# Are energy efficiency projects feasible under the CDM? A case study on industrial boilers in Peru

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## Keywords

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## Abstract

Energy efficiency projects under the Clean Development Mechanism (CDM) face particular difficulties: The determination of the baseline scenario is more complex, monitoring provisions require the measurement of several parameters, and indirect effects such as rebound effects have to be quantified. Especially small CDM projects have problems to comply with these requirements. As a result, only very few energy efficiency projects have been submitted to the CDM Executive Board up to now.

In this paper, we present the lessons learned from a feasibility study for a CDM project that aims at enhancing energy efficiency in industrial boilers in Peru. The project bundles about 100 boilers in Peru, thereby reducing transaction costs considerably. The institutional framework of the project includes the provision of economic incentives and a program for capacity building. A dynamic baseline is established and simplified monitoring requirements are defined. As part of the feasibility study, the efficiency is measured for about 40 boilers in Peru, energy efficiency improvement measures are identified and $CO_2$ abatement costs are quantified for each measure. With this bottom-up data and statistical data on all industrial boilers in Peru, the potential of the CDM project is estimated and a marginal $CO_2$ abatement cost curve is determined.

Based on the experiences in Peru and of other energy efficiency CDM projects, recommendations are provided on how difficulties in implementing energy efficiency measures under the CDM could be overcome and how transaction costs can be reduced without jeopardizing the environmental integrity of the CDM.

## Introduction

The Clean Development Mechanism (CDM) under the Kyoto Protocol aims at assisting developing countries in achieving sustainable development and industrialized countries in fulfilling their quantitative reduction targets under the Kyoto Protocol. With the adoption of the Marrakech Accords at the seventh Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC) in 2001, the CDM was made operational with the adoption of the CDM modalities and procedures[1] and the election of the CDM Executive Board. This prompt start of the CDM allowed project developers to start implementing CDM projects, even in advance of the Kyoto Protocol coming into force on the 16th February 2005.

According to market information supplied by PointCarbon[2], about 1 300 JI and CDM projects had been proposed globally by January 2005 and about 270 projects are at a more advanced state of development, including the elabora-

1. Annex to decision 17/CP.7. Document: FCCC/CP/2001/13/Add.2, p. 26-49
2. CDM & JI Monitor from 11 January 2005.

tion of a Project Design Document (PDD). The demand for Certified Emission Reduction Units (CERs) from CDM projects is also steadily growing: Several governments have set up procurement tenders to purchase CERs. In 2004, the European Union adopted a linking directive which allows companies in the European Emissions Trading Scheme (ETS) to use CERs to fulfil their commitments. Several other countries, including Norway and Canada, are also planning emission trading schemes which allow the use of CERs. The overall market for CERs is estimated to consist of about 1 250 million tons of $CO_2$ equivalents ($MtCO_2e$) up to 2012. In 2010, the demand for CERs is estimated to be 250 $MtCO_2e$ at a price of US$ 11 / $tCO_2e$, corresponding to an overall annual market volume of about US$ 2.75 (Haites 2004). However, a key prerequisite for a continuous supply of CERs will be that investors are assured of the post-2012 use of CERs.

In the last two years, the regulatory framework for the CDM has also been further elaborated: By the end of 2004, the CDM Executive Board had approved 19 baseline and monitoring methodologies, which can be applied by project developers to estimate and monitor emission reductions from CDM project activities. Four Designated Operational Entities (DOEs) – responsible for the validation of projects and certification of CERs – have been formally accredited and the first CDM project has been formally registered. 54 developing countries have appointed their Designated National Authorities (DNAs) to approve CDM projects.

Despite these promising developments, energy efficiency still plays a rather marginal role in CDM. While energy efficiency projects in developing countries have a very large and cost-efficient potential, only very few projects have been proposed so far, as illustrated by Figure 1. The current portfolio of proposed CDM projects is dominated by projects that abate non-$CO_2$ emissions by use of end-of-pipe technologies, such as the destruction of $N_2O$ in adipic acid production, the thermal oxidation of HFC23 in HCFC22 production and flaring or combustion of $CH_4$ from landfill gas, waste water treatment or other emission sources. These projects account for more than half of the emission reductions, while energy efficiency projects are practically irrelevant with a market share of 2%. All proposed energy efficiency and heating projects are expected to yield less than 100 000 CERs per year, with the exception of a heating project in Uzbekistan (OECD/IEA 2004). Similarly, the share of CERs from non-hydro renewable energy resources is very slight. Given the large potential of energy efficiency measures, this suggests that there are comparative disadvantages for energy efficiency projects under the CDM.

This paper presents the lessons learned from a feasibility study for a CDM project that aims at enhancing energy efficiency in industrial boilers in Peru. Based on the experiences in Peru and of other energy efficiency CDM projects, recommendations are provided on how difficulties in implementing energy efficiency measures under the CDM could be overcome and how transaction costs can be reduced without jeopardizing the environmental integrity of the CDM.

In the following, the requirements and procedures for CDM projects will be summarized. Then, the particular difficulties of and circumstances for energy efficiency projects are analyzed. Subsequently, an approach to improve energy efficiency in industrial boilers under the CDM is presented as a case study. Finally, based on the lessons learned from the case study and other CDM project activities, conclusions and recommendations are provided.

## The CDM project cycle

The development a CDM project activity involves several steps. The first significant step under the CDM is the preparation of the Project Design Document (PDD). The PDD includes a project description, the choice and application of a baseline methodology and a monitoring methodology, the calculation of emission reductions, an assessment of environmental impacts, and a description of how comments from stakeholders have been taken into account. The baseline methodology also includes an assessment of additionality, i.e. an assessment of whether the project would have occurred in the absence of the CDM.

Having prepared the PDD, project developers need to get approval by the host country and any involved industrialized

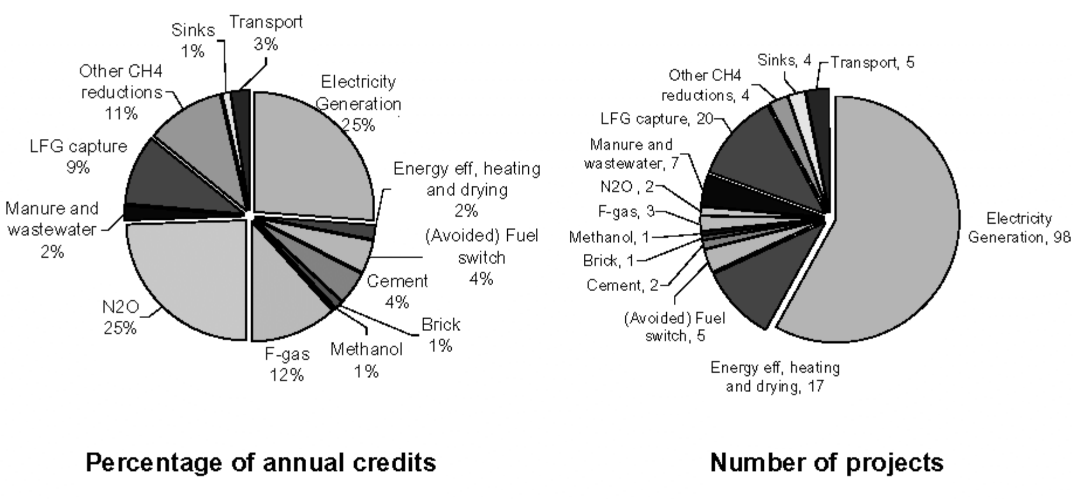


***Figure 1.*** *Portfolio of proposed CDM projects by September 2004 (Source: OECD/IEA 2004)*

country. The Designated National Authority (DNA) in the host country has to assess and confirm that the proposed CDM project contributes to sustainable development. The PDD is subsequently validated by an independent Designated Operational Entity (DOE), which confirms that all participation requirements are fulfilled and that baseline and monitoring methodologies have been applied correctly. During validation, the public has four weeks to comment the project. Once the validation is completed, the DOE submits a request for registration to the CDM Executive Board in the form of a validation report, including all project information. The CDM Executive Board takes the final decision on the project's approval (registration).

After project implementation, the achieved emission reductions are monitored (monitoring) and the monitoring report is verified by a DOE. The certification report by the DOE is submitted to the Executive Board and constitutes a request for issuance of CERs equal to the verified amount of greenhouse gas emission reductions.

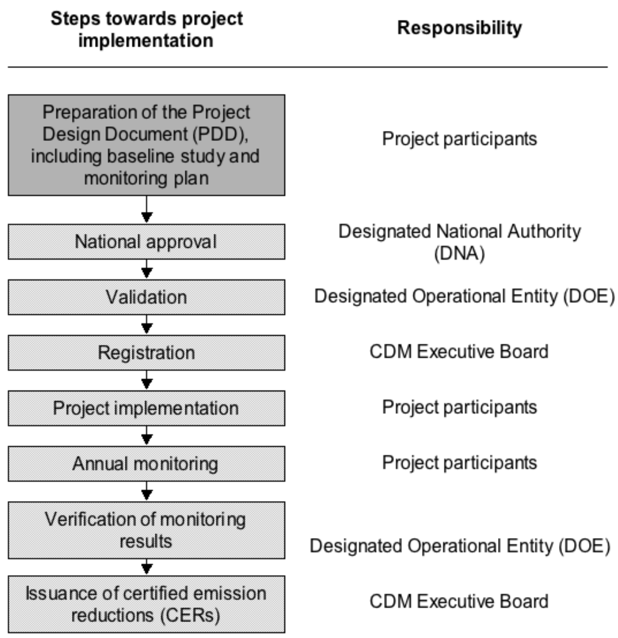


***Figure 2.*** *The CDM project cycle.*

## Challenges for energy efficiency projects under the CDM

In fulfilling these requirements, energy efficiency projects face particular difficulties. In the following, some particularly important aspects for the development of energy efficiency projects are assessed in comparison to other CDM project types.

### PROJECT SIZE

The project size is an important aspect of CDM projects, particularly because of the significant transaction costs associated with the CDM project cycle. Most energy efficiency projects are much smaller compared to non-$CO_2$ projects or large hydro projects. Transaction costs are consequently relatively higher. Haites (2004) came to the conclusion that projects delivering less than 100 000 CERs per year are currently unlikely to be cost-effective under the CDM. Although this figure can be regarded as the upper end of a scale, many energy efficiency projects deliver significantly fewer CERs.

In 2002, the CDM Executive Board elaborated simplified methodologies for small-scale projects, which were adopted by the Conference of the Parties in December 2002.[3] Energy efficiency projects with less than 15 GWh annual energy savings qualify as small-scale projects. However, this threshold is rather low compared to the thresholds for renewable electricity projects (15 MW) and other project categories (15 000 tons of $CO_2$ emissions or reductions). For example, 15 GWh of natural gas savings correspond to only 3 000 tons of emission reductions, while a renewable power plant of 15 MW operating for 5,000 hours may reduce $CO_2$ emissions by 60 000 tons, assuming the substitution of electricity in coal-fired power plants. Therefore, in comparison to renewable electricity projects or other project categories, small-scale energy efficiency projects are more costly to develop. This is supported by actual project developments: Of 32 small-scale CDM projects that had undergone validation and received public comments by the end of January 2005, only one project includes an energy efficiency component, while 26 projects produce renewable electricity (mostly hydro power).

### CALCULATION OF EMISSION REDUCTIONS

The calculation of emission reductions is more complex for most energy efficiency projects. Baseline and monitoring methodologies are particularly complicated in the case of demand-side measures since they often include different types of measures or involve many devices used by dispersed consumers. Where consumers change their behaviour – for instance in compact fluorescent lamp (CFL) programs under the CDM – the baseline scenario (e.g. CFLs sold without the CDM) is difficult to determine, since future consumer preferences are rather hypothetical and depend on many other influence factors. In addition, energy efficiency measures may lead to rebound effects. For example, in the case of CFLs, consumers may increase their lightening standards when CFLs become economically more viable due to a CDM project activity. However, quantification of such rebound effects is difficult.

### MONITORING

In addition, monitoring provisions are often more complex for energy efficiency projects. While non-$CO_2$ projects or renewable electricity projects require only straightforward measurements in the main (e.g. electricity generation or waste stream flow), the measurement or calculation of efficiencies is sometimes difficult and costly. Energy efficiency projects often include measures at different production sites as well. This requires the bundling of many small project ac-

3. Annex to decision 21/CP.8. Document: FCCC/CP/2002/7/Add.3, p. 18-27.

**Table 1. Assessment of the feasibility of different CDM project categories ("+" = advantageous factor, "o" = neutral, "-" = disadvantageous factor).**

| | Energy efficiency | Hydro electricity | Non-hydro renewable electricity | Non-$CO_2$-projects |
|---|---|---|---|---|
| Project size | - | + | -/o | + |
| Calculation of emission reductions | - | o | o | + |
| Monitoring | - | o | o | + |
| Demonstration of additionality | o | o | + | + |
| GHG abatement costs | + | o/+ | - | + |
| Potential | + | + | o | o |

tivities. Although bundling is possible under the CDM modalities and procedures, it may involve measurements at different sites and data collection from many participants, which would increase the transaction costs of projects.

#### ADDITIONALITY

The demonstration of additionality is particularly simple in the case of end-of-pipe technologies that do not generate other economic benefits. Where the abatement of GHG emissions is not required by regulation and is not a common industry practice, operators have no incentives other than the revenues from CERs to burden the additional costs of abating emissions. This is true for landfill gas capture, $N_2O$ destruction in adipic acid production or the destruction of HFC23 waste streams from HCFC22 production. In contrast, many energy efficiency improvements are no-regret measures economically, which makes the demonstration of additionality more difficult.

In October 2004, the CDM Executive Board approved a *consolidated additionality tool* that provides project participants with a stepbystep tool for demonstrating the additionality of a CDM project. This tool allows project developers to choose between an investment analysis or a barrier analysis to demonstrate additionality. Project developers do not need to demonstrate that the proposed project is economically unattractive but they may alternatively demonstrate additionality by showing that existing barriers impede the implementation of the project and that the CDM is able to overcome these barriers. This latter option is particularly relevant for energy efficiency projects which often face significant non-economic barriers.

However, the demonstration of additionality with a barrier analysis is not always straightforward (Stricker 2004). Firstly, many barriers are rather subjective and are difficult to verify for the DOE. Subjective barriers that can not be verified by a DOE, should all the same not be used to demonstrate additionality. Many examples of barriers that have been suggested in written submissions to the CDM Executive Board are of a rather subjective nature – for instance, the non-availability of skilled labour, the absence of regulation, the lack of an adequate institutional framework, the lack of willingness to change current practices, cultural barriers, etc.

Secondly, for some energy efficiency projects, it may be difficult to demonstrate how these barriers are overcome as a result of the CDM. If an energy efficiency measure is already economically viable and not undertaken due to a barrier, demonstrating that a further improvement of the economic viability due to revenues from CERs overcomes this barrier may be complicated.

#### GHG ABATEMENT COSTS AND POTENTIAL

An advantage of energy efficiency projects is that they have low GHG abatement costs or are even no-regret measures, whereas other project activities – in particular some renewable energy activities – face higher abatement costs. In principle, this allows energy efficiency projects even with low market prices for CERs to be undertaken. In addition, the global potential for increasing energy efficiency is very great.

#### SUMMARY

Table 1 summarizes both the advantageous and disadvantageous influence factors for the feasibility of different types of CDM project activities. The table shows that non-$CO_2$ projects are very favourable, while energy efficiency projects and non-hydro renewable electricity projects face some constraints. In the following, the constraints of and options for implementing energy efficiency projects under the CDM are assessed in the context of a case study on industrial boilers.

## Case study: Improving energy efficiency in industrial boilers[4]

The idea of improving energy efficiency in industrial boilers in Peru emerged in 1998, when the United Nations Development Program (UNDP) conducted a project to develop national capacities for the CDM. Emissions from industrial boilers are an important source of greenhouse gases and other important air pollutants in Peru. Carbon dioxide emissions from industrial boilers are estimated to amount to about 4 million tons in 2000, which corresponds to about 50% of emissions in Peru's productive sector. The fishing and textile industry sectors are particular important.

The circumstances for improving energy efficiency in industrial boilers are problematic in Peru. Many small and medium enterprises (SMEs) have – despite good economic prospects – a bad credit record. In addition, some small enterprises neither have clear legal status in order to avoid taxes, nor do they own official property rights to their production sites. This has led to a partly informal economy and to a systematic undercapitalization of Peruvian SMEs. The technical knowledge of how to operate and maintain boilers is poor in many companies.

#### CHARACTERISTICS OF INDUSTRIAL BOILERS IN PERU

The characteristics of industrial boilers in Peru and the potential to abate greenhouse gas emissions were assessed by a measurement program (CENERGIA 2001; Jimenez et al.

4. This study was financed by the German development cooperation Gesellschaft für technische Zusammenarbeit (GTZ).

2001), undertaken as part of the study, and a national survey on all boilers (MITINCI 2000). In the national survey, 369 companies participated; a total of 1 147 boilers with an accumulated rating of 5 610 MW were declared. Most of the companies participating in the survey were medium-sized and large industrial enterprises, which have the largest boilers and therefore constitute most of the installed capacity of the Peruvian boiler park. In the measurement program, detailed data was collected from 80 boilers, including measurements of energy efficiency (using the energy balance method) under different operation conditions, measurements of air pollutants in the flue gas, a description of the boiler and control technology, an assessment of the current maintenance practices and a cost estimation for different measures to improve energy efficiency.

These assessments revealed that boilers in Peru are operated inappropriately in many cases. Energy efficiency is about 82% on average, however it varies strongly, as illustrated by Figure 3. In many cases, relatively simple control technology, such as automatic excess air control systems, is not installed. The average age of boilers in Peru is 21 years, with individual boilers operating up to 70 years. There is, in general, an enormous need for modernization. Energy efficiency could be significantly increased in many boilers by the application of "good housekeeping" measures, the installation of additional equipment or the replacement of burners or boilers.

During the measurement program, several good housekeeping measures and investment measures to improve energy efficiency were identified. Good housekeeping measures include the manual adjustment of excess air, the reduction of the required temperature and pressure of vapour and typical maintenance measures, such as the cleaning or replacement of tubes. Investment measures include the installation of automatic excess air control systems, the installation of an automatic blowdown system, the replacement of inefficient burners, the installation of an economizer and the replacement of the boiler.

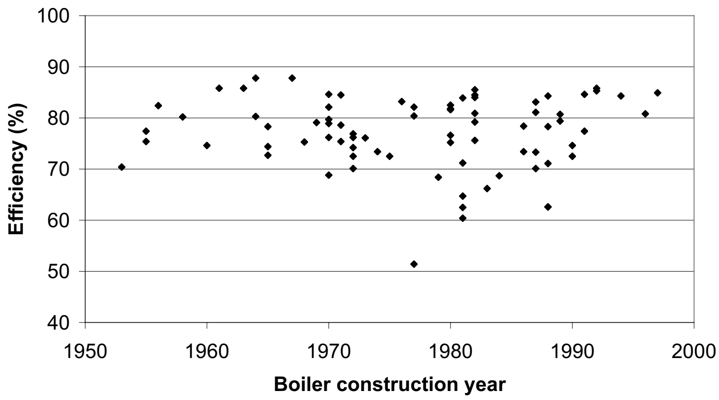


***Figure 3.*** *Energy efficiency of a sample group of industrial boilers. in Peru*

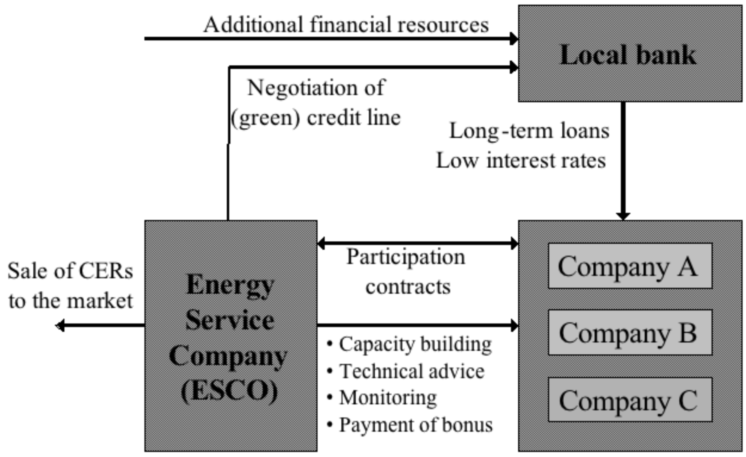


***Figure 4.*** *Institutional framework for the CDM project.*

#### INSTITUTIONAL FRAMEWORK FOR A CDM PROJECT

The improvement of energy efficiency in Peruvian boilers is impeded by a number of important barriers, the most important being the inadequate access of small and medium enterprises (SMEs) to capital and the lack of knowledge on how to operate boilers and identify measures to increase energy efficiency. A key requirement in the institutional set-up of a CDM project is to overcome these barriers without causing prohibitively high transaction costs.

It has been proposed that about 100 boilers be bundled into one CDM project activity and that an energy service company (ESCO) will develop and implement the project. A key element of the proposal is a green credit line with low interest rates, administered by a commercial bank. This credit line should facilitate access to capital for the participating companies – which is one of the major barriers to investments in energy efficiency. The ESCO is supposed to contact and select companies with boilers that enable sufficient emission reductions. The participating companies sign a participation contract with the ESCO. The ESCO provides the required technical advice and capacity building to companies for the improvement of energy efficiency (e.g. good housekeeping) and identifies how boiler efficiency should be improved. The ESCO then informs the commercial bank that the company qualifies for participation in the green credit line. The participating company receives a loan from the bank and subsequently implements the measures to improve the efficiency of the boiler. The ESCO monitors emission reductions, which are subsequently verified by an independent DOE. In the participation contract between the companies and the ESCO, the companies assign rights over future certified emission reductions (CERs) to the ESCO. In exchange, the ESCO pays a “bonus” to companies if they maintain a high level of energy efficiency. This bonus should be an additional incentive to participate in the CDM programme and to ensure that the improved level of energy efficiency in the boilers is maintained. The “bonus” payment and the services provided by the ESCO, including monitoring, should be financed by revenues from CERs. The additional costs of the green credit line would likely require additional financial resources in the context of development cooperation. The proposed institutional framework is illustrated in Figure 4.

The proposed institutional framework is supposed to help overcome the significant economic and non-economic barriers facing small and medium companies in Peru, in particular with respect to access to capital. This will allow participating companies to invest in the necessary modernization of boilers, to introduce new technologies, to increase their technical and environmental perception concerning boilers and energy efficiency by capacity building activities, to reduce costs for vapour production and to increase their competitiveness. With regard to other aspects, the project is also expected to contribute positively to Peru's sustainable development objectives. The proposed measures would not only reduce $CO_2$ emissions but also other pollutant emissions that currently cause serious health problems, destroy historical monuments and severely damage the economy.

## EMISSION REDUCTION POTENTIAL AND $CO_2$ ABATEMENT COSTS

The potential and the costs of greenhouse gas emission reductions are estimated with the help of a model, combining the bottom-up data from the measurement program (Jimenez et al. 2001; CENERGIA 2001) with data from the national survey (MITINCI 2000). A representative sample group of about 42 boilers was selected and all relevant options to increase energy efficiency were assessed for each boiler. $CO_2$ abatement costs are calculated for each option, taking into account the future development of energy prices, differentiated capital costs for differing types of companies as well as specific investment and operation costs. Emission reductions from good housekeeping activities and investments are assessed separately. The proposed measures could increase the energy efficiency of the boilers by about 6% in average.

The results of the sample group are extrapolated to the Peruvian national level, considering several restricting factors and barriers for the development of a CDM project:

- **Boiler size.** In boilers with a small capacity, efficiency improvements will generate a correspondingly small amount of CERs. As a minimum eligibility requirement to participate in the CDM program, the revenues from selling CERs generated by energy efficiency improvements should exceed the boiler-specific transaction costs of the CDM project. For the purpose of estimating the number of participating boilers, boilers with a capacity below 1.5 MW (approximately 150 BHP) are not considered. Efficiency improvements in boilers with a capacity of 1.5 MW reduce $CO_2$ emissions by approximately 10 to 50 tonnes annually. Assuming a price of around US$5 per tonne of $CO_2$ and an average crediting period of seven years, income from selling CERs would amount to approximately US$350 – 1 750, which is estimated to approximately cover the boiler-specific CDM transaction costs.
- **Technological performance.** Energy efficiency in Peruvian boilers varies considerably, as illustrated by Figure 3 above. In some cases, boilers already have a relatively high technical performance. Consequently, further efficiency improvements are not possible, or would only generate insignificant energy savings even if boilers were above the proposed capacity threshold of 1.5 MW. Secondly, boilers operate at a low annual load factor in some cases and energy savings are, as a consequence, small compared to boilers with a higher load factor. Boilers with relatively high energy efficiency and/or smaller capacity and insignificant potential for efficiency improvement and/or relatively low annual load factors are therefore not considered in the estimation of the potential, though some of them may be eligible to participate in the CDM programme. Based on the results of the measurement programme, it is estimated that this applies to only about 15% of the boilers.
- **Fuel type.** In the CDM project, only boilers fired with diesel or residual oil are considered. Boilers fired with liquefied gas usually have a relatively good technical performance and GHG emissions are lower due to the smaller carbon content in gas. Boilers fired with renewable energy, such as sugarcane residues, do not qualify since the improvement in energy efficiency does not lead directly to a reduction in GHG emissions.
- **Boiler age.** Some boilers are excluded because of their age, for different reasons: Firstly, new boilers generally have a relatively high performance and energy efficiency measurements would be costly. This aspect is covered mainly by considerations of technical performance mentioned above. However, for the purpose of a conservative estimation of the CDM potential, boilers less than 3 years old are not considered. Secondly, only boilers less than 35 years old are eligible for retrofitting, as energy efficiency improvements at the end of a boiler's lifetime would generate energy savings for only a few years, which in most cases is not economically attractive.
- **Financial and economical viability of companies**. According to the Peruvian Central Bank[5], some sectors of Peruvian industry, such as the fishing industry, have considerable debts. A number of companies are under regulation of a law[6], which limits their access to capital. According to information from the Peruvian Central Bank, it can be estimated that about 30% of companies are classified "with potential problems", or with a lower rating, and would therefore not qualify for participation in the CDM loan program.
- ***Other barriers.*** Experiences of energy efficiency programmes show that only a portion of potentially qualified companies participate in projects in practice due to a lack of information or other barriers. In our case, it is assumed that 50% of technologically and economically qualified companies would participate in the CDM programme.

Taking these restrictions into account, and projecting the bottom-up data from 42 boilers to the national level by using data from the national survey (MITINCI 2000), an overall marginal GHG mitigation cost curve for investments in boil-

5. Superintendencia de Banca y Seguros (SBS)
6. Ley de Reestructuración empresarial

ers in Peru under a CDM project is approximated (see Figure 5). The weighted average cost of capital was differentiated between large cooperate firms (11%), medium-sized enterprises (21%) and small enterprises (25%), based on typical interest rates for loans and own capital in Peru.

Figure 5 shows that $CO_2$ abatement costs of most of the proposed investment measures to improve energy efficiency are negative, which means that these measures could be implemented in principle without additional economic cost. However, due to the barriers described above, this potential is not yet being used. Assuming a price of about US$5 per tonne of $CO_2$, the economic potential of the investment measures amounts to about 170 000 $tCO_2$ emission reductions during the crediting period of the project. Also taking good housekeeping measures into account, total emission reductions of 400 000 $tCO_2$ can be achieved. Table 2 summarizes the main results.

Even though this potential is clearly less than that of some other CDM projects, it seems sufficient in order for the project to be undertaken. With an assumed price of US$5 per tonne of $CO_2$ revenues of about US$2 000 000 could be achieved to finance the ESCO's activities and bonus payments for the companies. Clearly, a major risk and uncertainty is the quantity of companies that would participate in such a CDM programme. In the national survey (MITINCI 2000), a large majority of companies indicated that they are interested in activities to increase the performance of their boilers. However, in an actual CDM project the number may be much smaller. This risk may be mitigated, if a number of larger companies are contracted in an initial phase of the project.

### BASELINE METHODOLOGY AND MONITORING PLAN

The establishment of a baseline methodology and monitoring of emission reductions are a particular challenge for bundled energy efficiency CDM projects. As part of the feasibility study, a detailed baseline methodology and a monitoring plan have been developed. Several approaches for determining the baseline level are analysed, of which the continuation of the current situation seems most appropriate, since companies would have a continued lack of access to capital and knowledge on energy efficiency improvements without the proposed CDM program. This means that the boilers would presumably continue to operate with the same energy efficiency in the absence of the CDM project activity.

Baseline and project emissions depend on the activity level (vapour demand) and the emission factor, which depends on the fuel type and the boiler efficiency. Emission reductions result from the difference between baseline and project emissions. For the Peruvian boiler project, it is assumed that rebound effects, such as an increase in vapour production due to lower heat costs, are very small, since the production capacity is limited in most industries by other factors (e.g. the processing plant) rather than vapour supply. In addition, in many sectors vapour production is only a minor cost factor. Therefore, the activity level (vapour generation) is the same in the baseline scenario and the project. Emission reductions resulting from efficiency improvements can be determined as follows:

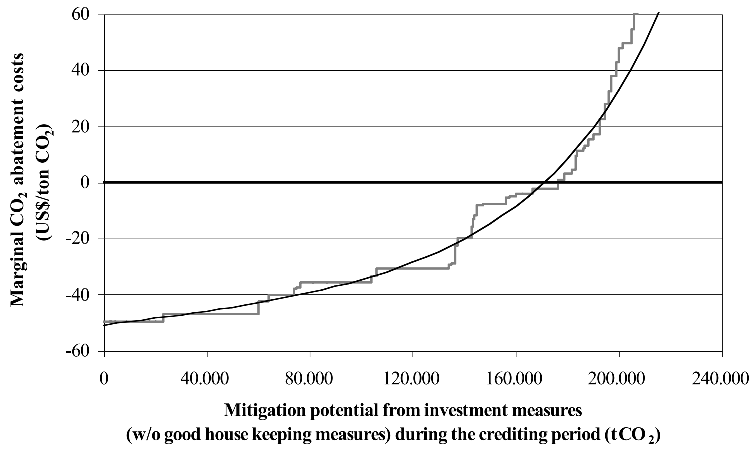


***Figure 5.*** *Marginal mitigation cost curve from investment measures in boiler efficiency under the CDM in Peru (excluding good housekeeping measures)*
*Note that this mitigation cost curve only includes investment measures, such as automatic excess air control systems or economizers, which result in a potential of about 170 000 t $CO_2$ at a price of US$5 per CER. In addition, about 230 000 t $CO_2$ can be mitigated through the implementation of good housekeeping measures in these boilers, resulting in an overall mitigation potential of about 400 000 t $CO_2$ during the crediting period.*

**Table 2: Potential of a CDM boiler programme in Peru.**

| | | |
|---|---|---|
| **Number of participating boilers** | - | 100 - 130 |
| **Total capacity of participating boilers** | MW | 1.272 |
| **Average annual $CO_2$ abatement** | | |
| Investment measures | tonnes/a | 25.396 |
| Good Housekeeping | tonnes/a | 35.209 |
| Total | tonnes/a | 60.605 |
| **Average annual energy savings** | | |
| Investment measures | GJ/a | 335.278 |
| Good Housekeeping | GJ/a | 463.536 |
| Total | GJ/a | 798.814 |
| **$CO_2$ abatement during crediting period** | | |
| Investment measures | tonnes | 170.638 |
| Good Housekeeping | tonnes | 231.566 |
| Total | tonnes | 402.204 |

$$\Delta E = \sum_{\text{Boilers}} C \cdot EF_{\text{Fuel}} \cdot \left(1 - \frac{\varepsilon_{\text{Project}}}{\varepsilon_{\text{Baseline}}}\right)$$

where $\Delta E$ are the $CO_2$ emission reductions in tons, C is the fuel consumption of the boiler in MWh, $EF_{Fuel}$ is the $CO_2$ emission factor of the fuel in t $CO_2$ per MWh, $\varepsilon_{Project}$ is the energy efficiency of the boiler after project implementation and $\varepsilon_{Baseline}$ is the energy efficiency of the boiler in the baseline scenario.

As Figure 3 shows, energy efficiency varies significantly between boilers, independent of the boiler's age. There is also no correlation between energy efficiency and boiler size or manufacturer. For that reason, application of a standardized baseline level (benchmark) for all boilers is not possible. A baseline with a benchmark efficiency, which may be determined based on the results of this study or a reference technology, would be in danger of overestimating emission reductions, as the ESCO would have a strong economic inventive to prefer boilers which already have a high energy efficiency, once the benchmark efficiency has been established. As a consequence, the average efficiency of participating boilers would likely be higher than the established benchmark efficiency. It is therefore proposed that the energy efficiency for each boiler be measured separately, prior to the implementation of improvement measures. As a consequence, the final baseline emission level will be determined only after monitoring, when data on the energy efficiency of participating boilers has been collected.

This dynamic baseline approach requires project developers to estimate baseline emissions *ex ante*, with the submission of the Project Design Document (PDD), and to adjust projected baseline emissions *ex post* as part of the monitoring and certification of emission reductions. Similar approaches have already been applied in other approved CDM methodologies.

As a part of the monitoring, data on fuel consumption and energy efficiency needs to be collected. Information on fuel consumption should be provided by companies (e.g. with invoices) and checked for consistency by the ESCO. Having implemented the improvement measures, energy efficiency will be measured once for each boiler. In order to reduce transaction costs, measurements of energy efficiency during the crediting period may be conducted for a sample group of about 10 to 20 plants, covering the different types and sizes of boilers.

Energy efficiency of boilers may be measured with the input-output method (direct method) or the energy balance method (indirect method). The input-output method determines all energy flows to and from the boiler, while the energy balance method estimates the different losses. Advantages and disadvantages of both methods are listed in Table 3. In most cases, the energy balance method yields lower overall test uncertainty because the measured losses represent only a small fraction of total energy. In practice, accurate measurement of steam properties and flow rates, which is necessary for the input-output method, is also quite difficult. With the energy balance method the measurement of flue gas composition and temperature can be conducted relatively easily and accurately, and this information already allows major losses to be determined. The main advantage of the input-output method is that all losses are automatically covered by measurements, whereas with the energy balance method some losses (e.g. convection) have to be estimated. Furthermore, the input-output method allows for an average seasonal efficiency to be determined, including losses due to standby operation or start-ups and discontinuous blowdowns. Measurements conducted with the energy balance method only yield efficiency during steady-state operation.

In the Peruvian context, the main advantage of the energy balance method is that it can be expected to yield a lower degree of uncertainty with relatively simple measurements. It is therefore proposed that this method be used for small boilers. For larger boilers, it is proposed that permanent measurement equipment be installed which permits the application of the input-output method. This continuous measurement of boiler efficiency enables the optimisation of maintenance intervals and increases the operators' awareness of the boiler performance.

## Conclusions and recommendations

In developing countries, there is great potential for improvements in energy efficiency. In many cases, an improvement in energy efficiency would be economically attractive but is not undertaken due to significant barriers. This is illustrated by the case study on industrial boilers in Peru. Most measures to improve boiler efficiency are economically efficient, with a no-regret $CO_2$ abatement potential of about 380 000 tons, but are not implemented. In this regard, the improvement of energy efficiency in industrial boilers is not primarily an economic issue but is impeded by the companies' lack of knowledge of how boilers operate and by the difficulties to access capital. Similar non-economic barriers impede improvements of energy efficiency in many other cases.

The issuance of CERs under the CDM gives greenhouse gas emission reductions an economic value. As the improve-

**Table 3: Comparison of methods to measure boiler efficiency.**

| | **Energy balance method** (indirect method) | **Input-output method** (direct method) |
|---|---|---|
| **Advantages** | The primary measurements (flue gas composition and temperature) can be made very accurately with relatively simple equipment<br><br>Uncertainty of test results is often lower than with the input-output method<br><br>Measurement of the different losses allows identification of sources of inefficiency | All losses are considered in the measurement, and estimation of some losses is not necessary<br><br>Seasonal efficiencies can be measured |
| **Disadvantages** | Some losses are practically immeasurable and have to be estimated (loss due to radiation, convection and conduction, boiler blowdown if operated discontinuously; operation losses due to standby or start-up) | Fuel flow, fuel heating value, steam flow rates and steam properties have to be measured very accurately to minimize uncertainty<br><br>Sources of inefficiency are not identified |

ment of energy efficiency is not primarily an economic problem in many cases, additional revenues from CERs usually do not provide adequate incentives to improve energy efficiency. This partly explains why there are so few CDM energy efficiency projects being developed up to now.

The case study on industrial boilers also illustrated that the establishment of the baseline is complex, since the efficiency of boilers is neither related to boiler types, nor to boiler size or boiler age. As a result, a simple benchmark approach cannot be applied. The ex-post calculation of the baseline and monitoring of emission reductions require many measurements. About 100 companies need to be contracted by an ESCO, which involves significant transaction costs, also in relation to the overall size of the project activity.

In summary, the difficulties of energy efficiency projects under the CDM can be categorized in three ways:

1. Improvements of energy efficiency are mainly impeded by *non-economic barriers* that are difficult to overcome due to additional revenues from CERs.
2. The typical *project size* of energy efficiency projects is small compared to most other CDM project activities, involving higher transaction costs per CER.
3. *Methodological issues*, such as the calculation of emission reductions and monitoring, are more complex for energy efficiency projects compared to most other CDM project activities.

These difficulties will limit the supply of CERs from energy efficiency projects. However, the following approaches and proposals may help to improve the chances of energy efficiency projects under the CDM.

Currently, a lack of baseline and monitoring methodologies for energy efficiency projects still exists. Two methodologies for cogeneration systems (AM0014 and AM0015) as well as two methodologies for steam system optimization (AM0017 and AM0018) were approved recently. The ongoing multilateral and bilateral capacity building activities for project developers should focus on the development of additional energy efficiency baseline and monitoring methodologies. In addition, capacity building activities should better include ESCOs, as they could play an important role in developing energy efficiency CDM projects.

In 2004, the CDM Executive Board started to develop *consolidated baseline and monitoring methodologies*. A consolidated methodology combines various approaches and proposals into one methodology, which should be broadly applicable to a certain project type. The development of consolidated methodologies was mainly initiated to avoid many similar methodologies being available for one type of project activity. With many different methodologies, project developers may have difficulties in choosing the most appropriate methodology. They would have economic incentives to choose the methodology which generates the most CERs but which may not accurately reflect real emission reductions, potentially leading to an overestimation of emission reductions. With one consolidated methodology, the requirements are clear and can be applied in a straightforward manner. By January 2005, two consolidated methodologies have been approved, one for landfill gas capture (ACM0001) and one for renewable electricity generation (ACM0002). The development of consolidated methodologies for energy efficiency projects could facilitate project development. For example, consolidated methodologies may be developed for energy efficiency improvements in power plants or for efficient household appliances, as the methodological aspects are similar for different power plants and different household appliances. In addition, the COP may consider increasing the threshold of 15 GWh for small-scale CDM project activities.

Energy efficiency projects may be particularly promising if the revenue from CERs is directly used to overcome non-economic barriers, e.g. to cover transaction costs of an ESCO, as in the case study for industrial boilers. In this case, the additionality can be demonstrated in a rather straightforward manner, since the CDM directly helps to overcome non-economic barriers. Investment analysis is preferable in the case of clearly economic disincentives to increase energy efficiency, for example in case of power plants.

Finally, transaction costs play an important role in energy efficiency projects, particularly with regard to demand-side projects. *Bundling* of activities at different sites reduces transaction costs, in particular costs for project development and monitoring. The costs of project development are significantly reduced in the development of the PDD (only one document), the validation by a DOE, the national approval of the project (one procedure) and the registration (one registration fee). The monitoring of several installations caters for synergies, for instance by limiting monitoring to sample groups.

*Benchmarks* should not be used for determining emission reductions in cases where energy efficiency varies among the installations of the bundled CDM project activity, since project operators would have economic incentives to only include installations with an energy efficiency lower than the benchmark, resulting in an overestimation of emission reductions. However, where installations or appliances with identical energy efficiencies are bundled to a CDM project activity, benchmarks could be used to calculate emission reductions.

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