to assess the value of future energy savings that are significantly higher than the discount rates applied in the engineering-economic calculations to indicate that particular technologies are cost-effective. Such higher discount rates make the energy savings less valuable and, hence, may lead to a conclusion that the technologies are not cost-effective for a particular user.

Socioeconomic potential also recognizes that the economic feasibility of particular technologies is constrained by social structures and cultural forces; it is possible to consider changing those structures because of GCC objectives. For example, if the land-use and transportation systems of the USA could be radically transformed, the potential for improvement of energy efficiency in the transportation sector would be much greater than anything that could be achieved taking those structures as given (see Section 5.4 below). Hence, part of the gap between the economic and socioeconomic potential represents the savings that could result from changes in the structure of such systems.

The last set of barriers to achieving technical potential relate to the cost and performance of the technologies. These can be improved upon by solving scientific and technological problems, so policies to overcome this category of barriers could be aimed at fostering the research and development (R&D) process, either in the public or private sectors. In addition, because production costs typically fall as experience with a particular technology accumulates, policies that foster adoption of new technologies can, over time, produce cost reductions and performance improvements. The effect of such improvements would be to make the technologies more cost-effective and consumer-favoured, thus moving both the economic and socioeconomic potentials towards the level of the technical potential.

Figure 5.1 provides illustrative examples of the barriers that separate one potential from another. Actions to overcome these barriers need not necessarily take place in the order of the potentials. R&D could take place to approach the technical potential at the same time that institutional and subsidy reforms are being carried out to approach the socioeconomic and economic potentials respectively. While the figure denotes a hierarchy in terms of the potentials, there is no hierarchy in the interventions that might be pursued to overcome the barriers. Furthermore, an intervention may overcome more than one barrier that need not be in a hierarchical order either, e.g., the provision of information could address all categories of barriers.

Because some interventions may be more effective than others, the gaps between the various potentials are likely to be reduced to varying degrees as well. Thus, the gap between the socioeconomic and economic potential may completely disappear, and yet that between the economic and market potential may remain in place. This indicates that while the market potential has moved up, it still could be improved by removing what economists refer to as market failures.

5.3 Sources of Barriers and Opportunities

Barriers to climate change mitigation are inherent to the process of development. Sustainable development in a participatory framework can minimize these barriers, but the inequitable distribution of income and wealth forms a core feature of barriers to effective implementation of any type of intervention, and those related to climate change are no exception. The poor in any society bear a disproportionate burden of the impact of externalities. Climate change affects them more, because they often lack the infrastructure to withstand its impacts. The poor also pay more as a proportion of their income for energy services, and often tend to use traditional fuels secured outside the formal market system. They are not able to access subsidized fuels for instance, because they do not have the collateral to access these fuels and the equipment to use them. Appropriate ways of financing would be one way to overcome such barriers, provided they explicitly account for the non-existence of markets for some segments of society. The issue of segmentation is valid for firms as well. Small and medium-sized firms for instance face information and market-structure barriers that well-structured large firms can readily overcome with the resources at their disposal.

Lifestyles, behaviour, and consumption patterns all evolve as societies develop within their own socio-cultural contexts. With the advent of global communications these factors are being increasingly influenced by changes that are taking place in societies residing thousands of miles away. The communication channels may be viewed as an opportunity to influence the manner in which tomorrow's society might develop in countries where modern but resource-consumptive technologies and lifestyles have not taken root. Progress in achieving climate change mitigation will depend on how well the seeds of mitigative technological change can be planted and nurtured.

As a prelude to the more detailed sectoral discussion in Section 5.4, this section provides a general overview of the process of technological innovation, and the different sources of barriers to the diffusion of new technology and practices, as well as the policy opportunities that they represent. This section is organized by the following categories: prices, financing, trade and environment, market structure, institutional frameworks**,** information provision; and social, cultural and behavioural norms and aspirations. Within each of these areas, some of the barriers represent failures or imperfections in markets, policies, or other institutions that lie between the status-quo of the market potential and the possible achievement of the economic potential. Other barriers are aspects of institutions or social and cultural systems that economists may not characterize as market imperfections, but which nonetheless limit diffusion of GHG-efficient technology. These latter barriers separate the economic and socioeconomic potentials. Within each of the subsections below barriers and opportunities in both categories are discussed.

5.3.1 Technological Innovation

Many governments and firms have focused their strategies for GHG mitigation on encouraging technological innovation – various processes of research, experimentation, learning, and technology development. Innovation may lead to improvements in technology performance, reductions in GHG emissions per unit of service provided, or reductions in cost for low-GHG technology, all of which can contribute to GHG mitigation. Innovation can help to raise the technological, socio-political, economic, and market potentials for adoption of low-GHG technology, and for GHG mitigation. Identifying the barriers to, and opportunities for, technological innovation depends on understanding the innovation process. Since the IPCC SAR, there has been a rapid growth of interest in the theory of innovation, and in the development and application of models to evaluate climate mitigation policies that take account of endogenous technological change (Azar, 1996; Goulder and Mathai, 2000).

5.3.1.1 The Innovation Process

Until the 1980s, policy analysts generally viewed innovation as a linear process from R&D through to demonstration and deployment. Policies were focused on "science push" and "demand pull" for new technologies (OECD, 1992). Over the last twenty years there has been a growing recognition of the interconnectedness of the many processes involved in technological change, and the possibility of finding new insights or knowledge anywhere from the research lab to the customer service department.

Technological change can take many different forms including: (1) incremental improvements in existing technology; (2) radical innovation to introduce completely new technology; (3) changes in a system of linked technologies, and (4) changes in the "techno-economic paradigm" involving widespread reorganization of production and consumption patterns (Freeman and Perez, 1988). These four types of innovation have different dynamics. Thus, the first type is likely to occur continually through the accumulation of experience, selection of successful techniques and adaptation to a changing economic, legislative and socio-cultural context. The second and third types of technological change involve more positive creativity, being linked to new information in the form of a discovery, idea, or invention; or to a creative application of an existing invention. The fourth type, again, involves creativity but, because it involves a radical change in culture and markets, may also depend on these being "ripe" for change – on a general perception of a major challenge requiring a radical response.

Technology diffusion, the spread of existing technology through the population of potential users, can be distinguished from innovation – the first commercial application of a new technology. At a local level, however, there may be little difference between the two. Wallace (1995) notes the importance of an active and creative absorption process in the uptake of the new technology.

Technological change is a complex process. It occurs through a variety of interdependent mechanisms (Nelson *et al*., 1967; Rosenberg, 1982; Dosi, 1988; OECD, 1992; Rosenberg, 1994; Lane and Maxfield, 1995), which can include:

- assessment of needs and potential markets;
- basic research: a search for new information;
- creative generation of new ideas;
- learning from experience;
- exchange of new information, ideas, and experience through the scientific and technical literature, patents, and a variety of other communication channels and networks including face-to-face contact and collaboration;
- experimentation to implement and test the new information and ideas;
- development of new technology;
- demonstration and market testing of new technology; and
- selection of successful technology, under the influence of the economic, social, legal, and physical context.

Because of the complexity of the technological innovation process, there are many different ways of looking at it. A variety of theories or models may be helpful, depending partly on specific circumstances.

From the perspective of neoclassical economics, innovation can be seen as the result of a process of investment in "knowledge capital", in the form of R&D to develop both formal and tacit knowledge (Griliches, 1979). The former includes the scientific literature and patents; the latter includes the skills and experience developed by those involved in developing new technology and can also be viewed as "human capital". Increasing capital, again, tends to feed into higher levels of economic output and improved efficiency. Sometimes this may contribute to GHG mitigation, but more often the improvement is in labour productivity, leading to increases in GHG emissions. In so-called "new growth" theory economic models (e.g., Grossman and Helpman, 1991, 1993), new knowledge may be assumed to result directly from R&D spending which, in turn, can be modelled as a result of the expected returns from the investment. In this framework, firms and research institutes are treated as rational investors in R&D. The size of their investment will depend on the opportunity cost of capital and the expected return from R&D. While new growth theory has generated useful insights into the sources of national differences in competitiveness at an aggregate or sectoral level, it is less useful for describing technology innovation for GHG mitigation.

In addition to R&D investment, knowledge capital can also be accumulated through the process of "learning by doing" (Arthur, 1994; Grubb, 2000). Empirical studies show that the cost of a generic technology such as solar photovoltaic cells tends to fall with the level of existing investment in that technology, including spending on R&D (Christiansson, 1995; Messner, 1996; Nakicenovic, 1996).

An alternative to the neoclassical investment approach to innovation is that pioneered by Nelson and Winter (1982), to view technological change from the perspective of the firm, as a stochastic process of search, imitation, experimentation, and learning (Winter *et al*., 2000). Recent developments in agent-based modelling adopt this type of "evolutionary" framework, helping to bring out the role of information networks, the importance of existing experience, and also some of the spatial aspects of technology development and diffusion.

Finally, several analysts have adopted models of technology competition and diffusion analogous to those used to represent species competition and diffusion in ecosystems. Regularities have been found, for example, in the market succession of technology in energy supply, transport, and the iron and steel industry (Häfele *et al*., 1982; Grübler and Nakicenovic, 1991; Nakicenovic, 1996). However, no approach can hope to foresee reliably the form of the next "wave" of technology in any of these sectors.

5.3.1.2 Barriers and Opportunities for GHG Mitigation through Technological Change

Barriers to GHG mitigation and opportunities for overcoming them arise throughout the innovation system. They relate both to the rate of technological change and its direction. The predominant concern of governments, firms, and researchers considering innovation policies has been to maximize the rate of technological change and its contribution to national competitiveness (e.g., Freeman, 1987; Dosi *et al.,* 1988; Grossman and

Helpman, 1991). Environmental concerns are usually recognized but are rarely a major priority for national systems for innovation. Indeed, there may even be a concern that paying more attention to innovation strategies about environmental objectives would be detrimental to competitiveness.

There may be many opportunities to find synergies between the goals of improving competitiveness and reducing GHG emissions. The most obvious of these opportunities are cases where GHG mitigation could reduce costs. A greater challenge for businesses and governments is to seize opportunities to create new markets for low-GHG-emitting technology. One case of a successful strategy is the Danish development of wind turbine technology (Kemp, 2000).

Communication – among firms, between firms and users, and between firms and universities or government labs – is an important contributor to technological change. Most innovations require some social or behavioural change on the part of technology users (Rosenberg, 1994). Product innovations, if they are noticeable by the user, demand a change in consumer behaviour and sometimes in consumer preferences (OECD, 1998a). Some product innovations – such as those that result in faster computers or more powerful cars – provide consumers with more of what they already want. Nevertheless, successful marketing may depend on consumer acceptance of the new technology. Other innovations, such as alternative fuel vehicles or compact fluorescent lights, depend on consumers accepting different performance characteristics or even redefining their preferences. While consumer preferences are often seen as barriers to technological change, some of the most successful firms are those that seize the opportunities they present, by working with their customers in the development of new technology and services (Lane and Maxfield, 1995).

One of the most obvious barriers to using innovation to address GHG emissions is the lack of incentives. Economic, regulatory, and social incentives for reducing GHG emissions will also act as incentives for innovation to find new means of mitigation. Another important type of barrier, which both slows technological change in general and tends to skew it in particular directions, is that posed by "lock-in" (see *Box 5.1*). The tendency for societies to lock in to particular clusters of technologies and patterns of development can prevent new, low-GHG emission technologies entering the market. Meanwhile, it is important to recognize when previously locked-in technology is beginning to change, so that the opportunity can be grasped to introduce low-emission technology.

Box 5.1. Lock-In

Schumpeter (1928) emphasized the effectiveness of the capitalist system in encouraging experiments and in selecting successes. This effectiveness can be ascribed partly to the capitalist's ability to invest in risky endeavours, trading off uncertainty against the size of the anticipated return. The competitive market system also introduces the element of "creative destruction" to the innovation process, analogous to natural selection, ensuring that an innovation that does not meet the needs of the market does not survive. Yet, despite their ability to select adequate technologies, markets sometimes "lock-in" to technologies and practices that are suboptimal because of increasing returns to scale, which block out any alternatives (Arthur, 1988, 1994). The QWERTY English keyboard layout is often mentioned as an example of an inefficient technology designed to solve a specific problem (to avoid keys sticking in mechanical typewriters) but which has become "locked in" (David, 1985). It has been claimed that alternative keyboard designs could double typing speeds, but these are not adopted because of the retraining costs that would be necessary for any change. Lock-in phenomena are familiar in the energy sector, with technologies and design standards in applications ranging from power stations to light bulbs and urban design to vehicles.

In many cases, a given technology helps to satisfy several different types of need. This is particularly evident in two of the most significant areas of energy use: cars and houses. Any individual may have a variety of potentially conflicting objectives when choosing a technology. This tendency of successful technologies to serve multiple needs contributes to lock-in by making it harder for competing innovations to replace them fully. Hence, many government attempts to introduce new, energy efficient or alternative fuel technology, especially in the case of the car, have failed because of a failure to meet all the needs satisfied by the incumbent technology. If alternative fuel vehicles have difficulty entering a market dominated by gasoline cars, alternatives to the car face even greater barriers. Owners have learned to associate their cars not only with personal mobility, but also with freedom, flexibility, fun, status, safety, a personal territory, and perhaps most powerful of all, a means of self-expression. Different owners may place emphasis on different needs. To succeed without some form of enforcement, any replacement must satisfy at least several of these needs better than the existing technology.

When a radical innovation does occur in a technology of fundamental importance, it may trigger an avalanche as a complex web of technologies and institutions require redevelopment (Schumpeter, 1935; Freeman and Perez, 1988). Such a shift may now be occurring with the spread of mobile information, communication, and networking technologies. Achieving substantial GHG mitigation may depend on recognizing when such transformations are occurring, and taking advantage of them.

5.3.1.3 The Context for Technological Change

The wider context plays an important role in shaping technological change and hence in determining the feasibility of GHG mitigation. There are several important elements or dimensions of the context for technological change:

- market conditions, including ease of entry for new firms and technologies; availability of capital; the degree of internalization of social and environmental concerns through taxes, subsidies, insurance, and other mechanisms; and the degree of competitiveness, including any oligopolistic practices or informal arrangements between government and the private sector;
- the legal system, including the system of intellectual property rights; the allocation (e.g., among firms or between the public and private sector) of liability for past and future environmental damage; freedom of speech and information; and ease of litigation;
- the physical infrastructure, including the design of cities and other settlements, transport systems, and utilities; and their flexibility in permitting the adoption of alternative technologies, lifestyles, and production systems;
- social and political structures, including the role of the public in decision-making; the location of power in institutional and social relationships; the presence of formal or informal alliances, for example involving government, industry, and the media; and the allocations of roles within households and communities;
- culture, including cultural diversity; the role of technology and material consumption in establishing individual identity, status, and social bonds; tendencies towards competition and co-operation, conformity, and distinction; and
- psychology, including awareness, understanding, and attitudes relating to climate change, its causes and potential impacts, and to changes in technology and lifestyles.

Of these dimensions, most attention has been paid in the literature, including the SAR, to the role of markets and legal systems. Existing market and legal incentives can pose barriers to some kinds of technological change, as discussed in later sections of this chapter. Changes in the market and legislative context can also provide opportunities for innovation. For example, the need to address local pollution through government regulations may stimulate innovation that can contribute to GHG mitigation. Porter and Van der Linde (1995a) argued that environmental regulation of industries could also promote their competitiveness through accelerated innovation, although this has been disputed by Palmer *et al*. (1995), who argues that most evidence is that regulation, as historically practised, has not fostered competitiveness, and has encouraged innovation only narrowly aimed at regulatory compliance (Berman and Bui, 1998; Xepapadeas and de Zeeuw, 1999).

The effects of physical infrastructure have been less studied, being harder to measure than those of prices and regulations. Infrastructure often acts as a constraint on changes in technology and behaviour: existing road systems and settlement patterns in many countries tend to encourage car dependency; the existing supply networks for domestic and transport fuels make it difficult for individual households or firms to adopt alternatives. In this chapter, the role of infrastructure is considered in relation to buildings, transport, and energy supply (see Sections 5.4.1 to 5.4.3).

The social capital passed on from generation to generation offers an opportunity for diffusion of GHG mitigation technologies in traditional and modern societies alike. Societies in which trust and civic co-operation are strong have significant positive impact on productivity, especially human capital productivity, and provide stronger incentives to innovate and to accumulate physical capital. More investment in consultation and participation of the local population in decision making about GHG mitigation technologies contribute both to information sharing, to building trust, and civic co-operation. The former may contribute to changes in beliefs, norms, and values if participants are convinced that they are better off after effecting the change (Gibson *et al*., 1998).

Reliance on market mechanisms alone, without an appropriate institutional framework that performs a co-ordinating function among sectors, is inadequate and may be destructive of social capital. Policy attention to learning by doing, and network externalities, together with policy stability and enforcement favour the diffusion of GHG mitigation technologies.

Addressing the last three dimensions listed above thus involves understanding human psychology, relationships, communities, institutions, and the process through which social norms and decisions are established. These aspects of climate mitigation are addressed in Sections 5.3.6 and 5.3.8 of this Chapter.

5.3.2 Prices

Prices can have an important influence on the consumption of resources and hence on GHG emissions. There is extensive literature on the use of prices to reflect environmental and other social costs associated with resource use. If such costs were fully reflected in prices, they would encourage producers and consumers to adopt environmentally sustainable technologies and practices. Where an adequate legal framework exists, it should be possible in principle for those suffering the effects of pollution or climate change to seek compensation from those responsible. In practice, markets in environmental and social damages function poorly, if at all, because transaction costs (e.g., the costs for victims to identify polluters and seek compensation) are high compared with the environmental and social costs suffered.

Where environmental and social costs are not reflected in markets (i.e., they are externalities), there are many ways in which governments can internalize them, notably through environmental regulations and taxes. However, governments have to balance a large number of objectives and the outcome may not be efficient in linking resource prices to GHG emissions. A variety of different types of government policy tend to reduce prices, in addition to the direct budgetary subsidies that are often introduced to support employment in particular sectors or to enable the poor to meet basic energy needs (OECD, 1997b). Examples include policies requiring electric utilities to provide universal, low-priced access to grid systems or even to maintain supplies when consumers fail to pay their bills (EBRD, 1999; World Bank, 1999). In India, electricity has historically been subsidized for residential consumers, serving as a disincentive for the adoption of efficient lighting and appliances (Alam *et al*., 1998). When energy subsidies are reformed or removed, transitional or permanent supports are often required for some of the former recipients (OECD, 1997b). For example, in Russia, the introduction of long-run marginal cost electricity pricing has led to pensioners being unable to afford their electricity bills, requiring support that amounts to 20%-35% of local authority budgets (Gritsevich, 2000).

Government policies to address a wide range of environmental and social problems can encourage GHG mitigation by increasing the prices of carbon-intensive energy sources or decreasing the prices of non-carbon options. Such policies include pollution taxes and charges for the use of infrastructure and services, subsidies for renewable energy, and regulations requiring producers to sell electricity generated from low-carbon sources.

The developers of new technologies often seek to recover their investment in R&D through license fees for the use of their innovations. Such license fees may inhibit the adoption of the best available technology for GHG mitigation in developing countries.

Energy price expectations can have a strong influence on investments in low-GHG technology. Where energy prices fluctuate in unpredictable ways, investors may tend to delay investments in new technology, and be unwilling to adopt low-emission technology where this entails increased up-front costs. The next section discusses the effects of risk on investment.

A substantial literature has developed on the tendency of consumers and businesses to pay more attention to initial investments than operating costs, when considering technology choices (Hassett and Metcalf, 1995; Jaffe and Stavins, 1995). In the past, prices for some types of appliance, such as refrigerators, have tended to show little correlation with energy intensity within a given range of size and performance characteristics (Greening *et al*., 1997). The prices of appliances and vehicles are influenced by many factors, not least their aesthetic features, and energy efficiency is usually a minor source of variation. On the other hand, several governments have used taxation to introduce a price incentive for buying cars with smaller engines, lower fuel consumption, and to encourage the use of alternative fuel vehicles (IPCC, 1996; ECMT, 1997).

5.3.3 Financing

Many environmentally beneficial technologies require significant “up-front” investment. This investment will be typically offset, over time, by the environmental benefits, out-of-pocket cost savings, or financial revenues associated with the new technology. There are, however, many circumstances where users are unable to purchase equipment that is financially viable to them or beneficial to the society, simply because they do not have access to the private or government investment funds necessary to install the equipment. To the extent that private entities are not willing to provide funds to implement investments that are financially viable and in addition reduce GHG emissions, they constitute failures of capital and financial markets that must be overcome to reach the level of economic potential. In contrast to private financiers, who are primarily concerned about the risk-adjusted financial return, governments are expected to evaluate desirability of investments in a wider context of the well-being of the whole society, including harms and benefits that some entities impose on others. To the extent that governments are not willing to finance investments that are socially desirable thanks to climate and other environmental benefits, they constitute policy failures that prevents achievement of socioeconomic potential. All these market and policy failures are aggravated in developing countries and low income transition economies, where they interact with poverty and capital constraints.

Commercial Banks

Notwithstanding the significant potential as a supplier of investment capital for climate-friendly technology transfer, commercial banks thus far have not developed large portfolios of environmental loans (Delphi Int. Ltd. and Ecologic GMBH, 1997). Banks face high up-front cost of developing new, “green” financial products (e.g., energy-efficiency loans). To bear these costs is often perceived risky by the bankers, given uncertain and policy-dependent future market conditions. Relatively low capital requirements and the long-term cash-flow profile of many climate friendly investments, as well as high transaction costs of servicing large numbers of small and medium-sized projects, further reduce comparative attractiveness of this sector to the commercial banks (Berry, 1995). Technologies such as energy efficiency or public transport often have low collateral value compared to their traditional alternatives, making it difficult for the banks to use some financing instruments such as project finance.

Even if the size of the loan for manufacturing or distributing climate friendly technologies would justify the attention of bankers, the debt carrying capacity of such projects hinges upon the availability of financing for the end users, e.g., households to enable them to purchase those technologies. These down-stream projects most often require completely different financial products, which commercial banks are often not able to offer (e.g., micro-credits or grants to low income households with no assets).

Different energy producers and consumers have varying access to capital in financial markets, and at different rates of interest. In general, energy suppliers can obtain capital at lower interest rates than can energy consumers – thus, an "interest rate gap". Differences in these borrowing rates may reflect differences in the knowledge base of lenders about the likely performance of investments, as well as the financial risk of the potential borrower. At one extreme, electric and gas utilities are able to borrow money at low interest rates. At the other extreme, low-income households may have essentially no ability to borrow funds, resulting in an essentially infinite discount rate for valuing improvements in energy efficiency. The broader market for energy efficiency (including residential, commercial, and industrial consumers) faces interest rates available for efficiency purchases that are also much higher than the utility cost of capital (Hauseman, 1979; Ruderman *et al*., 1987; Ross, 1990).

"Green" Financial Institutions

In response to the difficulties faced by the emerging environmental business sector in accessing traditional financing institutions, such as banks (Asad, 1997), a number of innovative approaches and specialized financial institutions have developed. These include environmental project finance (Stewart, 1993; Shaughnessy, 1995; Davis, 1996), green investment funds, leasing (Carter, 1996), environmental and ethical banks, environmental funds (OECD, 1999b), and energy service companies (ESCOs). Not clearly defined property rights to GHG emitting assets create obstacles to ESCOs and other similar institutions, that invest in the assets of third parties and rely on a contracts with owners to recuperate the return (WB and IFC, 1996). The growth of new "green" financial institutions hinges upon the long-term market growth prospects for the environmental business sector, which in turn depends fundamentally on the consistent and clear commitment by governments to climate policies (Delphi Int. Ltd. and Ecologic GMBH, 1997). Specific incentives, such as tax allowances, have been shown to stimulate the market penetration by green investment funds in some developed countries (e.g., The Netherlands).

In the last years of the decade sustainable forestry has started to attract private finance. Some new green financial institutions have worked towards capturing values of standing forests through innovative financial mechanisms. Sustainable forestry has provided attractive returns relative to stock markets. Forestry investment funds have typically achieved annualized returns in excess of 14% over the last decade. This was in excess of the returns on the S&P 500 index for the equivalent period (Ecosecurities, 1999). Forestry investments had lower volatility than stock markets, and could provide solid long-term returns. However, to the extent that these involve wood plantation where logging is an important part, the climate benefits are negligible. Managing forests and harvesting their products and services efficiently significantly improves financial return to the standing forests versus logging. The marketable goods and services of forests include pharmaceuticals (Simpson *et al*., 1996), genetic resources (Rosenthal, 1997), and ecotourism (Panayotou, 1997). An important factor stimulating financial viability of sustainable forestry is the move of government, world business, and consumer demand towards confining wood procurement to environmentally sustainable sources.

Investors

Individual and institutional investors send important signals to companies in the pricing of new capital raised by the companies and in on-going valuation of quoted companies. They can also exert direct influence by using their rights as shareholders and owners. The key concern for investors is the relationship between environmental performance and investment performance. Many investors remain unconvinced that the present value of their portfolios may be affected by the future consequences of climate change. They also are not convinced that environmental performance contributes to good financial performance.

There is some empirical evidence, however, that investors do value environmental performance of firms. Dasgupta *et al*. (1998) showed that capital markets in Argentina, Chile, Mexico, and the Philippines reacted positively (increasing the firms' market value) to the announcement of rewards and explicit recognition of superior environmental performance. They found capital markets to react negatively (decreasing the firms' value) to citizens' complaints and to news of adverse environmental incidents (such as spills or violations of permits). Environmental regulators could harness market forces by introducing structured programmes to release firm-specific information about environmental performance, and empower communities and stakeholders through environmental education programmes. Lanoie *et al*. (1997) arrived at similar conclusions, drawing on evidence from American and Canadian studies.

Insurance Firms

The potential of the insurance sector lies in its ability to diversify its investment portfolio and to have its premium structure reflect environmental risks (Delphi Int. Ltd and Ecologic GMBH, 1997). The insurance industry may provide project finance and insurance for preventive infrastructure projects, thereby enhancing their access to finance. The insurance industry also provides strong financial incentives for loss prevention and mitigation to their clients and the public, e.g., by means of deductibles (UNEP, 1999). Some insurance companies have launched the "Insurance Industry Initiative for the Environment", in association with UNEP.

User Charges

Generation of revenues from the users of public infrastructure can be an important source of funds for financing GHG emissions reduction in the power and district heating sector and other types of GHG emission-intensive infrastructure. Covering the costs of operation, maintenance, depreciation calculated according to the international accounting standards, and eventually debt service for investments is essential for the sustainability of infrastructure systems and important for attracting multilateral development banks (MDBs) and private finance (UNIDO, 1996; EBRD, 1999). In low-income countries this needs to take full account of affordability constraints. However, concern about the social impacts too often makes the governments reluctant to adopt higher tariff levels, even though evidence suggests consumers in many countries could afford and would be willing to pay more for improved service (Lovei, 1995; Gentry, 1997; AFDB, 1999).

Government-created Disincentives to Private Investment

Government policies may themselves be a source of risk to private investments, creating detrimental framework conditions for all, not only environmental, investments through unstable fiscal policy and a macroeconomic environment. This leads to high interest rates, elevated inflationary expectations, and fluctuating exchange rates. The traditional response to these problems through fiscal consolidation and tight monetary policies usually induces low liquidity in the enterprise and banking sector (EBRD, 1999). This liquidity constraint may be sharpened by obstacles to trade and bank credit, barriers to entry, especially for SMEs and foreign firms, barriers to foreign direct investments (FDIs) and to long-term foreign capital investments, all of which could otherwise relieve capital shortages (EBRD, 1997b; EBRD, 1998; EBRD, 1999). Weak governance, typically manifested by the lack of the rule of law, soft budget constraints, absence of competition in government procurement, and corruption, may foster a perverse microeconomic incentive structure that rewards private sector entities not for being competitive and efficient in using resources, but rather for "seeking rents" through friendly and not transparent relations with politicians (Gady and Ickes, 1998).

Governments sometimes introduce distortions directly to financial markets, constraining the private lending to investments. Imprudent government borrowing can raise interest rates and crowd out bank loans from the "real" sector of the economy (OECD, 1998b). Also, excessive subsidies to environmental investments may crowd out private sector financing (Peszko and Zylicz, 1998). The risk of lending for investments may additionally be increased by inadequate protection of creditors. This occurs when an underdeveloped legal and institutional system does not make it easy for creditors to seize collateral or initiate a turnover of management in the event of default.

Government-created Disincentives to Public Investments

Ill-designed taxation, as well as failures in budget planning and expenditure control may cause fiscal imbalances and high budget deficits, which contribute to high country sovereign risk, constrained access to foreign capital, and high cost of borrowing by the government. Increased nominal interest rates and related discount rates applied by the governments inhibit financing for most public environmental investments. Budget expenditure cuts usually involve ceilings for investment expenditures, while financing is made available for operation of existing technologies or infrastructure. This often leads to continuing operation of inefficient and polluting assets, even if their replacement through investment would bring a high rate of return.

A barrier to efficient use of government funds is poor management of public investment programmes and government budgets (OECD, 1998b). This is sometimes a result of an underdeveloped civil society, and absence of government accountability and transparency in budget preparation and implementation. Under these circumstances budgetary spending on environmental infrastructure and biodiversity tends to be neglected (OECD, 1999a; Partridge, 1996). An important opportunity to enhance government spending on climate friendly investments is through revising public sector expenditure choices (de Moor, 1997; Pieters, 1997). Many developing countries and the countries of the former Soviet Union could help both climate and economic development by phasing out ongoing subsidies to loss-making state owned, or even private enterprises.

Central and local governments have ample opportunities to create new mechanisms and new sources of finance for climate-related environmental investment (Tlaie and Biller, 1994; Pearce *et al*., 1997). Budgetary resources can be used more cost-effectively (Lovei, 1995) and more creatively (Clements *et al*., 1995) to leverage private capitalization of public environmental investments (World Bank, 1994; Partridge, 1996; UNIDO, 1996; Gentry, 1997; Peszko and Zylicz, 1998). Central governments can foster the use of economic instruments (tariffs, taxes, fees, etc.) to achieve environmental goals while generating budgetary revenues (Herber, 1997; Schlegelmilch, 1999). In the area of biodiversity pricing, instruments can result in a "double dividend". They can prevent the "tragedy of the commons" by limiting otherwise open access to vulnerable natural reserves. Prices also generate revenue to pay for the sustainable use of biodiversity resources and for afforestation. Successful examples of these government initiatives could be found in Latin America (Umana, 1996; Lopez, 1997), OECD countries (OECD, 1996) and Central and Eastern Europe .

Official Development Assistance

There is a mixed experience with donor aid programmes (Killick, 1997). Choice of beneficiary countries, sectors, and types of projects by the donor governments has often been driven by the geopolitical interests of donors rather than environmental or global priorities in the recipient countries. Bilateral aid is often a tool to support friendly regimes or strengthen the spheres of influence (Alesina and Dollar, 1998). Tied aid still dominates bilateral programmes, whereby the contracts are available only to firms from the donor country (Michaelowa, 1996).

Because of restrained competition tied aid may increase the costs of purchasing capital or providing services anywhere from 10% to 50%, and host governments are usually required to co-finance these projects. Some host governments have found themselves locked in the expensive, capital intensive, and inappropriate technologies that additionally created dependency for maintenance and spare parts. Tied aid may distort the efficiency of technology choice, and crowd out good technologies and viable business models (Graham and Hanlon, 1997). Tied aid has also had an impact on GHG emission reduction projects in the context of the Activities Implemented Jointly (AIJ) pilot phase (Michaelowa *et al.,* 1998).

Multilateral Development Banks

Sovereign guarantees required with most MDB lending involve host governments in making budgetary commitments that may be difficult to attain in many low income countries. Furthermore, strict adherence to sound banking principles (of not lower standards than in the highest-rated private banks) poses very high requirements for the internal financial viability of projects. It is not, clear, however that the MDBs can do otherwise. They can provide low cost lending only as a consequence of their high credit ratings. Maintenance of these high ratings requires very low exposure to default risk, which in turn depends on sovereign guarantees and sound financial parameters of a project.

Another problem with MDB loans is a longer time for and higher transaction costs of project preparation relative to the typical GHG emissions reduction project size. It usually takes 1.5-2 years and several hundred thousand US dollars to develop a project for financing. This can only be justified if the size of a project is minimum US$10-15 million. MDBs are trying to develop financial products that could reach small and medium-sized environmental projects (ADB, 1999). Trust funds and donor grants are used to lower project preparation costs. Smaller businesses are targeted trough intermediaries (local banks, leasing, ESCOs, or even NGOs) which "on-lend" MDB loans as a package of smaller financial products. Structural lending is used to finance multi-project programmes.

Most of the financing difficulties discussed above are most severe in developing countries, where they interact with poverty to severely constrain investment in GHG-efficient technology. Less developed capital and financial markets call for innovative financing to enable low-income households to afford GHG-mitigating technologies. This offers an important opportunity to integrate the broader objectives of development, equity, and sustainability (DES).

5.3.4 Trade and Environment

The barriers discussed in this section pertain to the whole economy of a country, and constitute a type of market failure. They inhibit the implementation of mitigation options indirectly by maintaining conditions in which investments in energy efficiency and fuel switching are ignored, undervalued, or considered too risky by economic actors.

High tariffs on imported goods or policies that constrain entry of imported products into the market can prevent new and GHG-efficient technology from entering the country. Since countries often rely on imports for high-efficiency equipment, duties can raise the price of imported equipment considerably. When both types of equipment are imported, the duty raises the price differential between the two.

An example of the limitations created by government regulation was a high import duty imposed on CFLs in Pakistan. When this duty was reduced from 125% to 25% in 1990, the price of CFLs dropped by almost half, and sales started to rise, leading to improved energy efficiency (US AID, 1996).

Government regulations that prohibit foreign firms from bidding on the construction of new industrial factories or power plants limit a country's access to new foreign technology. Conditions that constrain the entry of imported products, while beneficial in establishing a new industry or in achieving rapid expansion of an existing one, can also lead to the use of obsolete technology. The history of government intervention to address a severe paper shortage in India during the early 1970s illustrates this barrier. To address the shortage, the Indian government promoted the establishment of small paper mills that could be quickly set up (Datt and Sundharam, 1998). This led to the import of inexpensive energy-intensive and highly-polluting second-hand paper mills that were set up in many regions of the country. The inefficient mills grew to account for 50% of the country's paper production. Then, in 1988, the government removed the protection it had accorded the paper industry, which led to the shutdown of many of these small, inefficient plants. The elimination of government protection will in the long run increase GHG efficiency and economic productivity.

The transfer of modern technology takes place mainly through licensing of designs for local production, joint ventures, and export and/or import. Practices of transnational corporations, and policies of countries can inhibit these modes of technology transfer. Also, large fluctuations in exchange rates and inflation can inhibit capital flows. The fuel economy of motor vehicles across developing countries varies with the type of technology that is imported. Countries either import new (high fuel economy) or used (mostly lower fuel economy) motor vehicles, manufacture vehicles with outmoded low fuel-economy technology (Ambassadors in India or the VW Bug in Mexico and Brazil, the VW Jetta in China), and/or manufacture modern vehicles with some domestic components (Nissan in the Philippines, Maruti/Suzuki in India) (Sathaye and Walsh, 1992). Lack of suitable local firms to supply components and services, limited access to capital, and restrictions on repatriation of foreign exchange are some of the conditions that slow the introduction of modern efficient vehicles (Davidson, 2000, Section 8, Transportation).

There is not much empirical evidence for a relationship between trade and environmental regulation (Cropper and Oates, 1992; Rauscher, 1999) though there is a little more in the direction of the impact of trade on the environment (van Beers *et al*., 1997). This lack of empirical relationship is caused by two reasons. First, it is most cost effective to use the same technology everywhere and, therefore, to operate everywhere according to the most stringent environmental regulations (Levinson, 1994). Second, the industry cost of environmental regulation is too small relative to other costs, such as labour, to weigh heavily in location decisions (Dean, 1992; Jaffe *et al*. 1995; Markusen, 1999; Steininger, 1999). In particular, there is little empirical evidence that developing countries tend to become pollution havens. This is because their production is primarily for the domestic market, their comparative advantage lies in less-polluting labor-intensive sectors, and weak environmental standards often go hand in hand with other factors that deter investment such as social capital weaknesses (Frederikson, 1999; Markusen, 1999). There is no empirical evidence of systematic FDI in polluting industries (Leonard, 1988). The environmental effects of trade liberalization seem to be highly country- and policy-specific (Frederikson, 1999).

There is also little evidence, both on theoretical and empirical grounds, of a "race to the bottom" when other countries use environmental standards to retaliate against trade measures. A globally optimal solution remains a combination of free-trade and co-operative environmental policies. This does not mean that, as environmental resources become scarcer, free trade may not generate negative environmental impacts under some circumstances as suggested by theoretical models (Copeland and Taylor, 1994; 1995). Little is known both theoretically and empirically about the links among trade, environment, and innovation (Carraro, 1994, Steininger, 1999). There is also little evidence, both theoretical and empirical, in favour of the Porter Hypothesis that stronger environmental regulation creates a long-term technological advantage (Jaffe, 1995; Ulph, 1997). Regulatory capture through which interest groups striving for protection against foreign competition lobby against environmental standards and for environmental tariffs is a possible barrier to diffusion of technology. Capture is less likely under a market-based instrument approach to environmental policy, which regulates polluting substances than under a command-and-control one, which regulates polluters. This is because the former raises the cost of lobbying and decreases the agency problem as the regulated group is larger and more heterogeneous under the former regime than under the latter and has no incentive to hide information from the regulator (Rauscher, 1999). Many international environmental agreements allow for trade sanctions. Though, in a less than efficient world, trade sanctions for environmental violations can be justified, the latter are discriminatory and may jeopardize diffusion of required technologies (Rauscher, 1999).

5.3.5 Market Structure and Functioning

Market failures related to pricing, information and institutional imperfections are discussed elsewhere in this section. In this subsection a variety of other barriers and opportunities related to the behaviour of market actors and the features of specific markets are considered. The majority of these opportunities and barriers affect the demand for higher energy efficiency, but in many developing and transitioning countries there are also problems on the supply side of markets.

In considering opportunities and barriers related to market behaviour and features, it is important to recognize that consumers (broadly defined to include households, firms, and other actors) and producers and/or providers in specific markets are in continual communication. In general, suppliers deliver what they think consumers want. But in markets characterized by a high degree of inertia or aversion to risk on the part of suppliers, there may be latent demand for higher levels of energy efficiency than are readily available in the market. Suppliers may not expend the effort to cultivate the demand for more efficient products or to develop marketing approaches to help overcome some of the barriers on the demand side (such as financing schemes).

The importance of particular barriers varies among specific markets. On the demand side, barriers tend to be greater with respect to households and small firms than with large companies, who are more able to evaluate investments. Similarly, in markets where the supply side is heavily comprised of small firms with low levels of technical, managerial, and marketing skills, the barriers tend to be higher.

Network Externalities

Some technologies operate in such a way that any given user's equipment interacts with the equipment of other users so as to create what economists call network externalities (David, 1985; Katz and Shapiro, 1986). For example, since vehicles must be refuelled, the attractiveness of vehicles using alternative fuels is very dependent on the availability of convenient sites for refuelling. Furthermore, the development of a rich infrastructure devoted to distributing any given fuel is, in turn, dependent on there being sufficient vehicles using that fuel to generate a large demand for that infrastructure. This need to create an interacting network of equipment and infrastructure can be a barrier to the diffusion of new technology, in that a potentially superior technology may have difficulty diffusing because of the lack of necessary infrastructure, while the diffusion of the infrastructure is impeded by the low diffusion of the new vehicles.

5.3.5.1 Demand Side of the Market

The diffusion of GHG-efficient technology may be limited by "irrational" or less-than-rational behaviour of households and firms. Such behaviour may be observed because of the way individuals process and act on whatever information they may have. The behaviour of an individual during the decision-making process may seem inconsistent with their goals. More or better information alone may be insufficient to change behaviour, which is strongly influenced by habit or custom (Brown and Macey, 1983).

Within organizations, various factors discourage or inhibit cost-effective decisions regarding new technology. For businesses, the priority of other investment opportunities (e.g., to maintain or expand market share and production capacity) may cause the firm to reject cost-effective GHG-efficiency investment opportunities. Where energy costs are a small component of total production costs, management may not provide sufficient support for energy efficiency investments. In addition, within a firm, no single party or department may have clear and explicit responsibility for managing energy costs.

Another facet of behaviour that is often cited as a barrier to energy efficiency investments is the demand for a rapid payback that may be either explicit or implicit in behaviour. To some degree, the so-called high discount rate applied by consumers could be seen as an aspect of "irrational" behaviour. However, the demand for a rapid payback is also related to particular features of energy-efficient products or services (such as uncertain performance), specific circumstances related to home and appliance ownership, the context in which these products are placed, or to macro-economic conditions, such as high inflation or uncertain future energy prices.

5.3.5.2 Supply Side of the Market

Limited Availability of Products or Services
This may result from decisions and practices of manufacturers and/or distributors. Firms that provide services related to energy efficiency may be few in number. Availability is typically lower (and prices are higher) in rural areas than in large cities. To some extent, limited availability of products and services is a "chicken and egg" problem, which tends to be most problematic in the early stages of market development for a more efficient product or service.

Weakness of Suppliers in Market Research
Firms may lack the resources or capability to do adequate market research, thereby inhibiting the development of new products or services for which there might be a demand.

Weakness of Suppliers in Product Development
Firms may be lacking in skills required for the development of new products, or in capital for investment in new production capacity. Gaining access to advanced designs and/or manufacturing techniques may also be a problem (related to international technology flows).

Weak Marketing Capabilities of Suppliers
Firms may lack the skills for adequate marketing of more efficient products or services.

5.3.6 Institutional Frameworks

Economic actors interact and organize themselves to generate growth and development through institutions (and policy making). While organizations are material entities possessing offices, personnel, equipment, budgets, and a legal character; institutions are systems of rules, decision-making procedures, and programmes that give rise to social practices, assign roles to participants in these practices, and guide their interactions. Organizations may administer institutions (Young, 1994). Institutions exhibit substantial continuity and offer narrow and infrequent windows of opportunity for reform (Aghion and Howitt, 1998; Rip *et al*., 1998). Institutions operate in larger settings characterized by material conditions such as the nature of available technologies and the distribution of wealth, by cognitive conditions such as prevailing values, norms, and beliefs, and by transaction costs, costs of co-ordination, laws, etc. (Young, 1994; Coase, 1998). The market is a "set of institutions, expectations, and patterns of behaviour that enable voluntary exchanges" based on the willingness to pay of the parties to the exchange (Haddad, 2000). One major concern of the new institutional economics is the boundary between the market on which transactions are negotiated and organizations such as the firm (Simon, 1991).

On one level, all barriers can be considered institutional in origin, because markets, firms, governments, etc. are all institutions. In this section, however, the focus is on those barriers that derive from widespread or generic attributes of institutions. The distinctions are necessarily arbitrary, and some overlap between the discussion in this and other subsections is inevitable.

Institutions are a form of capital, social capital (Coleman, 1988). Social capital, like natural and human capital, is at the same time an input and an amenity. As an input, it enhances the benefits of investments in other factors and, thereby, shares the "shift" feature of technology (World Bank, 1997). Social capital is a public good and suffers, therefore, from underinvestment. Generally, weaknesses in social capital resulting from prevailing beliefs, norms, and values are an important generic barrier to the effectiveness of institutions. At the microeconomic level, social capital may be viewed as a social network, and as associated norms which may improve the functioning of markets and the productivity of the community for the benefit of the members of the association (Coleman, 1988; Putnam, 1993; World Bank, 1997; Young, 1999). At the macroeconomic level, social capital includes the political regime, the legal frameworks, and the government's role in the organization of production in order to improve macroeconomic performance as well as market efficiency (Olson, 1982; North, 1990). Institutions may remedy market failures due to asymmetric information through information sharing (Shah, 1991). Societies in which trust and civic co-operation are strong, a component of social capital, have significant positive impact on productivity and provide stronger incentives to innovate and to accumulate physical capital. Trust and civic co-operation tend to affect human capital productivity especially (Knack and Keefer, 1997).

5.3.6.1 Achievement of Economic Potential

High transaction costs and inadequate property rights
Substantial cost reductions may go unrealized when the trans-

action costs are high. Attempts to reduce transaction costs and to clarify property rights may yield substantial long-term gains. Uncertain property rights, especially as far as intellectual property rights are concerned, act to increase discount rates. Procurement routines which include energy consumption as a criterion, and accounting procedures which are adapted to the polluter-pays principle may need to be adopted to provide appropriate incentives for production units to reduce energy consumption. Intellectual property rights encourage foreign investment, but could also have a negative impact on the adaptation of existing technologies to local conditions (Blackman, 1999).

Demonstration projects, advertising campaigns, testing and certification of new technologies, subsidies to technological consulting services, and science parks are ways for governments to enhance the flow of information on new technologies. This information is bound to be imperfect, because firms have no incentive to supply information about new technologies to late adopters, and technology suppliers are more concerned about market share than about technology diffusion (Blackman, 1999).

Misplaced Incentives

In some situations, the incentives of the agent charged with purchasing a product or service are not aligned with those of the persons who would benefit from higher efficiency. An example is in rental housing where the tenant is responsible for the energy bill, so the landlord has little or no incentive to undertake energy efficiency improvements or acquire more efficient equipment. Other examples of misplaced incentives are present in contracts which pay fees to architects and technical advisors that are measured as a percentage of total project investment, and give rise to over-sizing and "gold-plating" without sufficient attention to the (energy) performance of the investments.

Inefficient Labour Markets

These may prevent the efficient movement of skilled workers among sectors. This may slow technology diffusion and therefore growth (Aghion and Howitt, 1998).

Co-ordination Problems between Technology-producing Sectors

Some technologies, dubbed "general purpose technologies" (or "GPTs", Bresnahan and Trajtenberg, 1995), are characterized by much initial scope for improvement, many varied uses, applicability across many diverse sectors, and strong complementarities among the uses in different sectors (Helpman, 1998). Development and diffusion of these technologies requires co-ordination between the sector or sectors producing the GPT and the application sectors, because rapid development of the GPT is dependent on improvements in the technologies in the application sectors, and vice versa.

Policy Uncertainty

Climate change uncertainties inhibit desirable investment in new technologies and long-term capital goods. The resulting uncertainty about energy prices, especially in the short-term, seems to be an important barrier. Therefore, policy uncertainty should not add to the incentive of holding off relatively irreversible investments. Policy stability is a virtue and institutions are patterns of routinized behaviour that stabilize perceptions, interpretations, and justifications (Giddens, 1984; O'Riordan *et al*., 1998; Schmalensee, 1998). Lack of credibility of technology forcing policy is a form of policy uncertainty as is illustrated by the example of the 1970 US automobile emissions standards (*Box 5.2*) (Rip and Kemp, 1998). Another form of policy uncertainty results from a crisis by crisis government management style, or from the fact that issues are sometimes championed by individuals and die off when these individuals leave the political scene.

5.3.6.2 Achievement of Socioeconomic Potential

Vested Interests

Organizations provide not only public goods to their members

Box 5.2. United States Automobile Emission Standards

Federal controls on US automotive air pollution (carbon monoxide, oxides of hydrogen, and hydrocarbons), inspired by a technology forcing philosophy, were first applied to 1968 model cars in the US. In the following years, the standards were gradually made more stringent (White, 1982). The 1970 Clean Air Act imposed stringent nationally uniform emission limitations on new motor vehicles requiring 90% reductions over uncontrolled emissions by 1975-1976 with fines of up to US$10,000 per car and limited provision for deadline extensions. The ambitious standards established proved to be difficult to achieve. By 1976, it became clear that many air quality areas were not going to meet the deadline for implementing the ambient standards (Ashford *et al*., 1985). The deadlines for achieving 90% reduction were repeatedly waived or statutorily postponed. The $10,000 fine was not credible (Stewart, 1981). The Clean Air Act was amended in 1977, and moved away from technology forcing by introducing market incentives such as innovation waivers (Ashford *et al*., 1985). Empirical results show, however, with very little ambiguity, significantly lower emissions from vehicles for 1968 and after, especially for the years in which emissions were tightened (White, 1982). Therefore, compliance was achieved despite the fact that industry argued, or that compliance with the regulation was doubtful or thought to be impossible. Rapid diffusion of add-on catalysts and minor modifications to the standard combustion engine were achieved but basic changes in engine technologies did not materialize. Uncertainty about whether a deadline or a fine will be enforced gives the signal to industry that a technology developed may ultimately not be needed, and that adopting low-risk existing technologies *i.e*., technology diffusion is the way to go (Stewart, 1981; Ashford *et al*., 1985).

but also selective incentives, i.e., private goods. These selective incentives may be sufficient to maintain the organization even if the public good it once provided is no longer needed. Organizations that represent a narrow segment of society do not have an incentive to increase society's output, but rather to increase the share of output going to its members. These organizations are themselves barriers by being rent-seeking coalitions which reduce efficiency and output, and increase the political divisiveness of society. Rent-seeking coalitions interfere with an economy's capacity to change because of their slow decision-making processes, and because they increase the complexity of regulation and the role of government (Olson, 1982).

A major barrier to the diffusion of technical progress appears to lie in the existence of vested interests among economic agents specialized in the old technologies and who may, therefore, be tempted to collude and exert political pressure on governments to impose administrative procedures, taxes, trade barriers, and regulations in order to delay or even prevent the arrival of new innovations that might destroy their rents (Olson, 1982). The duration of the delay will depend in part on the design of political institutions and in part on technological characteristics (learning by doing and knowledge externalities), and on the balance of power between innovators and incumbents. The more learning by doing and the more positive knowledge externalities on the older technology, other things being equal, the lower the frequency of new innovations (Jovanovic and Nyarko, 1994; Krusell and Rios-Rull, 1996; Aghion and Howitt, 1998).

Firms' Institutional Structures

Firms' institutional structures shape their responses to technological opportunities and policies. Firms that tend to maximize stability and tend to rely on single–source internal analyses for information are the least likely to be first adopters of a new technology. On the other hand, firms that maximize profitability, and rely on multiple internal and external sources of information were most likely to experiment with a variety of technologies, but unlikely to commit themselves to a single fuel or process (Braid *et al*., 1986; O'Riordan *et al*., 1998). A vertically integrated firm may be slower to absorb information and respond to change than a firm where lateral transfers are possible ("smart workplaces"). An integrated firm also has less incentive to innovate than a decentralized one ("Arrow replacement effect"). On the other hand, as a lot of climate change innovation research is of an applied nature, research is more productive when it is carried out by the firm itself than when delegated to a research institution. Delegation of the research function to a specific entity within the firm increases the incentive to acquire information, but also increases the probability of getting a suboptimal innovation (Aghion and Howitt, 1998; DeCanio, 1998).

Inadequate Attention to Institutional Design

This lack of attention, for example, is especially connected to the institutional context ("national innovation system") for the heuristic search which gives rise to a set of new findings, blueprints, artifacts ("selection environment"), and which may yield a protected space ("niche") in which a new product can survive more easily because of technology forcing. A national innovation system provides long-term goals, predictions of long–run outcomes, creation of an actors' network, adequate experimentation, and monitoring of outcomes, formulation of standards, tax and subsidies, etc. for alternative energy technologies (Freeman and Soete, 1997; Rip and Kemp, 1998).

National policy styles, as routinized institutional methods to deal with issues, in which the balance of authority is shifted from formal institutions toward informal networks and associations may help achieve economic potential. This shift favours the development of innovative policy formulation, and implementation (Wynne, 1993; O'Riordan *et al*., 1998).

Lack of Effective Regulatory Agencies

Many developing countries have excellent constitutional and legal provisions for environmental protection but the latter are not enforced (O'Riordan *et al.,* 1998). However, "informal regulation" under community pressure from e.g., non-governmental organizations, trade unions, neighbourhood organizations, etc. may substitute for formal regulatory pressure (Pargal and Wheeler, 1996). Informal regulation is correlated with the adoption of clean technologies (Blackman and Bannister, 1998). Differences in regulatory costs between the old and the new technologies affect the rate of return on the new technology and the speed of diffusion of technologies (Millman and Prince, 1989; Ecchia and Mariotti, 1994).

Reliance on Market Mechanisms when Inappropriate

Organizations co-ordinate behaviour by promulgating standards and rules, and by offering certification that allows actors to formulate stable expectations about the environment and about the behaviour of other actors. Markets perform such functions incompletely or not at all. Thus, reliance on market mechanisms, to the exclusion of the development of organizations needed to perform standard-setting and other co-ordination functions limits the spread of new technology by increasing uncertainty and preventing the realization of co-ordination benefits.

5.3.7 Information Provision

Consumers of energy-using technologies cannot make good decisions regarding which technologies to employ unless they possess the appropriate information. The need for information creates three potential types of market failures with respect to energy-using technologies (Jaffe and Stavins, 1994).

Information as a Public Good

Generic information regarding the availability of different kinds of technologies and their performance characteristics may have the attributes of a "public good", and hence may be underprovided by the private market. This relates both to information that consumers need to acquire about specific technologies, as well as to information that manufacturers need to acquire regarding the attributes and needs of consumers. This problem is exacerbated by the fact that even after a technology is in place and being used, it is often difficult to quantify the energy savings that resulted from its installation, since usage patterns and outside influences such as weather may have changed. Knowing that this uncertainty will prevail can itself inhibit technology diffusion, as internal or external advocates for a new technology may doubt that they will be able to justify investment decisions after the fact. Firms supplying products or services within a particular market learn from one another with respect to understanding the market and operating effectively in it. The processes and networks by which this learning takes place, such as professional associations, conferences, publications, and informal networks are often weak in developing countries and EITs.

Adoption Externalities
One of the mechanisms for the transmission of both generic information and application-specific information may be the process of technology adoption itself. That is, one way that a user learns about a new technology is by seeing it used or communicating with other agents that have used it. In this case, the adoption of the new technology by a given user creates a positive information externality, by lowering the cost for others to acquire useful information. This implies that the act of adoption has social benefits that exceed its private benefits, and hence will be inadequately undertaken by private agents.

Misplaced or "Split" Incentives
The third form of informational barrier arises in an institutional context in which investment decisions regarding energy technology must be made in an environment of "agency," that is, one economic agent must make an investment decision that affects the energy costs of some other agent. Examples include contractors who build for others, and tenant-landlord situations where investments are made by the landlord that reduce a tenants' energy costs (or vice versa). In these situations, the party making the investment can recover that investment from the party paying the energy costs only if the investor can credibly convince the consumer that the energy savings justify the investment. That may not happen, however, because information is costly to convey credibly.

The limitations that inadequate information places on decision-making depend on the context. Institutions play an important role both in transmitting information, and in determining the extent to which incentives exist to share and act on information. There is therefore a close relationship between informational and institutional barriers, as evidenced by the discussion of "misplaced incentives" in the previous paragraph and previous subsection. Finally, in many situations it is difficult to determine the extent to which apparently efficient decisions are limited by inadequate information, or whether instead the information is available but decision makers' bounded rationality limits their ability to utilize information effectively.

5.3.8 Social, Cultural, and Behavioural Norms and Aspirations

Perhaps the most significant barriers to GHG mitigation, and yet the greatest opportunities, are linked to social, cultural, and behavioural norms and aspirations. In particular, success in GHG mitigation may well depend on understanding the social, cultural, and psychological forces that shape consumption patterns.

5.3.8.1 Experience from Energy Efficiency Programmes

Conventional policy development is based on a model of human motivation that has been widely criticized (Stern, 1986; Jacobs, 1997; Jaeger *et al*., 1998). People are assumed to be rational welfare-maximizers and to have fixed values, which, along with the information and means available to them, determine their behaviour. Practical analysis of energy efficiency and other GHG mitigation options often makes the narrower assumption that people are cost-minimizers (Komor and Wiggins, 1988). Such assumptions are undermined by experience with energy efficiency programmes. It has long been recognized that consumers do not necessarily act on their stated values (Maloney and Ward, 1973; Verhallen and van Raaij, 1981), and fail to take up measures that appear on paper to be economically worthwhile (Stern, 1986; Komor and Wiggins, 1988). Some of the reasons, such as energy price uncertainty and transaction costs, have been discussed elsewhere in this chapter and are consistent with the conventional view of consumers as "rational actors". Another important influence on behaviour is the source and quality of information on mitigation measures (the experiences of friends and family are trusted more than the advice of industry, retail sales staff or government) (Anderson and Claxton, 1982; Stern, 1986; Komor and Wiggins, 1988). It is much harder for the "rational actor paradigm" to accommodate features of human behaviour such as the gap between attitudes and action, the tendency to adopt behavioural routines rather than to optimize continually the limited number of variables that individuals typically take into account in their choices, and the tendency for people to rationalize their choices after the fact.

The gap between current practice and the economic potential has been characterized in this chapter as being caused by "barriers". However, Shove (1999) argues that the language of potentials, gaps, and barriers is itself an impediment to finding socially viable solutions for energy saving, and that new, more socially-sensitive approaches are needed to the analysis of measures, with researchers, industry actors, and policymakers working closely together. One of the greatest challenges for GHG mitigation strategies is that, for most people, neither energy saving nor GHG mitigation is a high priority (see for example, Gritsevich, 2000). Consumers' decisions about energy use are often motivated less by cost-minimization than by improving comfort and convenience (Wilhite *et al*., 2000).

5.3.8.2 Drivers of Consumption

If energy use, GHG mitigation, and cost-minimization are peripheral interests in most people's everyday lives, it might be helpful to consider what does shape their consumption patterns. The influences on human behaviour are complex, and can be described and understood in many different ways. Insights can be found in several disciplines, including anthropology, biology, economics, mathematics, sociology, philosophy, and psychology. Michaelis (2000a) summarizes some of the different drivers of consumption patterns. They include

- demographic, economic, and technological change;
- resources, infrastructure, and time constraints;
- motivation, habit, need, and compulsion; and
- social structures, identities, discourse, and symbols

The first and second of these groups of influences are addressed elsewhere in the TAR and in this chapter, and will not be considered here. The current section focuses on the third and fourth groups. It draws partly on an IPCC expert meeting held in Karlsruhe in March 2000 (German Federal Ministry of Environment, 2000b). It also considers the insights to be gained from viewing behavioural change as an innovation process.

5.3.8.3 Human Need and Motivation

Human need is central to sustainable development as defined by the Brundtland Report: sustainable development is development that meets the needs of current generations without compromising the ability of future generations to meet their own needs (WCED, 1987). But the concept of human needs is controversial. The word "need" is used in many ways: as a strongly felt lack or want; as a positive motivation or desire; and as a necessary condition for something, such as survival, social acceptance, or health. The failure to distinguish these different meanings has confused efforts to agree on the morality of need-fulfilment (Michaelis, 2000b).

One major barrier to the success of many policies is the failure to take account of the full range of human motivations and goals. For example, an engineer may design an energy-efficient building that provides occupants with adequate shelter and warmth, but it may be hard to get people to live in it if it is in the wrong area, or lacks features normally associated with adequate social status. Similarly, public transport may provide fast, efficient mobility for certain trips, but young men may see car ownership as the only way to attract a girlfriend. Maslow (1954) explained motivation in terms of human needs, which he divided into categories: physiological needs, sense of belonging, esteem, and "self-actualization". He saw these categories as a hierarchy, arguing for example that we are only concerned about self-esteem when we have had enough to eat. While the idea of a hierarchy has been largely discredited (Douglas *et al*., 1998), Maslow's categorization of needs continues to be widely used. Max-Neef (1991) proposed a more complex categorization of needs, divided into "having", "doing", "being", and "relating" needs, and emphasized the distinction between needs and "satisfiers".

While some consumption may respond to perceived needs, much is habitual. Habit formation is an important barrier to GHG mitigation as consumers may be unwilling or unable to change their behaviour or technology choices. The continuation of rising consumption levels has been widely observed and was noted by Jean-Jacques Rousseau in 1755 (Schor, 1998; Wilk, 1999). What was once luxury rapidly becomes habit, and then need. This is partly a social, as opposed to an individual psychological phenomenon, and will be discussed further in the next section. Often, we may try to use inappropriate satisfiers to meet particular needs (Max-Neef, 1991) – for example, eating in response to feelings of loneliness. Consumption of such ineffective satisfiers can become compulsive, especially when they give a short-term feeling of relief but fail to satisfy in the long term.

There may be opportunities for GHG mitigation in identifying where low-GHG-emitting behaviour can help to meet needs better than existing behaviour. Argyle (1987) finds from a review of several studies that human happiness is influenced mainly by health, the quality of family life, marriage, and friendships. Having meaningful work is also important. Absolute levels of material wealth are relatively unimportant: many studies have found that, once basic material and health-care needs are met, happiness is largely independent of absolute income levels (Jackson and Marks, 1999; Inglehart, 2000), although relative income remains important as an indicator of social status. Efforts to promote low-GHG consumption patterns such as domestic energy conservation, cycling rather than relying on a car, living in higher density housing, or eating less meat might have the most success if they emphasize ancillary benefits in terms of improving health, family life, and community relationships rather than saving money.

Sen (1980, 1993) has developed a concept, related to human need, of the "capabilities" that individuals must have if they are to "flourish" or to live a good life. Individuals require different capabilities depending on their personal circumstances and the community they live in. While the good life is to some extent subjective, it is also socially defined. Some aspects of energy-using behaviour may be very hard to change because they play important roles in culture-specific ideals of the good life, varying from country to country. Wilhite *et al*., (1996) describe the cultural significance of lighting and heating in Norway, and of bathing in Japan, suggesting that energy saving measures in these areas would need to be very sensitive to cultural requirements. They also observe that other aspects of household behaviour, such as washing clothes, are less culturally significant and may be easier to change. International differences in habitual behaviour in such areas might provide opportunities for encouraging change through information and education programmes emphasizing best practice.

Moisander (1998) describes how motivation is shaped by both broad values and attitudes, and by more specific priorities, and also how the ability to act depends on both personal capabilities or resources, and external factors or opportunities. Surveys of public attitudes in the United States find an increasing level of concern about climate change, and agreement that action is needed to save energy and protect the environment (Kempton *et al*., 1992; Kempton, 1997). One of the challenges for individuals in acting on environmental values and attitudes is the need to reconcile divergent objectives. This is all the more difficult in the case of climate change, which is poorly understood by most people (Kempton, 1991, 1997; Lofstedt, 1992; Wilhite *et al*., 1996). Moisander (1998) finds that being concerned about the environment provides some motivation for environmentally friendly behaviour. But identity (as a "green consumer") and internalized moral ideals or imperatives play a much stronger role. Identity and ethics, which play an important role in shaping consumption patterns, are largely social phenomena and will be discussed in more detail in the next two sections.

5.3.8.4 Social Structures and Identities

Most of the perspectives discussed in the last section treat the individual as a self-contained person with intrinsic motivations. While this is a dominant assumption in modern Western societies, in many cultures, individuals are understood primarily in relation to others, and behaviour is largely explained in terms of the social context (Hofstede, 1980; Cousins, 1989; Markus and Kitayama, 1991; Dittmar, 1992). In fact, the social and cultural context of the individual is important in all societies. It contributes to individuals' moral ideals and identity, to their areas of empowerment or constraint, and to the options they perceive to be open to them. Social and cultural influences are mediated through the use of discourse and symbolism and through the actions of others. Individuals often conform to the cultural norms of their community because of their needs for safety, sense of belonging, love, and esteem.

Social structures help to shape consumption, for example, through the association of objects and activities with status (Veblen, 1899; Hirsch, 1977) and class (Bourdieu, 1979). Social structures also allow some individuals to influence the consumption patterns of others. In many societies, women are mainly responsible for purchasing food and clothing for other household members, while men are more influential over large household expenditures (Grover *et al*., 1999). Individuals within wider communities also influence each other's consumption patterns and habits in a wide variety of ways, depending on the social structure and their respective positions within it.

Much human behaviour can be understood as an expression of identity or self-definition (Meyer-Abich, 1997). In modern consumer societies, consumption patterns in particular are also used to establish and communicate identity. The combinations of goods people purchase help to confirm to themselves and express to others their personalities and values (Douglas and Isherwood, 1979; Tomlinson, 1990), their membership of particular social groups or communities (Schor, 1998), and their relationship to their social and physical environment (Dittmar, 1992).

Some of the consumption choices that have the greatest effect on GHG emissions, such as car and house ownership and international travel, are also among the most significant means of establishing personal identity and group membership (Schor, 1998). Where such consumption patterns are closely connected to individual and collective identities, they may be particularly difficult to change, although the role of consumption in society is changing.

Some argue that, with urbanization, conspicuous consumption may have become more important as a form of status display – in small, close-knit communities it is unnecessary because everybody knows each other (Kempton and Layne, 1994). The status and group membership function of consumption has also been altered with the spread of television. Some viewers experience emotional attachments to TV characters as if they were real people; viewers also use the characters and situations they see as reference points for their own lives, helping to shape and reinforce their own values and identities (McQuail *et al*., 1972). Those who watch a large amount of television increasingly compare themselves with the portrayed lifestyles of the super-rich, resulting in higher desired levels of consumption (Schor, 1998). While the media can pose a barrier to GHG mitigation by reinforcing current trends towards more GHG-intensive lifestyles, it may also offer opportunities. Raising awareness among media professionals of the need for GHG mitigation and the role of the media in shaping lifestyles and aspirations could be an effective way to encourage a wider cultural shift. The role of the media in GHG mitigation will be discussed further in the next section.

Ongoing developments in the media and communication technology could also generate barriers and opportunities for GHG mitigation. Many scenarios have been painted of the potential impacts of information and communication technology on society. The growth of Internet usage and other interactive communication forms are widely expected to stimulate economic development and technological innovation (Cairncross, 1997). However, they may also lead to increased social stratification, social exclusion, and a decline in trust and social solidarity (or social capital) (Castells, 1998). Such developments could have major implications for the feasibility of responding collectively to threats such as climate change. Fukuyama (1999) argues that, although social capital has declined in recent decades with the development of the information society, similar declines occurred during previous economic and technological upheavals and were followed by the creation of new institutions, leading to new heights of morality and social solidarity. Cairncross (1997) even suggests that free communication may lead to global peace. Slevin (2000) points to the development of personal web pages as a new, versatile, and sophisticated means of establishing personal identity. Inglehart

(1990) finds signs of the emergence of a new "postmaterial" culture that emphasizes networking and communication rather than possessions. However, Castells (1998) believes that more investment is needed in education and science if societies are to reap social benefits from new information and communication technologies and respond to environmental and other challenges.

5.3.8.5 Discourse and Symbolism

The spread of new communication technology may make it increasingly difficult for governments to exert a direct influence on social structure and culture. On the other hand, governments, along with the business community and NGOs, continue to have a substantial presence in the media and they all contribute to the shaping of the public discourse on climate change (see *Box 5.3*). Some of the essential features of that discourse are the differing views on the risks and uncertainties associated with GHG emissions; the costs and benefits of GHG mitigation; the allocation of blame for past and current emissions; and the rights of the victims of climate change to compensation. Disagreement on these various points poses an important barrier to GHG mitigation, especially where media presentation tends to emphasize controversy. There are many ways of helping to build of a common discourse, or narrative, about climate change, involving the various players taking all available opportunities to meet, discuss, and work together for common goals. An important example is the growing development of partnerships between transnational companies and environmental NGOs, for example, to develop accreditation schemes for green products or to design environmental strategies.

The linking of symbols to fundamental values may also be important in shaping behaviour. Ger *et al.* (1998) compare the symbolism of consumption patterns, based on interviews and observations in Denmark, Turkey, and Japan. They find that the symbolic attractions of resource-intensive consumption patterns are more powerful than those of more sustainable consumption patterns. The symbolic attachments are different depending on the country and the subculture within the country.

Narrative and symbols carried by the mass media form a large part of the means through which ideas, arguments, and values are transferred from the public to the private sphere, and ultimately may be integrated into individuals' consciousness and identity. Moisander (1998) has observed that consumption choices respond strongly to personal morals or ethics. It is in shaping ethics that the public narrative can play a particularly strong role.

5.3.8.6 Ethics of GHG Mitigation: the Commons Dilemma

There are several important ethical dilemmas both in the public discourse and in most people's minds regarding GHG mitigation. Essentially, they boil down to questions about human relationship with nature, about justice and equity between human beings, and about the nature of the "good life" (Michaelis, 2000b). In modern society, images of and narratives about the good life often emphasize individual independence and material well-being. These values may appear to conflict with messages about the interdependence of people around the world and the need to moderate the consumption of natural resources.

In addition to the perceived conflict with improving material wellbeing, ethical arguments for GHG mitigation face several barriers including the perceived weakness of the evidence that climate change is happening; the difficulty in understanding the risks associated with low-probability extreme weather events; the difficulty in tracing climate change impacts to particular emitters of GHGs; and the large physical and social distance between GHG emitters and victims of climate change (Pawlik, 1991). It seems that people are inclined to deny and remain passive about about those kinds of environmental nuisances and risks that they believe to be uncontrollable (Pawlik, 1990). From an institutional perspective, the "commons" dilemma charaterizes situations in which people are unable to co-operate to achieve collective benefits, because they are unable to change the rules affecting their perverse incentives; these incentives are themselves institution-dependent (Ostrom, 1990; Ostrom *et al*., 1993). Current climate may be seen as an infrastructure which is used jointly by many people, which is subject to many decision makers, including some in the public sector, and whose benefits and costs are perceived differently by different people because these are borne by many people who do not take the protection decisions. Lack of clear limits on using up resources such as current climate generates costs (climate change) on all participants through unsustainable exploitation because GHG concentrations and, therefore, current climate are stocks like fish and timber. Complex institutional arrangements are required to overcome perverse incentives (Ostrom *et al*., 1993). Commons dilemmas reflect persistent conflicts among (not between) many individuals (producers and consumers).

5.3.8.7 The Need for Social Innovation

Given the complexity of the social, cultural, and psychological drivers of human behaviour, there are no simple recipes for behaviour change. However, there are considerable opportunities to be grasped in taking advantage of the desire for change and the willingness to experiment and learn on the part of individuals, communities, and institutions.

There are many analogies between social and technological change: the two processes are closely linked, equally fundamental to the development of consumption patterns, and the processes behind the development and diffusion of behaviour patterns and cultures are similar to those of new technologies (Michaelis, 1997*a*, 1997*b;* Grübler, 1998). They include:

- Development and discovery of new narratives, ideas, symbols, concepts, behaviours, and lifestyles;

Table 5.2: *Strategies for risk management in social dilemmas and barriers to transformations of unsustainable behaviour (Vlek et al., 1999)*

Strategy	Method	Barrier
Provision of physical alternatives, (re)arrangements	Adjusting /depleting /changing behaviour options, enhancing efficacy	-Absence of physical or technical alternatives -Failure to identify, or disbelief in feasible alternatives -Unwillingness to make feasible alternatives available -Inability to utilize available alternatives
Regulation-and-enforcement	Enacting laws, rules; setting and/or enforcing standards, norms	-Absence of pertinent laws or regulations -Insufficient and/or ineffective law enforcement -Disbelief in effectiveness of law or regulation -Inability to abide by law or regulation
Financial-economic stimulation	Rewards and/or fines, taxes, subsidies, posting bonds	-Absence of financial incentives (rewards and punishments) -Inconsistency of financial incentive systems -Insufficient, ineffective financial incentives -Incentive systems justifying squandering (“I paid for it”)
Provision of information, education, communication reduction strategies	About risk generation, types and levels of risk, others’ perceptions and intentions, risk reduction strategies	-Lack of Knowledge (LoK) accumulating negative externalities -LoK about own causal role and possible contribution to solution -LoK about others’ problem awareness and willingness to co-operate -Uninformed expectations about effects of proposed policies
Social modelling and support	Demonstrating co-operative behaviour, others’ efficacy	-Absence of invisibility of model behaviour by opinion leaders -Fear of setting public examples and living by principles -Inability to understand and follow visible model behaviours -Failure of managers to provide needed social support
Organizational change	Resource privatization, sanctioning system, leadership institution, organization for self-regulation	-Too large organization, too much diffusion of responsibility -Organization form obscuring negative externalities -Inefficient organization requiring unnecessary energy, materials, and labour
Changing values and morality	Appeal to conscience, enhancing “altruism” towards others and future generations, reducing “here and now” selfishness	-Personal identity associated to material possessions and consumption -Importance of social superiority in spending capacity -View of “whole world as my playground” -Basic attitude biased against (“hostile”) natural environment -Inability to feel responsibility for future generations

- Exchange of ideas, behaviours, etc., among firms, communities, government organizations, *etc*.;
- Experimentation with new ideas, behaviours, etc., possibly selecting those that could contribute to GHG mitigation and other policy objectives;
- Replication of successful ideas, behaviours, etc.; and
- Selection by the contextual framework of markets, laws, infrastructure, and culture.

Barriers and opportunities take various forms in association with each of the above processes. The willingness of some groups in society to take risks and to experiment provides an important opportunity for GHG mitigation. New values and behaviour patterns on the part of consumers (e.g., “ethical” or “green” consumption) can spread, encouraging producers to change production methods and management practice. The media plays an important role in the exchange of ideas and in shaping the way new ideas are viewed, whether as exciting new opportunities, as threats, or as eccentric oddities. Alliances among powerful groups can encourage or inhibit experimentation and the replication of successful ideas. And the government can play a key role in setting the contextual framework to encourage shifts in behaviour that would reduce GHG emissions, as well as in removing bureaucratic and regulatory barriers and providing support for local initiatives. Where the institutional structure and culture supports innovation, and where all contextual drivers point in the same direction, changes in technology and behaviour can proceed very rapidly (Michaelis, 1998).

Box 5.3. Narratives about Climate Mitigation

Discourse or narrative – the written and spoken word – is one of the most important ways in which governments, businesses, NGOs, and the media influence each other and build agreement on policy directions. One of the most important barriers to GHG mitigation is the perception by some participants in national and international discourses that mitigation efforts might be costly, or might conflict with values such as individual freedom and equity. By analyzing these people's discourse, new opportunities may be identified for developing GHG mitigation measures that are consistent with their core values. It may also be possible to build new coalitions among institutions and actors, to seek mutually satisfactory GHG mitigation strategies.

Discourse and narrative can take many forms, including history, science, philosophy, folklore, and "common sense". Foucault (1961, 1975) has shown how narratives become an instrument for wielding power. MacIntyre (1985) offers a way of thinking about narrative as part of our cultural context or tradition, as something that we inhabit. Professional analysts, such as scientists and economists, are members of groups that define themselves by such traditions and have their own narratives about the world. Our narratives co-evolve with our notions of "the good", our understanding of our selves, our conception of society, our science (conception of nature), and our understanding of God or the spiritual dimension (Taylor, 1989; Latour, 1993). These understandings and conceptions are also central to our responses to climate change.

Analyzing discourses can provide essential insights into different people's assumptions and beliefs about the world. Thompson and Rayner (1998), Ney (2000) and Thompson (2000) have mapped out some of the essential features of the discourses that are used to describe and define positions on climate change. They focus in particular on two axes of the discourses: their view of nature and their conception of society. For example, some view the environment as robust, while others view it as fragile and vulnerable to human interference. Some believe that society works best through market-based institutions, while others believe that there should be more explicit emphasis on egalitarian, participatory approaches. Ney differentiates three main orientations: market-based, egalitarian, and contractarian or hierarchical. Some characteristics of these orientations are summarized in *Table 5.3*. Of these three, the market orientation clearly dominates international negotiations as well as the dialogue on climate change within many countries. It is also the source of the dominant discourse on climate mitigation policy within the IPCC.

Table 5.3: *Discourses on climate change (adapted from Thompson and Rayner, 1998)*

Discourse	Hierarchical	Market	Egalitarian
Myth of nature	Perverse, tolerant	Benign, robust	Ephemeral, fragile
Diagnosis of climate problem	Population	Pricing/market failure	Profligacy
Policy bias	Regulation	Libertarian	Egalitarian
Public consent to policy	Hypothetical	Revealed (voting)	Explicit (direct)
Intergenerational responsibility	Present>future	Present>future	Future>present

There are, in fact, many "axes" that can be used to map out discourses on climate change. Another important perspective is that of gender (Grover *et al*., 1999; Hemmati, 2000). To some extent, the different axes can be correlated with those chosen by Ney, Rayner, and Thompson: feminist discourses have tended to align themselves with egalitarian discourses and in opposition to the hierarchical and market discourses as defined in *Table 5.3*.

While analyzing different positions can be a first step to resolving differences, something more is needed: we need to understand how the dialogues that underlie the climate debate have evolved over time, and might change in the future. In particular, we need to be more aware of the links between our scientific understanding of nature, our political and economic structures, and our ethics. Michaelis (2000) finds traces in the climate debate of a long-running process of development of alternative cultures or traditions in our society:

- The modern tradition, with roots in the 17th-18th century European Enlightenment, is built on a separation of humanity and nature, with its central aims of economic and technological progress and its commitment to finding "the good" in the everyday working life. This tradition is dominant in the words of government, business, and science. To a large extent, the different positions analyzed by Ney, Rayner, and Thompson fall within the modern tradition. The climate debate within this tradition revolves around different ways of understanding nature and society.
- The romantic tradition, a reaction to the early Enlightenment in the late 18th and early 19th century, is committed to the emotional life of individuals, to romantic love and the family, and to an ideal harmony between humanity and nature. This tradition is dominant in the world

of entertainment, advertising, and individuals' private lives. It views climate change as a problem caused by the modern tradition, and tends to blame institutions such as businesses and governments which represent that tradition. However, narratives within the romantic tradition tend not to recognize the role of romanticism in shaping the consumption patterns for which industry produces.

- The humanist tradition, with much older roots going back to ancient Greece, is maintained by academic and intellectual circles in modern society, and is committed to the search for "the good life". Viewed from this tradition, the climate change problem appears to be caused by the failure of the modern and romantic traditions to understand human nature, and the nature of the good life. Less emphasis should be placed on material production and consumption, and more should be placed on developing family relationships, communities, civic involvement, and opportunities for learning and contemplation.

Writers such as MacIntyre (1985), Gare (1995), and Latour (1993) see little hope within the modern tradition for solving the problems of our time. MacIntyre advocates a revival of humanism. However, many social scientists have described the emergence of "postmodern" values, which recognize the multiplicity of valid traditions and narratives. This recognition sometimes leads to nihilism, but it could also be the basis for a renewed search for shared values and conceptions of the good life.

5.4 Sector- and Technology-specific Barriers and Opportunities

GHG emissions from some sectors are larger than those from others, and the importance of each GHG varies across sectors as well. Methane (CH_4) for instance is a much bigger contributor to emissions from agricultural activity than, for instance, from the industry sector. *Table 5.4* shows the carbon emissions from energy use in 1995. Emissions from electricity generation are allocated to the respective consuming sector. Carbon emissions from the industrial sector clearly constitute the largest share, while those from agricultural energy use form the smallest share. In terms of growth rates of carbon emissions, however, the fastest growing sectors are transport and buildings. With rapid urbanization promoting increased use of fossil fuels for habitation and mobility in many countries, the two sectors are likely to continue to grow faster than others will in the future.

Annual carbon emissions from land-use change were estimated in the IPCC Special Report on Land Use, Land-use Change and Forestry at 1.6 ±0.8GtC/yr for the period 1989 to 1998 (IPCC, 2000a). Tropical forests are estimated to be net emitters, but temperate and boreal forests are net sequesters of carbon. CH_4 emissions from livestock, rice paddies, biomass burning, and natural wetlands add up to 1.8GtC_{eq}/yr with considerable uncertainty about these estimates. Below we describe the sector-specific barriers to and opportunities for reducing the sectoral GHG emissions.

5.4.1 Buildings

The buildings (residential and commercial) sector accounted for about a third of carbon emissions from fossil fuel combustion in 1995. Its share of the total emissions has increased faster than in other sectors (Price *et al*., 1998). About half the emissions in this sector are from fuel use in the commercial sector, and the other half from the residential sector. Energy use in the sector is for cooking, space conditioning, water heating, and lighting and appliances. Aside from the use of modern energy, biomass use constitutes a significant portion of the energy supply, particularly in the developing world. The bulk of households in rural areas use biomass for cooking, and water

Table 5.4: *Carbon emissions from fossil fuel combustion (MtC)*

Sector	**Carbon emissions and % share**[1] **1995**	**Average annual growth rate (%)**	
		1971 to 1990	1990 to 1995
Industry	2370 (43%)	1.7	0.4
Buildings			
-- Residential	1172 (21%)	1.8	1.0
-- Commercial	584 (10%)	2.2	1.0
Transport	1227 (22%)	2.6	2.4
Agriculture	223 (4%)	3.8	0.8
All sectors	*5577 (100%)*	*2.0*	*1.0*
-- Electricity generation[2]	1762 (32%)	2.3	1.7

[1] Emissions from energy use only; does not include feedstocks or carbon dioxide from calcination in cement production. Biomass = no emissions.

[2] Includes emissions only from fuels used for electricity generation. Other energy production and transformation activities are not included.

Source: Price *et al.,* 1999

and space heating. Much of the biomass (particularly for firewood, and charcoal combustion and charcoal production processes) in developing countries is used in an unsustainable fashion and results in additions to anthropogenic emissions (CEEEZ, 1998).

Barriers to the full realization of the opportunities for improving energy efficiency in this sector have been extensively studied. The key barriers are traditional customs, lack of skills, social barriers, misplaced incentives, lack of financing, market structure, administratively set prices, and imperfect information (Golove and Eto, 1996; Brown, 1997).

Traditional Customs
Lack of appreciation in the design and manufacture of energy-using devices can inhibit their penetration. In the case of improved biomass stoves it has been shown (ESD, 1995) that despite savings on household charcoal budgets, improved stove commercialization still remains a problem, because of inconsistent design and quality control in the manufacture of stoves. In some programmes (CEEEZ, 1998), field surveys showed that most users of improved cookstoves returned to traditional stoves, owing to a preference for speed in cooking with traditional stoves as compared to the former.

Lack of Skills
Insufficient skills in the manufacture of efficient appliances can slow or stop their diffusion. For example, dissemination of improved stoves could not be sustained (CEEEZ, 1998), because of various reasons, among them being increased production time arising from the complexity of the stove design. As a result, local producers switched to the production of familiar items, which were easy for them to manufacture.

Behaviour and Style
Despite the existence of demand-side management programmes, in most developed countries, and the availability of more technologically efficient household devices (such as air conditioners) in the market place, changes in behaviour and style (associated with a desire to increase dwelling size) tended to increase the demand for energy services (Wilhite *et al*., 1996). Energy use for space heating increased in Norwegian homes from 1960 to 1990 thanks to a doubling of dwelling area per capita (Hille, 1997) in spite of more stringent building codes and the doubling of thermal efficiency.

Another example is space cooling in Japan, where air conditioners are technically very efficient, but space cooling demand is still increasing dramatically, because of changes in dwelling size, changing tastes, and modern building design which does not support natural cooling (Wilhite *et al*., 1996). For most home owners, the lowest first cost is more important than a higher energy efficiency level when purchase decisions are made about an appliance or a home (Hassett and Metcalf, 1995).

Misplaced Incentives
These result between landlords and tenants with respect to acquisition of energy-efficient equipment for rental property. Where the tenant is responsible for the monthly cost of fuel and/or electricity, the landlord is prone to provide the least-first-cost equipment without regard to its monthly energy use. Fee structures for architects and designers are based on capital cost of the building. Designing an energy efficient heating, ventilation, and air-conditioning system costs more, and reduces the capital and operating costs of the building, both of which serve as a disincentive to architects for the design of energy-efficient structures (Lovins, 1992). Also, in the buildings sector compensation to architects and engineers based directly or indirectly on a percentage of the costs of the building provides perverse incentives

Lack of Financing
This refers to the significant restrictions on capital availability for low-income households and small commercial businesses. Home mortgages for instance do not as a rule carry a lower interest rate for efficient homes, which have low annual energy costs. In case of switching to modern cooking stoves (electric, kerosene, or liquefied petroleum gas (LPG) for example) in rural areas of developing countries, the barriers result from household income, accessibility to modern fuels, the relative cost of traditional and modern fuels, and cooking habits (Soussan, 1987). For example, in view of both national and global benefits, use of low-cost electric stoves has been noted as a viable substitute for improved biomass cookstoves, as they can contribute effectively to preserve forests to enhance carbon sequestration (CEEEZ, 1998). Despite this realization, there has been a low level of switching from charcoal stoves to electric stoves. This is largely because of a lack of finance, resulting from low monthly income of which 35 % to 45 % is spent on fuel (CEEEZ, 1998).

Market Structure
This can imbue power to firms who may inhibit the introduction by competitors of energy-efficient equipment such as compact fluorescent lighting (Haddad, 1994). The design, construction and maintenance of buildings is largely fragmented. This is in part cause by the lack of integration and communication between sub-sectors, and in part a reflection of the diverse and large number of suppliers. This results in many instances of building design, insulation, and energy-using devices that do not exhibit high levels of energy efficiency (OTA, 1992). One response in Switzerland since 1978 has been to ensure that architects are fully integrated into the selection and construction of energy using devices in buildings (Jefferson, 2000).

Administratively Set Prices
These distort investment and the choice of energy forms and end-use equipment. Electricity has been historically subsidized to residential customers in India, and serves as a disincentive to faster penetration of efficient lighting and appliances (Alam *et al*., 1998). In contrast to subsidies in the electricity industries of India, non-availability of subsidies in the commercial dissemination of improved cookstoves in Kenya has lead to dra-

Box 5.4. Commercial Dissemination of Improved Cookstoves in Kenya

One of the most successful improved cookstoves in Africa is the Kenya Ceramic Jiko (KCJ) (Karekezi, 1991). The KCJ was introduced in Kenya in 1982 and mainly targets urban populations who used charcoal.

The KCJ is produced and marketed through the informal sector. One of the key characteristics of this project was the ability to utilise existing production and distribution system for the traditional stove to produce and market the KCJ.

The most important factor to the successful commercialization of the KCJ is the conscious decision made by the project initiators not to provide subsidies. Although stove prices were initially high, the ensuing competition between producers reduced the price from as high as US$15.00 to a prices of US$2.50 in 1989 (Karekezi, 1991). Purchases made by high income groups in the earlier stove dissemination, however, effectively subsidized the stove development process thus making it available for lower income groups (Otiti, 1991).

matic improvements in the marketing and distribution of improved stoves as shown in *Box 5.4*.

Economic Pricing
Economic pricing in the electricity sector, particularly in developing countries and countries in transition, has been hampered by a lack of adherence to economic tariff setting (based on long-run marginal cost (LRMC)). Attempts to rigorously follow this concept, however, have resulted in social problems. For example, in Russia, a country in the process of transformation to a market economy, LRMC has led to pensioners not being able to afford their electricity bills, requiring subsidies amounting to 20%-35% of the budgets of local authorities (Gritsevich, 2000).

Imperfect Information
The lack of adequate and accurate information, and the limited ability of users to absorb it adds to the cost of its provision to consumers. Since energy costs are typically small on an individual basis, it is rational for consumers to ignore them in the face of information gathering and transaction costs. For instance, Sony was able to reduce the standby power loss in TVs from 7-8 watts to about 0.6 watt, a saving of US$5 per year per TV. One reason for consumers to not buy more efficient appliances, despite a label advertising this fact, is that consumers are wary or mistrustful because of past experience with advertised misinformation (Stern and Aronson, 1984). Kempton and Montgomery (1982) have shown that residential consumers systematically underestimate energy savings, because they lack the ability to use the information to calculate and compare savings with investment. Furthermore, Kempton and Layne (1994) liken today's energy bills to receiving a single monthly bill for all groceries purchased with no identification of the cost of individual items.

5.4.1.1 Opportunities, Programmes, and Policies to Remove Barriers

Technological and social changes bring about opportunities to improve the efficiency of buildings and appliances. A change in the production line for the manufacture of an appliance offers an opportunity for introducing new energy saving features in an appliance. Likewise, when buildings are sold, a city government may have the opportunity to intervene and have energy saving features installed prior to the registration of that sale. Targeting opportunities at a point where the stock is likely to turnover physically or contractually can reduce the perceived and actual cost to producers and consumers.

Governments have designed policies, programmes, and measures to tap these and other opportunities, and in the residential and commercial buildings sector they fall into nine general categories: voluntary programmes, building efficiency standards, equipment efficiency standards, state market transformation programmes, financing, government procurement, tax credits, accelerated R&D, and a carbon cap and trade system. The last three items are generic and are not dealt with in this section.

Voluntary programmes, such as Energy Star, which is operated by the United States Department of Energy (DOE) and Environmental Protection Agency (EPA), exist for both residential and commercial buildings, and appliances (Harris and Casey-McCabe, 1996). The Energy Star programme works with manufacturers to promote existing energy-efficient products, such as residential buildings, personal computers, TVs, etc., and to develop new ones. Manufacturers can affix an easily visible label to products that meet Energy Star minimum standards. These programmes also facilitate the exchange of information between end-users on their experience with energy-saving techniques.

Building efficiency standards focus primarily on the building shell and/or the HVAC (heating, ventilation, and air conditioning) system, and in commercial buildings also on lighting and water heating. Standards are being implemented in California and other states in the USA, and also in Singapore and Malaysia, and have been proposed or are on the books in Indonesia, the Philippines, and Mexico (Janda and Busch, 1994).

Equipment standards require that all new equipment meet minimum energy efficiency standards. Standards on household appliances and lighting have been in place in the US for over a decade and are expected to be tightened between 2000 and 2005 (McMahon and Turiel, 1997). About 30 developed and developing countries and EITs have voluntary or mandatory standards and labels in place on more than 40 household appliances (CLASP, 2000).

Demand-side management (DSM) programmes provide rebates, targeted delivery of efficient appliances and lighting to low-income households, information campaigns, and the like. These were pursued vigorously in some states in the USA. The deregulation of the US energy supply sector has reduced the emphasis on these programmes. Nevertheless, in several states that previously had these programmes, public benefit funds for energy efficiency have replaced the DSM programmes, and are typically charged to the electricity consumer on his electricity bill (Kushler and Witte, 2000).

Financing programmes spread the incremental investment costs over time and reduce the first cost impediment to adoption of energy-efficient technologies. For commercial buildings, ESCOs offer energy savings performance contracts that guarantee a fixed amount of savings and are paid through the cost savings.

Government procurement policies have accelerated the adoption of new technologies in the USA and Sweden. In the USA, federal regulations regarding procurement were amended in 1997 to limit purchases to equipment that falls in the top 25% of energy efficiency for similar products (McKane and Harris, 1996).

To effectively enhance dissemination of improved cookstoves, policies, and measures need to be put in place. The introduction of affordable credit financing is widely recognized in Africa as one of the effective measures, which will go a long way in removing the financing barrier. Assistance is still needed in some locations on the design, introduction of centralized small and medium-sized production centres, and marketing of energy efficient stoves, especially where biomass fuels are commercialized – typically as part of small enterprise development. Further research and development work is also essential to increase the efficiency of improved biomass stoves. For example, the British NGO, Energy for Sustainable Development (ESD) is financing and supporting a team of Ethiopian professionals working in household management and supply. It has achieved remarkable success in developing and commercializing two types of improved biomass cookstoves through an iterative approach of needs assessment, product design, redesign, and performance monitoring (Farinelli, 1999). The team consists of consumers, stove producers and stove installers, and pays attention to promotion, technical assistance, and quality production.

5.4.2 Transport

Carbon emissions from fossil fuel use in the transport sector are rising faster than those from any other sector (Price *et al*., 1998). The transport modes responsible for most of the growth are car travel, road freight, and air transport.

Vehicular air pollution is a major environmental problem in many large urban centres in both developed and developing countries. Although urban air quality in developed countries has been controlled to some extent during, the past two decades, in many developing countries it is worsening and becoming a major threat to the health and welfare of people and the environment (UNEP, 1992).

Chapter 3 notes the existence of a range of technologies whose use in cars could substantially reduce emissions, including lightweight materials, gasoline direct injection engines, electric hybrid drive-trains, and fuel cell-electric drive-trains. Considerable and unexpected progress has been made in commercializing some of these technologies since the SAR. Chapter 3 also reviews studies that estimate the socioeconomic potential for energy efficiency improvements. The rapid emission growth from the sector, despite the considerable apparent mitigation potential, is mainly a result of a continuing increase in demand for mobility of people and goods. The energy intensity of personal travel is near-constant or increasing in many countries, with increasing use of sports utility vehicles and people carriers, and rising vehicle weight and power in most categories of vehicle (ECMT, 1997; Davis, 1999).

In addition to energy efficient technologies, IPCC (1996, Chapter 21) noted an extensive range of options for reducing GHG emissions, including the use of alternative fuels, public and non-motorized transport, and changes in transport and urban planning.

5.4.2.1 Barriers to Mitigation

IPCC (1996, Chapter 21) noted many reasons why GHG mitigation in the transport sector has proved difficult. Transport activity is closely interwoven with infrastructure, lifestyles, economic development, and patterns of industrial production. Partly because of these complex links, experts do not always agree on the best mitigation strategy. Climate change and energy saving is usually a minor factor in decisions and policy in the sector, and mitigation strategies may not be implemented if they seem to reduce the benefits provided by the transport system to individuals and firms. Appropriate mixes of policies need to be designed for local situations. And policies can be very slow to take effect because of the inertia of the infrastructure, technologies, and practices associated with the existing transport system.

Stated preference surveys in the United States have shown that consumers would prefer to purchase energy efficient cars, and would be prepared to pay US$400-600 for each litre/100km reduction in fuel consumption (Bunch *et al*., 1993; US DOE, 1995). This is about the amount that would be expected from the fuel savings over the life of the car (Michaelis, 1996b). However, there is no evidence that this valuation of fuel economy is reflected in the car market. There may be several reasons. First, many vehicle purchasers have to work within budgets set by the size of loan they can obtain to buy a car, and such budgets are likely to be set independent of the amount they will have to spend on fuel. Where they have a number of high priorities in their vehicle choice such as comfort, size, safety, and performance, they will spend their budgets on those priorities rather than on energy efficient technologies that increase vehicle price. Second, vehicle manufacturers have no incentive to promote energy efficiency, and a strong interest in selling more sports utility vehicles and mini-vans where their profit margins are higher than for cars. The outcome can be viewed as a rational response to consumer preferences subject to a budget constraint, but it has been repeatedly noted in European government-industry discussions that marketing helps to shape those preferences (Dietz and Stern, 1993; Michaelis, 1996a).

Cars may also provide a good example of the principal-agent barrier. The first owner of a car may be more concerned with its status value and other aspects, and less concerned with cost minimization than subsequent owners. Secondhand owners' preferences for cost minimization do appear to be reflected in the secondhand car market, where more fuel efficient cars tend to be more expensive (Daly and Mayer, 1983; Kahn, 1986), reflecting perhaps half to three quarters of the value of fuel savings they will offer (Michaelis, 1996a). The lack of control of vehicle users over technology is exacerbated by the concentration of the global car industry in Annex I countries, and in a small number of transnational companies (IPCC, 2000b).

While information on the fuel efficiency of vehicles is widely available, it may not be easy to find or assimilate for the average purchaser. Labelling laws and information programmes have been introduced in many countries to overcome this information gap (ECMT, 1997). Nevertheless, the fuel economy information on labels is usually obtained in standard test cycles, the information from which may be inaccurate, underestimating consumption in real driving conditions by 10%-20% (IPCC, 1996).

Car technology is also a good example of "lock-in". A century of development has put the gasoline engine, and the infrastructure to maintain it and supply its fuel, in a virtually unassailable position. Technologies based on alternative fuels, batteries, or fuel cells will have to compete with gasoline engine performance and cost levels that continue to improve.

The phenomenon of lock-in can also be seen to apply to road transport more generally. Cars are preferred over other transport modes partly because of their intrinsic advantages in flexibility, convenience, comfort, and privacy. A car makes it possible to live in a suburban or rural area poorly served by public transport, taking advantage of low house prices and pleasant surroundings. However, there are also many sources of "positive returns to scale", strengthening the incentives for using cars as their prevalence grows.

As car fleets have grown, modern western societies, cultures, and economies are increasingly built around motorized road transport. Car-oriented culture has charged cars with significance as a means of freedom, mobility and safety, a symbol of personal status and identity, and as one of the most important products in the industrial economy. Car-oriented infrastructure and settlement planning makes it hard to use any alternative transport mode. Many attempts to encourage a shift in planning provision away from cars, toward public and non-motorized transport also fail because of the strength of links among transport planners, construction firms and the financing institutions (e.g., Stenstadvold, 1995).

A second aspect of the lock-in to car transport is the result of economies of scale, and a century of R&D and learning from experience in car production. The real cost of owning and operating a car has declined over the last half century while public transport costs have risen. The declining number of people using buses, especially in rural areas, makes it uneconomic to operate services without subsidies. Falling bus and train occupancy levels also reduce their energy intensity advantage relative to cars, indeed, in some countries, trains consume more energy per passenger-km than cars (IPCC, 1996).

A third source of lock-in is linked to personal safety. With growing numbers of cars on the roads and declining numbers of pedestrians, the streets have become more dangerous. While travelling by car poses a higher risk of death or injury from accidents than travelling by bus or train, a car does offer protection from personal assault.

Because of the social and economic importance of transport, most governments provide budgetary subsides for construction and maintenance of transport infrastructure, and for transport services including many linked to car use (de Moor and Calamai, 1996; OECD, 1997b). Public finance for public and non-motorized transport has been generally less readily available than for road building since the 1950s. Other government instruments often support road transport, one example being planning laws that require off-street parking to be provided in new urban developments. It is the combination of policies and institutional relationships protecting road transport interests that poses the greatest barrier to change, rather than any single type of instrument (OECD, 1997b).

People have distorted perceptions of the relative convenience and cost of transport modes, usually justifying their habitual mode choices (Goodwin, 1985; OECD, 1997a). Bus users perceive trains as more expensive and less convenient than they really are, while train users have a similar misperception of buses. Car drivers believe that car use is cheaper and faster than it is.

GHG mitigation efforts in freight transport also face many barriers. The energy intensity of road freight can be reduced by improving fleet dispatching and routing, reducing the number of empty trips, and improving driving skills. While freight firms continue to make substantial efforts to minimize fuel use by trucks, speed, flexibility and responsiveness to customers is often a higher priority.

Moving freight by rail instead of by road can offer considerable energy savings in some countries (IPCC, 1996), mainly where long distances are involved and the freight can travel relatively slowly. However, nearly all freight movements must start and end by road, so that taking advantage of the low energy intensity of rail freight entails a loss of convenience as either containers must be loaded onto the train and unloaded for delivery, or trucks must be carried "piggy-back". Increasing rail freight depends on substantial investments in road-rail terminals. Meanwhile, it may be difficult for railways to operate efficiently with high levels of both passenger and freight traffic owing to the different operating patterns entailed.

5.4.2.2 *Opportunities for Mitigation*

Some of the most promising opportunities for GHG mitigation in the transport sector are linked to the growing need for action to address a wider range of concerns about the sector's social and environmental impacts. Several studies have evaluated environmental and social externalities associated with road transport (IPCC, 1996; ECMT, 1997; OECD, 1997a). Some have explored the effects of internalizing those costs through fuel taxes and other measures (EC, 1996; Michaelis, 1996b; ECMT, 1997). However, transport fuel taxes have proved very unpopular in some countries, especially where they are seen as revenue-raising measures (MVA, 1995), and may be an inefficient means of internalizing environmental costs other than those associated with carbon dioxide (CO_2) emissions. Charges on road users, including parking fees in many towns and tolls, especially on motorways, have been accepted where they are earmarked to cover the costs of road provision (Michaelis, 1997a). Several studies have explored the potential for adjusting the way existing road taxes, license fees, and insurance premiums are levied, and have found potential emissions reductions in the region of 10% in OECD countries (Wenzel, 1995; Michaelis, 1996b).

While it may be possible to adjust the price incentives in the transport sector, overcoming the many forms of inertia and lock-in is more difficult. Effective mitigation strategies would entail combinations of measures, just as the status quo is currently maintained by a combination of forces (IPCC, 1996). Often, the best opportunities for such concerted action arise at a local level, where the negative impacts of transport are most keenly felt (Michaelis, 1997a). There are several positive experiences of change, such as a Scottish example where a public consultation process led to a large shift in local government spending towards public transport (Macaulay *et al*., 1993), initiatives to introduce toll rings around Norwegian cities, and the comprehensive transport strategies in Singapore (Ang, 1993), Curitiba (Rabinovitch, 1993), and other cities (IPCC, 1996).

Achieving the promise of new technology may depend on international co-operation to develop larger markets for low-GHG-emission vehicles through fiscal and regulatory measures and public purchasing. During high oil price periods, car importing countries have imposed restrictions and incentives on car importers to discourage the use of more energy-intensive cars. Agricultural surpluses and foreign exchange shortages have been important stimuli for technology development in the past, in particular in the case of the Brazilian ethanol programme.

While several studies have found that people living in denser and more compact cities rely less on cars (Armstrong, 1993), energy savings alone are unlikely to motivate the shift away from suburban sprawl to compact cities advocated by Newman and Kenworthy (1990). However, there is a growing concern to reverse the decline in the environment and in communities in city centres by moving away from zoning and car-based transport, and towards multi-function, high-density pedestrian zones. There is a considerable opportunity for GHG mitigation in linking to this concern. In particular, there is scope where infrastructure is developing rapidly to implement planning measures that encourage more sustainable transport patterns, avoiding the pollution, congestion, higher accident rates, and GHG emissions associated with cars.

5.4.3 *Industry*

Under perfect market conditions, all additional needs for energy services are provided by the lowest cost measures for increased energy supply or reduced energy demand. There is considerable evidence that energy efficiency investments that are lower in cost than the cost of marginal energy supply are not being made in real markets, suggesting that market barriers exist. A study of the industrial electric motor market in France has demonstrated the existence of barriers arising from decision-making practices, within an environment characterized by lack of information and split incentives (de Almeida, 1998). Barriers may exist at various points in the diffusion process of measures to reduce energy use and/or GHG emissions. The diffusion process depends on many factors such as capital cost, operating cost savings, information availability, network connections, imitation effects, and other factors (DeCanio and Laitner, 1997). All of these factors influence the probability of a firm adopting a given technology at a particular point in time. Barriers may take many forms in this process, and should be reviewed in the context of the industrial and business environment (e.g., multi-criteria optimization, firm size and structure, market structure, opportunity, and information routes). While barriers exist, it is important to note that ESTs and practices may also represent a strategic and competitive advantage through the development of new markets or new market opportunities, as shown by various authors (Porter and Van der Linde, 1995b; Reinhardt, 1999). This section focuses on barriers and opportunities in the industrial sector, and cites examples of successful approaches that have been used to remove barriers.

Decision-making Processes

In firms, decision-making processes are a function of its rules of procedure, business climate, corporate culture, managers' personalities, and perception of the firm's energy efficiency (DeCanio, 1993; OTA, 1993) and perceived risks of the investment, stressing the importance of firm structure, organization, and internal communication (Ramesohl, 1998). Energy awareness as a means to reduce production costs seems not to be a high priority in many firms, despite a number of excellent examples in industry worldwide. For example, Nelson (1994) reports on a (discontinued) successful programme at a major chemical company in the USA, which resulted in large energy savings with internal rates of return of over 100%. However, such programmes are only reported in a relatively small number of plants. A recent analysis of the Green Lights programme in the USA demonstrated the shortcomings in traditional decision-making processes, as investments in energy efficient lighting showed much higher paybacks than other investments. (DeCanio, 1998). These analyses demonstrate the need for a better understanding of the decision-making process, to be appropriately accounted in modelling and policy development.

Lack of Information

Cost-effective energy efficiency measures are often not undertaken as a result of lack of information on the part of the consumer, or a lack of confidence in the information, or high transaction costs for obtaining reliable information (Reddy, 1991; Sioshansi, 1991; OTA, 1993; Levine *et al*., 1995). Information collection and processing consumes time and resources, which is especially difficult for small firms (Gruber and Brand, 1991; Velthuijsen, 1995). In many developing countries public capacity for information dissemination is especially lacking (TERI, 1997). The information gap concerns not only consumers of end-use equipment but all aspects of the market (Reddy, 1991). Many producers of end-use equipment have little knowledge of ways to make their products energy efficient, nor access to the technology for producing the improved products. Equipment suppliers may also lack the information, or ways to assess, evaluate, or disseminate the information. End-use providers are often unacquainted with efficient technology. In addition, there is a focus on market and production expansion, which may be more effective than efficiency improvements, to generate profit maximization. In the New Independent States (NIS) firms are more directed towards increasing competitiveness, although there are examples where firms have used energy efficiency as a means to reduce production costs (Gritsevich, 2000). Also, a lack of adequate management tools, techniques, and procedures to account for the economic benefits of efficiency improvements is an information barrier (see below). Finally, other policies and regulations may limit access to energy-efficient technologies. For example, import regulations for specific projects and industries in China (Fisher-Vanden, 1998) and India (Schumacher and Sathaye, 1999) limited or imposed high levies on the import of industrial technologies for some periods.

Limited Capital Availability

Energy efficiency investments are made to compete with other investment priorities, and many firms have high hurdle rates for energy efficiency investments because of limited capital availability. Capital rationing is often used within firms as an allocation means for investments, leading to even higher hurdle rates, especially for small projects with rates of return from 35% to 60%, much higher than the cost of capital (~15%) (Ross, 1986). In many developing countries cost of capital for domestic enterprises is generally in the range of up to 30%-40%. Especially for SMEs capital availability may be a major hurdle in investing in energy efficiency improvement technologies because of limited access to banking and financing mechanisms. When energy prices do not reflect the real costs of energy (without subsidies or externalities) then consumers will necessarily underinvest in energy efficiency. Energy prices, and hence the profitability of an investment, are also subject to large fluctuations. The uncertainty about the energy price, especially in the short term, seems to be an important barrier (Velthuijsen, 1995). The uncertainties often lead to higher perceived risks, and therefore to more stringent investment criteria and a higher hurdle rate.

Lack of Skilled Personnel

A lack of skilled personnel, especially for SMEs, leads to difficulties installing new energy-efficient equipment compared to the simplicity of buying energy (Reddy, 1991; Velthuijsen, 1995). In many firms (especially with the current development toward "lean" firms) there is often a shortage of trained technical personnel, as most personnel are busy maintaining production (OTA, 1993). In most developing countries there is hardly any knowledge infrastructure available that is easily accessible for SMEs. Also, the position within the company hierarchy of energy or environmental managers may lead to less attention to energy efficiency, and reduced availability of human resources to evaluate and implement new measures.

In addition to the problems identified above, other important barriers include (1) the "invisibility" of energy efficiency measures and the difficulty of demonstrating and quantifying their impacts; (2) lack of inclusion of external costs of energy production and use in the price of energy, and (3) slow diffusion of innovative technology into markets (Fisher and Rothkopf, 1989; Levine *et al*., 1994; Sanstad and Howarth, 1994). Regulation can contribute to more successful innovation (see above), but sometimes, indirectly, be a barrier to implementation of low GHG emitting practices. A specific example is industrial co-generation (CHP), which may be hindered by the lack of clear policies for buy-back of excess power, regulation for standby power, and wheeling of power to other users (*Box 5.5*). Co-generation in the Indian sugar industry was hindered by the lack of these regulations (WWF, 1996), while the existence of clear policies can be a driver for diffusion and expansion of industrial co-generation, as is evidenced by the development of industrial co-generation in the Netherlands (Blok, 1993). Finally, firms typically under-invest in R&D, despite the high paybacks (Nelson, 1982; Cohen and Noll, 1994), but recent analyses seem to suggest that public and private R&D funding for sustainable energy technologies is decreasing in developed countries (Kammen and Margolis, 1999).

5.4.3.1 Programmes and Policies for Technology Diffusion

A wide array of policies, to reduce the barriers or the perception of barriers has been used and tested in the industrial sector in developed countries (Worrell *et al*., 1997), with varying success rates. With respect to technology diffusion policies there is no single instrument to reduce barriers; instead, an integrated policy accounting for the characteristics of technologies, stakeholders, and countries addressed would be helpful.

Selection of technology is a crucial step in any technology transfer. Information programmes are designed to assist energy consumers in understanding and employing technologies and practices to use energy more efficiently. Information needs are strongly determined by the situation of the actor. Therefore, successful programmes should be tailored to meet these needs. Surveys in western Germany (Gruber and Brand, 1991) and the Netherlands (Velthuijsen, 1995) showed that trade literature, personal information from equipment manufacturers and exchange between colleagues are important information sources. In the United Kingdom, the ‘‘Best Practice’’ programme aims to improve information on energy efficient technologies, by demonstration projects and information dissemination. The programme objective is to stimulate energy savings worth US$5 for every US$1 invested (Collingwood and Goult, 1998). In developing countries technology information is more difficult to obtain. Energy audit programmes are a more targeted type of information transaction than simple advertising. Energy audit programmes exist in numerous developing countries, and limited information available from 11 different countries found that on average 56% of the recommended measures were implemented by audit recipients (Nadel *et al*., 1991).

Environmental legislation can be a driving force in the adoption of new technologies, as evidenced by the case studies for India (TERI, 1997), and the process for uptake of environmental technologies in the USA (Clark, 1997). Market deregulation can lead to higher energy prices in developing countries (Worrell *et al*., 1997), although efficiency gains may lead to lower prices for some consumers.

Direct subsidies and tax credits or other favourable tax treatments have been a traditional approach for promoting activities that are socially desirable. An example of a financial incentive programme that has had a large impact on energy efficiency is the energy conservation loan programme that China instituted in 1980. This loan programme is the largest energy efficiency investment programme ever undertaken by any developing country, and currently commits 7% to 8% of total energy investment to efficiency, primarily in heavy industry. The programme contributed to the remarkable decline in the energy intensity of China’s economy. Since 1980 energy consumption has grown at an average rate of 4.8% per year (compared to 7.5% in the 1970s) while GDP has grown twice as fast (9.5% per year), mainly thanks to falling industrial sector energy intensity. Of the apparent intensity drop in industry in the 1980s, about 10% can be attributed directly to the efficiency investment programme (Sinton and Levine, 1994).

New approaches to industrial energy efficiency improvement in developed countries include voluntary agreements (VA). A VA generally is a contract between the government (or an other regulating agency) and a private company, association of companies or other institution. The content of the agreement may vary. The private partners may promise to attain certain energy efficiency improvement, emission reduction target, or at least try to do so. The government partner may promise to financially support this endeavour, or promise to refrain from other regulating activities. Many developed countries have adopted VAs directed at energy efficiency improvement or environmental pollution control (EEA, 1997; IEA, 1997; Börkey and Lévêque, 1998; OECD, 2000). There is a wide variety in VAs, ranging from public and consumer recognition for participation in a programme (e.g., Energy Star Program in the USA) to legally binding negotiated agreements (e.g., the Long-Term Agreements in the Netherlands). Voluntary agreements can have some apparent advantages above regulation, in that they may be easier and faster to implement, and may lead to more cost-effective solutions. Initial experiences with environmental VAs with respect to effectiveness and efficiency varied strongly, although only a few ex-post evaluations are available as most voluntary approaches are recent (EEA, 1997; Worrell *et al*., 1997, Börkey and Lévêque, 1998). The Dutch long-term agreements on energy efficiency in industry have been evaluated favourably, and are expected to achieve the targets for most sectors (Universiteit Utrecht, 1997). The evaluation highlighted the need for more open and consistent mechanisms for reporting, target setting, and supportive policies. Preliminary evaluations show that VAs are most suitable for pro-active industries, a small number of participants, mature sectors with limited competition, and long-term targets (EEA, 1997). The evaluations also show that VAs are most effective if they include clear targets, a specified baseline, a clear monitoring and reporting mechanism, and if there are technical solutions available with relatively limited compliance costs (EEA, 1997). In some cases the result of a VA may come close to those of a regulation, i.e., in the case of negotiated agreements as used in some European countries. Outside developed countries, also some NICs, e.g., Republic of Korea, consider the use of VAs (Kim, 1998), while the Global Semiconductor Partnership is an example of an international voluntary agreement to reduce PFC emissions.

5.4.4 Energy Supply

There are two primary types of options available for reducing emissions. One is to increase the efficiency of energy supply, and the second is to switch from carbon intensive fuels to low or no carbon content sources of energy. The two options face different categories of barriers and the most relevant are described in this section.

Energy Prices

Low prices are, in part, a consequence of direct and indirect subsidies to producers, and the non-inclusion of external costs in their production and use (Watson *et al*., 1996; Harou *et al*., 1998). It is common in the energy supply sector to find price policies (public or private) which do not reflect the “full costs”. These full costs include environmental externalities, which, for example, are not included in any coal transaction or gasoline prices in the United States. Producers and users of new energy technologies are not usually rewarded for the associated environmental benefits (World Bank, 1999).

Lack of Consistency in the Evaluation of Energy Costs
Closely related to the price barrier faced by clean fuels is the selective evaluation of energy costs from different energy sources. There is a need to make a comprehensive evaluation of all costs and benefits.

Lack of Adequate Financial Support
Multilateral development banks, public banks, and private banks generally do not offer soft credit, or programmes aimed specifically at energy technologies. This acts as a further barrier to capital-intensive energy projects. The absence, up until now, of specific programmes and an administrative process adapted to this type of project has resulted in high transaction costs and a lack of discussion of this key issue as a solution in the climate change problem. The role of a multilateral system could be especially important for the development of a hydropower programme, financing of regional interconnections, and developing small, sound environmental technologies for energy supply like mini hydro, solar, and wind.

Institutional Transformation and Reforms
Privately-owned generation, transmission, and distribution entities are playing increasingly large roles in electric utility systems worldwide. Many national power utility systems have been totally or partially privatized.

The liberalization of the power industry, which introduces competition within the generation segment, could have a significant impact on the viability of renewable sources. Some observers may argue that subsidies of any sort are antithetical to the concept of a deregulated market, and that the purpose of liberalization is precisely to eliminate such subsidies and market distortion. In competitive markets where the process is replaced by the market-driven decisions of generation companies subsidies to renewable sources may become less acceptable (Bouille, 1998).

Segmentation of the electricity chain may reduce the incentives for electricity companies, especially electricity distribution companies, to act on end-use efficiency (Poole *et al*., 1995).

There are institutional and administrative difficulties associated with the development of technology transfer contracts. These are necessary to qualify regional construction companies as partners in any undertaking. There is a need for greater regional co-operation among developing countries in both research and development, and the development of an international commercial contracting network, to improve technology transfer.

Along with the institutional difficulties of technology transfer projects, high transaction and implementation costs act as barriers as well. Often, cost estimations of new technologies do not include items related to transaction costs or items associated with technology penetration (policy implementation costs). Both transaction costs and policy implementation costs are additional expenses to technology transfer, limiting competitiveness and market potential.

Legal and Regulatory Framework
Many energy supply sources are subject to a lack of regulation other than for safety, inadequate tariffs for transport and distribution, and no incentives to increase efficiency. For example, there is often no penalty for natural gas flaring. This reduces the motivation for improving the efficiency of the supply chain of such sources.

If electric utility companies sell electricity within a regulatory system that allows them to recover all operating expenses, including taxes and a fair return for their investments, they will show no interest in increasing their efficiency. Within this system, utilities will be reimbursed the operational costs independent of the quality of the service offered (US DOE, 1996).

Distributed electricity generators often face a complex bureaucratic process for authorizing the construction and operation of co-generation facilities. Complicated terms of grid connection, as well as technical, economic, and institutional rules limit access to the grid for distributed generators (Verbruggen, 1990,1992, 1996).

Lack of Information
While lack of information on energy technology performance, technical, and economic characteristics is not a very significant barrier in the energy supply sector, this market failure is related to market transparency. The inability of the private market to provide generic information (no transparency), and the possibility that "in the field" operation of a technology may differ from controlled environment operation by a technology producer, both increase uncertainty and risk in an investment. These problems are extensions of the information barrier[4].

Developed countries generally have more capital and technological resources than do developing countries (World Bank, 1999). This can greatly affect the decision-making process in developing countries, as they may not have the newest knowledge to adequately assess new technology opportunities.

Decision-making Process and Behaviour
Many organizations are interested in using the most economically competitive technology, in terms of cost and availability of fuels, though not necessarily in terms of energy or carbon

[4] Any decision-making process is one where the decision maker "buys" information to reduce uncertainty and risk in order to make a "better" decision. Lack of information means, essentially, uncertainty. The lower the degree of information the higher the uncertainty and the barrier to adoption of a specific technology.

efficiency. The most competitive investments offer short payback periods, minimize overall investment, and receive an attractive rate of return. In such a framework, a relatively narrow range of technologies exists. Most of them are efficient in the economic sense but not necessarily in relation to GHG emissions reductions or avoidance. This represents a significant barrier to both developed and developing countries. Co-generation as a distributed technology is an example of this type of barrier (*Box 5.5*). Another example of the "competitive" decision-making process as a barrier is typified in the case of Argentina, where systems with shorter payback periods (such as natural gas-fired systems) are favoured over others (*Box 5.6*). Changes similar to those described in *Box 5.6* are taking place in other developing and developed countries as well.

Box 5.5. Combined (Cooling) Heating and Power or Cogeneration

Co-generation is applied in utility district heating and in distributed on-site power units. Most barriers to on-site co-generation are the same barriers as the ones that impede the development of other types of distributed and/or independent power generation projects. The most important barriers are related to information, technology character, regulatory and energy policy.

Informational barriers

The significant technological advances of recent years (Major, 1995; Rohrer, 1996) are not spread widely enough. This barrier is the most stringent in developing countries and in small institutions and companies, especially when the latter have no technical background. When donors, international institutions, lending banks, etc. are not familiar with the co-generation technology, it will not be implemented by developing and transitional economies (Dadhich, 1996; Nielsen and Bernsen, 1996). Additionally, the economics of co-generation is relatively complex (Verbruggen *et al*., 1992; Hoff *et al*., 1996; Verbruggen, 1996). Optimization of co-generation projects requires extensive information about many determinants of profitability. This span of know-how makes its availability to small-scale independent projects exceptional. Finally, uncertainty about the main determinants like fuel prices, fuel availability, regulatory conditions, environmental legislation, contract terms with the power grid, etc. constitutes a significant barrier.

Decentralized character of the technology

Private investors impose high profitability standards on distributed generation projects. This payback gap is mainly due to a risk-averse attitude regarding non-core business activities. The distances to the energy grids (electricity, natural gas) limit the capacity or co-generation opportunities. Unequal treatment with respect to fuel supplies, authorization and licensing arrangements, and environmental and emissions regulation, constitutes an additional set of barriers that especially affect the small-scale distributed generation projects and add to the costs of the technology (COGEN Europe, 1997).

The terms of grid connection

In several countries, the position and attitude of the grid operator have been hostile towards distributed generation initiatives (Rüdig, 1986; Dufait, 1996). Incumbent power companies sometimes impose heavy regulations on producers or industries that file for a connection to the electricity grid, imposing technical prescriptions that cannot be set in standard packages. Tariff conditions are a particularly difficult issue, because the value of the kWh is dependent on time, place, quality, and reliability of supply, and differs for the three types of power flows that can be exchanged: surplus power that the co-generator delivers to the grid, shortage or make-up power bought by the co-generator at the grid, and back-up power (Verbruggen, 1990). Although there are widely accepted principles to fix the tariff for the different transactions, theoretical and practical difficulties in defining and measuring the costs constrain the development of contracts (Dismukes and Kleit, 1999). In many countries high tariffs on wheeling of electricity act as an additional barrier. In several countries the opportunities for small-scale distributed power generation are improving because grid connection is provided at neutral or even subsidized terms (the Netherlands and Japan; Blok and Farla, 1996).

Energy policy

Utility co-generation requires long-term planning from an integrated point of view (WEC, 1991). Very few nations own the intellectual and administrative capacity to realize an integrated energy policy plan that preserves the place for district heating and related co-generation. Some countries (e.g., Denmark) and international organizations have favoured the development of CHP (EC, 1997). Firm public policy and regulatory authority is necessary to install and safeguard harmonized conditions, transparancy and unbundling of the main power supply functions, and the position of independent players (Fox-Penner, 1990).

Box 5.6. Argentine Power Supply: Some Barriers Related to Institutional and Regulatory Topics

There is no doubt that the Argentine electric power system shows a trend towards the improvement of energy efficiency, both in final consumption as well in electricity-supply activities. Rising competition levels within the electricity industry are favouring efficiency in electricity generation. However, market trends show a rising dependency on natural gas to the detriment of the participation of non-GHG emitting technologies.

Several obstacles will have to be overcome to modify this trend. These are related to the following aspects.

Spot and contract prices. Within a context of falling prices at the spot market, distributors have been reluctant to long-term fixed price commitment. In fact, the indicator used to adjust the price at distribution level is the spot price. Should its supply be totally or partially contracted, the distributor cannot transfer to retail rates the costs of their contracts if they have, occasionally, a higher price than the spot. Long-term payback investment, with higher investment costs, major risks, and lower internal rate of return, are not favoured by a context based on spot prices.

Volatility of prices. A system with important hydro generation capacity shows variation depending on hydrological conditions. Dry and humid years represent important impacts on the income of hydroelectric generators and introduce an additional source of risk. This volatility could potentially increase if the interconnection with the Brazilian system becomes a reality in the short term. The Brazilian system is almost entirely supplied with hydroelectric generation, which has frequent surplus capacity. This surplus or non-firm energy, with zero value, could enter the Argentine wholesale market and introduce a fantastic volatility in the spot price market which would affect all generators.

Behaviour. Private investors are reluctant about options that imply higher risks, longer payback, lower internal rate of return, and high investment per unit of capacity. The decision-making process clearly shows this behaviour: all the new capacity installed after the privatization process is based on open and combined cycle thermal power plants using natural gas as fuel. In the past, Argentine public utilities, using lower discount rates, assuming higher risks, and making investments assisted by the multilateral financing system, developed an important hydropower system that represented near 50% of the supply. The new context offers lower opportunities for this “old” technology, and acts as a barrier to a more “costly” option from a private point of view.

Economics of the technologies. In the case of nuclear power plants, additional costs for waste treatment, plant decomissioning, and insurance reduce the competitiveness of this technology. In the case of hydroelectric stations, the payments of royalties, the need for insurance, and the transmission network expansion mechanism (payback in 15 years) increase the costs and decreases the possibilities of such technologies in the decision-making behaviour described above.

Uncertainty and risk aversion discourage long-term investments. Many forms of sustainable energy production require long-term investment. Most multilateral and international lending institutions are averse to technologically risky investments. As a result, both government and private entities may be reluctant to invest in high-tech projects that entail high capital costs (ECOSOC, 1994).

The lack of performance data for newer energy technologies often results in an unwillingness on the part of smaller firms to risk purchasing these more expensive technologies. While they may offer greater future savings than traditional technologies, the lack of test data prompts fears that reported energy savings may not materialize in practice.

The uncertainty inherent in new technologies leads investors to use high discount rates, which would make investments that are clearly cost-effective from a global perspective seem unattractive to private actors (Bouille, 1999). In the case of energy-efficiency investments, however, some may be for well-established technologies with low technological and economic risk.

Inclusion of renewable energy in a wholesale electricity market could affect price volatility for generators. Volatility is remarkably affected by hydroelectricity supply. Any mitigation action which increases the share of such a source in the electricity market will most likely contribute to further price volatility, increasing the level of risk for the actors.

Social and Cultural Constraints

The environmental impacts and risks of technologies, such as nuclear power and hydropower generation, may not be acceptable to many social groups. The real or perceived environmental risks of such technologies pose a significant barrier to their implementation (Bouille, 1998).

Cultural Aspects Related with Decentralized Systems in Rural Areas

There are cultural barriers that oppose the use of decentralized systems in rural areas. Renewable energy is often promoted in rural areas to reduce local environmental impacts, and accomplish social and welfare goals. While these technologies may be competitive, easy to operate, and adequate for the project needs, technology diffusion is often confronted with cultural barriers (Barnett, 1990).

In order to overcome cultural and social barriers, a project must take into account the needs of potential users of the project technology, and harmonize the diffusion strategy with local physical, human, and institutional resources. A project should also build local technical and institutional capabilities so the project may be fully realized (Barnett, 1990).

Capital Availability

There are substantial opportunities in developing countries for expansion of electricity supply. While the capacity being installed is improving in efficiency, this process is slowed by difficulties in accessing the necessary capital. Many ESTs require large up-front investments. In effect, the cost of pollution abatement is paid in advance. This is a serious obstacle for some technologies, particularly nuclear power generation and large hydropower schemes. These technologies also have other constraints, however. A reduction in nuclear unit size and/or improved safety and maintenance features could help to overcome this barrier.

Co-generation or combined production of power and heat is a much more efficient process than the production of each of these energy sources alone. Implementation of co-generation, however, faces barriers such as shortages of capital. There is also currently a lack of regulatory policies allowing commercialization of the excess electricity produced through access to existing grid systems (*Box 5.5*).

5.4.5 Agriculture

The Special Report on Land use, Land-use Change, and Forestry (IPCC, 2000a) estimated a significant potential for increasing carbon stocks in the agricultural sector. Improved management of cropland and grazing-lands, agroforestry, and rice paddies have the potential to sequester 398 MtC annually, and the conversion of cropland to agroforestry practices and grasslands can sequester an additional 428 MtC annually by 2010. These estimates are highly uncertain, however, and do not include the impact on the net emissions of methane (CH_4) or nitrous oxide (N_2O) from agricultural practices or wetlands and/or permafrost management.

CH_4 emissions from agriculture produce about eight per cent of the radiative forcing of all GHGs (Watson *et al*., 1996). CH_4 from manure can be captured and used for fuel; emissions from ruminants can be reduced with better diets, feed additives, and breeding; and emissions from rice paddies can be mitigated by nutrient management, water management, altered tillage practices, cultivar selection, and other practices (Mosier *et al*., 1998).

Many of the mitigation options to address these opportunities may provide multiple benefits to the farmer and society at large. Improving soil management for crop production, for instance, can also improve water relations, nutrient retention, and nutrient cycling capacity (Paustian *et al*., 1998). Retiring surplus agricultural lands can result in improved water quality, reduced soil erosion, and increased wildlife habitat. As Izac (1997) points out, however, farmers, who will be the ultimate decision makers about which mitigation option to adopt, have shorter planning horizons than national or international beneficiaries, and many mitigation options ask them to bear costs up front while the benefits are longer term and to the society at large.

Furthermore, in order to realize these opportunities a very large proportion of farmers who pursue diverse agricultural practices will have to be convinced to adopt mitigation options. Economic, cultural, and institutional barriers exist which restrict the rate of adoption of such practices. Farmers who are accustomed to traditional practices may be reluctant to adopt new production systems. Crop price supports, scarcity of investment capital, and lack of economic incentives for addressing environmental externalities are some of the economic barriers. Limited applicability of mitigation options to different types of agriculture, negative effects on yield and soil fertility for rice production, and the increased skilled labour requirements are some of the other constraints. Among these barriers the especially critical ones are highlighted here.

Farm-level Adoption Constraints

Several generic constraints characterize the adoption of most new agricultural technology. These include small farm size, credit constraints, risk aversion, lack of access to information and human capital, inadequate rural infrastructure and tenurial arrangements, and unreliable supply of complementary inputs. Participatory arrangements that fully engage all the involved actors may help to overcome many of these barriers.

Government Subsidies

Subsidies for critical inputs to agriculture, such as fertilizers, water supply, and electricity and fuels, and to outputs in order to maintain stable agricultural systems and an equitable distribution of wealth can distort markets for these products. These types of subsidies prevail in both developed and developing countries. Low electricity prices in India, for example, provide a disincentive for the use of efficient pump sets, and encourage increased use of ground water, which depletes the water reservoirs. In the OECD, for example, high levels of farm subsidies have also contributed to the intensification of farm practices and often provide incentives to increase fertilizer use, livestock density, etc. (Storey, 1997).

Lack of National Human and Institutional Capacity and Information in the Developing Countries

Several of the Consultative Group on International Agricultural Research (CGIAR) systems are experiencing difficulty as their funding slows. The systems have not transferred capacity to national centres in the developing countries that they are expected to serve. The national centres also lack access to information, and are not aware of technologies that suit their local conditions (IPCC, 2000b).

Lack of Intellectual Property Rights
To some extent the reduced public funding on new technologies has been replaced by the private sector's contribution. Private sector funding offers one approach to increasing investment for mitigation projects worldwide. Private plant breeding research has more than quadrupled in the USA in real terms between 1970 and 1990. Its international role is, however, controversial. Protection of intellectual property rights is weak, especially for commercially developed seed varieties (Deardorff, 1993; Frisvold and Condon, 1995, 1998; Knudson, 1998). On the other hand, hybridization will help to stimulate more investment from the private sector at the risk of increasing the farmers' dependency on the annual purchase of new seeds. There are also concerns that genetic resources that have not been considered as privately-owned intellectual property may get patented worldwide by private investors.

Several measures may be pursued to address the above barriers. These include

- The expansion of internationally supported credit and savings schemes, and price support, to assist rural people to manage the increased variability in their environment (Izac, 1997);
- Shifts in the allocation of international agricultural research for the semi-arid tropics towards water-use efficiency, irrigation design, irrigation management, and salinity, and the effect of increased CO_2 levels on tropical crops (Tiessen *et al*., 1998);
- The improvement of food security and disaster early warning systems, through satellite imaging and analysis, national and regional buffer stocks, improved international responses to disasters, and linking disaster food-for-work schemes to adaptation projects (e.g., flood barricades);
- The development of institutional linkage between countries with high standards in certain technologies, for example flood control; and
- The rationalization of input and output prices of agricultural commodities taking DES issues into consideration which would lead to more efficient use of input resources.

5.4.6 Forestry

In addition to the several generic barriers that are discussed in Section 5.3, the forestry sector faces land use regulation and other macroeconomic policies that usually favour conversion to other land uses such as agriculture, cattle ranching, and urban industry. Insecure land tenure regimes, and tenure rights and subsidies favouring agriculture or livestock are among the most important barriers for ensuring sustainable management of forests as well as sustainability of carbon (C) abatement.

The Special Report on Land Use, Land-use Change and Forestry (IPCC, 2000a) notes significant opportunities for forestry and other land-use change activities to sequester carbon. Afforestation and reforestation activities could capture between 197 to 584MtC/yr in all countries under the IPCC "definitional" scenario between 2008 to 2012. The estimated deforestation, however, would negate this sequestration potential. Halting deforestation offers additional opportunity to reduce emissions. Forest management and agroforestry options offer a potential to capture another 700MtC/yr by 2010. Capturing these opportunities, however, entails significant hurdles of the types noted below.

Lack of Technical Capability
In many developing countries, the national and state forest departments play a predominant role in all aspects of forest protection, regeneration, and management. Currently lack of funding and technical capabilities in most tropical countries limit generation of information required for planning and implementation of forestry mitigation projects. Apart from a few exceptions, developing countries do not have adequate capacity to participate in international research projects and to adapt and transfer results of the research to the local level. Research on forests has not only suffered from a lack of resources; it has not been sufficiently interdisciplinary to provide an integrated view of forestry (FAO, 1997). However, the majority of the forestry research institutions do not function as R&D laboratories as they do in industry, and the main focus is on research and not technology development and dissemination. Unlike in the energy or transportation sectors, the technologies or even the management systems are going to be forest type or country specific.

Lack of Capacity for Monitoring Carbon Stocks
Forestry-sector GHG mitigation activities and joint implementation projects generally face a wide range of technical issues that challenge their credibility. The twin objectives of using forestry to mitigate climate change and managing forests sustainably do pose a challenge in monitoring and verifying benefits from carbon offset projects in the sector (Andrasko, 1997). While methods generally exist to monitor carbon stocks in vegetation, soils and products, operational systems that could be readily implemented for this purpose are lacking in all countries (IPCC, 2000a). Monitoring and verification are key elements in gaining the credibility needed to capture the potential benefits of forestry sector response options, particularly in reducing deforestation (Fearnside, 1997). While this is a generic barrier to deforestation reduction initiatives, it also represents an opportunity for transferring the technologies needed to monitor land-use change and carbon stocks and flows. Among the mitigation options, there is a higher degree of certainty on reforestation and/or afforestation, less on forest management, and even less on forest conservation.

Under the GEF-UNDP sponsored Asian Least-Cost Greenhouse Gas Abatement Strategy (ALGAS), the US Country Studies Program (Sathaye *et al*., 1997a), and other forestry sector capacity building and analytical activities have identified mitigation options and technologies. Furthermore, the policies to promote technology transfer have been identified (e.g., regulations, financial incentives) and sometimes implemented (e.g., Mexico, Bolivia). Under the UNFCCC, each party is required to communicate a national inventory of GHG emissions by sources and sinks. A large portion of the parties has completed this task and is trying to understand forestry sector emissions and removals by sinks, which has improved dramatically. Many parties are taking steps to manage forest systems as C reservoirs (Kokorin, 1997; Sathaye *et al*., 1997a).

As a result of the UNFCCC and Kyoto Protocol, many developing and transitional countries are developing National Climate Change Action Plans (NCCAPs) which incorporate forestry-sector mitigation and adaptation options (Benioff *et al*., 1997). "No regrets" adaptation and mitigation options have been identified that are consistent with national sustainable development goals. Bulgaria, China, Hungary, Russia, Ukraine, Mexico, Nigeria, and Venezuela all have developed very specific forestry sector climate action plans.

The Russian Federation has a progressive forestry sector climate change action plan (Kokorin, 1997), although its implementation is uncertain under the current economic conditions. Based on current economic and climate change scenarios several mitigation and adaptation scenarios have emerged: (1) creating economic mechanisms to increase forestry sector effectiveness and efficiency in logged (removal) areas, (2) providing assistance for forestation in the Europe-Ural region, (3) promoting fire management and protection for central and northeastern Siberia, and (4) limiting clear-cut logging in southern Siberia. These steps are significant since Russia contains approximately 22% of the world's coniferous forests.

Forestry mitigation projects are likely to be largely funded by Annex I countries and implemented in non-Annex I countries and EITs. Technology, including management systems, is an integral part of all projects funded by bilateral or multilateral or commercial agencies. Thus, promotion of mitigation projects also automatically promotes the flow of technology from donor agencies or countries to host countries or agencies. In fact, technology transfer is already happening. Forestry sector options are of relatively low cost compared to those in the energy sector (Sathaye and Ravindranath, 1998). But there are some problems and uncertainties regarding the incremental C abated: its sustainability, measurement, verification, and certification. All forestry sector GHG mitigation projects must ensure that they meet accepted standards for sustainable forest management (Sathaye *et al*., 1997b). Independent verification of C abatement would help to increase the credibility and funding of forestry-sector mitigation projects.

5.4.7 Waste Management

Waste management represents an important challenge for the reduction of GHG emissions. Waste is also a potential resource, much of which can be recycled and reused (CPCB, 1998). Residential and commercial waste may be differentiated from industrial waste, a component of the latter being toxic and requiring special treatment. In all cases, there are options for bulk reduction at source. Thus, waste management entails the three R's – Reduction, Recycling and Reclamation – for recovery of usable components either directly (example: chemical recovery in pulp and paper mills) or indirectly through processing of waste (example: CH_4 recovery from landfills and from distillery effluents).

Wastes of various kinds including energy, raw materials, effluents, emissions, and solid wastes are omnipresent in different walks of life (ESCAP 1992, Debruyn and Rensbergen, 1994; Doorn and Barlaz, 1995). Non-availability of appropriate technology is often perceived as a major impediment (Nyati, 1994; Narang *et al*., 1998). However, there are cases to cite that even the proven technologies do not penetrate into society as rapidly as their potential would suggest (Reddy and Shrestha, 1998; Shrestha and Kamacharya, 1998).

5.4.7.1 Barriers to Mitigation

One of the major driving factors in waste management is the economic environment. Market forces favour waste utilization when there is a shortage of raw materials or their prices are high. Waste utilization is directly influenced by the economic incentive for recovery of usable materials (Vogel, 1998). Apart from market forces, the other barriers (Painuly and Reddy, 1996; Parikh *et al*., 1996; Mohanty, 1997) in waste management relate to the following:

- Lack of enabling policy initiatives, an institutional mechanism, and information on opportunities for reduction, recycling, and reclamation of waste;
- Organizational problems in collection and transport of waste from dispersed sources for centralized processing and value addition; and,
- Lack of co-ordination among different interest groups, although there are several examples of successful initiatives taken through private sector and NGO efforts as well as business-to-business waste minimization and recycling programmes.

5.4.7.2 Programmes and Policies to Remove Barriers

To overcome the barriers and to exploit the opportunities in waste management, it is necessary to have a multi-pronged approach which includes the following components:

- Building up of database on availability of wastes, their characteristics, distribution, accessibility, current practices of utilization and/or disposal technologies and their economic viability;
- An institutional mechanism for technology transfer though a co-ordinated programme involving the R&D institutions, financing agencies, and industry (Schwarz, 1997); and

- Defining the role of stakeholders including local authorities, individual house holders, NGOs, industries, R&D institutions, and the government.

The efforts of local authorities in waste management could focus on: the separation and reclamation of wastes through seperate collection of reusable wastes for recovery; provision of reclamation centres where the public can deliver wastes; arrangements for separation and reclamation at disposal sites and transfer stations (de Uribarri, 1998); arrangements for waste disposal with by-product recovery; and landfilling of residuals. Local authorities may enlist the support of the public and individual householders as well as NGOs to store recoverable wastes separately or deliver these to the reclamation centres. Local authorities can also consult the industry on how wastes could be best ultilized to meet their raw material requirement. Industry can be encouraged to accept wastes as secondary raw materials (NWMC, 1990).

R&D institutions could play an important role in waste utilization by development and dissemination of viable technological alternatives including pilot scale demonstration, organizing technology transfer workshops, and dissemination of information to industries. Land use and industrial estate planners can internalize waste utilization and/or minimization concerns in the process of siting industrial plants (Datta, 1999). The possibilities of siting industrial activities in such a way that wastes from one unit could be used as raw material for another could be explored. The arrangement might reduce capital outlay and operating costs, and also facilitate transfer and processing of products and/or raw materials.

Governments may introduce fiscal and regulatory measures for reduction of wastes and promotion of waste utilization. These may include incentives to producers and users to accept reduced packaging, incentives to consumers to return reclaimable wastes, incentives to local authorities to support reclamation and/or waste utilization activities, incentives to industries using recovered materials, financial support to R&D activities, awards to individuals and/or organizations for waste utilization, and penalties for not adopting waste minimization and/or utilization practices.

Programmes for providing training and education on waste minimization and utilization with an interdisciplinary approach could be developed. Waste utilization as a profession has no fixed boundaries. Skills of psychology, economics, material sciences, process design, and ecology are but some of the many requirements for the trained professional.

Even the best planned, designed, and executed waste utilization programme would fail without the effective participation of the public. Education of the public on waste utilization issues, therefore, would play a vital role in ensuring the success of the programme. A public education programme would be aided by the identification of appropriate communication systems (AIT, 1997; ESCAP, 1997; Bhide, 1998).

5.5 Regional Aspects

There are many barriers and opportunities, from the ones described before, which have a particular relevance to developing countries and EITs. The issues of sustainable and equitable development resonate in these countries as they undergo a rapid transformation towards market-oriented systems that are immersed in a global economy. Institutionally, the transformation in developing countries is significant, but it is often confined to specific sectors, such as the deregulation of the energy sector. On the other hand, the socialist economies are undergoing a more radical shift of the whole economy. These global patterns of change provide an opportunity for introducing GHG mitigation technologies and practices that are consistent with DES goals. At the macro-level the change to a market economy and the liberalization and opening of markets to foreign investment provides an opportunity to make significant improvements in the GHG intensity of the economy. Similarly, the restructuring of the energy sectors also offers an opportunity to introduce demand management and low or no GHG-emitting energy sources. As the sections below note, however, a culture of energy subsidies, institutional intertia, fragmented capital markets, vested interests, etc. presents major barriers to the introduction of such technologies and practices. The developed countries face different types of barriers and opportunities that prevent or slow the penetration of GHG mitigation technologies. These barriers and opportunities are related to their more affluent lifestyles. The sections below emphasize situations in the three groups of countries that call for a more careful consideration of the barriers and opportunities they face.

5.5.1 Developing Countries

As a group, the developing countries are undergoing rapid urbanization, which leads to increased industrialization and motorization that has altered the manner in which people relate to their environment (Rabinovitch, 1992). Much of their technology stock is derived from developed countries, and increased globalization tends to expose even remote populations to socio-cultural patterns observed in the developed countries. Yet, the majority of the population in these countries lives in rural areas, and often in absolute poverty. These underlying attributes and phenomena create or emphasize barriers and opportunities that are particular to this group of countries.

Trade and Environment
A larger external debt and balance-of-payments (BoP) deficit is a reality in many developing countries. If a GHG mitigation technology has to be imported, it is likely to add to this debt and BoP deficit. Another barrier to the technology transfer process is the requirement in technology transfer contracts of "intellectual property rights" (IPR), which guarantee that private firms are compensated for sharing their technology. If IPR laws are not effectively enforced, there is little incentive for private firms to share their technology. However, patents and licensing fees can

be very expensive and in such situations, developing countries may prefer the lowest priced, albeit possibly less efficient technology alternatives (Srivastava and Dadhich, 1999).

Institutional Framework
Deregulation and privatization offer an opportunity for improving energy efficiency and reducing GHG emissions in the energy sector. Studies and scenario analyses show, however, a consequent increase in emissions resulting from low fuel prices, displacement of hydro and nuclear plants by cheaper fossil-fired capacity, and a change in attitudes and behaviour of the energy suppliers (Bouille, 1999).

Distorted Energy Prices
Energy price subsidies have been in place in many developing countries in the name of reducing the financial burden on the poor. This has spawned a culture of dependency on energy subsidies that is gradually diminishing (Jochem, 1999).

Finance
Lack of available capital and lack of finance at low interest rates is pervasive in developing countries. Together with the absence of standards or energy labeling schemes, these barriers support the proliferation of inefficient equipment and first-cost-minimization philosophy. Additionally, low incomes and poverty constrain access to adequate finance, and oblige the purchase of inexpensive and often GHG-intensive equipment (Bouille, 1999). Provision of special funds targeted to the poor and government financing of the first cost of equipment are ways to increase the provision of energy services.

Barriers
Information gap hindering proper technology selection, lack of adaptation and absorption capability, lack of access to state of the art technology, and the small scale of many projects (Jochem, 1999) are specific and important barriers in low income developing countries to effectively exploit the full potential benefit of technology transfer. Lack of information also slows the decision-making processes in developing countries.

5.5.2 Countries Undergoing Transition to a Market Economy in Central and Eastern Europe and the New Independent States

The collapse of communism in Central and Eastern Europe and the subsequent disintegration of the Soviet Union brought the region's serious environmental problems to the attention of the international community. Although the countries in this vast area of the world are remarkably diverse, central economic planning had created a common pattern of environmental problems which included wastefulness, pollution-intensive economic systems, ill-designed and resource heavy technologies, and perverse incentives encouraging increase of output rather than enhancing efficiency of resource use. A universal feature was also the world's highest energy and carbon intensity of economies.

A Soviet-type economy has left a legacy of acute health effects from local pollution. Having very scarce resources, the transition economies have so far focused mainly on mitigating local pollution rather than emissions of GHGs. However, wherever environmental policies were successful in the region, they have also brought important climate dividends. Some countries in the region (e.g., Poland) have introduced specific climate change mitigation policy instruments, such as charges on CO_2 and CH_4 emissions.

At the end of first decade of the transition to a market economy, contrasts between different countries in the region have outstripped bygone relative homogeneity. Central Europe and the Baltic countries have made a successful leap in economic reforms and restructuring, while countries of the former Soviet Union (so called New Independent States - NIS) continue to struggle with economic recession and political instability (EBRD, 1999). Recent empirical studies on the interrelationship between environmental improvement and economic development in transition economies undertaken by the World Bank, EBRD, and OECD have demonstrated that countries that were more successful in economic development and structural reforms have generally also been more successful in curbing emissions through targeted environmental policies. Aggregated GDP among advanced reforming countries has been gradually increasing, while emissions of main air pollutants have continued to decrease. Energy consumption has been stabilized and a switch away from coal has been recorded mainly in Poland and the Czech Republic causing GHG-intensity of GDP to decrease. In contrast, in the slower reforming countries in NIS, falling output, rather than economic restructuring or environmental protection efforts, appears to have been the main factor behind the decrease of energy use and emissions of pollutants, including GHGs (OECD, 1999a).

In the more advanced economies of the region, economic reforms have helped generate resources for investment in cleaner, more efficient technologies; reduced the share of energy- and GHG-intensive heavy industries in economic activity; and helped curb emissions as part of the shift towards more efficient production methods (OECD, 2000). In some sectors, however, the transition has brought greater climate pressures. For example, in those countries returning to economic growth, the use of motor vehicles for both passenger and freight transport has increased rapidly.

Energy Pricing and Subsidies
Virtually all countries in the region have embarked on the liberation of energy prices and elimination of energy subsidies. Significant successes in this field have been achieved in Central European and Baltic States. However, in NIS a sharp reduction of explicit subsidies has resulted in an almost immediate build up of hidden subsidies to energy producers and users, such as arrears and non-monetary forms of payments for energy (EBRD, 1999).

Finance and Income

Lack of adequate access to capital for GHG emission reduction technologies is perceived as a bottleneck in many countries in the region (World Bank, 1998). However, in CEE financial and capital markets are becoming mature enough to provide increasingly better access to credit for fuel switching or energy efficiency, especially given stable macroeconomic conditions and relatively high energy prices. In these countries the main bottleneck to environmental finance is not the lack of finance, but rather the lack of a "pull factor". Lack of implementation of the Polluter Pays Principle, and weak enforcement of the environmental and climate policy framework does not stimulate sufficient demand for investments that would bring mainly GHG reduction benefits, with little private financial return (OECD, 1999b). In NIS, however, the weak policy framework is aggravated by the overwhelming lack of liquidity both in the public and private sector. Limited financial resources, which are available to authorities have not always been used in a cost-effective way. Opportunities to leverage additional financing from public and private, domestic and foreign sources were also underutilized (OECD, 2000).

Institutional Aspects

The countries in the region have undergone a rapid deregulation and privatization on a short time scale that has no precedence in the history of the world. This process in the Baltic and Central European countries has generally led to increased resource efficiency and replacement of obsolete and GHG intensive technologies. However, in a number of countries of the former Soviet Union, particularly in Russia and Ukraine, the rapid pace of liberalization and privatization has not been matched by the development of institutions as well as a regulatory and incentive framework necessary to support a well-functioning market economy. Perverse incentives that had generated many of the environmental problems of centrally planned economies, such as rent seeking and lack of incentives for efficiency and restructuring, now undermine restructuring of already private enterprises (EBRD, 1999). But successful economic policies have not been a panacea for successful GHG-mitigation improvements. Targeted environmental policies and institutions in Central Europe were required to harness the positive forces of market reform, and ensure that enterprises and other economic actors improve their environmental performance which are still weak in the NIS (World Bank, 1998).

5.5.3 Developed Countries

Compared to the developing countries and those undergoing an economic transition, the GHG emissions in the developed countries originate increasingly from the energy used by households and other consumers for personal activities. Mitigation opportunities therefore lie increasingly in the area of personal transport, space conditioning, and other home use of energy, and in the energy used by the commercial sector, although opportunities exist in all sectors. Financial and income-related, social and behavioural, and institutional barriers thus become predominant in limiting the choice of mitigation technologies in these countries.

In the household sector, for instance, although a CFL offers a relatively short payback period, the large price differential between the CFL and an incandescent bulb poses a significant first-cost barrier to consumers. Most programmes to promote CFLs have focused on a subsidy to lower its first cost (Mills, 1993; Meyers, 1998). Raising the efficiency of other consumer appliances encounters barriers such as the relatively low energy cost, bundling of higher efficiency with other higher value attributes, and lack of information about energy consumption. Standards and labels are being implemented in several countries in order to overcome these barriers. While many communities and national governments have regulations for more efficient construction, rising affluence has increased the demand for homes with a larger floor area, which negates efficiency gains. Disincentives may also exist in the market structure, e.g., a building owner may not be interested in energy efficient designs if the user is responsible for paying for the energy used.

In the transport sector, manufacturers are producing cars that have more efficient engines and lower air resistance, but coupled with higher weight and more power (and other options), there has been little or no gain in vehicle fuel economy. Fuel economy is also not an important criteria in most purchasing decisions (see Section 5.4.3). The movement of households to suburban areas increases the distance traveled to work, and for leisure, and adds to a vehicle's fuel consumption. The lock-in of transport into motorized private transport is an important barrier to new efficient forms of mass transport, while the well-established gasoline-based infrastructure is a barrier to the introduction of new less GHG-intensive fuels and associated technologies.

Energy efficiency and GHG-intensity in industry still vary widely among and within developed countries, suggesting the existence of barriers. Decision makers do not have sufficient information to evaluate GHG mitigation opportunities. The relative high transaction costs reduce the changes of innovative technologies. Output growth is slow or stagnant in the large energy-intensive industries. The resulting slow stock turnover has slowed the penetration of new GHG mitigation technologies in these industries. As industries improve their labour productivity, concentration on a few core activities has led to a lack of skilled personnel to evaluate and implement new technology.

The energy supply sector is undergoing changes in the regulatory structure in almost all developed countries. These changes may not all be conducive to the goal of GHG mitigation. Increasing profitability through reduction of capital costs may lead to less efficient power generation options, and reduce the penetration rate of generally capital intensive renewable energy technologies. In general, grid operators (i.e., utility companies) have put up high barriers against more efficient generation options like co-generation (CHP) through low buyback tariffs, high interconnection charges, or power quality demands (*Box 5.5*). Deregulation experiences have differed with respect to the treatment of co-generation and renewable energy.

5.6 Research Needs

The earlier chapters show a significant potential for GHG mitigation in energy and non-energy sectors. All types of barriers limit this potential. These barriers are specific to a technology, sector, and region, and they evolve over time. Research would be useful in several areas to collect data, establish databases, improve methods, and develop computerized models that would help decision makers to devise improved policies and measures to address these barriers:

- What is the quantitative global and regional market potential for different categories of mitigation technologies? Chapters 3 and 4 note the technical and socioeconomic potential but a parallel quantitative estimate for market potential is yet to be developed. Data and models that explicitly incorporate barriers to achieving the market potential would be helpful.
- What mix of barriers prevents the adoption of major mitigation technologies? Are social capital and related investment policies more or less important, and how might these vary across cultures and physical environments? What are the decision processes that foster technology transfer? Can technology transfer be managed such as to support sustainable and equitable development? The IPCC-SRTT provides one framework for a technology transfer process. Models of processes that reflect "real world" decision-making are needed, however, in order to identify and elaborate on the barriers that prevent or slow the diffusion of mitigation technologies. The models would also need to take alternative development pathways into consideration. An improved understanding of technology transfer both within and across countries would be required since the actors and barriers tend to be very different.
- What is the appropriate role for stakeholders in the above decision-making processes? The roles of governments and other stakeholders change over time. This is particularly important in sectors where the social, cultural, institutional, and market context is changing rapidly. An identification of their emerging roles would help decision makers manage technology transfer better.
- Does market globalization favour or hamper the diffusion of mitigation technologies? Does environmental regulation confer to firms and nations a long-term technological advantage? Market globalization offers opportunity to plant seeds of mitigation technologies that are less GHG intensive, but it could also bring about proliferation of polluting technologies. It is important to understand the ongoing processes and to determine ways to assist the transfer of less GHG-intensive technologies.

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