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Barrier busting in energy efficiency in industry

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Barrier busting in energy efficiency in industry

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Abstract

The theoretical part of this report provides a taxonomy for the nature of barriers to energy efficiency at the macro and at the micro level, highlighting differences between developed and developing countries, and discussing the rationale for policy intervention. The empirical part analyses barriers to energy (and carbon) efficiency for 119 projects under the UNFCCC Clean Development Mechanism, distinguishing between "poorer" and "richer" host countries. On average, 2.5 barriers per project are reported. Projects in "poorer countries" are associated with more barriers, in particular, at the micro level, where technical and financial risks appear to be the most relevant barriers. At the macro level, lack of human capital, lack of technical infrastructure and lack of external access to capital are the most relevant barriers.

1 Introduction

Improving energy efficiency, i.e., increasing the level of energy services per unit of energy input, is often seen as the fastest and most cost-effective way to reduce greenhouse gas emissions. For example, according to the simulations in the recent IEA World Energy Outlook (IEA 2009), most of the emission reductions until 2030 to achieve the 450 ppm target will be achieved via energy efficiency measures. In 2020, almost 60 percent of all reductions will come from improved end use energy efficiency. By 2030, this share will drop slightly to 56 percent. The lion's share of these reductions will come from China, which will account for 41 percent of all end use energy efficiency improvements in 2030 (IEA 2009).[1]

From a more national perspective, improving energy efficiency may also improve the security of energy supply, lead to employment or productivity gains (including competitive advantages for industry) and alleviate energy poverty. At the more regional level, higher energy efficiency leads to health benefits from lower emissions of local pollutants (e.g. nitrogen oxides and sulfur). Finally, at the company level, improving energy efficiency reduces energy costs and may improve profitability and competitiveness. However, maximizing energy efficiency does not always correspond to maximizing economic efficiency, since the latter implies the optimal use of all resources - not just energy inputs (Sutherland 1994). Thus, if increasing energy efficiency requires more use of other factors (capital, labour, other resources) than is saved in terms of energy, overall economic efficiency would be reduced.

From an economic perspective the level of energy efficiency is governed by economic incentives. These depend, among others, on the level of energy prices and the information available. If energy prices are too low - for example, because of distorted energy prices they do not provide adequate economic incentives. Consequently, investment in energy efficiency will be too low. Empirically, the thrust of engineering-economic type analyses suggests that there is a large potential for energy efficiency measures that appear profitable under actual economic and institutional conditions, that is, even if energy prices factors are not at their socially optimal levels (e.g. IPCC 2007). Such potentials not also exist in developed but, in particular, in developing countries and countries in transition (e.g. Sathaye, 2001: Taylor et al. 2008). Because of barriers to energy efficiency these seemingly profitable measures are not being adopted. Following Sorrell et al. (2004, Chapter 1), these barriers may generally be characterized as "postulated mechanisms that inhibit a decision or behavior that appears to be

[1] Therefore, investments in energy efficiency between 2010 and 2030 in China will amount to around 1260 billion US$ (expressed in 2008 US$).

both energy efficient and economically efficient." There is a large body of literature on the nature of ***barriers to energy efficiency at the micro and the macro level,*** which draws on partly overlapping concepts from neo-classical economics, institutional economics (including principal-agent theory and transaction cost economics), behavioural economics, psychology and sociology (Stern, 1986; Howarth and Andersson, 1993; Jaffe and Stavins, 1994a; Howarth and Sanstad, 1995; Brown, 2001; Sathaye et al., 2001; Sorrell et al., 2004, Masselink, 2007). Barriers at the macro level involve price distortions or institutional failures. In comparison, the literature on barriers at the micro level tries to explain why organizations fail to invest in energy efficiency even though it appears to be profitable under current economic conditions determined at the macro level - a phenomenon that is also known as the "energy efficiency gap" or the "energy efficiency paradox" (Jaffe and Stavins, 1994b). Most of the theoretical and empirical literature on the "energy efficiency gap" relates to industrialized countries. Improving energy efficiency in industry sectors in developing countries (and countries in transition) often involves issues of technology transfer. According to Worrell et al. (2001, p. 34), these countries "suffer from all barriers that inhibit technology transfer plus a multitude of other problems."[2] Understanding the nature of the barriers to energy efficiency is crucial for designing effective policy measures to help overcome these barriers.

As a background to the UNIDO report titled **"If industrial energy efficiency pays, why is it not happening?"** this report aims at (i) conceptualizing a taxonomy for the nature of barriers to energy efficiency; (ii) discussing the rationale for policy intervention and (iii) empirically analysing barriers to energy (and carbon) efficiency for projects under the UNFCCC Clean Development Mechanism.

The report is organized as follows. Section 2 includes a conceptual overview of barriers to energy efficiency at the macro and organizational levels, including a brief discussion of policy implications. Section 3 discusses the rationale for policy intervention thereby further distinguishing between barriers that may warrant policy intervention and those that may not. The empirical work in Section 4 categorizes the barriers identified in the project design documents for projects under the Clean Development Mechanism (CDM) of the Kyoto Protocol according to the taxonomy developed in Section 3. In light of the focus of the UNIDO report, CDM projects involving investments in the industry sector in developing countries are chosen for the analyses. The host countries of these projects include among others, Brazil, China, India, Mexico and South Africa.

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[2] See also UNFCCCC (2008) for more specific aspects of technology transfer and financing in developing countries.

2 Taxonomy of barriers to energy efficiency

This section provides a conceptual overview of barriers to energy efficiency, referencing the literature which allows for a more formal grounding of the concepts within the various strings of economic theory, and recognizing that there is a great deal of overlap between these concepts. First, barriers at the macro level are discussed. Then, barriers at the level of organizations, the micro level, are presented. As an overview, Table 1 and Table 2 include summaries for the taxonomy of barriers to energy efficiency used at the macro level and at the micro level, respectively.

2.1 Nature of barriers to energy efficiency at the macro level

2.1.1 Distorted energy prices

Energy production and consumption is typically associated with resource use and environmental costs (e.g. CO2 emissions, local pollutants). According to standard economic theory, optimal resource allocation requires that prices equal marginal social costs. Energy prices may be below their true marginal social costs because they do not adequately reflect these environmental costs, or because final energy or fuel uses are sub-sidized[3]. Energy subsidies often address particular policy objectives, such as encouraging domestic production of particular fuels to improve security of supply or to achieve employment targets or lowering energy expenditures for households to reach social objectives. Energy subsidies include, but are not limited to price-controls, energy-related services provided by the government (or government-owned enterprises) at less than full cost, direct payments related to fuel use or electricity use for companies or households, and grants or low-interest credits for investments in energy supply. If energy prices are below social marginal costs, energy use is higher and investment in energy efficient technologies is lower than socially optimal.

According to UNEP (2008), the few studies that have attempted to quantify subsidies on a global scale, demonstrate, that non-OECD countries account for the bulk of them. For example, Iran's annual energy subsidies (for households) are estimated at US$37 billion (in 2005 US$). Among developing countries, China, Saudi Arabia, India, Indonesia and Egypt also each have subsidies exceeding US$10 billion per year (IEA 2006, pp. 277). Further, the majority of energy subsidies in non-OECD countries lower energy prices paid by consumers (often via state-owned companies). In contrast, subsidies to producers, usually in the form of direct payments or

[3] In principle, failure to account for concerns about national security of supply would also have to be included in the "true" social costs. These concerns primarily arise from the dependence on oil imports from unstable regions of the world.

support for research and development, are more prevalent in OECD countries. While oil/gas-abundant non-OECD countries often subsidize the use of these energies, some - usually oil-importing - non-OECD countries (as well as most OECD countries) levy taxes on oil use. In terms of the focus of the UNIDO report, however, the literature provides little evidence for the existence of energy subsidies on electricity use in the industry sector in developing countries.

2.1.2 Lack of human capital infrastructure

If skilled and/or properly trained labour to install, operate and maintain the technology is not available, risk of malfunctioning and underperformance is high, and adoption and diffusion of technologies is hampered. Investors will ask for higher returns or not invest at all. Lack of human capital infrastructure is a significant barrier in most developing countries, even though major technology suppliers tend to be located in some populous developing countries like China, India or Brazil. Similarly, subsidiaries of companies located in developed countries are more likely to adopt new energy-efficient technologies because they can resort to the technological know-how of the mother company. For example, analysing 644 registered Clean Development Projects, Dechezlepretre et al. (2008) conclude that the probability of technology transfer is 50 percent higher in projects implemented in a subsidiary of an Annex 1 company.

In terms of project financing, Gboney (2009, p. 510) notes (for the case of Ghana) a lack of human capacity in banking and non-bank financial institutions with regard to infrastructure project finance or project risk allocation. Similarly, project developers and energy service companies (ESCOs) lack the capacity to adequately prepare feasibility studies and business plans, or to carry out environmental impact assessments. Naturally, the relevance of this barrier however varies with the state of countries' development. Lack of adaptation and absorption capability and lack of access to state of the art technology are specific and important barriers in low income developing countries (Sa-thaye, 2001, p. 388, Jochem 1999). In their analysis of CDM projects, Dechezlepretre et al. (2008) find that the technological capacity of a country boosts technology transfer.

2.1.3 Lack of technical infrastructure

Lack of technical energy infrastructure may constitute a barrier to energy efficiency, in particular in developing countries (e.g. Reddy 1991, p. 951). For example, if there is no electricity grid independent power producers (CHP) cannot sell electricity to the grid. Likewise, lack of access to a gas network would not allow using gas-based energy efficient technologies. Also, in terms of lowering greenhouse gases, substituting gas for coal or oil requires access to the gas grid. Technical energy infrastructures (networks) are typically characterized by decreasing marginal (and average) costs, which are usually associated with a natural monopoly. Since in this case access to the technical network as well as pricing may have to be regulated (see also barrier "Institutional factors") lack of technical infrastructure may be the result of regulatory failure. For example, regulation needs to ensure that grid operators/investors are able to recover costs, or they will not invest/operate.

2.1.4 Lock-in effects

Because of increasing returns to scale, network-effects and sunk costs, markets and decision-makers in organizations may "lock in" to technologies and practices that are sub-optimal (e.g. Box 5.1. in Sathaye et al. 2001, Arthur 1989, Arthur et al. 1987, David 1985, Nelson and Winter 1982). Such lock-in effects may inhibit access of new entrants and new technologies and lead to path dependence, in particular in large technical systems. Consequently, these lock-in effects slow technological change (speed of innovation) and skew it in a particular way (direction), preventing energy-efficient technologies to enter the market. According to Unruh (2000), industrialized countries have become locked into fossil fuel technologies over time because of past investment and policy decisions.[4] In this case, improvements in energy efficiency are primarily driven by stock replacement or retrofit for within the prevailing technological paradigm.[5] In terms of global warming, there is concern that rapidly growing developing countries like India or China follow and lock into a fossil-fuel driven economic development path similar to those of industrialized countries (Unruh and Carrillo-Hermosilla 2006).

2.1.5 Lack of external access to capital

High interest rates for borrowing capital may reflect organizations' limited *external* access to capital and may prevent energy efficiency (and other) projects from being undertaken even if they exhibit a high expected rate of return. Limited access to external capital for capital-intensive investments in energy efficiency may stem from financial market imperfections. In some developing countries in particular, the local banking sector is (close to) dysfunctional, in the midst of a reform, or otherwise operates in an unstable political and regulatory environment, hence making it difficult for local banks to act as financial intermediaries (Taylor et al. 2008). It is generally recognized, that developing countries suffer from limited financial infrastructure, underdeveloped finance institutions, especially for more complex structuring, and lack of

[4] Brown et al. (2008) distinguish between three major categories of carbon lock-in barriers: cost effectiveness, financial/legal and intellectual property barriers.
[5] See Worrell and Biermans (2005) and Ruth and Amato (2002) on the relevance of stock turnover for energy efficiency improvements in the steel industry.

appropriate risk assessment and management tools (UNFCCC 2008, p. 27). As noted in the IPCC Third Assessment Report "lack of available capital and lack of finance at low interest rates is pervasive in developing countries" (Sathaye et al. 2001, p. 388). Access to external capital is of particular importance in emerging economies since companies' incentives to use internal funds for energy-efficiency investments tends to be low in these countries in light of the opportunities provided by strong market growth.

If the financial sectors in developing or emerging market economies are immature and weak, there are likely to be no developed markets for futures, options, and derivative instruments. Hence, risks associated with new investments are difficult to manage. As a consequence, project investors will use higher discount rates to assess investments in new plants as well as retrofits.

For small and medium-sized companies in particular, lack of access to capital is considered to be the strongest barrier to economic development in developing countries (UNIDO 1997). Further, if local currencies cannot be converted to foreign currencies, technology imports are hampered. Financial market imperfections, however, affect investments in all technologies, not just in energy-efficiency technologies. As argued for example, by Thiruchelvam al. (2003, p. 980) though, "...most energy efficiency activities require low investment, they do not generate a separate revenue stream that could provide financial institutions some form of collateral for their loans." This counterargument though should hold primarily for investments in (often generic) energy-efficiency technologies which are not part of the core production process like electric motor and drives.

2.1.6 Institutional factors

In general, lack of political stability, reliability and effectiveness as well as corruption can create uncertainty translating into higher discount rates for investors - in particular in developed countries and in particular for investments in new technologies. Arguably, this barrier not only holds for investments in energy and energy-efficiency technologies. However, since political stability predominantly affects investments in long-term capital goods, investments in capital intensive energy-efficiency projects and energy technologies (e.g. involving broad restructuring and/or core production processes) are particularly hampered by this barrier in developing countries.

The legal and regulatory framework, including ease of market entry for new firms and technologies are important factors for the diffusion of new technologies, including energy efficiency technologies. For example, monopolistic or oligopolistic behaviour by incumbents may deter market entry. For new energy technologies in particular, securing adequate access of independent power producers and a transparent network pricing framework, could be a barrier for energy produced from combined heat and power plants (or renewable energy sources). In this case, selling back power to the electricity grid would be hindered. In terms of environmental regulation, including regulation on energy use of technologies like minimum technology standards or performance standards, requirements in developing countries tend to be less stringent than in industrialized or emerging countries (e.g. IPPC in EU). Hence, failure to regulate energy performance of technologies contributes to the observed less investment in energy efficiency in developing countries. Exploring adoption of environmental regulation across developed and developing countries Lovely and Popp (2008) find that developing countries adopt environmental regulation as access to abatement technologies improves and costs of abatement decline. This highlights the role of international technology diffusion for environmental regulation in developing countries.

Further, regulations for new investments at national, state or local levels may involve time consuming permitting processes. This barrier holds for all types of technologies, not only for energy efficiency and energy technologies, but is likely to be more relevant in developing countries than in developed countries.

Finally, in terms of technology transfer the lack of protection of intellectual property rights has been identified as a barrier particularly relevant in developing countries (Worrell et al. 2001, UN 1998). Like other barriers, uncertain property rights (IPR) act to increase the discount rates applied in investment appraisal. In general IPR regulation affects all types of technologies, but it is likely to be less of a problem for energy efficiency and energy technologies than for pharmaceuticals, for example.

Transfer of modern technology typically takes place mainly via licensing of designs for local production joint ventures and export and /or import. Hence policies impeding licensing agreements, constraining the import of goods (e.g. import tariffs) or restricting repatriation of foreign exchange can prevent energy-efficient technologies from entering the domestic market.

Table 1 Taxonomy of barriers to energy efficiency at the macro level

Barrier	**Claim**
Distorted energy prices	Energy prices are lower than socially optimal because of: • failure to account for negative **environmental externality;** **• subsidies for energy or fuel use** (e.g. coal, gas, oil) -primarily for political reasons;
Lack of human capital infrastructure	**Lack of skills/trained personnel** in host country • to operate and maintain the technology, leading to an unacceptably high risk of equipment disrepair and malfunctioning or other underperformance; • in financial institutions with respect to project financing; • to prepare feasibility studies and business plans, or environmental impact assessments; **Lack of service** infrastructure for implementation, logistics and maintenance of the technology;
Lack of technical infrastructure	**Technological networks** (e.g. electricity or gas grid) are missing;
Lock-in effects	**Increasing returns to scale, networks effects and sunk** costs prevent entry **of** new firms (technologies)
Lack of external access to capital (external	If the organization cannot raise sufficient **external funds,** energy-efficient investments may not go ahead, because of: • financial market constraint: **underdeveloped banking and financing sector;** **• lack of convertibility** of local currency; **• high costs of company or technology risk assessment;**
Institutional factors	Lack of **political stability** and **reliability translate** into higher discount rates/required returns on investment; Time consuming **permitting processes/inefficient administration;** **Lack of adequate regulation** at national, state and local level on market access (monopoly/oligopoly regulation), energy performance of technologies, intellectual property rights etc.

2.2 Nature of barriers to energy efficiency at the micro level

This section develops a taxonomy of barriers to energy efficiency at the micro-level drawing on concepts from neo-classical economics, institutional economics (principal-agency theory and transaction cost economics), and behavioural economics and relying heavily on the presentation and discussion in Sorrell et al. (2004) and Schleich (2009). Since standard neoclassical economics assumes that individuals act perfectly rational, it is not compatible with untapped profitable opportunities to save energy, i.e., the energy efficiency gap. If such a potential existed, unboundedly rational individuals would undertake efforts to capture it. Departing from the "Homo economicus" paradigm (as in behavioural economics), or adding insights from institutional economics allows for a more realistic representation of individual's and firm's decision-making.

In general, barriers to energy efficiency are more likely to be found in organizations where the share of energy costs in total production costs is low (typically under 5 percent) - such as in the services sectors, public administrations, or in industries like mechanical engineering and the food sectors. In comparison, the importance of energy costs in energy-intensive industries like the iron and steel industry, the cement industry or the chemical industry, for example provides a strong economic incentive to find and realize efficiency potentials. This holds, in particular, for core production processes, energy use is more likely to be automatically considered in investment decisions. Nevertheless, barriers to energy efficiency have also been analysed for energy intensive industries (e.g. de Groot et al. 2001, Cooremans 2007, or Thollander and Ottosson 2008). Unlike for macro level barriers to energy efficiency, there is virtually no empirical literature related to micro level barriers in developing countries. A priori though, there is no reason to assume that barriers at the micro level are less relevant for developing countries than for developed countries.

2.2.1 Imperfect information

An organization's lack of information about energy use, energy efficiency opportunities or the energy performance of technologies may translate into underinvestment energy efficiency. In general, information problems possibly hindering investments in energy efficiency can be categorized into two broad groups.

First, there could be inadequate information on the level and pattern of energy use. Gathering and analysing information on energy use is associated with costs for investment and staff. Typically, these types of costs are not taken into account in engineering-economic analyses and reflect a particular category of transaction cost. Such information costs depend on the level of sub-metering, the information content of utility bills, the availability of relevant benchmarks, the use of electronic information systems, etc.

Second, organizations may lack adequate information about specific energy-saving opportunities such as heat recovery technologies. There are several facets to this. One problem that arises in this context concerns the extent to which organizations have exerted another type of transaction costs: evaluating energy efficiency opportunities, e.g. via energy audits. Since the value of an audit becomes known only after the audit is carried out, the organization can only judge ex post, whether expenses for audits paid off. Another problem relates to the costs and performance of specific energy-saving technologies. Since the search costs for (new) energy-efficient technologies are likely to be much greater than those for natural gas, fuel oil or electricity, they may systematically bias organizations' investment choices against energy efficiency. For example, the performance of control systems, motors, and variable-speed drives may be difficult to monitor and evaluate even after purchase because detailed metering is not feasible. Thus, feedback on the performance of the energy-efficient technology is not available. Further, information on the technical and economic performance of new energy-efficient technologies is known to the investor, but would be of value to other potential investors as well. Because information available on the performance of such technologies is a public good markets undersupply such information[6]. Finally, information on the energy performance of new energy efficient technologies could be asymmetric, resulting in adverse selection and thus inefficient outcomes. For example, the market value of an energy-efficient technology should, among many other characteristics, also reflect its energy performance. While this information may be available to the seller, potential buyers, however, have difficulty in recognizing and evaluating energy performance. Likewise, buyers may not entirely trust the information provided by the technology provider. As a consequence, buyers' willingness to pay for the new technology may be too low. Eventually, unless the buyer can adequately assess the energy performance the technology, or unless the seller is able to credibly disclose this information (e.g. through demonstrations, publication of technical materials), only technologies with a lower energy efficiency performance could be offered on the market. In that sense, the logic originally developed by Akerlof (1970) for the second-hand car market (lemons), may also hold for energy-efficient technologies (adverse selection).

[6] A public good is a good that is non-rival and non-excludable. 'Non-rival" means that consumption of the good by one individual or firm does not limit the availability of the good for use by other individuals or firms. 'Non-excludable' means, that no individual or firm can be effectively excluded from consuming the good.

For several reasons, lack of information is likely to be even more of a barrier to energy efficiency in developing countries than in developed countries. First, the information infrastructure at the private and public levels tends to be less developed than in industrialized countries. For example, energy management systems or energy benchmarking are less pervasive in developing countries.[7] Likewise, developing countries suffer from limited public capacity for information dissemination (Worrell et al. 2001, p. 34), limited private technical capacity to access information (e.g. via internet), or lack of intermediary institutions providing information on energy use of companies, processes or technologies (e.g. via sector associations or company networks). Second, since acquiring and processing information depends on human capital infrastructure (see also Section 2.1.2) companies in developing countries are less suited to effectively use existing information. Also, relevant information on, say technology performance, may only be available in a foreign language.

2.2.2 Other transaction costs

Transaction costs as defined by Coase (1991) and Williamson (1985) include all the organizational costs associated with establishing and maintaining an energy management scheme, investing in specific energy-saving technologies, and implementing specific energy-efficient options within broader investment programmes (for example, choosing an energy-efficient motor rather than a standard one). Thus, the concept of transaction costs is broader than the search costs discussed in the previous section in the context of "imperfect information". Transaction costs encompass the general, *overhead costs of energy management,* which typically involve staff time. At least to some extent, the level of these costs depends on factors beyond the control of organizations, such as government regulations on energy labeling for energy-using technologies. These overhead costs, however, also depend on factors within the organization such as organizational procedures for purchasing and procurement. Government regulations on labelling of technologies, etc. tend to be positively correlated with economic development. Likewise, organizational procedures (including environmental management schemes) are more prevalent in industrialized countries - with the possible exception of multinationals and subsidiaries. Hence, from this perspective, overhead costs can be assumed to be even more of a barrier in developing countries. Other types of transaction costs relevant for investments in energy efficiency include the costs for identifying opportunities, detailed investigation and design, formal investment appraisal, or procedures for seeking credit approval.

[7] Although exceptions exist, like Thailand.

Compared to developed countries, labour costs in developing countries are relatively low, in particular relative to energy costs - unless energy use is heavily subsidized. Lower relative labour costs would suggest that overhead costs of energy management may be a less relevant barrier to energy efficiency in developed countries. However, this labour-cost argument would not hold for tasks requiring higher levels of skills, which is typically the case for more complex technologies in the industry sector (in particular for technologies involving the core production processes or broad restructuring).

2.2.3 Risk and uncertainty

From an economic perspective, improved energy efficiency often requires investment decisions which imply tradeoffs between (certain) higher initial capital costs and (uncertain) lower future energy operating costs. Empirical studies often find high (implied) discount rates for investments in energy efficiency. In essence, however, high discount rates are an indicator for the existence of the energy efficiency gap rather than its source (see Jaffe and Stavins 1994, p. 806). In particular, *stringent investment criteria* and the failure to adopt particular energy-efficient technologies may be a rational response to perceived risks. These risks may result from *financial risks* such as *business-specific risk*, *regulatory risk*, or *general economic risk*[8] caused by the business cycle, fluctuation of energy prices and exchange rates, etc. In general though, the effect of fuel cost induced *financial* risk on the adoption of energy-efficient technologies is ambiguous. On the one hand, volatile prices for energy commodities render returns on investments in energy-efficient technologies uncertain. From this perspective, risk-averse company managers would be expected to invest less. On the other hand, investments in energy efficiency also lower energy bills or the level of carbon emissions and thus reduce the financial risks resulting from uncertainty about energy prices (Ho-warth and Sanstad 1995; Ben-David et al. 2000). Consequently, if investors took into account the effects of improved energy efficiency on total company profits, they might actually invest more and uncertainty should encourage energy efficiency rather than act as a barrier (Sutherland 1996). The relative magnitude of both effects is company-specific and generally ambiguous. Regulatory and general economic risks tend to be higher in many developing countries than in developed countries. Hence, domestic and foreign investors require higher rates of return reflecting higher risks in these countries.

New energy-efficient technologies may also be associated with *technical risks*. If energy-efficient technologies are less reliable than standard technologies, the risk of breakdowns and ensuing production disruptions might outweigh any energy cost savings. Thus, since technical

[8] To some extent, these risks may also be caused by unstable institutional environment described in section 2.1.6.

service support for new technologies tends to be lower in developing countries (in particular LDCs), technical risk is usually higher in these countries than in industrialized countries.

Finally, there may be an *option value* associated with waiting to invest in irreversible energy efficiency technologies if future economic, technological or policy conditions are uncertain (Hasset and Metcalf 1993; van Soest and Bulte 2001). For example, investing in a more energy-efficient technology may turn out to be unprofitable if energy prices fall afterwards. Similarly, technology may improve significantly or government grants for investments in energy efficiency may be introduced after implementation. Thus, there is an *option value* associated with postponing investments (McDonald and Siegel 1986; Dixit and Pindyck 1994). By the same token, there may be potential costs of delaying energy efficiency investments (Howarth and Sanstad 1995). For example, including a heat recovery system in the design of a new plant is cheaper than retrofitting one afterwards. Likewise, government support for energy-efficient technologies may cease to exist. Hence, to the extent that government support schemes are (expected to be) less predictable and less stable in developing countries, the "option value barrier" to energy efficiency is more relevant in developing countries than in industrialized countries.

2.2.4 Lack of internal access to capital

In addition to lack of external access to capital, there may be *internal capital budgeting* procedures[9] discriminating against energy efficiency projects. For example, applying (short) payback periods rather than discounted cash flow analyses as an investment criterion tends to be common practice in companies' investment appraisals but neglects the (expected) positive cash flow from energy cost savings in the longer run. Likewise, relatively high hurdle rates may be required for small projects (including energy efficiency projects), because the transaction costs of determining the profitability of such investments represent a larger portion of the expected savings. Further, energy efficiency investments are often considered discretionary maintenance projects and hence usually assigned lower priority than essential maintenance projects or strategic investments (Sorrell et al. 2004, Cooremans 2007). Because of top management's constraints on time and attention, energy-cost savings may not be seen as a strategic priority. Instead, top management may favor larger, more strategic or more prestigious projects. Likewise, managers may prefer projects which expand production, in particular in growing markets like advanced developing economies. Findings from the management literature for

[9] Internal capital availability also reflects priority setting in companies, which is the terminology used in various empirical studies including Schleich and Gruber (2008), Thollander and Ottosson (2008), or Schleich (2009).

developed countries suggest that the strategic character of an investment is the primary reason for its approval, even more important than profitability (e.g. Butler et al. 1993; Carr and Tomkins 1998)[10]. According to Teece et al. (1997), upper management tends to value energy rather lowly because it is seen as being part of the organization's material resources, unlike, for example, information, which is part of the highly valued non-material resources. Based on an empirical study among Swiss companies, Cooremans (2007) concludes that energy efficiency projects are discarded primarily because they are not perceived as "strategic". Unlike other investment opportunities requiring up-front capital like capacity expansion, opening up new product lines or penetrating new markets, investing in energy efficiency means operating-cost savings "only". To summarize, the internal "access to capital" problem may not only result from hard investment criteria such as the rate of return or payback time of an investment project, but also from soft factors such as strategic priorities, the status of energy efficiency, reputation, or the relative power of those responsible for energy management within the organization (Morgan 1985; DeCanio 1994; Sorrell et al. 2004).

When analysing the relevance or energy efficiency for investment decisions, it is useful to distinguish between investments in existing and in new projects on the one hand and between projects specifically aimed at improving energy performance like purchasing electric motors or replacing boilers and projects involving broad restructuring. In the industry sectors, the latter typically affects the core production processes. For new projects, improving energy efficiency is particularly important over the longer term, especially in fast-growing, advanced developing economics (e.g. Taylor et al. 2008). For projects involving broad restructuring energy efficiency is only one of many factors in companies' investment decisions. In contrast, energy efficiency can be expected to weigh more heavily in projects aimed specifically at improving energy performance.

2.2.5 Split incentives and appropriability

The classical example for split incentives in the context of energy use is the user/investor or landlord/tenant dilemma (e.g. IEA 2007). Neither the landlord nor the tenant may have an incentive to invest in energy efficiency in a building if the investor is not able to adequately benefit from the resulting energy-cost savings. First, the landlord may not invest in energy efficiency if the investment costs cannot be passed on to the tenant who benefits from the lower energy costs. Second, tenants have no incentives to invest if they are likely to move out before

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[10] See also the brief survey on the organizational decision-making literature in Cooremans (2007).

fully benefiting from the savings in energy costs. In principle, this dilemma could be avoided if the investor was able to credibly transmit the information about the benefits arising from the investment and to enter into a contract with those benefiting from the investment. However, the costs of verifying energy-cost savings and the costs for the contractual arrangements are often prohibitive. As Jaffe and Stavins (1994b) point out, asymmetric information and transaction costs are the sources for the investor/user dilemma. The landlord/tenant problem arises mainly in the private housing sector (Scott 1997), but also in the commercial and services sectors (Schleich and Gruber 2008). It is assumed to be less pervasive in the heavy industry sectors, where companies tend to own rather than rent their buildings. Similar to the landlord/tenant dilemma for buildings, split-incentives problems may also arise in the context of other technologies. If the energy performance of a product or a system cannot easily be observed (e.g. inefficient motors as part of a larger technical system), developers may 'get away with' cheaply installed systems that the purchasing company discovers to be sub-optimal afterwards.

However, there are also situations where the source for split incentives problems preventing adequate investments in energy efficiency rests within the organizational structure in companies. As already referred to in the previous section, if managers remain in their post only for a short time, they may have little incentives to invest in energy-efficient projects, which have a longer payback time. Similarly, depending on their compensation scheme, managers may prefer making rather than saving the same amount of money even though the effects on company profits would be the same. For smaller companies in particular, the split-incentives problem may be less of a problem in developing countries, where companies are more likely to be family-owned and family-run than in industrialized countries. While this argument may hold for companies in the paper or ceramic industries, it is unlikely to hold for the large energy-intensive companies in the steel, aluminum or chemical industry.

Further, unless departments (in larger organizations) pay for their own energy costs, department managers have little incentive to invest in energy efficiency because the benefits in terms of cost savings accrue elsewhere. Similarly, the person responsible for purchasing equipment may have a strong incentive to minimize capital costs, but may not be accountable for operating costs (including energy costs).

2.2.6 Bounded rationality

The standard neoclassical economics model for individual decision-making rests on axioms and implies that decision-makers make a rational choice among alternatives given the available information. Findings from numerous empirical studies including controlled lab-based experiments, however, suggest that in practice, individuals often do not act as a “homo oeconomicus".[11] Alternative models for explaining actual individual decision-making like behavioural economics and cognitive psychology allow for cognitive limits and biases. Accordingly, lack of time, attention, or limits on the ability to adequately process information may prevent optimizing behaviour. Instead, bounded rationality may result in satisfying behaviour, using routines, or rules of thumb (Simon 1957, 1959). Thus, decision-makers will neglect some energy efficiency opportunities even if they do not suffer from lack of information or distorted incentive structures. For example, small motor end-users focus on delivery time or price rather than total life-cycle costs when purchasing a new motor to replace an old one (de Almeida 1998). Similarly, when prioritizing investments companies are likely to focus on the core production process rather than on ways to save energy costs and making money via investments in cross-cutting technologies. Finally, companies may apply identical investment criteria (e.g. payback time) when appraising investments in core production technologies and (cross-cutting) energy saving technologies, even though the economic risks associated with the former tend to be much higher.

[11] For recent overviews on behavioural economics see for example Camerer et al. (2004), with respect to firm behaviour in particular, see Armstrong and Huck (2010), and in relation to environmental and resource economics see Shogren and Taylor (2008). The conceptual overview by Wilson and Dowlatabadi (2007) on residential energy use also includes the psychological and sociological perspective.

Table 2 Taxonomy of barriers to energy efficiency at the micro level

Barrier	Claim
Lack of information	**Lack of information on energy efficiency opportunities** may lead to cost effective opportunities being missed.
Other transaction costs	Overhead costs of **energy management,** costs for **identifying energy efficiency opportunities, investment procedures** or for **seeking credit approval,** which may be lowered via organizational procedures and regulation;
Risk and uncertainty	**Short paybacks** required for energy efficiency investments may reflect a rational response to higher • **technical risk;** there is a risk of technological failure which is significantly greater than for other technologies that provide comparable services or outputs; • **financial risk: business, and market uncertainty;**
Internal access to capital	Investment inhibited by **internal capital budgeting procedures,** investment appraisal rules, and the short-term incentives of energy management staff;
Split incentives	Energy efficiency opportunities are likely to be foregone if **investors cannot appropriate the benefits of the investment.**
Bounded rationality	Owing to constraints on time, attention, and the ability to process information, **individuals do not make perfectly rational decisions.** As a consequence, they may neglect energy efficiency opportunities, even when given good information and appropriate incentives.

Source: Partially based on Sorrell et al. (2004).

3 Policy intervention

3.1 Rationale for policy intervention

The various concepts underlying the barriers to energy efficiency provide different insights into the nature of these barriers, providing differentiated rationales for policy intervention. In particular, neoclassical economics highlights the difference between barriers which root in market failures and those which do not (Jaffe and Stavins 1994b). Market failures result from failure to account for environmental externality or energy subsidies, the public good attributes of information, or from asymmetric information in energy service markets. These types of market failure provide a necessary condition for public intervention to improve economic efficiency. Hence, while the term barrier may refer to any factor which explains why presumably cost effective technologies are not taken up, only a subset of these may correspond to recognized market failures. Therefore, from the perspective of neoclassical economics, only a subset of the identified barriers may justify policy intervention (Jaffe and Stavins 1994b, p. 805, Gillingham et al. 2009). Furthermore, while the mere existence of market failure is necessary to justify market intervention, it is not sufficient. Instead, policy intervention would only be justified for market failures if the benefits arising from intervention exceed the costs of the intervention (Jaffe and Stavins 1994b). On the benefit side, neoclassical economics considers improved energy efficiency a "by product" of improved economic efficiency. Other benefits include lower local and global environmental externalities (like global warming) or improved security of energy supply. That is, energy efficiency is seen as a means rather than an end (e.g. Sutherland 1994 or Brookes 2000). While raising energy prices to reflect externalities (or to end subsidization) is justified and should incentivize improvements in energy efficiency, distorted energy prices cannot explain the "energy efficiency gap", i.e., the neglect of investments which appear cost effective at current energy prices. Hence, simply getting the energy prices right via subsidy removal or energy taxation will not be sufficient to overcome the "energy efficiency gap". At the same time, there are other barriers to energy efficiency such as uncertain energy prices or real costs arising from *inferior performance* of energy-efficient technologies with respect to dimensions other than energy services or higher *production costs*[12], which are not market failures and would not warrant policy intervention (see Table 3). Concepts from institutional economics provide additional insights into barriers which are internal to the organizations, such as information costs, overhead costs of energy management, incentive structures and appropriability. In particular, transaction cost economics maintains that policy intervention and different institutional structures may lower transaction costs. Finally, departing from the presumption of individual rationality, concepts from behavioural economics, organizational theory, sociology and psychology have contributed to a better understanding of actual decision-making in organizations - also in terms of energy efficiency. Clearly, policies lowering transaction costs or adequately addressing behavioural failures could warrant policy intervention.

In terms of policy intervention individual measures are usually not able to achieve numerous objectives. Instead a menu policy options would be required to tackle the multiple types of barriers (see also Jochem and Gruber (1990) and Gruber and Brand (1991)). Effective policy

[12] In the literature, these type of costs are also termed “hidden costs” (e.g. Sorrell et al. 2004; Ostertag 2003). Examples for inferior performance include increased noise or lower product quality (e.g. if the clinker ratio is very low in cement production; or energy-efficient light bulbs providing a different lighting quality). Examples for production costs include additional maintenance, replacement, early retirement, retaining or hiring staff, or for production interruptions during equipment installation. Failure to account for these costs (or rather profit losses) results in overestimating the energy efficiency gap. Of course, energy-efficient technologies may also be associated with “hidden benefits” such as reduced noise, lower health risks for workers, higher product quality, lower maintenance costs, or higher reliability. Failure to account for hidden benefits would result in too little investment in energy efficiency.

intervention however, would depend on the nature of the barrier. Existing research suggests that the relative contribution of these barriers may vary between technologies as well as within organizations, across organizations within the same sector and across sectors or sub-sectors in the economy (e.g. Sorrell et al. 2004, Schleich and Gruber 2008, Schleich 2009). In terms of the focus of this report, barriers may also depend on the economic development of a country or region, i.e., the relevance of a particular barrier differs not only between industrialized and developing countries, but also across developed countries.

Table 3 Barriers and market failures

	Explain efficiency gap	**Do not explain efficiency gap**
Barriers that are market failures	• Public good attributes of information • Positive externalities of technology adoption • Asymmetric information in energy service markets (adverse selection, split incentives	• Environmental externalities • Distortions in energy pricing
Barriers that are not market failures	• Disruptions to production, lower performance, higher maintenance costs • Reduced product performance (e.g. lower reliability) • Option value of delaying investment	-

Source: Based on Sorrell et al. (2004) and Jaffe and Stavins (1994).

3.2 Implications for policy intervention to address barriers

In particular, policy interventions are justified to address *distorted prices* resulting from market failures. For example, energy taxes could be imposed so energy prices reflect environmental externality. Higher energy prices incentivize energy savings.[13] If the tax revenue was used to reduce other inefficiencies in the economy (e.g. labour taxes) overall welfare could be improved, including competitiveness of the industry sector. Hence, depending on the use of tax revenue and pre-existing distortions, energy taxation may lead to a "double dividend" (Goulder 1994, Bovenberg and de Mooij 1994). The first dividend would be improved environmental

[13] According to Fisher-Vanden et al. (2006) who analyse the improvements in energy efficiency in a panel of 22,000 Chinese large and medium-sized enterprises for the period 1997-1999, 54 percent of the observed decline in energy use of 17 percent can be attributed to changes in energy prices.

quality, and the second dividend would be increased benefits in other dimensions including improved competitiveness, GDP, or employment gains.

Removing energy subsidies originally imposed to address poverty is particularly difficult in developing countries (but also in many developed countries or countries in transition), where social security systems are weak at best. Hence, removing these subsidies would have to be accompanied by compensating social-support measures to cushion the adverse distributional effects on the poor. However, in many developing countries, it is not always the poorest households which would be hurt from the removal of energy subsidies, since their fuel or electricity use is rather low (because of income/capital constraints). Hence, to alleviate social hardship it may be more appropriate to promote access to energy for the poorest households in developing countries, rather than subsidizing fuel or electricity use per se.

In terms of energy efficiency in industry the literature provides little evidence for the existence of subsidies for electricity use in the industry sector in developing countries. Where subsidies for electricity use or for particular fuel use exist, they should be removed. Arguably, addressing the barriers to energy efficiency caused by *lack of human capital infrastructure* via capacity development would be the most effective policy option. On the one hand, improving the absorption capability of developing countries includes training and education on the technology side, i.e., for enhanced operating and maintaining of energy efficiency technologies. On the other hand, training programmes need to progress the skills required for adequate project financing (primarily in financial institutions), or for preparing feasibility studies, business plans, and environmental impact assessments. Effective capacity development not only includes training and education, but also accounts for the fact that existing expertise can be put to good use. This holds in particular for more advanced countries like china, Brazil and India, where the problem is less a lack of human capital but rather how to bring the existing expertise to bear (Taylor et al. 2008).

Policies to address the *lack of technical infrastructure* include a long-term, credible rural electrification policy along with a regulatory framework which allows investors and operators to recover full costs. Depending on the local, regional or national economic, social and technological circumstances though, decentralized systems may be preferable.

Institutional barriers may be addressed by an appropriate regulatory and legal framework, which - among others - secures access to the grid, protects intellectual property rights, allows for efficient permitting processes, limits corruption, and facilitates the implementation of regulations deemed appropriate (e.g. via cost-benefit analyses) to foster the diffusion of energy efficient technologies. Important factors for the *development of financial institutions and* *markets* - including markets for energy services (like contracting) - include (Taylor et al. 2008): (i) governments' (national central banks') ability to maintain stability of the domestic currency over time; (ii) governments' ability to repay its own debt[14]; and (iii) the ability of enterprises and individuals to create and follow through on promises and agreements involving formal and informal contracts.

In contrast to the costs related to inferior performance and production costs, *information and other transaction costs* are heavily dependent on organizational and contractual structures, procedures, incentives, and routines (Ostertag 2003). In addition to internal organizational factors, they also depend on regulation. Hence, policy interventions lowering information and other transaction costs may be adequate and justified. According to Reddy (1991), lack of information not only refers to end users, but to all aspects of the market. If private markets - because of the public goods character" fail to provide adequate information, policy interventions (such as energy labeling) could be justified. Information programmes appear to be the most obvious policy approach. However, if specific knowledge and skills are required, education and training programmes such as re-skilling courses geared towards engineers are expected to be more effective than general information programmes. Such training may not only be necessary at the level of the company implementing the measure but also for market intermediaries (e.g. trade). In addition, organization-specific (rather than general) courses improving organization-wide skills on energy reporting may be adequate. If information programmes are to be employed, both the manner in which information is presented and the credibility of the source need to be taken into account. The bounded rationality perspective highlights the importance of framing and reference points (e.g. for information-related policies), of default setting (e.g. temperatures in buildings), and for targeting heuristics for improved decision-making. Altering economic incentives via policy intervention may only have limited effects. Instead, minimum energy efficiency standards might be more effective.

In this case, policy should set performance standards rather than specify a particular technology because performance standards allow for more flexibility and provide larger innovation incentives. Likewise, requiring energy labels for buildings or technologies (e.g. electric motors) would lower transaction/information costs for assessing their energy performance. Such labeling would also directly address the source of the *landlord/tenant problem.*

[14] See also Celasun and Agca (2009) who find that an increase in the external debt of emerging market governments „crowds out" foreign credit to the domestic corporate sector, thereby significantly raising the costs of borrowing for these companies.

Government intervention to address *financial risks* associated with stochastic energy prices etc. can hardly be justified. Similarly, organizations' ignoring of new energy efficient technologies may be perfectly rational and avoid inefficient outcomes. Whether such technologies actually carry a higher risk than standard technologies would likely have to be assessed on a case by case basis. Government-sponsored information programmes about the technological reliability of new energy efficient technologies, however, may - as for other new technologies - be justified because of the public goods character of such information. To overcome the "option value barrier", credible long term government policies would reduce the value of waiting to invest, and hence accelerate the diffusion of energy efficient technologies.

Lack of external capital is not necessarily an indicator for capital market imperfections. For example, high external capital costs for small and medium-sized companies by itself may reflect higher economic risks for lenders (Sutherland 1996) rather than capital market imperfections. In particular, smaller companies may only have limited collateral to offer. Likewise, their product portfolio tends to be less diversified, and hence more vulnerable to negative economic shocks. If investments in energy efficiency were more risky than investment in other projects, higher costs of capital for energy efficiency projects would be economically justified. Empirical evidence, however, would not suggest that investments in energy efficiency are systematically more risky than investments in other projects. From the perspective of transaction cost economics though, it may be that the costs necessary to investigate the creditworthiness of small companies render such loans unprofitable (Golove and Eto 1996). Likewise unfamiliarity with a particular technology, with the appropriate risk assessment methodologies, or lack of detailed factual data increases the transaction costs of risk assessments by banks (and investors).[15] To some extent, these barriers could be overcome by adequate training and provision of information about particular technologies.

In terms of *internal capital constraints,* managers' short term incentives could be addressed by appropriate contracts, which arguably better reflect shareholders' objectives. In general though, options and possibilities for government regulation of companies' organizational structures are rather limited in developed as well as developing countries.

The insights from the management literature on the (lack of) strategic character of energy efficiency imply that financial incentives (via prices or subsidies) may be neither necessary nor sufficient to accelerate the diffusion of energy efficient technologies. Similarly, improving

[15] In developing countries, financing energy efficiency projects typically represent only a small niche in major banks (Taylor et al. 2008, p. 11).

information may be ineffective. Instead, the possible importance of energy efficiency for the long-term success of the company (e.g. in terms of impacts on competitiveness) would have to be highlighted.

4 Analysis of barriers to energy efficiency in CDM projects

This Section presents the findings from a "barrier analysis" of the project design documents for projects under the Clean Development Mechanism (CDM) of the Kyoto Protocol. The barriers mentioned in these documents are categorized according to the taxonomy developed in Section 3 and further analysed by countries and country groups.

4.1 The Clean Development Mechanism

To meet their targets under the Kyoto Protocol industrialized countries and countries in transition (i.e., those with emission targets, so called Annex B countries) may rely on the Clean Development Mechanism. The CDM allows emission-reduction projects in developing countries (so called non Annex I countries) to earn credits (so called certified emission reductions, CER), which may then be sold to Annex B countries to help meet their emission targets under the Kyoto Protocol. In addition to national governments, private companies participating in the EU Emissions Trading System (EU ETS) may - according to the so-called Linking Directive - use CERs to comply with their obligations under the EU ETS. That is, to avoid penalties companies need to surrender a sufficient number of certificates to cover their installations greenhouse gas emissions in a particular period. The CDM allows industrialized countries flexibility in how they meet their emission targets (at lowest cost) and is expected to not only reduce carbon emissions but also contribute to sustainable development in the host country, whose approval is required to be considered for registration of a project with the UNFCCCC. Successful projects must undergo a rigorous public registration and issuance procedure governed by the respective rules for the CDM under the UNFCCCC. These rules are designed to ensure real, measurable and verifiable emission reductions that are additional to what would have occurred without the project (the so called baseline). As part of the procedure project partners need to complete a so called project design document (PDD). Among others, the PDD needs to explain „how and why this project activity is additional and therefore not the baseline scenario... " (CDM Executive Board EB 41 Report Annex 12, p. 12). To demonstrate additionality, developers need to prove that the suggested project is not the most profitable among several credible alternatives. If the investment appraisal finds the project not to be profitable, it will pass the additionality criteria. If the project is found to be profitable, project developers need to demonstrate via a qualitative or quantitative assessment that one or more barriers prevent (an otherwise profitable) project from being implemented. Small scale projects only need to pass the barriers test.[16] These barriers may include:

(a) *Investment barrier* a more profitable alternative to the project activity would have resulted in higher emissions;

(b) *Technological barrier:* a less technologically advanced alternative to the project activity involves lower risks due to the performance uncertainty or low market share of the new technology adopted for the project activity and so would have led to higher emissions;

(c) Barrier due to *prevailing practice:* prevailing practice or existing regulatory or policy requirements would have led to implementation of a technology with higher emissions; (d) *Other barriers:* without the project activity, for another specific reason identified by the project participant, such as institutional barriers or limited information, managerial resources, organizational capacity, financial resources, or capacity to absorb new technologies, emissions would have been higher.[17]

Registration stands for the formal acceptance of a validated project as a CDM project activity by the CDM Executive Board and is a prerequisite for the eventual issuance of CERs . As of 16 November 2009, there are 1899 registered CDM projects projected to deliver around 324 Million CERs annually and more than 1,679 Million CERs by 2012 (http://cdm.UNFCCC.int). About 35 percent of these projects are located in China, 25 percent in India, almost 9 percent in Brazil and around 6 percent in Mexico. South Africa accounts for less than 1 percent. In terms of scope, about 60 percent of all registered projects are in the energy sector and almost 18 percent refer to the waste handling and depositing activities. Projects in the manufacturing industries account for almost 5 percent, the chemical industry for 2.6 percent; demand projects for 1 percent and metal production for less than 0.3 percent of all registered projects. Hence, energy efficiency projects account only for a relatively small share of all projects.

4.2 Projects included in analyses

In light of the focus of the report, only projects categorized as projects in the industry sector are taken from the UNFCCC data base (http://cdm.UNFCCCc.int/Projects/registered.html). Since

[16] Small scale projects are defined as (FCCC/KP/CMP/2006/10/Add.1): (i) renewable energy project activities with a maximum output capacity of 15 MW; (ii) investments in energy efficiency which reduce energy use, on the supply and/or demand side, with a maximum output of 60 GWh per year; (iii) any other activities resulting in annual emission reductions of at most 60 kt CO_2.
[17] See http://cdm.UNFCCCc.int/methodologies/SSCmethodologies/AppB SSC AttachmentA.pdf

the interest of the IDR is on the industry sector, only projects falling into the following sector categories are included: "manufacturing industries", "chemical industries", "metal production" and "energy demand". Finally, the analyses are limited to projects involving CO2 emissions, rather than all six Kyoto greenhouse gases, because technical measures to reduce CO2 emissions are typically associated with energy efficiency improvements. It should be noted though that the projects considered also include fuel switching, which reduces CO2 emissions but not necessarily energy use.

The host countries for these projects are presented in Table 4 along with the number of projects in each country. Also countries are categorized according to the most recent World Bank groups by income. A large share of projects (73 out of a total of 119) is located in India, while all other countries host few projects only. Hence compared to all CDM projects, India is overrepresented while most other countries, including China, are under under-represented. In terms of World Bank categories, about 2.4 percent of all projects analysed are located in "high income economies", 17.9 percent in "upper-middle income economies"; 78.4 percent in "lower-middle income economies" and 1.4 percent in "low income economies".

Most of the projects take place in the "manufacturing industries" (79 percent), followed by "energy demand" (17.6 percent), the "chemical industry" (2.5 percent) and "metal production" (0.8 percent).

The barriers mentioned in the project design documents were categorized according to the broad groups of barriers presented in Section 3. Where a sufficient number of observations were available, some of these broad groups like "risk and uncertainty" were further split allowing for a more disaggregate presentation of these barriers.

HI: High income economies;
UMI: Upper-middle income economies;
LMI: Lower-middle income economies;
LI: Low-middle income economies;

Table 4 Number of projects by country

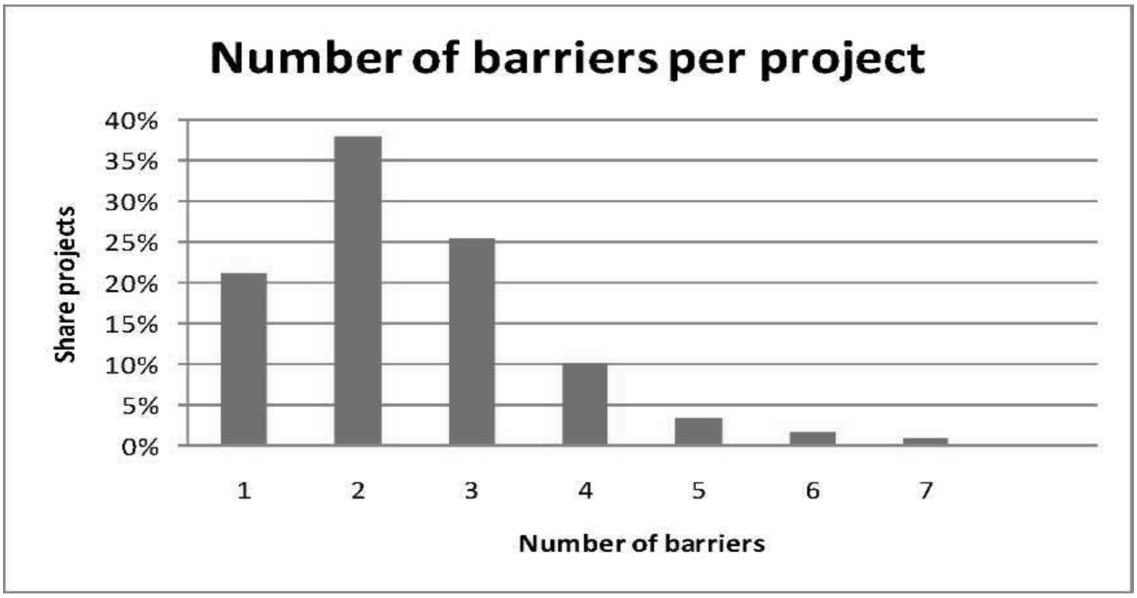
Country	Number of Projects	World bank group*
Argentina	2	UMI
Brazil	3	UMI
Cambodia	1	LI
Chile	1	UMI
China	7	LMI
Colombia	3	UMI
Costa Rica	1	UMI
India	73	LMI
Indonesia	7	LMI
Israel	3	HI
Laos	1	LI
Malaysia	5	UMI
Mexico	3	UMI
Nigeria	1	LMI
Peru	2	UMI
South Africa	3	UMI
Sri Lanka	1	LMI
United Arab Emirates	1	HI
Uruguay	1	UMI

4.3 Average number of barriers by regions

For most projects, multiple barriers were mentioned. On average, 2.5 barriers per project are reported. Figure 1, almost 80 percent of the project design documents report at least two types of barriers and more than 40 percent mention three or more types of barriers.[18]

18 Split incentives were not mentioned as barriers in any of the project design documents analysed.

Figure 1 Number of barriers per project



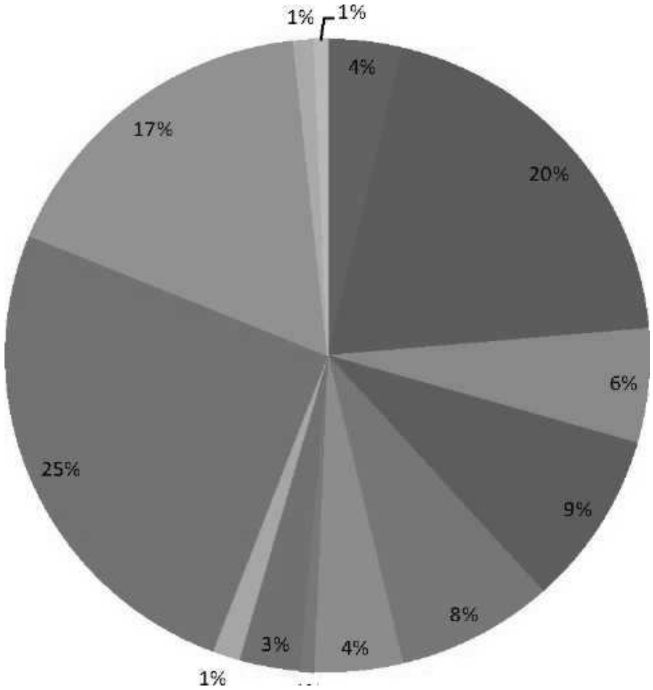
Taken together, the low income and the lower-middle income groups ("poorer countries") account for about 73 percent of the projects, but 80 percent of the barriers. Hence, as expected, relatively more barriers are found in poorer countries. Also, the average number of barriers reported per project is larger in poorer countries (2.7 barriers/project) than in the richer countries (i.e., the combined group of high income and upper-middle income countries) (1.9 barriers/project). While at the micro level, the average number of barriers is almost the same (1.3 for poorer versus 1.2 for richer countries), there are twice as many barriers per project at the micro level in poorer countries than in richer countries (1.4 to 1.7).

4.3 Barriers by types and regions

Figure 2 displays the barriers by types. Accordingly, technical risk, lack of human capital and financial risk are by far the barriers reported most. Barriers which were also mentioned rather frequently are lack of technical infrastructure, lack of service infrastructure and lack of access to external capital. In contrast, barriers like lack of information and other transaction costs were rarely mentioned. To some extent, this finding may be explained by the types of projects typically carried out as CDM projects. These projects are rather high capital investment projects, hence information and transaction costs do not significantly affect the profitability of the project and are unlikely to be listed in the CDM approval process as crucial barriers which prevent (otherwise profitable) project from being implemented[19]

[19] For example, the average investment costs for CDM project in the cement sector is calculated at around 9 million euro.

Figure 2 **Distribution of barriers by types**



■Distorted energy prices, lack of human capital
■Lack of service infrastructure
■Lack of technical infrastructure
■Lack of external access to capital
■Institutional factors
■Lock in effects
■Lack of information, other transaction costs
■Technical risk
■Financial risk
■Lack of internal access to capital
■Bounded rationality

Since - apart from India - for all countries, only a few CDM-projects are included, detailed country-level analyses of the types of barriers reported would not be appropriate. Instead, the barriers were reported for categories of countries, where the categories are based on the World Bank income groups (see Table 4). Results are shown in Figure 3 and Figure 4. Accordingly, energy and carbon efficient projects in poorer countries suffer more than in proportion from lack of service infrastructure, lack of information, technical risks and financial risks.

Figure 3 **Macro-level barriers by types and regions**

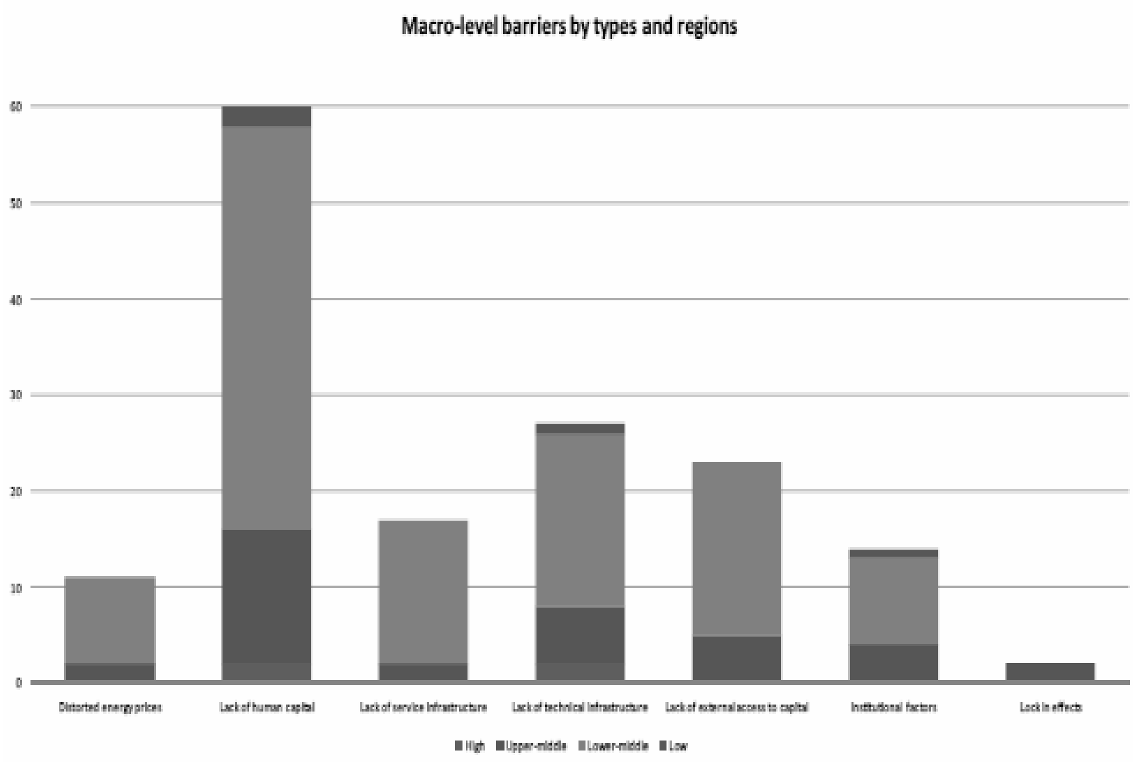
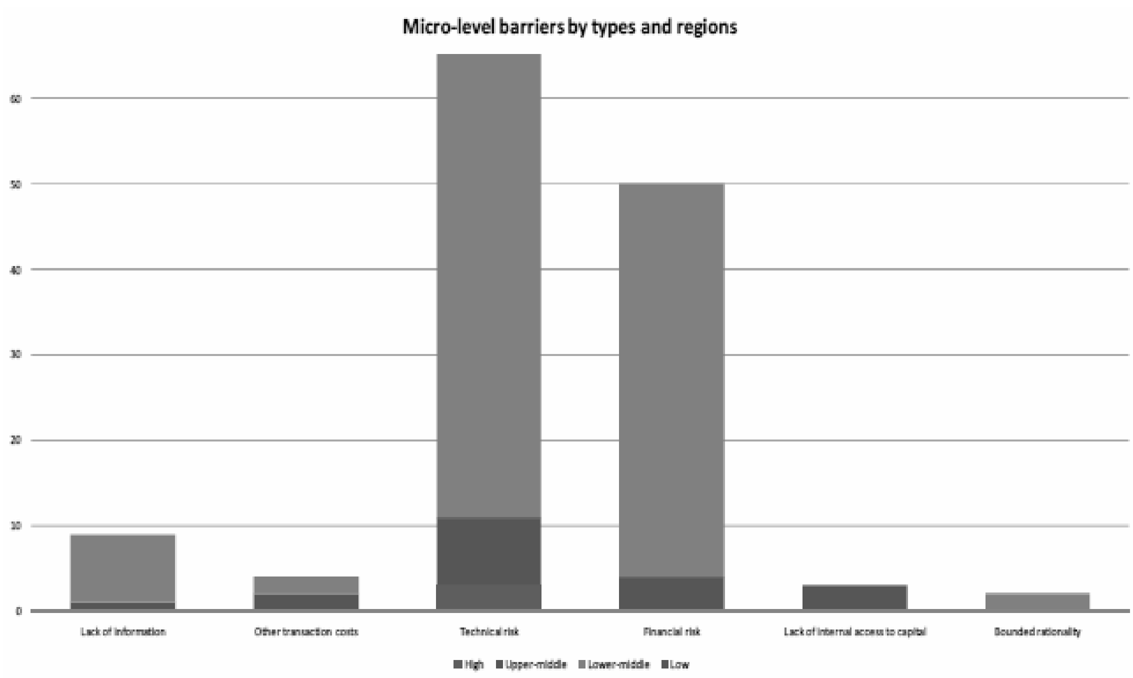


Figure 4 **Micro-level barriers by types and regions**



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