Improving Energy Efficiency in Peruvian Boilers with the CDM

Feasibility study for a bundled CDM Project

Final Report
for *Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ)*
and the *Peruvian Ministry for Production (PRODUCE)*

January, 2003

Project lead:
- Anke Herold (Öko-Institut)
- Lambert Schneider (Öko-Institut)
- Natalia Vizcarra

Project team:
- Victor Arroyo (CINYDE S.A.C.)
- Adler Chumbimuni
- Marco Gonzalez (Finanzas Ambientales)
- José Salazar (Finanzas Ambientales)

Öko-Institut, Institute for Applied Ecology		
Freiburg	*Darmstadt*	*Berlin*
Binzengrün 34a	Elisabethenstraße 55-57	Novalisstraße 10
D-79114 Freiburg i.Br.	D-64283 Darmstadt	D-10115 Berlin
☎ 0761-452 95-0	☎ 06151-8191-0	☎ 030-280 486-80
0761-47 54 37	06151-8191-33	030-280 486-88
www.oeko.de		

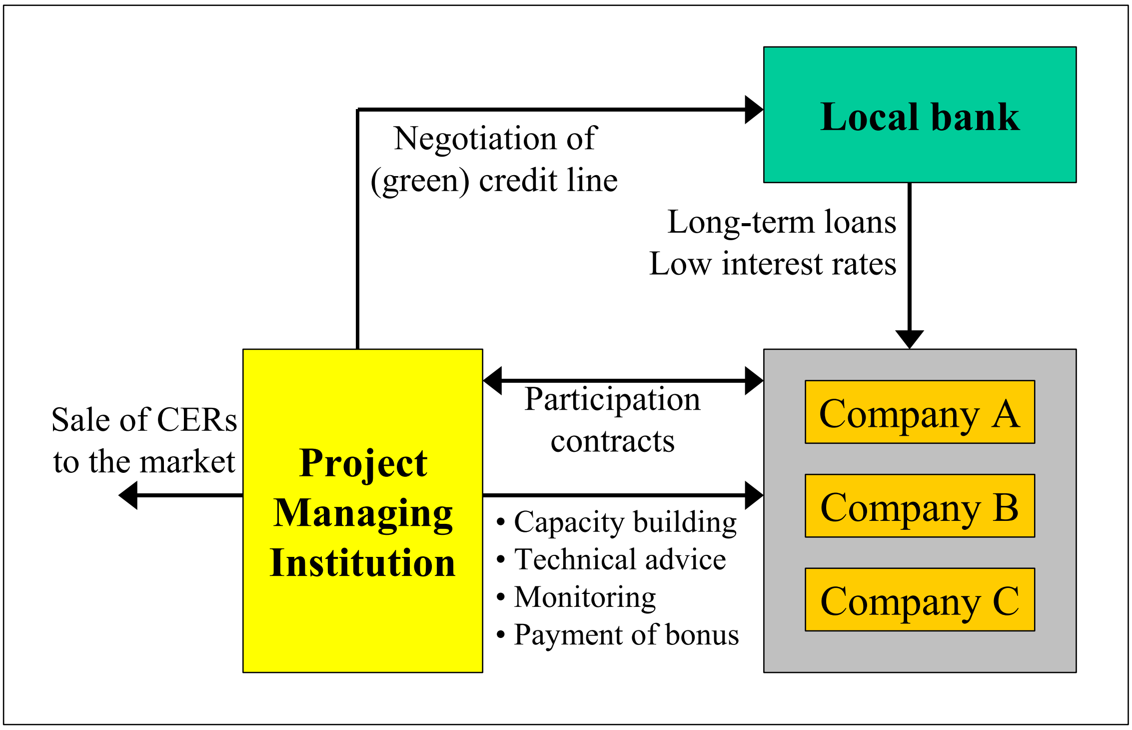
Executive Summary

This study, sponsored by GTZ, assesses the feasibility of a Clean Development Mechanism (CDM) project to improve energy efficiency in industrial boilers in Peru. The idea of such a CDM project came from activities undertaken within the project "Development of the National Capacity for Projects on CDM Activities," sponsored by the United Nations Development Programme (UNDP) in 1998. As a first step, in 1999, a pre-feasibility study was conducted.

Building on these results, this study analyses the specific characteristics and circumstances of vapour production in Peru, provides a thorough assessment of the potential, costs and risks for greenhouse gas mitigation, suggests a CDM baseline methodology and a monitoring plan, illustrates the necessary institutional framework for the implementation of the proposed CDM project and analyses how the project contributes to Peru's sustainable development objectives.

One of the most outstanding characteristics of this project is the bundling of more than 100 small boilers into one CDM project activity. This requires a cautious setting-up of institutional arrangements and procedures, as well as good project management. The proposed general institutional framework of the project is illustrated in Figure 1.

Figure 1: Institutional framework for the financing of investments in boilers



Source: Environmental Finances, Öko-Institut

One single institution should have overall responsibility for the project. This **project managing institution (PMI)** may be formed as a consortium from existing institutions in Peru. The project managing institution will manage the project and also assume the economic opportunities and risks.

A key element of the proposal is a **special credit programme** administered by a commercial bank. With this special credit programme, access to capital for the participating companies would be facilitated through relatively low interest rates and lower transaction costs.

The project managing institution will provide technical advice and capacity building to companies for the improvement of energy efficiency. Participating companies commit themselves to implement measures to improve energy efficiency or to replace boilers. Following implementation of the measures, the PMI will be responsible for monitoring emission reductions and certification through an independent operational entity. In a participation contract, companies undertake to provide the PMI with necessary information. Furthermore, companies assign rights over future certified emission reductions (CERs) to the PMI. In exchange, the PMI pays a “bonus” to companies if they maintain a high level of energy efficiency. The payment of this bonus should create an additional incentive for participation in the CDM programme. The PMI may finance this bonus with the future sale of CERs.

The proposed institutional framework is expected to help to 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 through capacity building activities, to reduce costs for vapour production and to increase their competitiveness. Also with regard to other aspects, the project is 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.

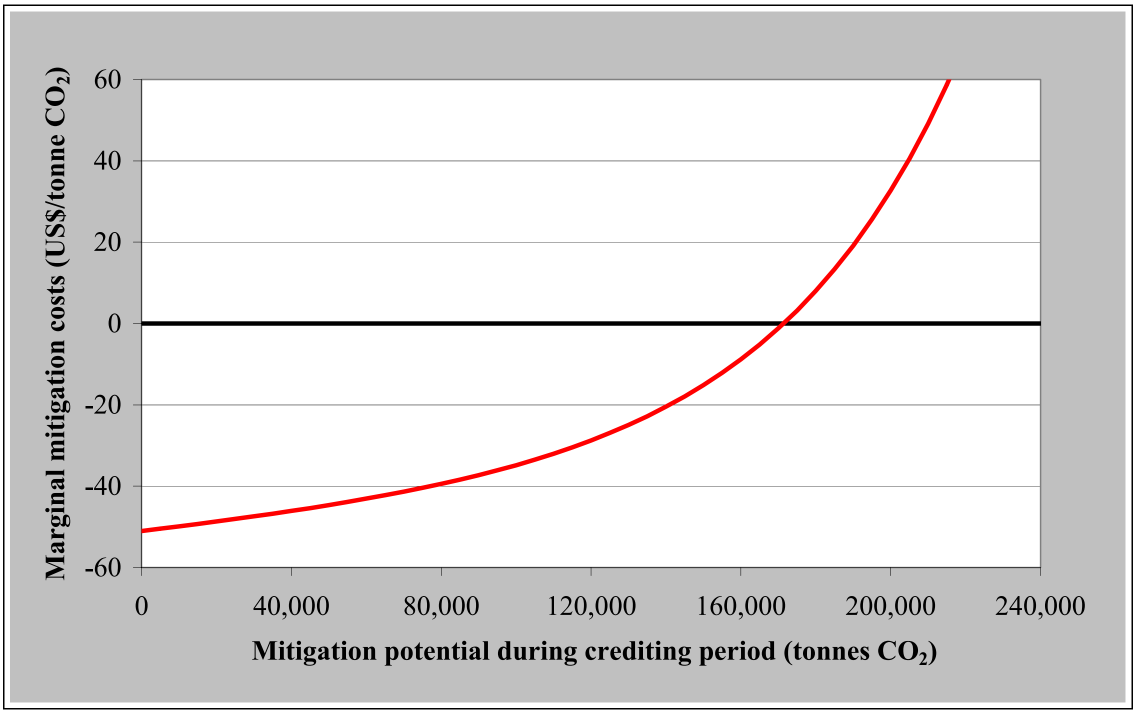
Currently, boilers in Peru are in many cases operated inappropriately. A detailed evaluation of about 80 boilers revealed that average energy efficiency is about 82%, and maintenance practices are often poor. In many cases, relatively simple control technology, such as automatic excess air control systems, is not installed. The average age of boilers in Peru is 21 years, with individual boilers operating up to 70 years. Generally, there is an enormous need for modernization. It appears, however, that energy efficiency could be increased significantly in many boilers through the application of "good housekeeping" measures, the installation of additional equipment or the replacement of burners or boilers. These measures are in many cases cost-efficient, though they are not implemented due to existing barriers.

Emissions from industrial boilers in Peru are an important source of greenhouse gases and other important air pollutants. Carbon dioxide emissions from industrial boilers are estimated to amount to about 4 million tonnes per year, which correspond to about 50% of emissions in Peru's productive sector of. Sulphur dioxide emissions come mainly from the combustion of residual oils and, at about 26,000 tonnes per year, are also significant.

Potential and costs of GHG emission reductions are estimated with the help of a detailed model, using a combined bottom-up and top-down approach. A representative sample group of about 40 boilers is selected and several options to increase energy efficiency are assessed for each boiler. For each option, mitigation costs are calculated, 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, since application of good housekeeping activities are not considered to be additional.

The calculated results of the sample group are extrapolated to the Peruvian national level, considering several restricting factors and barriers, such as the size, age and efficiency of the boilers, the willingness of companies to participate in such a CDM project and the ability of companies to access capital. As a result, an overall marginal GHG mitigation cost curve of the project is approximated, which allows estimation of the feasible potential of the project (see Figure 2).

Figure 2: Marginal mitigation cost curve of the CDM boiler project



Source: Calculations by Öko-Institut

The figure shows that GHG mitigation costs of most of the proposed measures to improve energy efficiency are negative, which means that these measures can be implemented without additional economic cost. There are, however, several barriers that hinder their actual implementation. The project intends to overcome those barriers by applying different strategies including technical assistance, capacity building and special credit lines to facilitate access to capital. In this respect, GHG emission reductions associated with investments in the improvement of energy efficiency are assumed to be additional. It is also important to mention, that calculations in this study have been made using conservative underlying assumptions in order not to overestimate emission reductions.

Assuming a price of about 5 US$ per tonne of carbon dioxide, the **economic potential** of the project amounts to about **165,000 tonnes of CO_2** during the crediting period of the project. Another 225,000 tonnes of CO_2 can be reduced by implementation of good housekeeping activities. These estimates include the diffusion of Camisea natural gas in the Lima region. Table 1 summarizes the main results.

Table 1: 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 mitigation		
CDM measures	tonnes/a	25,396
Good housekeeping	tonnes/a	35,209
Total	tonnes/a	60,605
Average annual energy savings		
CDM measures	GJ/a	335,278
Good housekeeping	GJ/a	463,536
Total	GJ/a	798,814
CO_2 mitigation during crediting period		
CDM measures	tonnes	**170,638**
Good housekeeping	tonnes	231,566
Total	tonnes	402,204
CO_2 mitigation during crediting period (with Camisea gas)		
CDM measures	tonnes	**166,188**
Good housekeeping	tonnes	225,528
Total	tonnes	391,716

Source: Own calculations

Even though this potential is clearly smaller than that of huge CDM projects (hydro-power-plant projects, for example), it seems sufficient to place the project in the future CDM market. With an assumed price of US$ 5 per tonne of CO_2 and excluding good housekeeping measures, an income of approximately US$ 850,000 could be generated from project activities. However, the global economic performance of the project can only be fully assessed after all costs and proceeds have been analysed in a business plan.

The implementation of the project is associated with **uncertainties** and certain **risks**. The main uncertainty has to do with the transaction costs of the project and the amount and size of the boilers that would participate in the project. A careful assessment of all transaction costs, on the basis of this study, will surely be crucial to assess the minimum required number of companies, and to select those boilers with the highest emission reduction potential. It is recommended that pre-contracts or letters of intent be concluded with a number of companies already in an early phase of project implementation.

This study also develops a detailed **baseline methodology** and a **monitoring plan**. Estimation of the baseline level of energy efficiency and monitoring of energy efficiency improvements are key factors for the environmental integrity of the project. Several approaches for the determination of the baseline level are analysed, of which the continuation of the current situation seems most appropriate. Energy efficiency appears to vary significantly between boilers, independent of size and age. For that reason, application of a standardized baseline level for all boilers is not possible. It is proposed to measure energy efficiency for each boiler prior to 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.

It is proposed to limit the overall **crediting period** of the project to ten years. The crediting period of single boilers varies, depending on the type and technical lifetime of measures applied. In order to avoid implementation of business-as-usual as part of the CDM project, eligibility criteria for the participation of boilers are elaborated.

Monitoring will be conducted by the project managing institution, or a subcontractor. As a part of monitoring, data on fuel consumption and energy efficiency needs to be collected. Information on fuel consumption will be provided by companies and checked for consistency. After implementation of the improvement measures, energy efficiency will be measured for each boiler once and in regular intervals thereafter for a sample group. Correct and accurate measurement of energy efficiency will be crucial for the whole monitoring process. It appears that there are still some difficulties in accurately measuring energy efficiency in Peru. Therefore, special attention should be given to the technical capacity of the institution responsible for monitoring and calculating emission reductions.

Considering difficulties in the measurement of energy efficiency and the still unknown magnitude of the transaction costs, a viable option will be to implement the project without using the CDM. This will considerably facilitate project management and reduce transaction costs, in particular those related to monitoring requirements and other costs inherent to the CDM project cycle. The option of doing without the CDM should be objectively compared with the CDM option. Related costs and opportunities for each option should be carefully assessed in the further process.

In summary, project implementation seems feasible, viable and promising, especially due to the great benefits for small and medium companies and the project's contribution to the sustainable development of the country.

This study sets out the proposed steps to assess the final viability of the project and to get it started:

1. The **project managing institution** has to be founded, and responsibilities need to be assigned clearly among the institutions involved.
2. A sound **business plan** for the project has to be elaborated, including both options, implementation with and without CDM.
3. **Acquisition of companies.** Prior to negotiations with donors and banks, it is suggested that promising companies be contacted with a view to signing **letters of intent** or **preliminary contracts.**
4. Negotiations with donors, banks and purchasers of CERs on the establishment of a special credit line with favourable interest rates and facilitated access to capital.

Finally, after completion of previously mentioned steps and a positive evaluation of the opportunities as a CDM project, the necessary steps for the **approval of the CDM project by the Executive Board** can be undertaken.

Content

1 INTRODUCTION 13

2 CLIMATE CHANGE AND CLEAN DEVELOPMENT MECHANISM 17

3 INSTITUTIONAL AND FINANCIAL CONCEPT 23

4 NATIONAL CONDITIONS FOR ENERGY EFFICIENCY IMPROVEMENTS IN INDUSTRIAL BOILERS 33

5 CHARACTERISTICS OF INDUSTRIAL BOILERS IN PERU 53

6 EVALUATION OF TECHNOLOGICAL OPTIONS FOR THE MITIGATION OF CO2 71

7 EMISSION SOURCES AND CDM PROJECT BOUNDARY 81

8 CURRENT EMISSIONS OF INDUSTRIAL BOILERS IN PERU 87

9 BASELINE METHODOLOGY 105

10 MONITORING PLAN 129

11 POTENTIAL AND ABATEMENT COSTS OF THE CDM PROJECT 149

12 EVALUATION AND RISK MANAGEMENT 165

13 PROJECT CONTRIBUTION TO SUSTAINABLE DEVELOPMENT 173

14 CONCLUSIONS 179

REFERENCES 183

Table of Contents

1 INTRODUCTION 13

2 CLIMATE CHANGE AND CLEAN DEVELOPMENT MECHANISM 17

2.1 Climate change 17

2.2 International negotiations on climate change and CDM 17

2.3 CDM Modalities and Procedures 18

2.3.1 Role of the Conference of Parties serving as the meeting of the Parties to the Kyoto Protocol (COP/MOP) 18

2.3.2 The Executive Board 19

2.3.3 The CDM project cycle 19

2.4 The Peruvian approval procedure 21

3 INSTITUTIONAL AND FINANCIAL CONCEPT 23

3.1 General institutional framework 23

3.2 Project managing institution (PMI) 25

3.3 Identification of tasks and responsibilities 25

3.4 Credit programme design 31

4 NATIONAL CONDITIONS FOR ENERGY EFFICIENCY IMPROVEMENTS IN INDUSTRIAL BOILERS 33

4.1 Reform projects in the energy sector 33

4.1.1 Policy regarding fossil fuel taxation 33

4.1.2 Privatization process 34

4.1.3 Energy efficiency 35

4.1.4 Promotion of renewable energy 35

4.2 Adopted and planned legislation 35

4.2.1 Efficient energy use 35

4.2.2 Air pollution 36

4.3 The Camisea Gas Project 37

4.3.1 Background of the Project 37

4.3.2 Gas Exploitation 38
4.3.3 Hydrocarbon transportation 38
4.3.4 Current project progress 39
4.3.5 The gas market 40
4.3.6 Impact of Camisea gas on the industrial boiler sectors 42
4.3.7 Barriers to the introduction of natural gas 43
4.3.8 Installation cost of natural gas in the residential, commercial and industrial markets 45

4.4 Financial situation in the country 46

4.5 Current economic situation of relevant sectors with boilers 46
4.5.1 Fishing industry 46
4.5.2 Textile Industry 46
4.5.3 Beer subsector 47

4.6 Financial barriers to innovation in Peruvian industry 47

4.7 Climate 50

5 CHARACTERISTICS OF INDUSTRIAL BOILERS IN PERU 53

5.1 Introduction 53

5.2 Technology 54
5.2.1 Power 54
5.2.2 Burner 55
5.2.3 Controls 55
5.2.4 Fuel 56
5.2.5 Instruments 56
5.2.6 Blowdowns 57
5.2.7 Thermal insulation 57
5.2.8 Age 57
5.2.9 Brands 58

5.3 Boiler operation 58
5.3.1 Operation 59
5.3.2 Fuel consumption 60
5.3.3 Vapour generation 60
5.3.4 Load factor 60
5.3.5 Sectors 61
5.3.6 Location 61
5.3.7 Maintenance 61
5.3.8 Shutdown and start-up times 64

5.4 Energy efficiency 65
5.4.1 Methodology for the determination of energy efficiency 65
5.4.2 Energy efficiency in Peruvian boilers 67

5.5 Auxiliary services 69
5.5.1 Water treatment 69
5.5.2 Fuel preparation 70

5.6 Vapour distribution and condensate return 70

6 EVALUATION OF TECHNOLOGICAL OPTIONS FOR THE MITIGATION OF CO2 71

6.1 Boiler replacement 71

6.2 Options to improve energy efficiency 72
6.2.1 “Housekeeping” measures 72
6.2.2 Investment measures to improve energy efficiency 74

7 EMISSION SOURCES AND CDM PROJECT BOUNDARY 81

7.1 Principles for determining the project boundary 81

7.2 Emission sources 81

7.3 Direct on-site emissions 83

7.4 Direct off-site emissions 83
7.4.1 Emissions in the fuel supply chain 83
7.4.2 Electrical generation 84

7.5 Conclusion 85

8 CURRENT EMISSIONS OF INDUSTRIAL BOILERS IN PERU 87

8.1 Characteristics of combustion in boilers 87

8.2 Methodology 87
8.2.1 CO_2 Emissions 87
8.2.2 SO_2, NO_X and CO Emissions 88

8.3 Fuel consumption in Peru 89
8.3.1 Peruvian fuel consumption 89
8.3.2 Peruvian industry fuel consumption 89
8.3.3 Fuel oil demand and GDP 90

8.3.4 Fuel demand trends....90

8.4 Fuel consumption of industrial boilers in Peru 92
8.4.1 Results of the National Boiler Survey....92
8.4.2 Projection of fuel consumption and number of boilers 93

8.5 Emission factors....99
8.5.1 Carbon dioxide emission factors 101
8.5.2 Carbon monoxide emission factors 102
8.5.3 Sulphur dioxide emission factors 103
8.5.4 Nitrogen oxides emission factors 103

8.6 Emission estimates....104

9 BASELINE METHODOLOGY....105

9.1 General approach 105

9.2 Disaggregation of baseline into activity level and emission factor....105
9.2.1 Activity level 106
9.2.2 Emission factor....107

9.3 A dynamic baseline approach....109

9.4 Bundling many boilers into one CDM project....110

9.5 Baseline aggregation level....111

9.6 Methodological Approaches in the Marrakech Accord....112

9.7 Options for baseline energy efficiency....113
9.7.1 Option 1: actual energy efficiency 113
9.7.2 Option 2: Decreasing energy efficiency....114
9.7.3 Option 3: Energy efficiency of a reference technology....115
9.7.4 Selection of baseline approach 116

9.8 Impact of the Camisea gas project on baseline and project emissions 117

9.9 Additionality 118
9.9.1 Treatment of good housekeeping activities....119
9.9.2 Windfall effects in bundled projects....120
9.9.3 Eligibility criteria for participation....121

9.10 Crediting period....122
9.10.1 Classification of energy efficiency improvement measures....122

9.10.2 Rules for the determination of boiler-specific crediting periods............124
9.10.3 Overall project crediting period 126

9.11 Leakage effects...127

10 MONITORING PLAN 129

10.1 Multi-project monitoring and verification..129

10.2 Methodological Approach..131

10.3 Energy Efficiency...132
10.3.1 Technical standards 132
10.3.2 Energy balance method and input-output method....................................133
10.3.3 Influence of load factor and maintenance activities on energy efficiency136
10.3.4 Two-track approach in the case of Peruvian boilers 137
10.3.5 Special case: Monitoring of energy efficiency enhancement from measures related to boiler blowdown and boiler insulation....................................138
10.3.6 Uncertainty in the determination of energy efficiency............................139

10.4 Fuel consumption...140

10.5 Fuel type 141

10.6 Execution of measurements...141

10.7 Calculation of emission reductions 143
10.7.1 Project emissions 143
10.7.2 Baseline emissions..143
10.7.3 Emission reductions..144

10.8 Quality assurance and quality control procedures............................145
10.8.1 Energy efficiency...145
10.8.2 Fuel consumption and fuel type 145

10.9 Leakage effects..146

10.10 Overview of the process of boiler baseline determination, monitoring and certification 146

11 POTENTIAL AND ABATEMENT COSTS OF THE CDM PROJECT 149

11.1 Methodological approach 149
11.1.1 Assessment of energy efficiency improvement options...........................149
11.1.2 Calculation of marginal CO_2 mitigation costs..150

11.2 Key economic factors of influence ... 151
11.2.1 Fuel prices ... 151
11.2.2 Capital costs ... 153
11.2.3 Technical and economic life of investments ... 156

11.3 Potential and mitigation costs: sample group ... 157
11.3.1 Selection of the sample group ... 157
11.3.2 Evaluation of boilers ... 157

11.4 Potential and mitigation costs: CDM boiler project ... 160

11.5 Certified emission reductions (CERs) ... 163

11.6 Conclusions ... 164

12 EVALUATION AND RISK MANAGEMENT ... 165

12.1 Risks in the project development phase ... 165

12.2 Risks during the project elaboration phase ... 166

12.3 Risks during project operation ... 167

12.4 Risks during the CERs trading phase ... 168

12.5 Risk matrix ... 169

13 PROJECT CONTRIBUTION TO SUSTAINABLE DEVELOPMENT ... 173

14 CONCLUSIONS ... 179

REFERENCES ... 183

List of Tables

TABLE 1: SUMMARY OF TASKS AND PROPOSED RESPONSIBILITIES 29
TABLE 2: PROFILE OF THE ENTITIES RESPONSIBLE FOR THE TASKS 31
TABLE 3: EVOLUTION OF FOSSIL FUEL TAXATION, 1990-1999 (US$ PER GALLON)..... 34
TABLE 4: PROVEN GAS RESERVES IN THE CAMISEA AREA (PERU) 37
TABLE 5: TOTAL INDUSTRIAL CONSUMPTION 40
TABLE 6: PENETRATION RATES RELATED TO THE INDUSTRIAL MARKET CONSUMPTION LEVEL 40
TABLE 7: THE INDUSTRIAL MARKET ACCORDING TO HYDRO QUEBEC INTERNATIONAL HQI (TJ/YEAR) 41
TABLE 8: INDUSTRIAL MARKET CONVERTIBLE TO NATURAL GAS: 2004 – 2010 (TJ/YEAR) 41
TABLE 9: COMPARISON OF RESULTS RELATED TO THE POTENTIAL INDUSTRIAL MARKET 42
TABLE 10: FUEL CONSUMPTION OF BOILERS 43
TABLE 11: FUEL CONSUMPTION OF BOILERS CONVERTIBLE TO GAS (LIMA) 43
TABLE 12: COSTS OF DUAL BURNERS 45
TABLE 13: FINANCIAL AND NON-FINANCIAL BARRIERS TO ACCESS TO CAPITAL FOR SMEs IN PERU 50
TABLE 14: CHARACTERISTICS REPRESENTATIVE OF BOILERS 54
TABLE 15: AVERAGE POWER OF BOILERS FOR DIFFERENT FUELS 54
TABLE 16: INSTALLED CAPACITY OF BOILERS ACCORDING TO TYPE OF FUEL 56
TABLE 17: AGE OF BOILERS 58
TABLE 18: OPERATION OF BOILERS 59
TABLE 19: MAINTENANCE ACCORDING TO THE NATIONAL SURVEY ON BOILERS 63
TABLE 20: ENERGY EFFICIENCY IN PERUVIAN BOILERS 67
TABLE 21: REFERENTIAL COSTS OF STEAM BOILERS 71
TABLE 22: INVESTMENT COSTS FOR AUTOMATIC EXCESS-AIR CONTROL SYSTEMS 76
TABLE 23: INVESTMENT COSTS FOR AUTOMATIC BLOWDOWN CONTROL 77
TABLE 24: INVESTMENT COSTS FOR DUAL BURNERS 79
TABLE 25: INVESTMENT COSTS FOR ECONOMIZERS 79
TABLE 26: GENERAL RESULTS OF THE NATIONAL SURVEY ON BOILERS 93
TABLE 27: LOWER HEATING VALUE (LHV) AND SPECIFIC GRAVITY OF FUELS 94
TABLE 28: ESTIMATION OF FUEL CONSUMPTION, NUMBER OF BOILERS AND BOILER CAPACITY IN MANUFACTURING COMPANIES 96
TABLE 29: ESTIMATION OF FUEL CONSUMPTION, NUMBER OF BOILERS AND THEIR CORRESPONDING BOILER CAPACITY IN FISH PROCESSING COMPANIES 97
TABLE 30: TOTAL ESTIMATION IN MANUFACTURING AND FISH PROCESSING COMPANIES 97
TABLE 31: CONSUMPTION OF FUELS IN THE PRODUCTIVE SECTOR IN 1999 98
TABLE 32: NUMBER OF COMPANIES AND STEAM BOILERS IN THE PRODUCTIVE SECTOR 99

TABLE 33: EMISSION FACTORS PROPOSED BY EPA FOR DIFFERENT FUELS FOR INDUSTRIAL BOILERS WITH A CAPACITY BELOW 3000 BHP (29,400 MW) 100
TABLE 34: EMISSION FACTORS APPLIED TO PERUVIAN BOILERS.................................. 100
TABLE 35: PROPOSED EMISSION FACTORS FOR CARBON MONOXIDE (CO)................... 102
TABLE 36: SULPHUR CONTENT OF PERUVIAN FUELS FOR INDUSTRIAL BOILERS 103
TABLE 37: EMISSIONS OF INDUSTRIAL BOILERS IN PERU IN 1999................................ 104
TABLE 38: AGGREGATION LEVEL OF DATA COLLECTION AND CALCULATIONS............ 112
TABLE 39: ELIGIBILITY CRITERIA FOR REPLACEMENT OF EQUIPMENT OR BOILERS...... 121
TABLE 40: TECHNICAL LIFETIME AND CLASSIFICATION OF MEASURES TO IMPROVE ENERGY EFFICIENCY IN PERU.. 123
TABLE 41: ADVANTAGES AND DISADVANTAGES OF ENERGY BALANCE METHOD AND INPUT-OUTPUT METHOD.. 135
TABLE 42: EQUIPMENT TYPICALLY USED IN PERU FOR THE MEASUREMENT OF ENERGY EFFICIENCY WITH THE INPUT-OUTPUT METHOD............................ 139
TABLE 43: EQUIPMENT TYPICALLY USED IN PERU FOR THE MEASUREMENT OF ENERGY EFFICIENCY WITH THE ENERGY BALANCE METHOD....................... 140
TABLE 44: PROJECTION OF CRUDE OIL PRICES AND OIL DERIVATES SOLD IN PERU (US$/BBL) 152
TABLE 45: ESTIMATED FUTURE FUEL PRICES IN PERU IN THE NATIONAL CURRENCY (SOLES).. 152
TABLE 46: ESTIMATED FUTURE FUEL PRICES IN PERU US$ 153
TABLE 47: CLASSIFICATION OF COMPANIES IN PERU... 153
TABLE 48: ESTIMATED CAPITAL DISCOUNT RATES AND INTEREST RATES FOR DIFFERENT FIRMS.. 155
TABLE 49: CAPITAL COSTS FOR DIFFERENT TYPES OF COMPANIES IN PERU 155
TABLE 50: THEORETICAL AND COST-EFFECTIVE GHG MITIGATION POTENTIAL OF THE SAMPLE GROUP 159
TABLE 51: POTENTIAL OF A CDM BOILER PROGRAMME IN PERU 163
TABLE 52: RISK MATRIX 170

List of Figures

Figure 1: The CDM project cycle ... 20
Figure 2: The Peruvian approval process for CDM projects ... 22
Figure 3: Institutional framework for the financing of investments in boilers ... 24
Figure 4: Financing problems in Peruvian industry ... 49
Figure 5: Annual fuel consumption according to the national survey on boilers ... 60
Figure 6: Number of boilers per sector ... 62
Figure 7: State of the combustion systems in 50 steam boilers ... 64
Figure 8: Energy efficiency of boilers according to age ... 68
Figure 9: Energy efficiency of boilers according to capacity ... 69
Figure 10: Automatic excess-air control system ... 75
Figure 11: Automatic blowdown control system ... 78
Figure 12: Energy consumption in Peru in the year 2000 ... 89
Figure 13: Energy consumption in the industrial sector ... 90
Figure 14: Development of GDP and oil consumption in Peru from 1990 to 2000 ... 91
Figure 15: Projected demand for different fuels in 2001 – 2010 in Peru without consideration of a fuel switch to natural gas ... 91
Figure 16: Projected demand for different fuels in 2001 – 2010 in Peru with consideration of a fuel switch to natural gas ... 92
Figure 17: Baseline with continuation of actual energy efficiency ... 114
Figure 18: Baseline with decreasing energy efficiency ... 115
Figure 19: Baseline with reference technology ... 116
Figure 20: Change of project and baseline emissions in case of fuel switch. 118
Figure 21: Crediting period of single boilers and overall project crediting period ... 126
Figure 22: Multi-project monitoring and verification ... 130
Figure 23: Energy balance and project boundaries of a boiler ... 133
Figure 24: Methodology for the calculation of marginal abatement costs ... 151
Figure 25: Marginal CO_2 abatement cost curve for the sample group of 43 boilers without consideration of measures to improve housekeeping ... 158
Figure 26: Marginal mitigation cost curve of the CDM boiler programme. 162
Figure 27: Generation of CERs during the ten-year overall crediting period ... 164

1 Introduction

This study aims at assessing the feasibility of a Clean Development Mechanism (CDM) project to improve energy efficiency in Peruvian industrial boilers. As part of this study, current emissions from boilers in Peru are estimated, and the potential and mitigation costs for energy efficiency improvements as a CDM project are assessed, including a detailed analysis of different baseline options and an initial monitoring plan. A key element is also the development of the institutional set-up of the project, which includes bundling many small boilers into one CDM project.

The idea for this project came from activities undertaken within the project designated "Development of the National Capacity for Projects on CDM Activities," sponsored by the United Nations Development Programme (UNDP) in 1998. While vapour production is one of the most energy-consuming processes, energy efficiency in industrial boilers is often quite low. Therefore, the potential for emission reductions through the improvement of energy efficiency in industrial boilers, either through their optimisation or replacement, was identified as an option for a project to be developed. Thus, UNDP enabled the National Environmental Council (CONAM) and the Ministry of Industry (MITINCI) to conduct a pre-feasibility study[1]. This study confirmed that industrial boilers are an important source of GHG emissions, which could be reduced through a CDM project.

The pre-feasibility study also stated that some of the proposed measures to improve energy efficiency could be profitable per se, that is, economically and financially viable. However, they were not undertaken by the private sector because of strong financial barriers that make access to capital difficult for companies, especially for small and medium-sized companies.

Therefore, the creation of a financing fund in combination with a CDM project was considered. This fund would enable most of the current financial barriers to be overcome, and encourage companies to implement measures to improve energy efficiency. At the same time, it would lead to energy savings, reduced production costs and reduced local contamination that notoriously affects people's health.

In order to develop a more comprehensive study, MITINCI collaborated with the main institutions and organizations from both the public and private sector and created the Peruvian CDM-Industry Commission. This Commission decided to carry out a national survey to obtain technical information on the number, location and operational characteristics of Peruvian boilers.

The mandatory survey, published in the official newspaper *El Peruano*, was responded to by more than 360 companies around the country, recording a total of 1,147 boilers, with an installed capacity of over 567,000 BHP (5,560 MW). The survey reached every

---

[1] Geng, Morales, Justo (1999)

location around the country where industrial boilers are operated, providing information on companies from 61 economic activities. With this information and the support of co-operation agreements signed with the *Andean Development Corporation* (CAF) and the *Deutsche Gesellschaft für Technische Zusammenarbeit* (GTZ / German Technical Co-operation GTZ), this study was set in motion. Two experts on boilers, a financial specialist and a study co-ordinator, were employed, who worked under the guidance and technical assistance of *Öko-Institut* (Institute for Applied Ecology) in Germany and the GTZ.

Even though the Industrial Boiler National Survey provided important information on the characteristics and some operational parameters of the 1,147 reported boilers, in some cases the information was inconsistent. Therefore, a verification process was performed on-site in order to collect more reliable information. The verification process was focused on energy efficiency measurements, operational parameters of boilers, and the identification of technical improvements to be implemented. These verification tasks were put in the hands of the Energy and Environmental Analysis Service (*Servicio de Análisis Energético y Ambiental - SAE*) of the *Pontificia Universidad Católica del Perú* (PUCP) in the case of 40 boilers in Lima, and the Centre for Energy and Environmental Conservation (*Centro de Conservación de Energía y del Ambiente - CENERGIA*) in the case of 40 boilers in the provinces. The results of these two on-site verification tasks provide the main support for this study.

The study is structured as follows: **Chapter 1** addresses the greenhouse effect issue that led to the establishment of the United Nations Framework Convention on Climate Change (UNFCCC), and later on, in 1997 to the adoption of the **Kyoto Protocol**. Results of international negotiations and agreements during the Seventh Conference of the Convention (COP7) in November 2001 in Marrakech[2] are discussed in this chapter, particularly those related to the **modalities and procedures for CDM.** In order to familiarize readers with the CDM criteria and rationale, the different stages of the CDM project cycle at an international level are described, along with the rapid procedure for approval of CDM projects established by CONAM at a national level.

The next step is to structure the institutional set-up and define the actors, their functions and their responsibilities, in order to provide the necessary organizational support for implementation of the different stages of the project. Thus, **Chapter 3** develops the **proposal for institutional implementation and project financing.** The proposed institutional framework shows the different steps of the CDM project cycle, the needs of a CDM project activity and the specific circumstances of the Peruvian boiler industry. Various models were initially considered, to determine the type of institution to be entrusted with the project. Finally, the creation of a project managing institution (PMI) is proposed, which will consist of one or more existing institutions organized as a consortium. This chapter also develops a proposal for a special credit programme to be man-

[2] Annex to decision 17/CP.7, contained in FCCC/CP/2001/13/Add.2

aged by a commercial bank, which would facilitate access to capital for participating companies.

Chapter 4 analyses the **national conditions for energy efficiency improvements** in Peru. Important factors, which may influence the proposed CDM project, are identified and described. This includes an analysis of relevant environmental initiatives and legislation in the energy sector, the financial situation of the relevant sectors and an assessment of barriers to innovation in energy efficiency in Peruvian industry. An important factor for the project is also the supply of natural gas from Camisea to the Lima region.

Chapter 5 describes in detail the **characteristics of the national boiler park** by assessing the results of the National Boiler Survey[3] and the measurements made on a sample group of boilers over several months during on-site checks. The purpose is to describe the current situation of Peruvian boilers, in particular with regard to energy efficiency as a critical factor on which the amount of emissions depends. This information, in turn, sets the grounds for establishing the project baseline.

Technological options to improve energy efficiency in industrial boilers are assessed in **Chapter 6**. This includes the replacement of boilers, the increase of energy efficiency through additional investments, for example, appropriate control technology or the replacement of burners, or the introduction of appropriate good housekeeping measures. Investment costs and energy efficiency improvements associated with each option are estimated.

As a first step towards establishment of the baseline, **Chapter 7** determines relevant **sources of emissions** and defines **the CDM project boundaries**. For the purpose of determining the project boundaries, direct on-site and off-site emission sources must be taken into account. It is not proposed to consider indirect effects.

On the basis of estimations of industrial boiler fuel consumption and emission factors, **Chapter 8 calculates the amount of emissions of industrial boilers in Peru.** It describes the methods and assumptions used to estimate the number of industrial boilers, the overall fuel consumption and the relevant emission factors. **The resulting emissions inventory** encompasses emissions of carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxides (NO_X), carbon monoxide (CO) and particulate matter.

Chapter 9 describes in detail the methodology for the **project baseline,** that is, the emissions that would take place in the absence of the project. The aim is to build up a scenario that shows the future development of emissions in the absence of the project. To do so, it is necessary to determine the three major influence factors: energy efficiency, vapour demand (level of activity) and fuel type. Different baseline options are analysed and the choice of a conservative approach is justified. The baseline methodology suggests a dynamic baseline, which is fixed only during project implementation, depending on the number and characteristics of the companies that will participate in the CDM project. Taking into account the special characteristics of a bundled project

3 MITINCI (2000)

activity, where several boilers are bundled into one CDM project, eligibility criteria for the participation of specific boilers in the CDM programme are suggested. The criterion of additionality is addressed by analysing the character of energy efficiency improvement measures and by assessing possible windfall effects. Finally, the crediting period of the project is defined and possible leakage effects are assessed.

Chapter 10 develops the **Monitoring Plan** according to CDM modalities and procedures. Monitoring of emission reductions requires special attention, since several boilers are bundled. The proper monitoring of energy efficiency improvements obtained through the project is crucial to guaranteeing environmental integrity of emission reductions. Therefore, this chapter also describes necessary measurements in different phases of project implementation, as well as the technical standards to be referred to and applied, considering their advantages and disadvantages.

Chapter 11 determines the **potential of certified reductions and overall GHG reduction costs**. These are estimated on the basis of a combined "bottom-up" and "top-down" proposal, which helps draw a marginal cost curve for GHG emission reduction. Project potential in terms of total capacity of the involved boilers, energy savings and mitigation of tonnes of CO_2 are calculated by way of this proposal. All these elements will finally determine the amount of certified emission reductions (CERs) generated during the project crediting period.

Chapter 12 includes an **assessment of risks as well as of measures to manage those risks**. In this chapter, economic, technical, environmental and institutional risks are identified and assessed in order to be able to achieve the estimated emission reductions. Additionally, a set of measures to manage and minimize risk effects is developed.

Chapter 13 explains the **project contribution to the sustainable development** of the country in relation to the National Agreement recently signed between the main sectors of Peruvian society. This is the framework for a set of state policies aiming at four main objectives: democracy and a constitutional state, equity and social justice, competitiveness and an efficient, transparent and decentralized state.

Finally, in the **conclusions** in **Chapter 14**, the opportunities and risks of the proposed bundled CDM project to increase energy efficiency in industrial boilers in Peru are assessed, and prerequisites for implementation of the project are identified.

2 Climate change and Clean Development Mechanism

2.1 Climate change

Climate change, which is mainly caused by anthropogenic emissions of greenhouse gases, is one of the most challenging environmental pressures. Combustion of fossil fuels is the main source of greenhouse gases. Increasing concentrations of greenhouse gases, accumulated over hundreds of years by developed countries as a result of their industrialization processes and consumption patterns, will significantly raise the temperature of the planet. Global mean temperature is forecast to increase by the end of the 21st century by 1.4 to 5.8 degrees centigrade above the level of 1990. This will result in an increase of sea level ranging from 9 to 88 centimetres (IPCC 2001). The impacts of this phenomenon on the economic and social conditions of several countries around the world will be quite severe.

According to preliminary studies, conducted by the National Environmental Council (CONAM)[1], on the country's vulnerability to climate change, Peru would be potentially vulnerable in two ways. Firstly, the effect on glacial areas and their respective water resources, and secondly, the impacts of the Niño phenomenon on the Peruvian marine ecosystem, the public health system, agriculture and infrastructure. The impacts of the Niño phenomenon over the past decades have already been proven by an inventory[2], which shows a drastic reduction in glacial areas with a clear increase in the negative balance over the past 15 years. This is why the country should direct its attention to the global climate change issue and undertake measures to slow down the warming process induced by human activities.

2.2 International negotiations on climate change and CDM

The importance of this issue led, firstly, to the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, and, secondly, to the Kyoto Protocol in 1997. The Kyoto Protocol aims at reducing overall GHG emissions by 5.2%, compared with 1990 levels, in the commitment period 2008 to 2012 in developed countries and countries with economies in transition included in Annex I of the Convention.

For this purpose, the Kyoto Protocol proposes three flexible mechanisms. *Emissions trading* and *joint implementation* among Annex I Parties, and the *Clean Development Mechanism (CDM)* among Annex I Parties and developing countries.

1 First Peruvian National Communication to the United Nations Convention on Climate Change, June 2001

2 Results obtained in the inventory of glacial surfaces and mass balance made as part of the Peruvian National Communication.

Through CDM (Article 12, Kyoto Protocol), industrialized countries (Annex I Parties) can develop emission reduction projects in developing countries (non-Annex I Parties) as a way to comply with part of their reduction commitments. Thus, Annex I Parties can invest in emission reduction projects in non-Annex I Parties and generate Certified Emission Reductions (CERs) that they can use to meet their reduction commitments. The purpose of CDM is to assist developing countries in achieving sustainable development, and to assist Annex I countries in reducing the implementation costs for their commitments. In many cases, it seems economically more convenient to reduce GHG emissions in developing countries than Annex I Parties. Thus, Parties included in Annex I will benefit from GHG emission reduction at a lower cost, and developing countries will benefit from investments in emission reductions with a likely positive economic, social and environmental impact, which will contribute to sustainable development.

According to Article 12 of the Kyoto Protocol, CDM projects have to contribute to the sustainable development of the host country and generate real, measurable, long-term emission reductions that are additional to any that would occur in the absence of the project (additionality).

This premise enables Peru to participate in projects under the CDM. For this purpose, the Committee for Clean Development Mechanism in Peruvian Industry was created. This Committee is led by the DNI-MITINCI and comprises CONAM, FONAM, SNI, APFCC, UNI, PUCP, PAE, and CENERGIA. It aims at promoting and supporting clean production in the industrial sector within the scope of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol.

2.3 CDM Modalities and Procedures

The Kyoto Protocol provides the general framework for the CDM. More detailed guidance was provided in the Marrakech Accords agreed during the Seventh Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in November 2001 in Marrakech. In the Annex to decision 17/CP.7[3], the modalities and procedures for the CDM give detailed guidance on the whole CDM process.

2.3.1 Role of the Conference of Parties serving as the meeting of the Parties to the Kyoto Protocol (COP/MOP)

The maximum authority on CDM is the Conference of Parties serving as the meeting of the Parties to the Kyoto Protocol (COP/MOP). The COP/MOP provides guidance to the Executive Board for the CDM by taking relevant decisions on the recommendations made by the Board in its Annual Report. Furthermore, the COP/MOP designates operational entities accredited by the Executive Board, examining their regional and sub-regional distribution. The COP/MOP also helps raise funds for CDM project activities.

[3] FCCC/CP/2001/13/Add.2

2.3.2 The Executive Board

The Executive Board for the CDM comprises ten members from Parties to the Kyoto Protocol. It **supervises the CDM** on the authority and under the guidance of the COP/MOP, approves CDM projects and may also develop and propose methodological guidance to the COP/MOP, for example relating to baseline methodologies or simplified procedures for small-scale CDM projects. It is also responsible for the accreditation of operational entities.

2.3.3 The CDM project cycle

The overall CDM project cycle is illustrated in Figure 1. As a first step, project participants have to develop the CDM project, which usually involves an assessment of the project potential, mitigation costs and associated risks. A baseline reflecting emissions in the absence of the project needs to be established, along with a monitoring plan providing for the procedures and arrangements for measurements and calculations of emission reductions. The environmental impact of the project and the contribution to sustainable development need to be assessed. The final project proposal is presented in a Project Design Document (PDD).

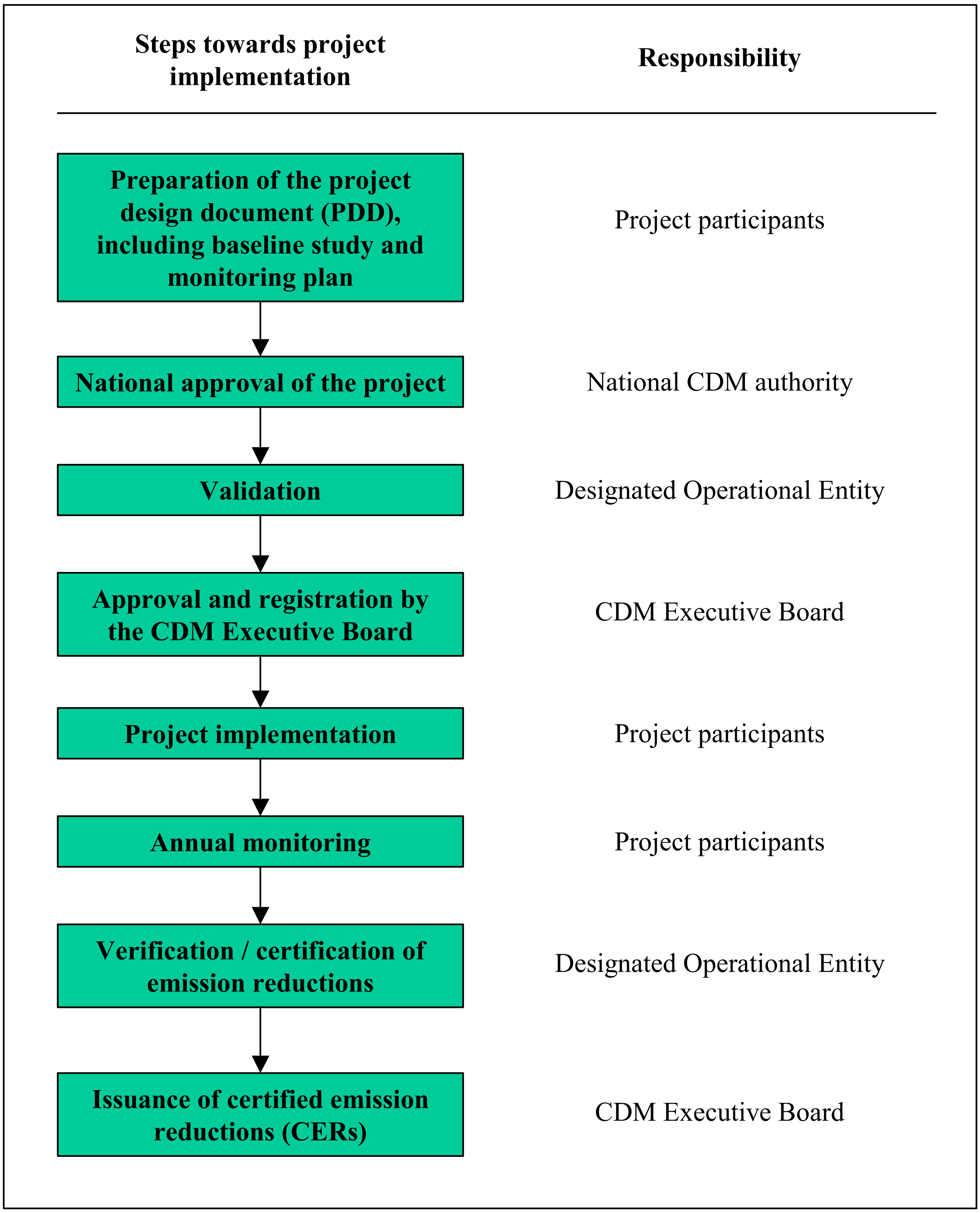
After approval of the project by the government of the host country, an independent operational entity decides whether the project proposal is in accordance with the modalities and procedures for the CDM as set out in the Annex to decision 17/CP.7 (validation). Independent operational entities are independent companies or institutions, which need to be accredited by the Executive Board.

The designated operational entity will inform the project participants of its decision on the validation of the project activity. If the proposed project activity is deemed valid, the operation entity will submit a request for registration to the Executive Board in the form of a validation report including all project information. This validation report will be made available to the public upon transmission to the Executive Board.

The Executive Board takes the final decision on the project's approval (registration). Usually, registration by the Executive Board will be deemed final eight weeks after the date of receipt by the Executive Board of the request for registration.

After registration by the Executive Board, the project can be implemented. After project implementation, the achieved emission reductions need to be monitored (monitoring). Actual emissions are measured and/or calculated and compared with baseline emissions. The difference between project emissions and baseline emissions are achieved emission reductions attributable to the project activity. Project participants need to follow the methodology in the monitoring plan approved by the Executive Board upon registration. Emission reductions are monitored at regular intervals (for example, annually).

Figure 1: The CDM project cycle



Source: Öko-Institut

Finally, verification is a periodic independent review and *ex post* determination by the designated operational entity of GHG emission reductions that have occurred as a result of the project activity during the verification period. Certification is the written assurance by the designated operational entity that, during a specified period of time, a project activity achieved the verified GHG emission reductions. The designated operational entity contracted by project participants to perform verification will inform them of its decision in writing immediately upon completion of the certification process and make the certification report available to the public.

The certification report by the designated operational entity is to be submitted to the Executive Board and will constitute a request for issuance of CERs equal to the verified amount of GHG emission reductions.

On being instructed by the Executive Board to issue CERs for a CDM project activity, the **CDM registry administrator will promptly issue the specified quantity of CERs** to the account of the Executive Board in the CDM registry. Upon such issuance, the CDM registry administrator will then

a) set aside 2% of CERs for the purpose of covering administrative expenses and assisting developing countries in meeting costs of adaptation[4], and

b) forward the remaining CERs to the registry accounts of Parties and project participants, as requested.

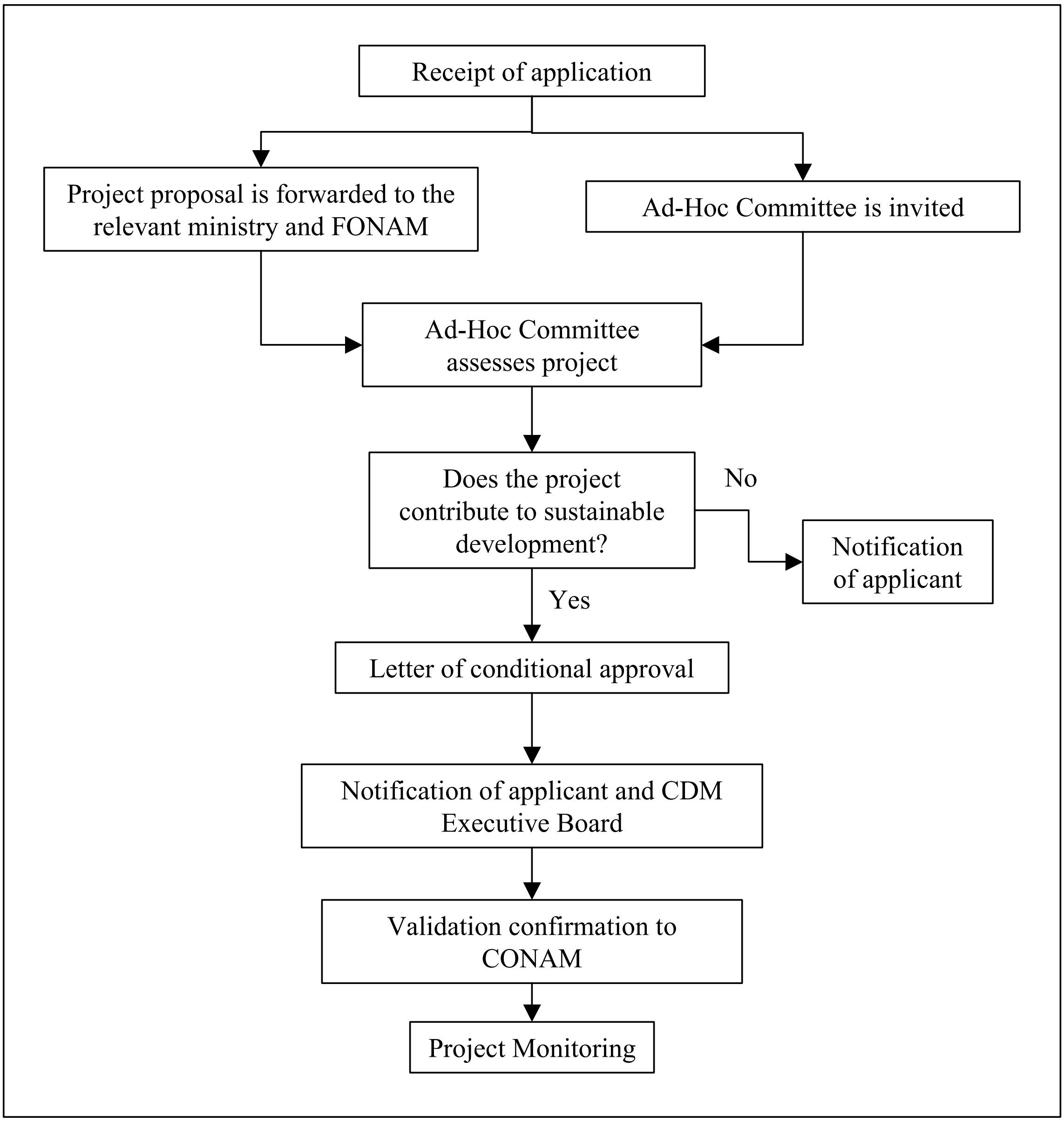
2.4 The Peruvian approval procedure

In Peru, a procedure for government approval of the proposed CDM projects has been established by CONAM (National Environmental Council) in the document "*Procedure for Rapid Evaluation of Clean Development Mechanism Projects "CDM"(CONAM-P-34 27 – 12 01)*"[5]. The different steps of the Peruvian approval procedure are illustrated in Figure 2 on the next page.

4 Such adaptation aid is administered in a fund,which has been set up for this purpose.

5 See at www.conam.gob.pe

Figure 2: The Peruvian approval process for CDM projects



Source: CONAM-P-34 27 –12 01(CONAM´s web page).

3 Institutional and financial concept

This chapter contains a proposal for institutional implementation and the financing of investments in boilers. The institutional framework should reflect the different steps of the CDM project cycle, as described in Chapter 1, as well as the needs emerging from a CDM project that bundles several small units. The institutional framework should also consider the specific circumstances of the Peruvian boiler industry.

An Energy Service Company (ESCO) was considered among the options regarding the institution to carry out the project. The main advantage of ESCOs is that these companies are highly specialized and have qualified technical personnel. However, this option was discarded, since Peru does not have a specific regulation in this respect or any companies currently operating as ESCOs. Moreover, CENERGIA, the company interested in creating an ESCO, does not have the necessary financial resources.

In the year 2000, the International Finance Corporation (IFC) and the Global Environmental Facility (GEF) launched an initiative with an important energy operator, expecting that it would operate as an ESCO and promote energy efficiency in Peru. This initiative was unsuccessful, because the proposed company, which had the economic and technological capacity to be an ESCO, had a conflict of interests. Given that the proposed company is an energy supplier in an oligopolistic market, the energy efficiency programme would have represented a reduction in its potential sales volume, which would indicate failure on the part of this private company.

A neutral institution is therefore needed; an institution that plays the role of an energy efficiency promoter and does not have a vested interest in the projects. The creation of a **project managing institution (PMI)** was thus proposed. The PMI would comprise one or more existing institutions, and operate as a consortium.

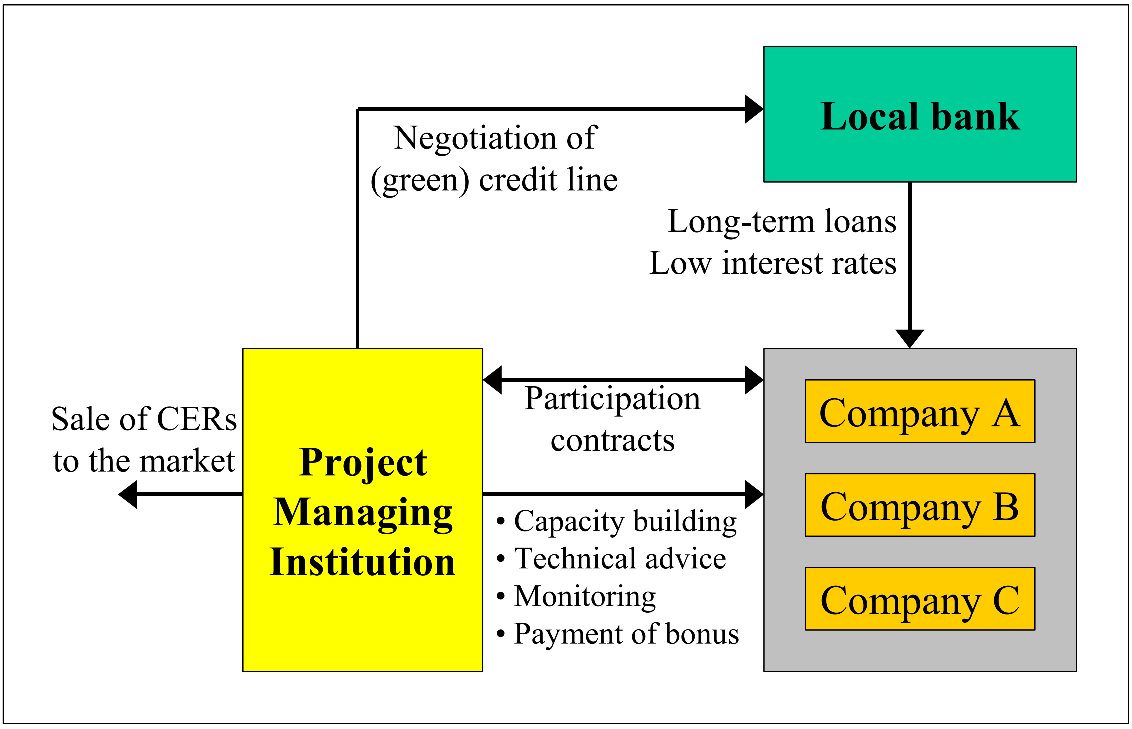
3.1 General institutional framework

The proposed institutional framework for investment financing is shown in Figure 3. The projects should be operated and managed by the project managing institution (PMI). This institution has general responsibility for the project, including economic opportunities and risks. Unlike a "contractor" or an ESCO, the PMI does not invest directly in the improvement of energy efficiency or the replacement of boilers in companies, but provides the necessary framework for such investments. The PMI should collect payments from co-operating sources in order to meet initial operating costs and carbon transaction costs during the pre-operating stage.

A key element of the proposed option is a **special credit programme** run by a commercial bank. With this special credit programme, access to capital for participating companies is facilitated through relatively low interest rates and lower transaction costs. The PMI should negotiate with local – and international – banks the conditions for this special credit programme. Interested companies have access to the credit programme through a **participation contract** with the PMI.

The PMI provides technical assistance to companies in the improvement of energy efficiency, including capacity building for technical staff. In the participation contract, the companies undertake to finance efficiency measures or the replacement of boilers by way of loans. In doing so, they follow the technical advice of the PMI.

Figure 3: Institutional framework for the financing of investments in boilers



Source: Finanzas Ambientales, Öko-Institut

After implementation of the measures, the PMI will be responsible for monitoring emission reductions and certification through an independent operational entity. In the participation contract, the companies undertake to provide the necessary information and assign the right to future certified emission reductions (CERs) to the PMI. In exchange, the PMI pays a *bonus* to the companies if they maintain a high level of energy efficiency. This bonus should be an additional incentive to participate in the CDM programme. The PMI finances the bonuses with future sales of the CERs.

The figure shows the functionality of the bundling scheme. This scheme allows companies without access to credit on the local finance market to benefit from income coming from global carbon markets under an alternative ownership scheme. All being companies under the bundling scheme, the presentation of CDM projects is strengthened and becomes more competitive, thus eliminating the atomicity of projects and legal ownership problems that increase transaction costs.

3.2 Project managing institution (PMI)

The PMI has different roles and responsibilities, as described above. This company, or institution, not only develops and manages projects; it also contributes capital, takes profits and assumes associated risks. The PMI is responsible for the entire co-ordination of the project. The PMI acts as an intermediary between the markets and companies characterized by their inability to cover their transaction costs. Barriers are thus eliminated and costs minimized, opening the markets to those companies, which would not otherwise have access to the carbon market. The activities involved are numerous and the type of project is new. For this reason it is proposed that the PMI be a consortium comprising several institutions with diverse know-how in Peru.

It is suggested that the PMI be appointed by the National Environmental Fund (FONAM) and the Ministry of Industry, Tourism, Integration and International Trade Negotiations (MITINCI), two government entities with complementary financial and industrial roles.

The proposal establishes that the PMI is a consortium formed for a specific-purpose, whose earnings comprise:

a) CERs that have been assigned to the PMI,

b) payments received from co-operating sources, and

c) contributions from each member of the PMI.

The CERs will be sold to a broker, a bank or the government of an Annex I country, which will provide a flow of income proportional to the sold CERs, the proceeds of which will be used for:

a) the payment of efficiency bonuses to the participating companies, and

b) the transaction costs of the project (including, for example, technical assistance, costs for the generation of CERs – including transaction costs of the project design document, validation, monitoring, etc. – and negotiation of CERs). The exact amount corresponding to each part will be stated in the PMI's business plan.

3.3 Identification of tasks and responsibilities

From another perspective, and in more detail, the project managing institution might co-ordinate the following activities based on this feasibility study:

Pre-operation stage:

- Preparation of the project's business plan.
- Negotiation of a special credit line with the banks.
- Diffusion of the project and involvement of companies, as well as the conclusion of pre-contracts with participating companies.

- Elaboration of the Project Design Document (PDD), including the Baseline Study and the Monitoring Plan.
- Registration in the CDM office in Peru, invitation for public comments and request to CONAM for approval of the project.
- Negotiation with donors on their contribution to the programme.
- Negotiation with the Public Treasury.
- Contracting an operational entity, which validates the project.
- Registration by the Executive Board for the CDM.

Operation Stage:

- Training of companies' personnel.
- Advising companies on measures for energy efficiency improvement and its implementation.
- Monitoring of greenhouse gas (GHG) emissions.
- Contracting an operational entity, which verifies and certifies emission reductions.
- Commercialisation and sale of CERs.
- Payment of bonuses to efficient companies.

The tasks of the PMI are described in the following in more detail. Based on this study, the PMI should prepare the **business plan** of the CDM programme. The complete project proposal has to be submitted to the National Environmental Council (*Comisión Nacional de Cambio Climático - CONAM*), the local designated authority for approval of CDM projects. The CONAM submits the project to the National Climate Change Commission, which analyses the project's additionality and impact on sustainable development in Peru. If the results are positive, **CONAM approves the project** and issues a letter of approval. The cost of this procedure is covered by the PMI and financed from future sales of CERs.

Subsequently, the PMI contracts an independent operational entity to validate the project. The project proposal, including the project design document and the letters of approval of CONAM and the independent operational entity, are submitted to the Executive Board. After an internal process, the Executive Board approves and registers the proposal. In this first stage, property rights to the future CERs are laid down.

In Peru, the PMI negotiates a **special credit line** with local banks for the companies affiliated to the project. At the same time it negotiates payments from donors, and a balancing contribution with the Public Treasury. The PMI needs these contributions for initial capital to meet pre-operation and operation expenses. When these three financing sources are confirmed, the PMI is able to fully run the programme.

The companies have access to long-term credits from the participating banks, possibly with a partial support of the PMI. The amount of PMI support has not yet been laid down, but it will be financed from future sales of the company's CERs. The improvement of energy efficiency of boilers provides the main source for loan repayment.

Simultaneously, the **process of training the companies' personnel** starts, in order to achieve the estimated CO_2 reductions that result in savings in fuel expenses and constitute the source of repayment of the loan.

The **monitoring** process starts after modernization of boilers. This process is carried out according to the provisions of the Monitoring Protocol. It is proposed that this work be executed by an external entity. According to the procedures described in Chapter 10, the institution responsible for monitoring must collect the information, carry out selective tests of internal control, calculate greenhouse gas reductions, hold interviews with the personnel operating boilers and also support the companies in the implementation of energy efficiency improvements of their boilers. This institution should have qualified personnel, credibility and infrastructure, and it must be located in Peru. The costs generated by its activities are covered by the PMI from future sales of CERs.

After the monitoring process, an independent operational entity, which needs to be accredited by the Executive Board for the CDM, verifies the monitoring results (**verification**) and certifies that emission reductions have actually occurred (**certification**). This independent operational entity draws up a report that is submitted to the Executive Board, which, in turn, issues the CERs.

The PMI receives its CERs and is able to sell them. A proportion of 2% has to be paid to the adaptation fund of the CDM, and 1% of the CERs is received by the CONAM. From the remaining amount, the PMI then passes on a percentage of sales of CERs (for example, 30%) to efficient companies that have attained their reduction goals. The companies receive the payment in the form of monetary bonuses.

If the company fails to pay the bank, the bank requests the PMI to honour the guarantee. The PMI pays the creditor bank the guaranteed amount, which is a percentage of the CERs issued by that company under the project.

From a cash flow perspective, the PMI needs capital to ensure the proper functioning of the project and the generation of carbon credits. Consequently, the PMI would have a cash flow structure with relatively high expenditure during the early years of the project activity, while income is only generated gradually during the crediting period. That is why the PMI must have sufficient funds to cover initial costs.

The carbon buyer (for example, Prototype Carbon Fund) usually offers only a long-term purchase agreement, setting the price at current rates (between US$ 3 and US$ 4 per tonne of CO_2), and, in exchange, offering to pay part of the project transaction costs (approximately US$200,000). This means that the buyer pays for CERs against delivery at the price set at the beginning of the project, and does not finance the generation of CERs to reduce the supply risk.

The disadvantages of a long-term purchase agreement are the following:

- The local banking system may not accept a *purchase agreement* as collateral because the CER is a by-product of an eco-efficient activity rather than a segregated product of the company and, at present, a liquid secondary market does not exist.
- In accordance with the Peruvian legislation, this agreement is not considered to be a preferred guarantee. Credit improvement is not possible, because it is a commitment to future payment against the delivery of CERs between the years 2004 and 2012.
- The buyer is not exposed to the risk of non-delivery of the carbon, and pays a low price for the imperfections of the carbon market, which is still in the process of formation.
- The buyer guarantees today's carbon price despite the price increase foreseen for the first commitment period (2008-2012). Therefore, the PMI does not benefit from a possible increase in the value of CERs over a certain period of time.

If the banks do not accept long-term purchase agreements as a guarantee, the PMI has several options: it can request the donors to provide additional funding to be used as a guarantee; it can negotiate with a carbon broker for the issuance by a first-class international bank of a *stand-by letter of credit* in the name of the PMI; or, it can negotiate a budget item with the Ministry of Economy and Finance to cover the minimum guarantee required for full operation of the project. These financial alternatives depend upon negotiation with interested banks, which concluded, in 2002, a similar agreement with the Clean Technology Fund of the US Agency for International Development (USAID), which is associated with the Technological Efficiency Centre (*Centro de Eficiencia Tecnológica - CET*).

In the following pages, Table 1 and Table 2 summarize the tasks, profile, responsibilities of the involved institutions.

Table 1: Summary of tasks and proposed responsibilities

Task	Task description	Proposed responsible instution
Project development, pre-operation stage		
Elaboration of the project's business plan	Develop a comprehensive project proposal (including, inter alia, budget financing, evaluation of transaction costs and risks, settlement of disputes).	Project administrator
Information to companies	Inform potential companies of the advantages of the project and define eligibility criteria. Sign letters of intent or preliminary contracts with interested companies. This is considered to be central for the following negotiations with banks, since participation of companies is one of the major risks, which could be dealt with in this way	CDM office, project manager
Negotiate green credit lines with the banks	Sign general agreements with banks for a special credit programme for selected companies (e.g. interest rates, repayment period, etc)	Project manager
Negotiate with donors	Seek funds from donors to cover the PMI's initial operating expenditure. Emphasize in negotiations with donors the impact of the project on the reduction of emissions and on the efficiency of the Peruvian industry as well as its demonstrative effect.	Project manager
Negotiate with eligible companies	Sign participation contracts with companies, including PMI advice, training, ownership and uses of the CERs, payment of bonuses and mechanisms for the settlement of disputes; fine-tune budgets.	Project manager Companies
Elaboration of the Project Design Document	Final elaboration of the Project Design Document, based on this study, including the Baseline Study and the Monitoring Protocol	Project manager
Registration in the CDM office in Peru	Formal presentation of the proposal to the Peruvian CDM office; obtaining of a letter of approval from the CDM office in Peru; its impact on sustainable development in Peru is verified.	Project manager, CONAM
Negotiate with the Public Treasury	A balancing entry may be requested from the Ministry of Economy and Finance to "close" negotiations with donors.	Project manager

Project validation	An Independent Operational Entity validates the Project Design Document, including the baseline study and the monitoring protocol.	Independent Operational Entity
Registration by the Executive Board for the CDM	Final decision on the acceptance of the proposal and official registration of the project as a CDM project.	Executive Board for the CDM
Project operation		
Technical advice to companies	Technical advice on the improvement of energy efficiency.	Project manager / Subcontractor
Financing	Provision of the necessary funds to achieve projected eco-efficiency.	Banks, companies
Implement the measures	Boiler replacement and/or measures to improve energy efficiency.	Company
Training of the companies' personnel	Train the companies' personnel to ensure optimum maintenance of boilers and facilitate monitoring.	Project manager
Monitoring of emissions	Monitor and calculate GHG emission reductions in accordance with the monitoring protocol	Project manager / subcontractor
Certification of reductions	Verification and certification of monitored emission reductions by an independent operational entity.	Independent Operational Entity
Sale of CERs		
Contracts for the sale of CERs	The PMI sells the CERs to brokers or companies or governments from countries included in Annex I.	Broker, PCF, CAF, others
Payment of the guaranteed amount	If the company fails to pay the loan to the bank, the PMI possibly pays the guaranteed amount to the bank.	Project manager, bank
Payment of bonus	If the companies have proper energy efficiency, the PMI pays a bonus to the company.	PMI, company

Table 2: Profile of the entities responsible for the tasks

Roles	***Candidates***	***Desired profile***	***Risks***
Local authority	CONAM	Authority with government support, institutional capacity, qualified and credible personnel.	Changes in the sector policy.
CDM Office	ProInversión	Financial capacity to promote investments; political guarantee.	Lack of political support, lack of financing for the pre-operating stage.
Project manager	FONAM, MITINCI	Credibility, and financial capacity.	Loss of initial capital, an inefficient management delays commencement of the project
Monitoring	CENERGIA, CET-Peru	Technical capacity, credibility.	Problems in measuring energy efficiency accurately.
Certifier	Several (e.g. SGS)	Technical capacity, credibility, financial capacity.	Loss of its accreditation in Peru.
Broker	PCF, CAF	Financial capacity, specific expertise, rating in the market.	Current prices may be below future market prices.
Local bank	Crédito, Wiese	Financial capacity, relationship with the companies	Credit risk of non-payment
Companies		Financially viable companies	Lack of creditworthiness with banks, potential insolvency due to external factors

3.4 Credit programme design

A key feature of the CDM project is a special credit programme for participating companies. The local financing system should be involved in the design and management of the credit programme from the beginning.

In 2002, the USAID negotiated with a local bank a credit line with partial risk coverage for the Technological Efficiency Centre (CET) to facilitate industrial modernization. A similar approach is suggested here. The concept implies the assumption of the credit risk by the financial entity in exchange for a reasonable spread.

Banks usually request a collateral security and a certain down payment in order to reduce the associated risk. In some cases banks also require "preferred guarantee". However, local companies, in particular SMEs, are not able to invest in high down payments and do not have sufficient guarantees to back-up their financial credits. The proposed option suggests that, in addition to the collateral security and the average down payment, the future flows of CERs resulting from technological changes are also used as a guarantee.

In Peru, neither the commercial banks nor the regulator (SBS) – nor even the company itself – would consider this guarantee as valid, for this guarantee is not considered a preferred guarantee according to the Peruvian financial regulations in force. Therefore, the project managing institution or another entity would need to offer a guarantee to the bank or increase the down payment. In return, the project managing institution secures the rights to the CERs in the agreements with the companies and can sell them to the market. In this way, the future flow of CERs would be used indirectly to create an additional guarantee for the bank.

4 National conditions for energy efficiency improvements in industrial boilers

This chapter aims at providing an overview of important aspects of the Peruvian energy sector for energy efficiency improvements of industrial boilers. It starts with an analysis of Peruvian political reforms in the energy sector, where the Camisea gas project will be of particular importance in the coming years. Relevant Peruvian legislation for boilers, and on air pollution generally, is briefly described. The economic situation of Peru and the relevant sectors is assessed and financial barriers to investment in boilers are identified. Finally, it is analyzed how the climate itself and climate change influence the production of vapour in some sectors.

4.1 Reform projects in the energy sector

In the 1990s, Peru executed a structural reform plan in order to liberalize and deregulate the economy. At a sector level, this programme resulted in a new set of regulatory measures. These energy policies affect GHG emissions, since they influence the behaviour of variables such as energy efficiency, consumption habits, the decision to buy a specific fuel, etc. Such policies include the following:

- Imposition of taxes on fossil fuels
- Privatization process
- Energy efficiency
- Promotion of renewable energy
- Promotion of the use of natural gas (see section 4.3)

4.1.1 Policy regarding fossil fuel taxation

In the hydrocarbon subsector, the Government has eliminated subsidies for oil-derived fuels. Direct and indirect subsidies previously granted to kerosene, diesel oil and imported carbon considerably distorted the market for alternative fuels. However, the decision to eliminate such subsidies has not prevented, and shall not prevent per se, the distortion of the market. Distortions may be caused by relative prices, differentiated rates of turnover tax, or by the formation of oligopolies (as in the case of domestic gas).

At present, there is a selective excise tax on fossil fuels, with differentiated rates according to the product. This tax benefits the national treasury flow, but does not meet environmental criteria.

Table 3: Evolution of fossil fuel taxation, 1990-1999 (US$ per gallon)

Effective date	Diesel 2	Gasoline 84	Gasoline 95	Gasoline 97	Residual 6	Kero-sene	LPG
August 1990	0.88	1.11	0.97	--	0.63	0.90	0.00
August 1991	0.64	1.10	1.51	--	0.54	0.59	0.58
August 1992	0.43	0.90	1.29	--	0.39	0.39	0.36
August 1993	0.21	0.54	0.59	--	0.40	0.21	0.18
August 1994	0.33	0.63	0.94	0.95	0.21	0.15	0.23
August 1995	0.33	0.62	0.91	0.93	0.17	0.16	0.24
August 1996	0.33	0.63	0.93	1.02	0.19	0.16	0.22
August 1997	0.39	0.60	0.87	0.95	0.05	0.17	0.23
August 1998	0.40	0.59	0.86	0.95	--	0.17	0.17
September 1999	0.39	0.61	0.87	0.96	--	0.14	0.14

Source: Referential Plan of Hydrocarbons – Ministry of Energy and Mines (MEM 1999)

Current taxation does not clearly reflect environmental concerns and external environmental costs. For example, residual fuels are the most "dirty" fuels, with a high proportion of sulphur and relatively low carbon content, but they have been free of taxation since August 1998. Boiler operators therefore prefer to buy residual fuels rather than diesel because of its lower price, provided that the size of the boiler is appropriate (generally boilers under about 1 MW are diesel-fired).

4.1.2 Privatization process

In 1993, after approval of the Law on Electricity Concessions and the General Law on Hydrocarbons, the energy sector suffered a radical change. The two most important subsectors – electricity and hydrocarbons – became more dynamic, because the above-mentioned laws promoted national and foreign private investments. Nevertheless, seven years later, if international standards are taken into account, energy costs for users have significantly increased.

On the other hand, privatization processes have led to an improvement in the energy efficiency of the sector, which is reflected in the reduction of losses in the distribution system from 20.6% in 1994 to 11.8% in 1999.

4.1.3 Energy efficiency

In 1994, the Ministry of Energy and Mines (MEM) created the Energy Saving Project (ESP)[1] to confront the deficit in electricity supply with respect to estimated future demand. The project aimed at improving the consumption habits of the population, and also at promoting the use of energy efficient equipment (particularly in the residential sector).

ESP's activities have focused on the organization of intensive campaigns to create awareness of the efficient use of energy in several sectors (dwellings, schools, businesses, public buildings, industries, etc.). For this purpose, different media were used, namely, television, newspapers, magazines, brochures, videos, public expositions, speeches addressed to specific audiences, and so forth.

As a result of ESP's activities, demand was reduced by at least 70 MW in 1995. In addition, the average monthly consumption level of a Peruvian family was lowered by more than 15%. Finally, four years ago only 14% of the population turned off light bulbs unnecessarily left on at home; now this percentage has increased to 55%.

According to estimates, the energy efficiency programme implemented by ESP accounted for an average reduction of 100,000 tons of CO_2/year. At present, ESP activity has decreased, also because electricity supply is nowadays much higher than electricity demand.

4.1.4 Promotion of renewable energy

In May 1999, Peru undertook a project for rural electrification with photovoltaic energy. The main objective is to eliminate barriers to rural electrification using photovoltaic technology in remote rural areas.

The project will demonstrate the viability of microenterprises to sell, maintain and operate photovoltaic systems, and provide public and private sectors with incentives to invest more in rural electrification on the basis of this technology. One of the most important measures to attain this objective is the drafting of legislation governing the concession of renewable-energy rural electric services. The scattered geographical location of rural dwellings, as well as transportation problems in rural areas, imposes high transaction costs on concession systems.

4.2 Adopted and planned legislation

4.2.1 Efficient energy use

In September 2000, the Peruvian Government enacted Law 27345, Law for the Promotion of the Efficient Use of Energy. This law designates the Ministry of Energy and Mines (MEM) as the competent authority, conferring upon it powers to co-ordinate the

1 Proyecto para Ahorro de Energía (PAE)

development of policies for the efficient use of energy with other economic sectors. The law also lays down that all energy-consuming devices are obliged to bear a label containing a comparison of its consumption with the efficiency standards established for the country, so as to improve consumer guidance.

In this context, technical committees for the standardization of the rational use of energy and energy efficiency, as well as sub-committees for industrial boilers, electrical engines, solar systems, refrigeration and lighting, were set up for the purpose of drafting the respective technical regulations.

The industrial boilers sub-committee is currently drafting a technical regulation with the support of representatives from the three sectors involved: the production sector (producers and marketers), the consumption sector (users such as associations and public or private entities) and the technical sector (unions, schools, associations and universities). The regulation focuses mainly on the following points: testing methodologies, measurements and limit values as well as labelling.

The technical regulation is expected to enter into force in the second half of 2002, following approval by the Commission for Technical and Commercial Regulations[2]. These regulations will be voluntary. However, labelling of all energy-consuming equipment will be obligatory. In the case of boilers, harmonization of the criteria for determining energy efficiency is foreseen, applying the indirect method.

4.2.2 Air pollution

Environmental policy is based on a protectionist approach rather than on the encouragement of the efficient use of resources. The conception of repairing the damage caused by contaminating activities, rather than incorporating the prevention principle, was present in the regulations until the early 1990s.

Since enactment of the Environmental Code[3], in 1990, there has been a clearer understanding of the importance of the environmental issue for the productive activities of the country, and regulations have been issued in a more comprehensive manner. It is important to point out that the Environmental Code has introduced several major contributions in relation to environmental management principles and tools, which include the polluter-pays principle and environmental impact assessments.

Subsequently, issues related to conservation and prevention have been included in the regulations. Based on the foregoing – and involving CONAM, the organization responsible for drawing up and implementing environmental regulations – work commenced on regulations governing national environmental quality standards for air, which also establish maximum permissible limit values. These regulations were enacted in June 2001.

2 Comisión de Reglamentos Técnicos y Comerciales (CRT) del Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual (INDECOPI).

3 Código del Medio Ambiente (CMA)

4.3 The Camisea Gas Project

At present, natural gas is a very small component of national energy supply. Nevertheless, given the structure of national energy reserves, the use of natural gas is expected to become importance for the economy in the medium and long term.

The major natural gas field in Peru is located in Camisea (Department of Cusco). It is one of the largest fields in South America (13 quintillion cubic feet and 660 million barrels of condensates), and is capable of supplying energy to the country for approximately 80 years.

In the following, we analyze the introduction of Camisea gas on the Peruvian energy market and its possible effects on the industrial sectors, in particular industrial boilers. We start by describing the main aspects of the Camisea project, current project progress, the comparison of some projections made by institutions involved in this issue and, finally, making some assumptions about the level of penetration of natural gas in those sectors using boilers.

4.3.1 Background of the Project

Between the years 1983-1987, the Shell Company discovered the Camisea gas fields (San Martin and Cashiriari in Cusco), which are located 500 km to the east of the city of Lima, the capital of Peru. The Camisea area reserves are of a retrograde gas condensate type, supported by water drive, the extent of whose water-bearing formations is unknown. Additionally, these reserves have double porosity and permeability behaviour due to the presence of natural fractures. Proven hydrocarbon reserves in the Camisea fields are shown in Table 4.

Table 4: Proven gas reserves in the Camisea area (Peru)

Structures	Gas (Tcf, quintillion cubic feet)	Liquids (MMBls, millions of barrels)
Cashiriari area	5.4	330
San Martin area	3.3	215
Total	8.7	545

Source: Ministry of Energy and Mines of Peru, PETROPERU

In 1996, after multiple negotiations with the Shell Company, Petroperu entered into a contract for the exploitation of this field with the Shell-Mobil Consortium, but in July 1998 these companies decided not to pursue the matter. Subsequently, by December 2000, the process of calling for tenders and the execution of the contract for the Camisea natural gas project were concluded. For the development of this project, two modules were designed and offered as integral projects: the module for exploitation of the fields, and the module for transportation of gas and gas liquids from Camisea to the Peruvian coast and gas supply in Lima and El Callao.

The module for exploitation of hydrocarbons was awarded to the consortium made up by Pluspetrol (Argentine), Hunt Oil Co. (USA), SK Corp. (Korea) and Hidrocarburos Andinos (Argentina), and the respective Licensing Agreement was executed in December 2000. Likewise, the module for transportation and supply was awarded to the consortium made up by Techint (Argentine), Pluspetrol (Argentine), Hunt Oil Co. (USA), SK Corp. (Korea), Sonatrach (Algeria) and Graña y Montero (Peru). Concession contracts were also executed in December 2000.

In order to secure development of the project, the government decided to guarantee Camisea bidders the sale of 250 MMCFD of natural gas as from the first year. The government also guaranteed additional growth of 35 MMCFD per year, over 8 years, in order to reach a sales volume of 450 MMCFD (guaranteed by the Government). However, it set a maximum rate for both wellhead gas and its transportation.

The rate for steam power plants will be 1.70 US$/MMBTU, which is equivalent to 10.65 US$/barrel of oil. This rate will allow thermal producers operating from gas turbines to be more competitive than hydroelectricity. The rate of natural gas for industries, including the cost of distribution, will amount to around 3 US$/MMBTU, equivalent to 18.80 US$/barrel of oil.

4.3.2 Gas Exploitation

The plan for the development of the structures of the project contemplates the drilling of humid gas producing wells and of dry gas injection wells, the objective being the maximum recovery of liquids from the gas produced, as well as the supply of gas to the internal market. The programme envisages the possibility of commencing production in the year 2004 with a total of 8 wells, of which 6 will be producers and 2 will be reinjectors.

The project entails collecting and leading the natural gas towards a liquid separation plant. In this plant, water will be separated from the liquid hydrocarbons contained in the natural gas. Natural gas will then be conditioned to be transported through the gas pipeline to the markets on the coast. Excess gas will be reinjected into the natural reserves. On the other hand, separated liquids will be injected into the liquids pipeline to be carried to the coast, being received at the plant, where they will be distilled into commercial quality products (LPG and condensates) and subsequently forwarded to the market by ship and/or tank truck.

4.3.3 Hydrocarbon transportation

To reach the market, hydrocarbons will be transported from Camisea to the Central Coast, for which purpose two parallel ducts will be built: one for the transportation of natural gas and one for the transportation of liquid gas products. The first pipeline will be around 540 km long, and the second around 680 km long. They will cross the Jungle and the Andes at heights over 4,500, and will finally descend the coastal deserts.

Finally, a natural gas distribution network will be installed in Lima and El Callao, which at first will be used mainly for supplying gas to industry and to electric power plants, and subsequently also for commercial and residential supply. The development of natural gas distribution projects in both the Northwest region of Peru and the Central Jungle has been encouraged. These projects might create their own markets for natural gas, with the possibility of being interconnected in the medium term to the future Camisea gas pipeline network. The Camisea network may become the largest supplier once reserves located in the Northwest region and Aguaytía (Central Jungle) have been exhausted.

4.3.4 Current project progress

In March 2001, the Belgium company Tractabel was appointed by the Ministry of Energy and Mines as pre-qualified strategic operator to carry out the project for the distribution of Camisea gas through a network of pipelines in Lima and El Callao. An investment ranging from US$ 170 millions to US$ 200 millions is expected to be made for the construction and exploitation of the gas distribution network in Lima.

The installation of the main gas pipeline will start in November 2002, and it will serve as a basis for the construction of the network, which will distribute the resource to industries and dwellings in Metropolitan Lima. The project details are being finalized and steps are being pursued to secure respective permits.

According to information furnished by officers of the company to the "El Comercio" newspaper[4], Tractebel has undertaken to serve some 10,000 consumers in the early years and 70,000 consumers in the sixth year. The target is to have more than 100,000 users in the year 2010. Likewise, income of US$ 30 million is estimated for the first year of operations. Income is expected to grow from US$ 40 million in the second year to US$ 170 million in the thirtieth year. The company's executives have expressed their intention to foster the development of the gas market in Lima. With regard to the industrial sector, which is expected to provide the largest demand for gas, companies are expected to adapt their production systems as they benefit from natural gas. This adaptation will obviously entail access to capital for the required investments, which, in the case of the conversion of boilers, will amount to at least US$ 40,000. As analyzed in this study, capital costs in Peru are high, due to the equally-high risk perception of the local financial system, which in turn results in high interest rates for small and medium-sized companies (SMEs), which in most cases are not considered eligible. This significantly hinders access to the capital required for conversion of boilers and production systems in general, for which reason it will definitely be necessary to create better conditions through financial instruments providing access to lines of finance that facilitate this industrial conversion process.

[4] Diario el comercio del 23 de Marzo del 2002

4.3.5 The gas market

Several studies have been made to determine the potential market for natural gas in Lima and the length of the southern highway between Lima and Pisco. Some of the results of the different studies conducted are commented on below.

4.3.5.1 The industrial market according to studies conducted by STONE & WEBSTER and SHELL

In 1997, industrial consumption in Lima was distributed as follows:

Table 5: Total industrial consumption

	Barrels/day	TJ/Year
Residual 6	14,000	31,718.5
Residual 500	20,000	45,333.0
LPG	4,800	7,044.5
TOTAL		84,096.0

Source: Latin American Energy Organization – Olade (2001)

The studies conducted by Stone & Webster and Shell on the consumption level of the industrial market do not significantly differ (see Table 6).

Table 6: Penetration rates related to the industrial market consumption level

Studies conducted	Penetration rate in 2010	Penetration rate in 2020
Stone & Webster/Flemming	32%	45%
Shell	37%	

Source: Latin American Energy Organization – Olade (2001)

These penetration rates have taken account of current (35 US$/oil barrel) and estimated future prices (24 US$/oil barrel) compared to the price of natural gas in Lima (18.80 US$/oil barrel).

4.3.5.2 The industrial market according to studies conducted by HYDRO QUÉBEC INTERNATIONAL (HQI)

The evaluation by Hydro Quebec International (HQI) of the study conducted by OLADE on the progression of consumption is more moderate during the early years, since it uses a penetration rate a little lower than 25%.[5] As may be appreciated in the following table, HQI has considered a combination of the consumption estimated by both Stone & Webster/Flemming and Shell. Experience has shown that industrial conversions are expensive and do not reflect anticipated planning. In the case of conversion of boilers, we have already stated that their technological adaptation requires investment of between US$ 40,000 and US$ 50,000, and will depend to a great extent on the access to capital that industrial companies may have at the time.

Table 7: The Industrial market according to Hydro Quebec International HQI (TJ/year)

2003	2004	2010	2020	2021	2022	2023
10,731	13,991	27,702.8	37,028.8	37,595	38,277.9	38,325

Source: Latin American Energy Organization – Olade (2001)

4.3.5.3 The industrial market according to studies conducted by the Ministry of Energy and Mines (MEM)

According to the 2001 Referential Plan for Hydrocarbons elaborated by the Ministry of Energy and Mines, industrial consumption convertible to natural gas in the "Middle Scenario" is expected to grow from 18,887 TJ/year in 2004 to 25,397 TJ/year in 2010. Furthermore, besides replacing carbon, Camisea natural gas is expected to replace oil derivates, reaching approximately 12,681 TJ/year in 2004 and 18,311 TJ/year in 2010 (See the tables below).

As may be observed in the table of comparative results, the three studies conducted are similar, except that the results of the one carried out by Shell appear to be very optimistic compared to those of the others.

Table 8: Industrial market convertible to natural gas: 2004 – 2010 (TJ/year)

	2004	2005	2006	2007	2008	2009	2010
Conversion industrial companies	18,886.56	21,104.30	23,608.20	24,037.44	24,538.22	24,538.22	24,538.22
Small companies	-	321.93	321.93	608.09	858.48	858.48	858.48
Total	18,886.56	21,426.23	23,930.13	24,645.53	25,396.70	25,396.70	25,396.70

Source: Latin American Energy Organization - Olade (2001)

[5] From the Study "The Situation of Hydrocarbons in Peru", conducted by OLADE, Consulgaz – HQI. Dec.2000.

Table 9: Comparison of results related to the potential industrial market

Studies	Penetration rate as of 2010	2003 (TJ/year)	2004 (TJ/year)	2010 (TJ/year)	2020 (TJ/year)
Stone &Webster/Flemming	32%	13,468	18,870	26,900	38,361
Shell	37%	21,827		31,134	
HidroQuebec International	25%	10,731	13,991	27,703	37,029
Referential Plan for Hydrocarbons 2001 – MEM	32%		18,887	25,397	

4.3.6 Impact of Camisea gas on the industrial boiler sectors

According to the national survey on boilers (MITINCI 2000) and the forecasts in Chapter 8 of this study, there are a total of 182 companies located in Metropolitan Lima and El Callao with a fuel consumption of 19,094 TJ/year. For the purposes of forecasting consumption convertible to gas, we will assume that it is this consumption segment of boilers in Lima and El Callao that will be replaceable by Camisea gas as from the year 2004.

Furthermore, we will assume that there will be a linear increase in this consumption, starting in the year 2005 and reaching a natural gas penetration rate of 35% as of the year 2010, which is a figure compatible with the results of the other studies (see Table 11). Thus, fuel consumption of boilers convertible to natural gas is expected to be 1,114 TJ/year in 2005, and to grow to 6,683 TJ/year in 2010. Taking into consideration the distribution of companies in the Lima-Callao region and in the rest of the country, it is expected that around 2.5% of the most important boilers throughout Peru will have changed to natural gas by the year 2005 and around 15% by the year 2010. Considering the above scenarios, it is assumed that after the year 2010 the penetration rate of natural gas will slowly increase with an additional 3% per year.

Table 10: Fuel consumption of boilers

	Number of companies	**Residual TJ/year**	**Diesel 2 TJ/year**	**Total**
Total Lima – Callao	182	17,743	1,352	19,094
Total Provinces	153	23,789	1,812	25,602
Total	335	41,532	3,164	44,696

Source: MITINCI (2000)

Table 11: Fuel consumption of boilers convertible to gas (Lima)

Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Penetration rate	0	5.8%	11.7%	17.5%	23.3%	29.2%	35.0%
TJ/Year	0	1,114	2,228	3,441	4,455	5,569	6,683

Source: Own calculations

4.3.7 Barriers to the introduction of natural gas

According to studies conducted by OLADE[6], a new energy market has arisen in Peru as a result of the introduction of Camisea natural gas. Natural gas is thus competing with products of a mature industry with articulated interests in the entire value chain. This new scenario imposes an analysis of forces operating in the industry that could create barriers to the introduction of natural gas onto the market in Peru. These possible barriers derive from the present structure of the Peruvian energy market and its regulatory instruments. At present, there is a legal regulation guaranteeing competitiveness, free access and institutional guarantees, as well as a market structure with the characteristics of an oligopoly, particularly in the refining stage. This structure therefore imposes barriers to any new participant introducing a new product, new technologies and competitive prices, as is the case with Camisea natural gas. Natural gas may face a price war without being able to stay in the market. As this product will compete with other producers of natural gas liquids, a price war could take place in the internal market.

The reaction of fuel consumers, including companies using boilers, will hardly be associated with the cost of fuel replacement. It is related more to the need for investment, which companies will experience when having to modify their production processes and their undertakings with fuel suppliers, as a result of the entry of a new fuel. Therefore, companies will have to be persuaded that this cost may be rapidly recovered by reduc-

[6] Documents corresponding to the Study conducted by OLADE/CONSULGAS/HQI. May 2001.

ing energy costs and improving the efficiency and competitiveness of their final products. Regarding the financing of conversion, in the case of the industrial sectors and particularly the boiler sector, it is obvious that, due to the magnitude of required investments, credit lines channelled through the financial system are required under more favourable conditions than at present. This involves low interest rates and flexible payment conditions, or, as has happened in some countries where gas distributors finance replacement by gas and charge the costs to the customer indirectly.

The Camisea gas project is expected to have several impacts, including:[7]

- **Impact on tax policy.** The policy regarding the long-term transformation of the Peruvian energy matrix, as a result of the introduction of natural gas to the market, will undoubtedly have an impact on tax collection. However, the evaluation of such impact is not a trivial task, given the great number of interests involved in the value chain of the Camisea project. This evaluation requires stating the role of fuels in tax collection, and determining how the convergence of replacement prices affects tax collection. The answers will depend to a great extent on the tax policy adopted by the government.
- **Reaction of the liquid derivates production sector.** It is predicted that the entry of Camisea natural gas may unbalance the liquid derivates market, where around 4,878 TJ/day are currently sold. This production comes from the refineries installed in the country.
- **Reaction of the liquid derivates distribution sector.** The greatest impact on the distribution of liquid derivates is foreseen in the area of influence of the Camisea-Pisco-Lima gas pipeline. In this respect, the studies conducted by the MEM[8] show that between the years 2003 and 2008 diesel will lose 8.1% of its market share with the entry of natural gas into the industrial and electricity sectors. As a great proportion of steam power plants using diesel are located within the area of influence of the *Norperuano* oil pipeline, diesel distribution will not be much affected. However, in steam power plants within the area of influence of the Camisea-Lima gas pipeline, diesel distribution will be significantly affected.
- **Reaction of (internal and external) suppliers of liquid derivates.** Peru imports liquid derivates from Venezuela, Columbia and Trinidad & Tobago. While this is completely private commerce, it is governed by long-term supply contracts that may require flexibilization agreements.
- **Reaction of dealers in liquid derivates (kerosene and LPG).** This sector is directly associated with producers. They operate as distribution centres for the production area of refineries or for importers of liquid derivates. It is expected

[7] Frederico Marinho et al. Entry Barriers for Natural Gas- OLADE-CEPAL 2001.

[8] Referential Plan of Hydrocarbons 1999.

that they will lose a substantial part of their market share in Lima and its surroundings.

- **Reaction of Camisea gas producers.** Camisea natural gas liquids reserves are calculated at around 567 MMB. As the market value of these liquids is higher than that of natural gas, it is presumed that those producers who desire a rapid return on their investments will give priority to their commercialization. As they will compete with natural gas liquids of other producers, competition could provoke a price war on the internal market or an arrangement of interests through the rapid or gradual reduction of imports, as previously explained.

4.3.8 Installation cost of natural gas in the residential, commercial and industrial markets

In the case of industries, the replacement cost varies significantly depending on the type of industry. For boilers, an amount ranging from US$ 40,000 to US$ 50,000 is considered to be the minimum, assuming that only the replacement of the burner is required. Table 12 below details costs of dual burners for different boiler sizes. These costs relate to high technology burners, it being possible to find cheaper, less sophisticated burners (probably representing 60% or 70% of the costs indicated). In all cases, it is necessary to use safety valves and control technology for the gas supplied to the boiler burner, the cost of which is also indicated (US$ 10,000). Besides, a pressure reducing and gas measurement station must be installed at the entrance of the plant, its total cost ranging from US$ 8,000 to US$ 12,000, without considering the meter, which is provided by the distributing company. In addition, gas distribution pipelines must be installed in the plant. The cost of the pipelines varies, depending on boiler capacity and gas consumption.

Table 12: Costs of dual burners

BOILER SIZE	**COST OF DUAL BURNER (US$ excluding VAT) Peru**
100 BHP	30,800
600 BHP[9]	36,250
700 BHP[9]	39,150
900 BHP[9]	39,600

Source: Own estimates

[9] Without fan, pump, heater (their existence is assumed). It does not have a train of natural gas valves either, the cost of which is approximately US$10,000 in average.

4.4 Financial situation in the country

The political crisis that broke out in Peru in recent times had an impact on the perception of the country-risk. This mainly entails possible increases in interest rates for external loans, more requirements to be satisfied to invest in the country and, consequently, greater problems in reducing the high interest rates for loans prevailing on the national market.

This delicate situation has been affecting the economy for two years and is marked by stagnation in investment and a serious tax deficit, which led to a reduction in public expenditure in the year 2000 –contributing to the recession in the productive system (particularly in the construction sector) – and resulted in the weakening of internal demand and in the critical financial situation of companies. Only exports regained dynamism during this period. This situation was worsened by the difficult political situation experienced by the country due to the general elections, aggravated by the resignation of the president two months after commencing a new term of office. This created a negative climate, which put a damper on expectations of a recovery in the economy in the short term, and led to postponed investment decisions on the part of economic agents. The decisions adopted by the transition government established in November 2000, and led by the President of the Congress, contributed to quieting down the situation.

4.5 Current economic situation of relevant sectors with boilers

4.5.1 Fishing industry

The productive activity of the fishing industry fluctuates and depends on the availability of marine species and on the duration of the closed seasons imposed by the competent authority in order to guarantee the preservation of resources.

Fishing activity grew by 8.1% in the year 2000 compared with the previous year. This result was supported by an increase in the production of fishmeal of around 24.8%, while the manufacture of canned fish went up by 15.9%.

Increased demand in Asian markets and the relative recovery of the international price of fishmeal had a positive impact on exports of this product. However, there is still concern about the restrictions that the European Community may apply on the use of fishmeal to feed cattle to prevent the propagation of mad cow disease. Another concern is the difficult economic and financial situation being faced by many companies due to excessive investments made in the expansion of the fishing fleet.

4.5.2 Textile Industry

Production evolution in the 1990s showed an irregular behaviour, which was due in part to the effects of policies adopted in the subsector and to the increased dynamism of the textile industry in other countries.

Production in this subsector registered an expansion of 9.1%, which is supported by the high growth rates achieved in the first half of the year. This result reflected the increased production of knitted fabrics, where production volume increased by 13.7% compared with 1999.

Exports in the year 2000 rose 26.9% as a result of the efforts of producers to diversify their products and markets. 80.5% of these exports went to the United Status, 9.4% to Germany, 3.1% to Chile, 2.9% to Spain and 1.4% to the United Kingdom.

4.5.3 Beer subsector

During the period 1991-2000 this subsector registered an average annual growth rate of –0.4%, while manufacturing industry registered an average annual growth rate of 4.8%.

A permanent reduction in production levels has been observed since 1995, due, among other factors, to low consumer purchasing power and the negative effects caused by the Selective Excise Tax imposed on the beer sector. Thus, production of lager beer decreased from 753.4 million litres in 1995 to 558.8 million litres in the year 2000. Dark beer registered a production of 28.3 million litres in 1995, decreasing to 11.8 million litres in 1999.

4.6 Financial barriers to innovation in Peruvian industry

Analyzing the demand side of the Peruvian credit market, several problems or financial barriers can be identified that derive from the economic recession cycle of the second half of the 1990s. The main problems are the following:

- **Bad credit record.** Many small and medium-sized industrial enterprises (SME) have had financial problems. Enterprises with stable economic prospects but financial problems with creditors were involved in capital restructuring processes (Reestructuración Patrimonial). INDECOPI[10] is the entity that evaluates which enterprises qualify for this restructuring scheme.[11] Such enterprises are no longer acceptable for the credit system because they are highly indebted. Some creditors (banks) propose long-term refinancing to SME.
- **Decreasing net margins.** Inflation in Peru has been relatively low and stable during the last decade. Operative margins of enterprises drastically decreased and future margins for SME are expected to decrease further if they do not diversify their activities or products.
- **Informal economies.** Certain small enterprises have a lax attitude towards legal matters. In some cases, property rights are not clearly defined; in others, companies within the informal sector of the economy evade taxes and do not submit accounting information.

10 National Institute for Consumer Defence and Intellectual Property, regulator of competence practices.

11 Similar to the "Chapter 11" scheme in the USA

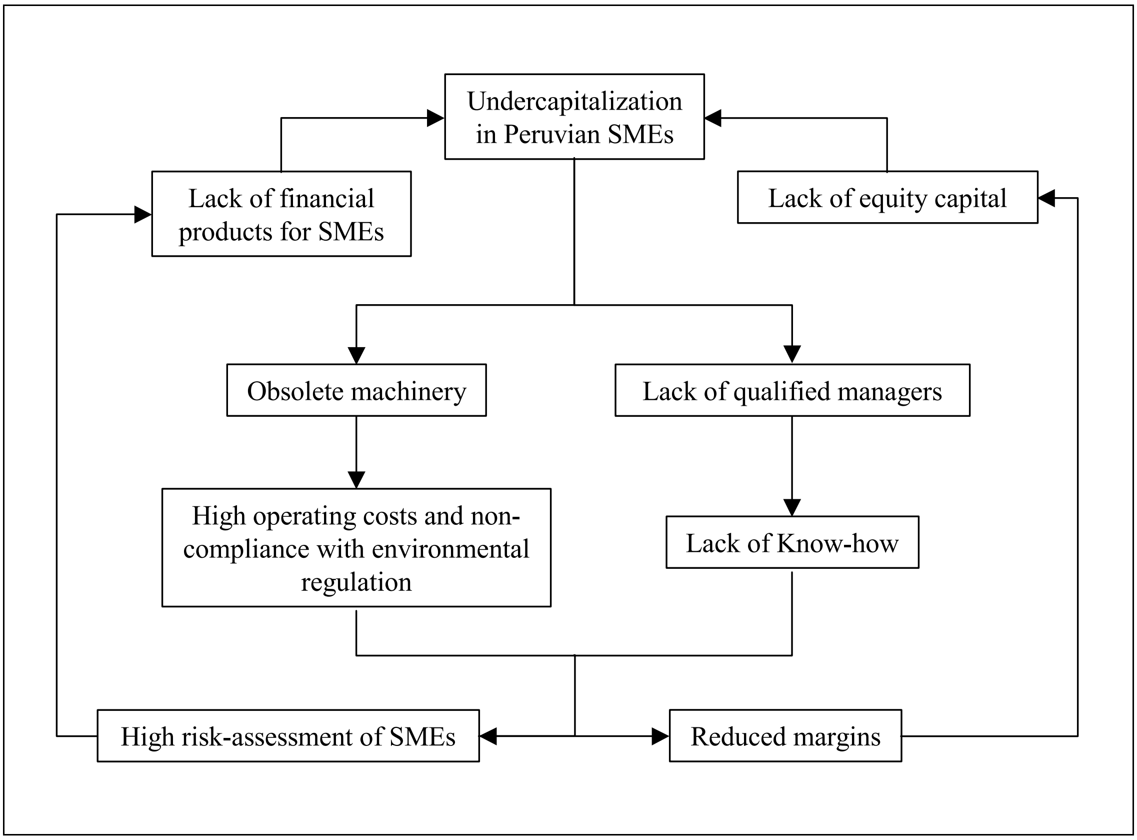
- **Level of credits.** The level of credits requested by small enterprises is hardly attractive to the private banking system, because of the sector's implicit risk. Uncertainty in dealing with small enterprises is translated into shorter repayment periods, higher collateral and interest rates, thus generating investment-limiting conditions.
- **Lack of knowledge on environmental projects.** The lack of differentiation of projects aiming at improvement in energy efficiency is an additional problem. Financial institutions do not have a clear perception of the relationship between their activities and the environment. Furthermore, the environment has not been identified as a risk variable to be analyzed. So there is a lack of differentiation in the portfolio of customers between those projects that respect the environment and those that do not. Due to this lack of differentiation, all projects are handled similarly and based on the same pattern of financial analysis. In addition, companies may be found in a bank's portfolio of customers that pose a high risk to the environment but have a good credit rating due to their historical financial statements or the projection of the price of their products (in most cases "commodities"), for which the level of risk to the environment has not even been evaluated.

Credit rating is currently limited to the preparation of future projections based on past statistical data, failing to consider the various qualitative variables that affect present and future periods. Credit ratings have been more centred on the evaluation of guarantees and collateral than on the evaluation of the sustainability of the projects and cash flows. On the other hand, solid small and medium-sized enterprises, which had submitted duly supported projects, have not been granted any financing due to the inertia of the evaluation methodology used by banks and to the lack of suitable financial products. Consequently, as a result of this lack of capital, small and medium-sized enterprises are losing competitiveness, as may be appreciated in Figure 4.

The problem does not lie in the availability of short-term financial resources, but in the interpretation of the risk faced by SMEs (for uncertainty rather than for analysis). Banks have more difficulty in placing resources than in raising them. This is due to the lack of information on SMEs and their projects. At the same time, SMEs claim not to have access to financial capital.

The credit rating system is governed by the supervisory role of the regulator SBS and the informative role of central risk-rating enterprises. SBS is in charge of reporting the financial situation of firms, including current debts in bank and commercial systems. Central risk-rating enterprises are divided into those reporting on enterprises' values or instruments and those dedicated to economic and financial research.

Figure 4: Financing problems in Peruvian industry



Source: Finanzas Ambientales / Öko-Institut / UNDP DTIE

Despite decreasing interest rates in the interbank market, scepticism on the part of banks regarding SMEs discourages them from offering lower interest rates. Higher risk premiums are the consequence of bad experience.

As the typical cost of energy efficiency investments in boilers or the replacement of boilers is about US$ 10,000 to US$ 80,000, the Peruvian banking system would typically finance a three-year loan with a 20-30% down payment.

In Table 13 the main financial and non-financial barriers to innovation and the use of clean production processes in Peru are summarized.

Table 13: Financial and non-financial barriers to access to capital for SMEs in Peru

Barriers	*Sub-categories*
Finance	• High cost of capital in Peru due to risk perception • High local interest rates • Inadequate banking collateral • Environmental costs not internalized in current accounting practice • Neither local banks nor companies interested in environmental impacts • Scepticism about and poor knowledge of specific projects on the part of the financial sector • Inadequately-defined property rights in small enterprises
Economic	• Income tax is unclear with respect to incomes from sales of certified emission reductions (CERs) or similar carbon credits • Low environmental awareness
Political	• Lack of political support for clean technologies • No existing environmental policy for industrial boilers • Institutional: A Peruvian CDM office is not yet in place
Institutional and legal aspects	• Energy Service Companies (ESCOs), which might promote the efficient use of energy and facilitate access to capital for investments in energy efficiency, do not yet exist in Peru. • No legal basis to hold and possess Certified Emission Reductions (CERs) within the Peruvian CDM registry
Technical	• Unreliable indicators on the environmental performance of companies in Peru

Source: Finanzas Ambientales

4.7 Climate

In Peru, the natural phenomenon of "El Niño" is of particular importance for water resources, ecosystems and biodiversity, and has severe impacts on socio-economic sectors, particularly agriculture, fisheries and forestry. This natural phenomenon may increase in its frequency and its severity due to climate change. The fishery sector is particular vulnerable to an increase in the "El Niño" phenomenon, which also affects vapour production in boilers, since the fishery sector is also the most important sector so far as the use of boilers for vapour production is concerned.

In the case of the main fishing resources there are two scenarios. In the first, the species suffer a negative impact, resulting in migration, changed habits and extinction, as is the case with the "anchoveta" (Peruvian anchovy). This has also had a negative effect on fishing. In some cases, this problem is accompanied by a diminution of their habitat, which leads to an increase in density per unit of area and facilitates over-fishing. A positive impact is also caused to the species population and its habitat, which, as in the case of the "hake", in many instances reaches much greater depths; however, these changes have a negative effect on fishing.

The greatest damage caused by the "El Niño" phenomenon includes a reduction in the fishing of predominantly commercial species and direct damage to the infrastructure of both continental and marine fishing. Finally, there have been major repercussions on local jobs, which has directly affected fishermen with low incomes in the northern region of the country.

5 Characteristics of industrial boilers in Peru

5.1 Introduction

This section contains a description of the characteristics, operating conditions, energy efficiency and auxiliary services of the current Peruvian boiler park. To assess in detail the characteristics of Peruvian boilers, the following studies were carried out:

1. **National survey on boilers (MITINCI 2000).** During the year 2000, the National Bureau of Industry of the Ministry of Industry, Tourism, Integration and International Trade Negotiations (MITINCI) carried out a national survey on boilers, with the participation of 369 companies from the productive and services sectors. In this survey, a total of 1,147 boilers were declared. This sample accounts for an accumulated power capacity of 5,610 MW (572,000 BHP). Most of the companies participating in the survey were medium-sized and large industrial enterprises, which have the largest boilers and therefore concentrate most of the installed capacity of the Peruvian boiler park.

2. **Evaluation of boilers.** In order to verify the results of the national survey on boilers, in particular those related to energy efficiency and energy improvements to be implemented, it was deemed necessary to perform an energy and environmental assessment of a sample of 80 boilers, as follows:

   - Evaluation of 40 boilers in 5 departments (La Libertad, Ancash, Ica, Arequipa, and Moquegua) performed by *CENERGIA* in 2001 (CENERGIA 2001).
   - Evaluation of 40 boilers in Lima, performed by *Pontificia Universidad Católica* (Pontifical Catholic University) in 2001 (Jimenez et al. 2001).

   These evaluations showed that the determined energy efficiency levels of the 80 boilers differ somewhat from those reported in the national survey on boilers.

   The energy efficiency values of the 80 boilers were determined by means of the indirect heat-loss method under different operating conditions (see paragraph 5.4.1.2). In the case of the national survey on boilers, even though companies were told to use the indirect method, there is no certainty that data was correspondingly processed. Some incongruities in the values question the reliability of the data provided by companies.

The following analysis is based on the results of the two aforementioned works, among other sources.

5.2 Technology

A steam boiler is heat transfer equipment in which hot gases, produced by the combustion of fossil fuel with air in a burner, transfer heat through tubes to the water supplied to the boiler, finally generating vapour.

85% of boilers in Peru are firetube boilers, and the remainder are watertube boilers (MITINCI 2000); their general characteristics are shown in Table 14.

Table 14: Characteristics representative of boilers

Fluid layout:	Firetube
Type of circulation:	Forced
Heat transmission:	Radiation and convection
Fuel:	Petroleum
Pressure	8 bar to 13 bar

Source: MITINCI (2000)

5.2.1 Power

The arithmetical average of the power of the 1,147 boilers included in the national survey on boilers is 5,032 kW (513 BHP). Power ranges from 20 kW (2 BHP) to 49,040 kW (5.000 BHP). Medium-sized and large enterprises use boilers with power equivalent to or greater than 981 kW (100 BHP). The manufacturing sector mostly uses boilers of up to 9,808 kW (1,000 BHP). The energy (steam power plants) and agroindustrial (sugar plants) sectors use boilers exceeding 9,808 kW (1,000 BHP).

According to the national survey on boilers, the average power of the boilers according to the type of fuel is as follows:

Table 15: Average power of boilers for different fuels

TYPE OF FUEL	kW	(BHP)
Residual oil 500	7,013	715
Residual oil 6	6,140	626
Diesel oil 2	1,363	139
Bagasse	13,427	1,369

Source: MITINCI (2000)

5.2.2 Burner

The burner is one of the most important components of the steam boiler, its function being to mix air with the fuel to produce combustion and release the heat necessary to generate vapour.

An important factor for combustion efficiency is the proper atomization of the fuel in small droplets (10 to 200 micrometers), so that it may be closely mixed with air, and the reaction of carbon and hydrogen contained in the fuel with oxygen in the air is facilitated, thus producing a minimum quantity of unburned products (CO, soot, etc.). Another important factor is excess air, that is, the quantity of air used in the burner above the stoichiometric value (minimum quantity of air to complete the reactions of combustion). If excess air is greatly reduced, the fuel is not combusted completely, which leads to high concentrations of CO and soot in the flue gas. If the level of excess air is high, part of the fuel is used to heat the excess air, the result being in both cases boiler inefficiency.

Most of the burners in Peruvian boilers have a steam or air atomization system or a pressure atomization system and, in few cases, a rotary cup atomization system.

The firing rate of burners may be regulated in three different ways according to boiler size:

- Boilers < 400 kW : On-off
- Boilers < 1,000 kW : High-Low-Off
- Boilers > 1,000 kW : Modulating.

5.2.3 Controls

All boilers have a mechanism (pressure switch) that turns the burner off when the vapour pressure in the boiler reaches the pre-determined maximum level, and turns it on when the pressure reaches the minimum level. Likewise, they have a mechanism (level control) that turns the burner off and the water feed pump on when the quantity of water inside the boiler reaches the predetermined minimum level. These controls are automatic and of an electromechanical type.

From the energy point of view of, the most important control mechanism is the one that regulates flows of air and fuel (air-fuel relation) towards the burner, that is, excess air. Combustion control is carried out in different ways, there being control systems of different levels of sophistication according to boiler size:

- In boilers of less than 400 kW, combustion control is manual, since the burner (On-off), when started, delivers a constant flow of fuel that is independent of air, the flow of which is manually adjusted.
- In boilers of less than 1,000 kW, there is a mechanism in place, which allows the regulation of air and fuel flow at the same time according to the firing position of the burner (High-Low-Off).

- In boilers exceeding 1,000 kW, which have modulating burners, the control system is more developed, including a mechanism, which allows the regulation of air and fuel flows throughout the full working range of the burner.

Some boilers of greater capacity are equipped with mechanical and electronic systems, which control air and fuel on the basis of the analysis of oxygen contained in the flue, constituting the most sophisticated systems found in boilers.

In general, Peruvian boilers use mechanical automatic controls without analysis of gases contained in the flue.

5.2.4 Fuel

Oil derivates are the most commonly used fuels. Small boilers (< 981 kW or 100 BHP) generally use diesel oil 2 (PD2) and, in some cases, liquefied petroleum gas (LPG). Medium-sized and large boilers (≥ 981 kW or 100 BHP) use residual oil 6 or 500 (PR6 or PR500). Boilers in sugar companies mostly use cane bagasse and residual oil 500 (PR500). Carbon and natural gas (NG) consumption is insignificant.

The number of boilers and the corresponding accumulated power by type of fuel according to the national survey on boilers are shown in Table 16.

Table 16: Installed capacity of boilers according to type of fuel

TYPE OF FUEL	N° BOILERS	ACCUMULATED POWER	
		KW	BHP
PR500	421	2,918,645	297,578
PR6	263	1,593,300	162,449
PD2	400	534,791	54,526
Carbon	2	16,673	1,700
LPG	35	220,219	22,452
Bagasse	25	325,832	33,221
TOTAL	1,147	5,609,460	571,927

Source: MITINCI (2000)

5.2.5 Instruments

All boilers are equipped with steam pressure gauges and water-level indicators. In most cases, boilers have thermometers to measure the temperature of flue gases, fuel and feed water and fuel pressure gauges. Some boilers are equipped with fuel-flow meters. There are very few boilers with steam-flow meters and even fewer boilers with analyzers of the oxygen content of flue gas.

5.2.6 Blowdowns

Boiler blowdown is carried out to prevent excessive concentration of solids dissolved in the water inside the boiler. To that effect, it is necessary to extract part of the water (blowdown) on a periodical or continuous basis (depending on boiler size) in order to renew it with fresh soft water containing less dissolved solids. Thus, the formation of incrustations and carryovers is prevented.

In most boilers, water blowdown is manual and intermittent and entails opening the drainage valves from time to time. As a result, it is very likely that boilers lose a great amount of water and energy where there is excessive blowdown. It is also very likely that, in any case, they accumulate dissolved solids with the formation of deposits in the boiler tubes, which hinder the transmission of heat from the gases to the water, resulting in loss of energy efficiency.

According to the evaluation of 40 boilers (CENERGIA 2001), the concentration of total dissolved solids in feed water ranges from 16 mg/l to 4,250 mg/l, the maximum permissible limit inside the boiler being 300 mg/l pursuant to Rule UNE 9075 (1992) (UNE 9075: 1992 steam boilers, characteristics of the water).

5.2.7 Thermal insulation

The thermal insulation of the shell of most boilers is made with glass wool. In the case of almost all boilers, such insulation has not been changed since the purchase of the equipment. In most cases, the insulation is of good condition and, in some cases, it has deteriorated due to deformation caused by mechanical damage and humidity. In the latter case, heat losses increase.

5.2.8 Age

The average age of the boilers is 21 years (MITINCI 2000). The age of the boilers ranges from 1 year to 70 years. The number of boilers and the corresponding accumulated power according to age are shown in Table 17.

According to the manufacturers, the physical life of a boiler may be as long as 30 years; it may be longer or shorter depending on the particular operating and maintenance conditions to which boilers are subjected. According to the national survey on boilers, the age of 24% of the boiler park is in excess of 30 years.

One of the main reasons why there are such old boilers in Peru is that, in many cases, important parts of the boiler are replaced (e.g. tubes, plates, etc.), which is almost the same as having a new boiler. However, this is done gradually so as to split the cost of repairs into amounts that can be managed by the companies.

Table 17: Age of Boilers

Age of boilers (years)	Manufacturing Year	Number of Boilers	Accumulated Power		
			kW	BHP	%
More than 70	1925 - 1930	2	2,452	250	0.04
65 to 69	1931 - 1935	0	0	0	0,00
60 to 64	1936 - 1940	7	81,112	8,270	1.45
55 to 59	1941 - 1945	0	0	0	0.00
50 to 54	1946 - 1950	13	82,966	8,459	1.48
45 to 49	1951 - 1955	19	94,677	9,530	1.69
40 to 44	1956 - 1960	56	271,162	27,647	4.83
35 to 39	1961 - 1965	92	465,292	47,440	8.29
30 to 34	1966 - 1970	101	483,525	49,299	8.62
25 to 29	1971 - 1975	147	938,184	95,655	16.73
20 to 24	1976 - 1980	118	542,755	55,338	9.68
15 to 19	1981 - 1985	113	341,917	34,861	6.10
10 to 14	1986 - 1990	120	474,285	48,357	8.46
5 to 9	1991 - 1995	199	1,157,952	118,062	20.64
Less than 4	1996 – 2000	130	522,354	53,258	9.31
n/c		30	150,827	15,378	2.69
TOTAL		**1,147**	**5,609,460**	**571,927**	**100.00**

Source: MITINCI (2000)

5.2.9 Brands

According to the national survey on boilers, Peruvian boilers comprise 151 different brands. Most boilers are of the following brands: Distral (14.4%), Cleaver Brooks (9.6%), Powermaster (8.0%), Apin (6.5%), York Factory (4.6%), and Metal Empresa (4.4%). Of the aforementioned brands, only Apin and Metal Empresa are Peruvian, the rest being foreign brands, mainly from the United States of America.

5.3 Boiler operation

A boiler must meet the variations in vapour demand of the plant. If vapour demand increases, vapour pressure inside the boiler falls and the burner increases its firing rate to generate more vapour and compensate the fall in pressure. On the other hand, if vapour demand decreases, the vapour pressure inside the boiler rises and the burner reduces its firing rate, even switching off if vapour pressure reaches the predetermined maximum level. Similarly, if pressure reaches a predetermined minimum level, the burner switches on again to produce more vapour and increase its pressure. If there is high and continuous vapour demand, the burner will remain on for a long period of time, either in a high firing position or modulating between medium and low firing. On the other hand, if vapour demand is low compared to boiler capacity, the burner will remain on for a short period of time reaching the maximum pressure very fast, after which it will switch off. In this case, the burner will switch off and on very frequently and the operation time with firing may reach a proportion of 60% to 80% of the hourly time.

5.3.1 Operation

The average operating time of boilers is 4,530 h/year (MITINCI 2000). This means that boilers are in operation, on average, for 12.9 hours/day. Table 18 provides information on the number of boilers and the corresponding accumulated power according to range of operation.

Table 18: Operation of boilers

Operation h/week	**N° Boilers**	**Accumulated Power**		
		KW	**BHP**	**%**
Up to 9	48	139,931	14,267	2.49
10 to 19	45	79,288	8,084	1.41
20 to 29	69	220,288	22,460	3.93
30 to 39	40	95,628	9,750	1.70
40 to 49	90	282,716	28,825	5.04
50 to 59	40	113,714	11,594	2.03
60 to 69	63	188,000	19,168	3.35
70 to 79	75	246,240	25,106	4.39
80 to 89	57	286,286	29,189	5.10
90 to 99	39	202,839	20,681	3.62
100 to 109	58	450,011	45,882	8.02
110 to 119	13	84,839	8,650	1.51
120 to 129	36	177,289	18,076	3.16
130 to 139	8	115,832	11,810	2.06
140 to 149	105	639,344	65,186	11.40
150 to 159	22	216,718	22,096	3.86
160 to 169	155	1,321,442	134,731	23.56
n/c	184	749,057	76,372	13.35
TOTAL	1,147	5,609,460	571,927	100.00

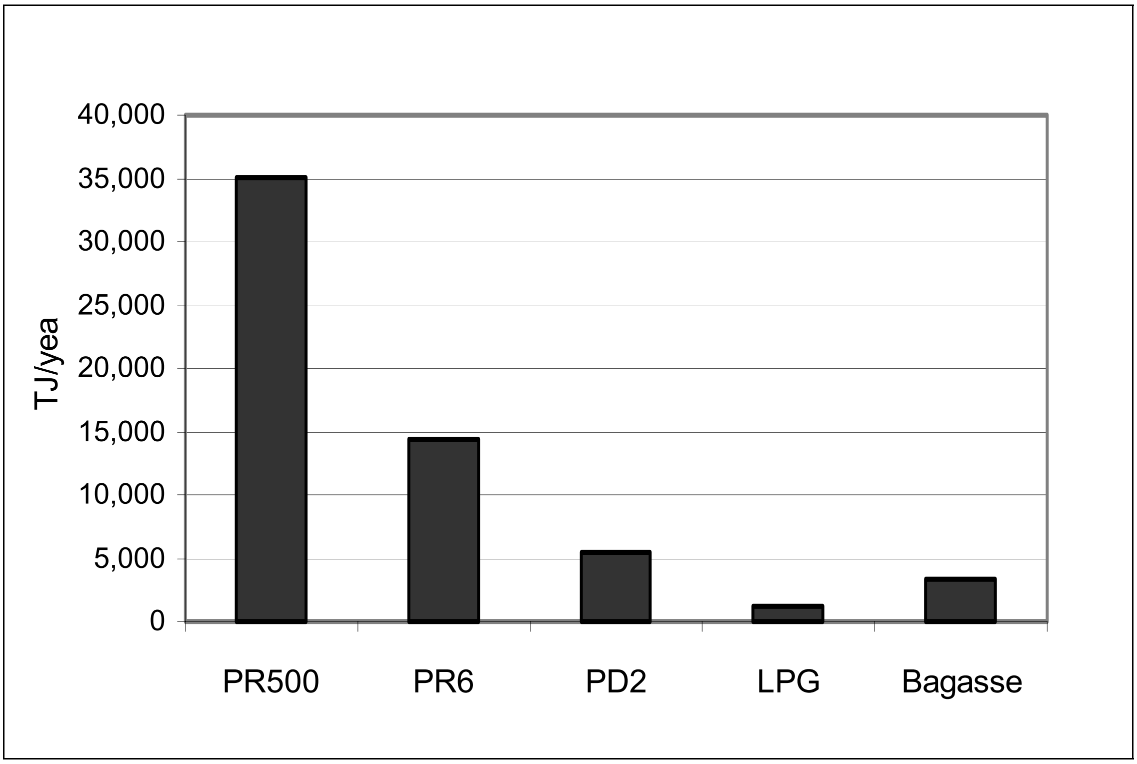
Source: MITINCI (2000)

Fuel consumption and CO_2 emissions depend, to a great extent, on operation time and vapour demand level in the plants. In many cases, the short operation time of Peruvian boilers is due to the economic recession in the production and services sectors. This has compelled companies to reduce working shifts in the plants, thus also reducing the operation time of boilers. At present, the Peruvian Government is concentrating a great part of its efforts on the economic recovery of Peruvian manufacturing industry as a strategy for job creation, which is one of the most urgent priorities and needs.

5.3.2 Fuel consumption

The most commonly used fuels in boilers are residual oil 500 (PR500) with 58.9%, residual oil 6 (PR6) with 24.3%, diesel oil 2 (PD2) with 9.2% and cane bagasse with 5.6% (MITINCI 2000), see Figure 5. Oil-derived fuels account for 94.4% of the total fuel consumption of boilers. Biomass accounts for the remaining 5.6%.

Figure 5: Annual fuel consumption according to the national survey on boilers



Source: MITINCI (2000)

5.3.3 Vapour generation

Most boilers produce saturated vapour at a pressure between 7 and 8 bar (MITINCI 2000). No real information on vapour generation (t/year) is available, because most companies fail to measure the amount of vapour generated in boilers due to the lack of measurement instruments.

5.3.4 Load factor

The load factor is defined as the relation between the current vapour production level of the boiler and its maximum vapour production capacity. According to information furnished by national survey on boilers, it has been estimated that boilers operate with an average load factor of 43%. The evaluation of the 40 boilers in 5 Departments (CENERGIA 2001) revealed that there is an average load factor of 62%. The evaluation of the 40 boilers in Lima (Jimenez et al. 2001) showed an average load factor of 38%. In this case, the load factor has been calculated on the basis of current and nominal fuel consumption, which is not the most adequate procedure, and consequently this figure is not very reliable.

In general, these results show a vapour generation level below the maximum capacity of boilers. It is advisable that boilers operate at least at 60% to 70% of their vapour generation capacity, which is the range within which a boiler typically reaches its maximum efficiency. A typical symptom of the fact that a boiler is operating with a low load factor is that it switches off and on many times, particularly if the boiler has a burner with On-off regulation.

In Peru, the serious economic recession experienced in recent years has systematically affected the growth of the production sector. In the opinion of businessmen who participated in a survey conducted by INEI[1], this is mainly due to demand shortage, unavailability of credits and unfair competition (smuggling and informal commerce). Thus, most companies are currently operating below their installed capacity, and the same occurs with their vapour generation systems, resulting in the reduction of energy efficiency of boilers and an increase in the level of CO_2 emissions in relation to vapour generation.

5.3.5 Sectors

Boilers are owned by companies assigned to 61 ISIC[2] codes (Third Revision) (MITINCI 2000). As may be appreciated in Figure 6, the sectors with a greater number of boilers are: preparation and canning of fish and fish products (ISIC 1512, 29.8%), preparation and spinning of textile products (ISIC 1711, 10.8%) and hospital activities (ISIC 8511, 8.0%).

5.3.6 Location

The boilers are located in 21 of the 24 Departments into which Peru is politically divided (MITINCI 2000). The greatest number of boilers is located in the Departments of Lima (36.7%), Ancash (13.4%) and La Libertad (7.5%). The highest accumulated power is to be found in the Departments of Lima (25.5%), Ancash (18.1%) and La Libertad (11.7%).

5.3.7 Maintenance

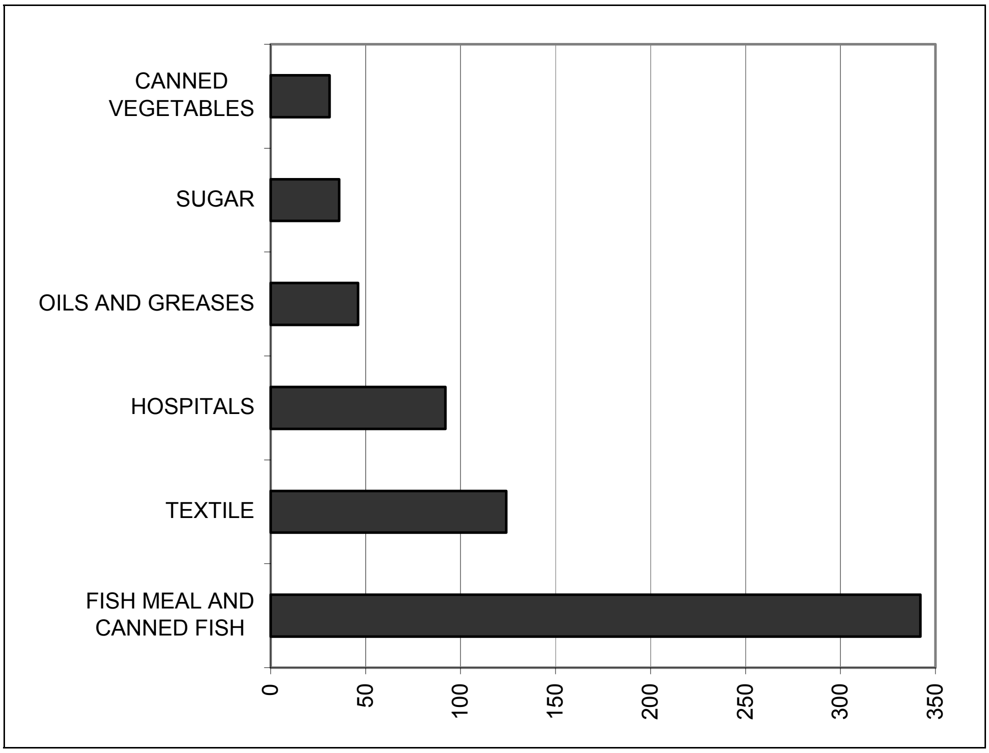
Preventive maintenance is a key factor in ensuring proper operation and the achievement of a high level of energy-efficiency of boilers. A maintenance programme enables all boiler components to be kept in good conditions of operation and efficiency. Boiler manufacturers usually recommend a preventive maintenance programme that includes daily, weekly, monthly and annual maintenance activities, performance tests, records and actions in the event of failures. Such maintenance programmes should form part of the routine activities of companies.

---

1 National Institute of Statistics and Informatics

2 International Standard Industrial Classification

Figure 6: Number of boilers per sector



Source: MITINCI (2000)

In the case of the companies that participated in the national survey on boilers, there is not a widespread preventive maintenance culture, and in many cases corrective maintenance is preferred, whereby the boiler or its components are repaired only when failures occur. This is mainly due to the fact that the economic crisis faced by companies does not allow them to allocate fixed budgets for preventive maintenance, because of other priorities such as aspects of production, the payment of salaries, energy, etc.

According to the national survey on boilers, 24.3% of the companies have an annual maintenance programme, 33.6% a semi-annual maintenance programme and 14.6% a monthly maintenance programme, which means that not all the companies attach the same importance to maintenance activities. Furthermore, 16% of boilers need to be overhauled and 11% need to be replaced by new boilers, as can be seen in Table 19. The remaining companies have failed to report on the maintenance of their boilers. In general, maintenance quality varies from one company to another.

Table 19: Maintenance according to the national survey on boilers

Situation	N° boilers	Accumulated power		
		KW	BHP	%
Overhaul	187	945,707	96,422	16.86
Replacement	130	753,500	76,825	13.43
n/c	830	3,910,253	398,680	69.71
	1,147	5,609,460	571,927	100.00

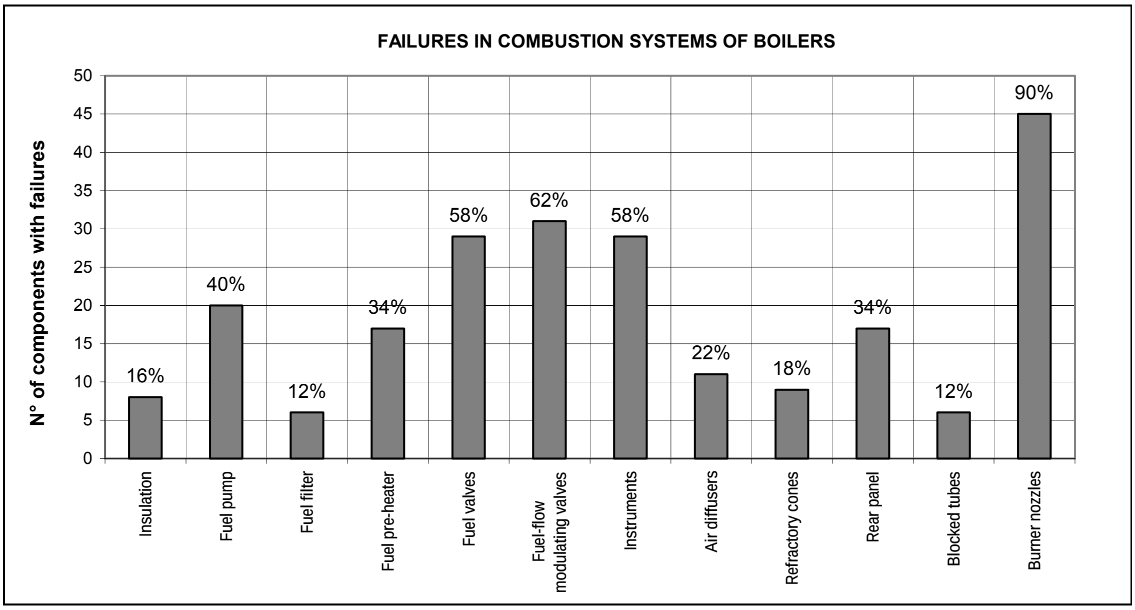
Source: MITINCI (2000)

In many cases, besides receiving poor maintenance, boilers are operated inefficiently, which aggravates the problem. This is mainly due to the lack of measurement instruments and the lack of operators with technical skills (in several cases boiler operators have performed other duties in the plant and not received formal training in boiler operation).

The Peruvian consulting company CINYDE S.A.C. carried out a series of combustion system adjustment and diagnostic inspections of 50 boilers belonging to several industrial plants all around Peru, which form part of the fishery, paper and battery sectors, during the year 2001 (V. Arroyo 2001). These inspections showed that the components that experienced the most failures were burner nozzles (45 of 50 boilers), mainly due to waste caused by their age of up to 15 years in some cases (the advisable physical life for nozzles is no more than 3 years). That implied bad atomization of fuel and an inadequate mix with air.

Other important deficiencies were the failure of pressure reducing and fuel-flow modulating valves. Moreover, the poor conditions of the instruments aggravated the problem, since it was impossible to ascertain the precise values of the combustion parameters (basically fuel injection pressures, atomization medium and fuel injection temperature). In addition, the poor conditions of the refractory cones and air diffusers led, in several cases, to inefficient combustion, which uses more excess air than necessary, resulting in high consumption of fuel and very low energy efficiency of boilers.

Figure 7: State of the combustion systems in 50 steam boilers



Source: V. Arroyo (2001)

It can be assumed that the effectiveness of maintenance activities will be improved progressively in companies as their economic situation improves. This will in turn allow an improvement in management aspects and the allocation of more resources to preventive maintenance and personnel training, so as to be more in line with sound management practices and international standards in this respect. To this effect, in addition to the operation of the financing funds, it will be necessary to consider the specific creation of a programme for personnel training in "good housekeeping", as well as the adoption of energy efficiency measures for companies participating in the CDM Project.

5.3.8 Shutdown and start-up times

The average operation time of boilers is 90 hours/week. This evidences intermittent operation of boilers, due either to low production (which does not allow working in three daily shifts) or to low vapour demand (which leads to the shutdown of boilers for a while, with a high frequency of shutdowns).

In companies, neither the effective operating time of boilers nor numbers of shutdowns or start-ups is recorded. What is clear is that the more shutdowns, the greater the number of boiler start-ups. It is known that the greater the number of start-ups, the greater the fuel consumption, since the boiler gets a little cold when shutdown and loses fuel when warming up again to its working temperature. On the other hand, losses occur due to the production of solid and gaseous unburned products, derived from inefficient combustion, which are always produced in the firing processes of the burner when the boiler is started.

5.4 Energy efficiency

The energy efficiency of a boiler is defined as the relation between the amount of energy coming from the fuel, which is absorbed by the water, and the total energy released by the fuel to the boiler. Energy efficiency is a key factor in the operation of a boiler, since it has a direct influence on fuel consumption and on the level of CO_2 emissions generated during its operation. A boiler that operates with low energy efficiency will consume more fuel to generate vapour and, therefore, will emit a greater volume of flue gases.

In the following, the methodology used to determine the energy efficiency of steam boilers is explained and the results of measurements of energy efficiency in Peruvian boilers are illustrated.

5.4.1 Methodology for the determination of energy efficiency

Internationally accepted regulations applicable to the determination of energy efficiency establish the use of direct and indirect methods (ASME PTC 4.1, DIN 1942, BSI 845). The following is a brief description of both methods for calculating energy efficiency. Section 10.3 contains more information on both methods, as well as on their respective advantages and disadvantages.

The direct method determines average energy efficiency during a certain operation period of the boiler. Average energy efficiency reflects the influence of variation in the state of operation of the boiler, including start-ups and shutdowns of the burner as well as boiler blowdowns. Application of this method mainly requires that the generated vapour and the consumed fuel be measured, which is difficult in most Peruvian boilers because of the lack of the necessary instruments.

The indirect method merely determines the instantaneous energy efficiency of the boiler. To this effect, it determines first the main heat losses, which not only allows determination of how the heat provided by the fuel is distributed, but also facilitates the evaluation of proceedings to improve the energy efficiency of the boiler. The application of this method is mainly based on analysis of the gases contained in the flue and does not require measurement of the generated vapour.

5.4.1.1 Direct method

The direct method determines the average energy efficiency (E) of the boiler by applying the following formula:

$$E = \frac{V \times (H - H_W)}{F \times LHV} \qquad \textit{(Equation 1)}$$

where

V *Steam flow, kg/h*

H	*Steam enthalpy, kJ/kg*
H_W	*Feed water enthalpy kJ/kg*
F	*Fuel consumption, kg/h*
LHV	*Lower heating value of the fuel, kJ/kg*

5.4.1.2 Indirect method

The indirect method (also called the heat-loss method) determines instantaneous energy efficiency (E) by applying the following formula:

$$E = 100 - (P_g + P_i + P_r + P_p) \qquad \textit{(Equation 2)}$$

where

P_g	*Heat loss caused by flue gases (%)*
P_i	*Heat loss caused by solid and gaseous unburned products (%)*
P_r	*Heat loss caused by radiation and convection (%)*
P_p	*Heat loss caused by blowdowns (%)*

In order to determine the heat loss caused by flue gases, it is necessary to analyze the oxygen content and the temperature of gases coming out of the flue.

In order to determine the losses caused by unburned products, it is necessary to analyze the CO content (gaseous unburned product) and to measure the concentration of particles in flue gases (solid unburned products).

In order to determine the losses caused by radiation and convection, if the insulation is in a good condition and the temperature of the external surface is lower than 60 °C, the following practical formula is applied (adapted from DIN 1942):

$$P_R = \frac{1.13 \times P^{0,7}}{Q} \qquad \textit{(Equation 3)}$$

where

Pr	*Heat loss caused by radiation and convection (%)*
P	*Boiler power, MW*
Q	*Instantaneous vapour generation, MW*

The loss caused by blowdowns was estimated at 1%, taking into account that it is not possible to determine the exact loss.

5.4.2 Energy efficiency in Peruvian boilers

During the national survey on boilers, energy efficiency data on only 16% of boilers (184 units) was obtained, which represents 26% of the installed capacity of the total sample. From such information it is inferred that boilers would have an average energy efficiency of only 76%, with values as low as 50% (MITINCI 2000).

It is important to point out that the information reported in the national survey on boilers on the energy efficiency is not very reliable, since the companies provided information based on simple estimates and, in some cases, on measurements obtained mainly by means of the indirect method. Likewise, the calculation of efficiency was based, in some cases, on the lower heating value (LHV) of the fuel and, in other cases, on the higher heating value (HHV).

Most companies are unaware of the energy efficiency of their boilers, due to lack of information and/or training or advice. Many boiler operators have a practical understanding of why their boilers do not operate efficiently. It is possible that those boilers whose energy efficiency was not reported on are the most inefficient, because there is no monitoring of energy efficiency. Moreover, in many of the companies that participated in the survey there is confusion between energy efficiency and combustion efficiency. The value of the latter is always higher than that of the former.

In addition, those companies that carried out measurements did not follow an accepted technical procedure. For this reason, the measurements made by Jimenez et al. (2001) and CENERGIA (2001) in the companies significantly differed in several cases from the values reported in the national survey on boilers.

Table 20: Energy efficiency in Peruvian boilers

Energy Efficiency [1]	**N° Boilers**	**%**
<70	4	5.00
70 – 74.9	6	7.50
75 – 79.9	9	11.25
80 – 84.9	29	36.25
85 – 89.9	31	38.75
> 89.0	1	1.25
Total	80	100.00

Source: Own calculations
(1) based on the LHV

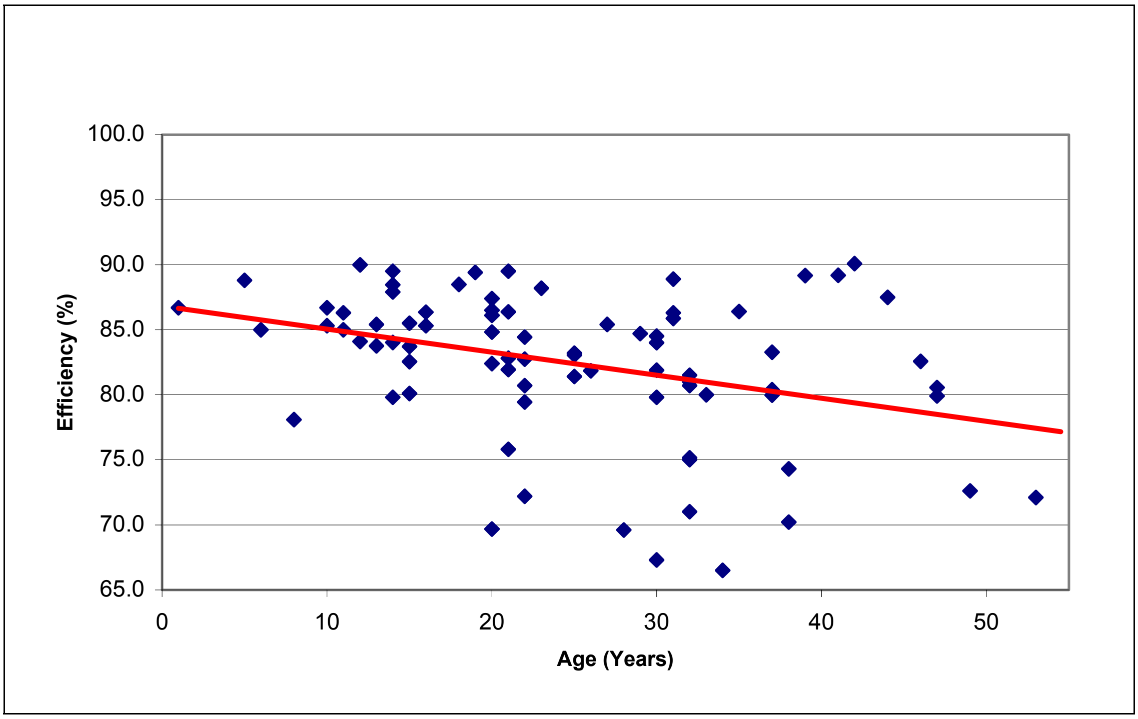
Additionally, there were some variations between the formulas used by CENERGÍA (2001) and Jimenez et al. (2001) to determine the losses through the indirect method. This led to partly different results which are not directly comparable. For this reason, energy efficiency of the 80 boilers was recalculated, based on the data obtained from field measurements made by Jimenez et al. (40 boilers in Lima) and CENERGIA (40 boilers in 5 departments of Peru). Results of the recalculation are shown in Table 20.

The recalculation showed that in the case of boilers evaluated by Jimenez et al. (2001) average energy efficiency is 82.7 %, and in the case of boilers evaluated by CENERGIA (2001) average energy efficiency is 82.1 %.

Considering the 80 evaluated boilers as a whole, average energy efficiency is 82.4 %, which is higher than the average efficiency of the boilers (76%) for which information was furnished in the national survey on boilers (MITINCI 2000). As a matter of fact, the efficiency values determined for the 80 boilers are more reliable, because they were based on standardized measurements and calculations.

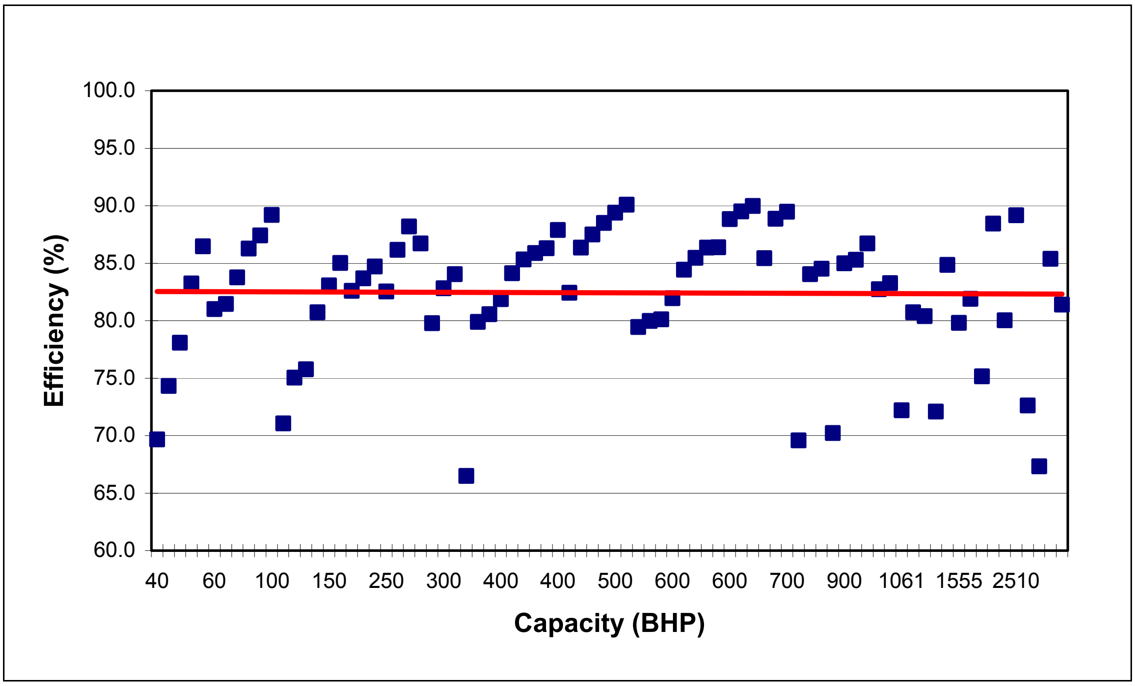
Figure 8 shows the variation of energy efficiency according to age of the aforementioned 80 boilers. Boilers more than 30 years old have an average energy efficiency of 80.2 %, whereas boilers less than 30 years old have an average energy efficiency of 83.8 %. Over the 62-year range of boiler age, average energy efficiency decreases by 0.17% per year. Furthermore, it has been determined that not only the energy efficiency of boilers decreases with age, but also operating and maintenance costs increase (greater frequency and magnitude of repairs).

Figure 8: Energy efficiency of boilers according to age



Source: CENERGIA (2001), Jimenez et al. (2001), own calculations

Figure 9: Energy efficiency of boilers according to capacity



Source: CENERGIA (2001), Jimenez et al. (2001), own calculations

In Figure 9, the variation of average energy efficiency according to the capacity (BHP) of the aforementioned 80 boilers can be observed. No significant variation between average energy efficiency and the power of the boiler is to be ascertained.

5.5 Auxiliary services

The main auxiliary services of a boiler are water softening and fuel supply systems.

5.5.1 Water treatment

In almost all industrial companies in Peru the treatment of the water fed to boilers involves water softening by means of ionic exchange resins. Through this process, the calcium and magnesium ions contained in the water (they produce incrustations) are removed, being exchanged for Na^+ ions, which do not produce incrustations. The resin will be regenerated with a solution of sodium chloride at 10%.

In addition to such softening, the boiler water is internally treated to eliminate any residues of calcium and magnesium salts as well as dissolved oxygen contained in the already softened water. Typically, this is done by adding chemicals such as phosphates and sodium sulphite.

According to evaluations performed in different industrial companies, water softening and internal treatment are not always carried out efficiently, for which reason salt incrustations are eventually produced in the tubes of the boilers, which reduces heat transmission and the energy efficiency of the boilers.

5.5.2 Fuel preparation

Boilers using residual oil 6 or 500 (PR6 or PR500) have fuel heaters both in the feed tanks and in the pipeline that supplies fuel to the burner. Their function is to achieve the proper viscosity for easy pumping and the correct atomization in the burner, thus facilitating its combination with air and favouring good combustion.

On many occasions this operation is not carried out properly, due to failures in the heating elements, the bad condition of temperature regulating and measurement devices, etc. For this reason, in some cases the fuel reaches the burner with a viscosity that hinders good atomization and, as a result, a greater quantity of unburned products is produced (mainly CO, soot).

5.6 Vapour distribution and condensate return

In general, vapour distribution from the boiler to users (heating equipment, steam-driven machines, processes, etc.) is made through pipelines, the vapour being transported by the pressure existing in the boiler. Once vapour has delivered its energy to the user (either heat or work), it is condensed. It returns to the boiler in the form of feed water, prior storage in a condensate tank, or it is simply discharged into the drain of the plant, in which case its residual energy is not recovered (sensible heat).

In almost all companies, vapour distribution and condensate return pipelines are insulated, though sometimes there is some vapour leakage, either through the pipelines themselves or through steam traps in bad conditions. In general, condensates are recovered in most companies, though the recovery level varies from one company to another, possibly within a range of 10% to 95%. While such aspects have an influence on global fuel consumption in the plant, they do not influence the efficiency of the boilers.

6 Evaluation of technological options for the mitigation of CO_2

6.1 Boiler replacement

In Peru, there are several suppliers of boilers of different brands, types, power, pressures and fuels, manufactured both locally and abroad, mainly in Colombia, the United States and, to a lesser extent, in European countries. There are also suppliers of equipment for boilers, automatic control systems, heat recovery equipment and fuel system components, as well as of diverse spare parts.

Boilers provided by suppliers generally have a standard equipment regarding energy efficiency. For example, they have mechanical excess air control mechanisms rather than electronic controls with oxygen correction, and they have manual valves for blowdowns rather than automatic blowdown controls based on the conductivity of the water inside the boiler. Furthermore, they do not have economizers for heat recovery, and the burners are conventional (that is, they are not low NO_X). Additional equipment for the efficient use of energy is usually acquired at a higher cost on an optional basis. That is why users do not consider such additional equipment. In many cases, however, the additional investment would be profitable, being reimbursed from energy savings.

The referential costs of standard boilers range from US$ 20,900 to US$ 174,900 for power between 50 and 1,000 BHP (490 to 9,808 kW), as can be seen inTable 21. The cost of boiler assembly, which could represent some 3% to 5% of the cost of the boiler, is not included.

Table 21: Referential costs of steam boilers

POWER		TYPE	COST
kW	BHP	FUEL	US$
490	50	PD2	20,900
981	100	PD2	39,600
2,942	300	PR6	65,880
4,904	500	PR6	91,699
7,846	800	PR500	144,160
9,808	1,000	PR500	174,900

Source: APFCC (2001)

It is worth mentioning, that most manufacturers of steam boilers in Peru (no more than 10 companies) only manufacture boilers with power of up to 800 BHP, and there is only one company that manufactures boilers with power of up to 5000 BHP. In the case of suppliers of boilers manufactured abroad, units may be supplied with power of more than 5000 BHP.

According to the manufacturers, the expected physical life of a boiler is around 30 years or more, depending on the maintenance and operating conditions to which is subjected. According to the national survey on boilers, 24% of boilers in Peru are 30 years old and 3% of boilers are even more than 50 years old.

One of the reasons why there are such old boilers in Peru is that many companies do not have the necessary economic resources to purchase a new unit (economic crisis, recession, other priorities, etc.). For this reason, and although it means higher expenditure in the long term compared to the cost of a new boiler, they prefer to renew a boiler progressively (for example, by replacing some or all of the tubes, the shell, the burner, etc.).

Based on experience, and from the point of view of energy efficiency, an old boiler may be of just as efficient as a new boiler if it is properly maintained and operated. Unfortunately, this is not the case for most old boilers in Peru, since, as in the case of many new boilers or those that are not yet old, they are neither well maintained nor operated with maximum efficiency. Likewise, many old boilers have to operate in low demand conditions (low load factor), because their structures (tubes, shell, etc.) are weak, which means operating with less efficiency.

6.2 Options to improve energy efficiency

There are several measures that may be adopted to increase and maintain the energy efficiency of a boiler at optimum levels, which would save energy and reduce operating costs and emissions to the environment.

There are measures that form part of preventive maintenance and normal operation of boilers (which is called "housekeeping"), and the cost of their implementation forms part of the operating cost of boilers. If such measures are not implemented, or if they are implemented inefficiently, boilers operate at low efficiency, or simply cannot operate, either because a component is not working properly, or for safety reasons.

There are other measures, which constitute options to improve the efficiency of boilers, which are usually not incorporated in units when purchased, since they require greater investment. This investment is in many cases justifiable, but this aspect is usually not analyzed when purchasing a boiler.

6.2.1 "Housekeeping" measures

There follows a brief description of the measures that form part of the maintenance and normal operation of boilers, some of which do not require any investment.

1. **Adjusting excess air.** This entails adjusting the airflow in the burner until an oxygen level of 3.5% to 4% is reached in flue gas, avoiding the generation of many un-

burned products (carbon monoxide, soot) in combustion products. The adjustment is made throughout the full range of modulation of the burner by 1) positioning the air-fuel regulating mechanism of the burner (rods and cam) that all boilers have; 2) observing the appearance of fumes, that is, the presence of soot (gross adjustment) or 3) analyzing flue gases (fine adjustment), which yields better results. The adjustment is usually made by a third party that has a portable gas analyzer and experience in combustion adjustment methodology. Few companies have gas analyzers and personnel trained in the making of adjustments with this analyzer.

2. **Adjusting temperature and pressure for the injection of fuel into the burner.** This involves working with the optimum operational parameters indicated in the boiler's manual, field adjusted according to the quality of fuel, thus contributing to efficient combustion.
3. **Adjusting the draft (pressure inside the furnace).** This is done by positioning the flue damper, until a proper pressure is reached that enables good combustion and flame.
4. **Operating the boiler at load factors between 60 and 70%.** Within this range, the boiler operates at its maximum efficiency. This improvement may be achieved by operating the boiler burner in "manual" position, which may be applied to boilers found in those plants with stable processes. The implementation of this measure depends on the characteristics of vapour demand in the company (that is, whether it is stable or fluctuating), and on the capacity of the boiler (in small boilers whose burners are not modulating, it is not possible to apply this measure).
5. **Reducing vapour pressure as much as possible.** This entails adjusting the maximum working pressure limit in the boiler's pressure switch, so that a vapour pressure and temperature may be obtained that is convenient for users, without the need to generate it at very high pressure, with correspondingly high energy consumption.
6. **Maintaining combustion system components in good condition.** This entails performing adequate preventive maintenance on the pump, fuel heater (as is the case with residual oils), modulating valve, cam, burner (particularly the atomization nozzle), refractory cone, diffuser, etc. The efficient operation of these components ensures good combustion with low levels of excess air and high boiler efficiency.
7. **Maintaining instruments and controls in good condition.** This involves maintaining manometers, thermometers as well as pressure and fuel flow regulators in good operating condition, in order to ensure good combustion in the burner.
8. **Maintaining refractory cones and insulation in good condition**, in order to prevent heat losses through boiler walls.
9. **Cleaning tubes in gas and water areas.** This involves sweeping the tubes in the gas area or eliminating salt deposits in the water area, allowing an improvement in heat transmission from gases to the water and an increase in boiler efficiency.

10. **Replacing tubes when necessary.** This entails replacing malfunctioning tubes (which are then usually closed to prevent leakage of water, thus reducing the heat transmission area and the efficiency of the boiler).

Based on the Peruvian experience, it has been determined that the first seven measures are not properly taken into account by all boiler users, for which reason many units, though new or more or less new, are of low efficiency. The most common deficiency in boilers is improper maintenance of combustion system components, particularly the burner and controls. This forces operators to use more excess air than normal to prevent the presence of an excessive amount of soot in the flue, thus reducing boiler efficiency.

6.2.2 Investment measures to improve energy efficiency

With respect to investment measures to increase the energy efficiency of boilers, the most important in the Peruvian context are the following:

1. Installation of an automatic excess air control system.
2. Installation of an automatic blowdown system.
3. Replacement of inefficient fuel oil by a dual gas-fuel and oil burner.
4. Installation of an economizer.

These measures require investments ranging from US$10,000 to US$60,000, depending on the respective measure and the size of the boiler to which the measure is going to be applied. The first two measures bear almost no relationship to boiler size, whereas the last two do.

It should be mentioned, that these measures involve additional maintenance expenditure to ensure their operational capacity, and require the application of “housekeeping” measures to guarantee the savings that may be generated by their implementation. Thus, for example, the automatic excess air control system will be unsuccessful if the burner nozzle is worn out and produces bad combustion, or if fuel pressure and temperature are inadequate. Any of these factors will lead to the use of more excess air, not allowing the control system to fulfil its function.

Technology for the optimization of Peruvian boilers comprises the optional measures mentioned above. Such energy technologies have the following characteristics:

- They are technologies that have been commercially proven worldwide.
- A high level of energy efficiency can be achieved.
- They may be installed in all boilers with energy improvement potential, the only limitation being the return on investment.
- The useful life of such technologies – 10 years on average – is adequate, taking into account the remaining useful life of most of the boilers in which they would be implemented.

- Adequate preventive maintenance is required not only for the technology but also for the boiler in general.

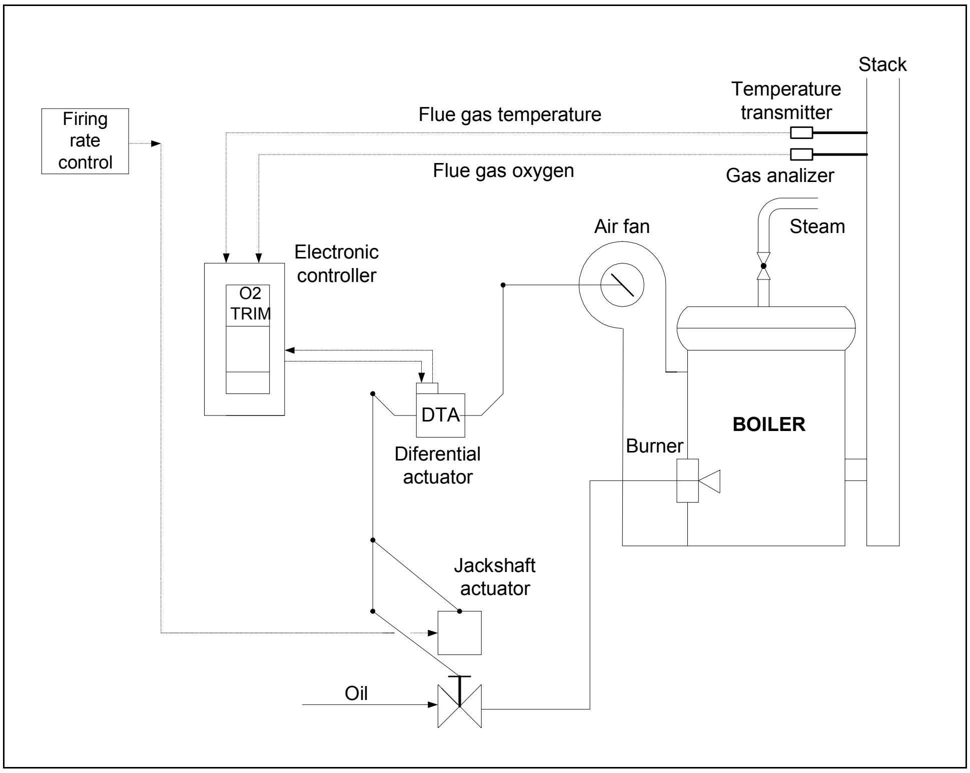
There follows a description of the technologies proposed to improve the efficiency of boilers.

6.2.2.1 Installation of an automatic excess-air control system

This entails regulating air and fuel flows in the burner until an oxygen level of 3.5% to 4% is reached in flue gas, without the production of many unburned products. Excess air below the recommended amount causes the presence of unburned products in combustion gases (CO, soot, etc.). On the other hand, excess air above the recommended amount entails greater consumption of energy when unnecessary additional air is heated.

The regulation is carried out throughout the full modulation range of the burner by automatically positioning the fuel valve and the air damper with an electronic controller, which receives a continuous signal from an oxygen sensor installed in the flue. This constitutes an improvement of conventional mechanical systems installed in the whole boiler. The fuel valve and air damper are moved simultaneously by rods driven by a modulator, which in turn responds to changes in the vapour pressure of the boiler, since it additionally includes an electronic controller (processor), a differential actuator, an oxygen sensor and a recorder, if desired. Figure 10 shows a typical automatic excess-air control system.

Figure 10: Automatic excess-air control system



Source: Adapted from Preferred – Rimcor Instruments (Bulletin CS-PCC-II-1034, USA)

The use of this automatic control system is mainly justified in the case of boilers with a capacity above 300 BHP (diesel) or 600 BHP (residual) and with continuous operation above 5000 h/year. The local cost of such an automatic control system, whose components are imported, amounts to US$ 17,000 (including installation). The system generates maintenance expenditure primarily on account of the replacement of the oxygen sensor (zirconium oxide) and calibrations. The cost of the system itself varies little according to the size of the boiler, because the main and most expensive components (oxygen sensor and controller) depend to a minimum extent on the size of the boiler.

The improvement in energy efficiency is between 2% and 4%. The required investment is US$ 16,000 to US$ 18,000 for power of between 981 kW and 9,808 kW (300 BHP to 1000 BHP), as shown in.Table 22

Table 22: Investment costs for automatic excess-air control systems

CAPACITY kW	CAPACITY BHP	COST US$
981	100	16,000
2,942	300	16,000
4,904	500	18,000
7,846	800	18,000
9,808	1,000	18,000

Source: Local quotation

In the case of boilers of lower capacity it is advisable to monitor excess air on a periodical basis (every month or two months) with a portable electronic gas analyzer (O_2, CO_2, CO), which is inexpensive. In this case, the cost of the equipment amounts to only US$ 1,800. The equipment generates maintenance expenditure for the replacement of gas analysis cells approximately every two years.

6.2.2.2 Implementation of an automatic blowdown system

A boiler must be blown down to prevent the concentration of salts dissolved in the water contained in the boiler. If the blowdown is excessive, greater loss of energy, water (hot water) and chemicals may arise.

Blowdowns are usually performed manually. A small amount of water is extracted from inside the boiler and replaced with fresh feed water. Blowdowns may be performed from the bottom (drainage from the lower part of the boiler) and from the surface (near the water level) inside the container. As a rule, only bottom blowdowns are performed on small boilers, while both bottom and surface blowdowns are performed on large boilers.

A completely automatic boiler water blowdown system eliminates the problems posed by manual blowdowns and is composed of the following (see Figure 11):

- **Surface blowdown system:** This is a system consisting of a conductivity sensor (measures indirectly the content of total solids dissolved in water contained in the boiler), whose signal is received by a controller operating a valve in the blowdown line. If conductivity is above the “set point”, the controller opens the blowdown valve, and if is below the “set point”, the blowdown valve closes. This results in a adequate quantity of blowdown, preventing the waste of energy resulting from excessive manual blowdown.
- **Bottom blowdown system:** This consists of a timer controlling a bottom blowdown valve of the boiler that opens under a certain frequency and for a short period of time determined through testing.

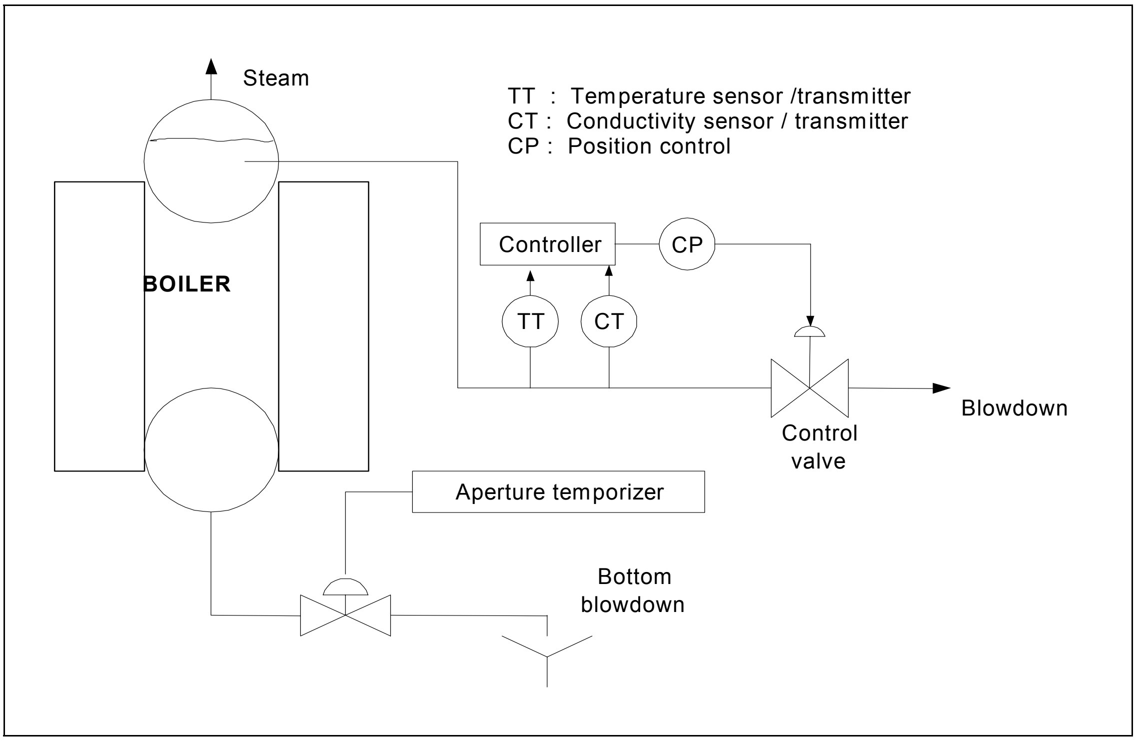
The maximum cost of a completely automatic blowdown system is US$ 10,000 (including installation), as shown in Table 23. This system likewise generates maintenance expenditure, basically on account of the replacement and gauging of the conductivity sensor. Its use is justified mainly in boilers with a capacity of more than 100 BHP (diesel) or 300 BHP (residual), and with continuous operation of more than 5000 h/year. The energy saving achieved with automatic blowdown is within the range of 0.5% to 2%.

Table 23: Investment costs for automatic blowdown control

CAPACITY kW	CAPACITY BHP	COST US$
981	100	8,000
2,942	300	8,000
4,904	500	10,000
7,846	800	10,000
9,808	1 000	10,000

Source: Local quotation

Figure 11: Automatic blowdown control system



Source: Own elaboration

6.2.2.3 Replacement of an inefficient fuel oil burner by a dual gas-fuel oil burner

This entails replacing obsolete, damaged and inefficient burners (in some cases spare parts for burners are not found on the local market) with new, high efficiency burners, which allow operation of the boiler with a low level of excess air and unburned products.

The replacement strategy would consist in using dual burners (oil-natural gas). This would allow the efficient burning of oil (achieving fuel savings of up to 6%) until natural gas is available in Lima (March 2004), where the gas market is mostly concentrated. It would then allow the burning of natural gas, achieving even greater savings due to its lower energy cost, as well as reduced emissions to the environment.

The investment required to replace the burner depends on the size of the boiler and may vary as shown in Table 24. Such investments include the cost of the dual burner and its installation. They exclude, however, the cost of gas pipelines, valve train and pressure reducing station, which would be necessary if natural gas is used. According to the manufacturers, the useful life of a burner is at least 10 years.

Table 24: Investment costs for dual burners

CAPACITY kW	CAPACITY BHP	COST US$
981	100	30,800
2,942	300	33,000
4,904	600	36,250
7,846	800	39,150
8,827	900	39,600
9,808	1,000	40,800

Source: SAACKE – manufacturer of burners

6.2.2.4 Installation of an economizer

An economizer is a gas-water heat exchanger that allows the recovery of part of the heat contained in the boiler's flue gases, heating the water fed to the boiler. The economizer consists of a shell, which is installed in the flue line, inside which there is a bundle of finned tubes through which the water to be heated circulates, and outside which gases circulate. Thus, the temperature of the flue gas is reduced and boiler efficiency is increased. Most boilers, particularly firetube boilers, are not sold with an economizer, unless the user so requires, which is not generally the case in Peru but may be profitable (this is often unknown to the user).

The cost of the economizer depends on the size of the boiler in which it is installed, since a larger economizer is required for a greater flow of gases (see Table 25). In general, its installation is justified for boilers with a capacity of more than 300 BHP (diesel) or 700 BHP (residual) and with a continuous operation of more than 5000 h/year. The energy saving usually achieved is up to 3%.

Table 25: Investment costs for economizers

CAPACITY kW	CAPACITY BHP	COST US$
2,942	300	36,000
4,904	500	39,000
7,846	800	43,000
9,808	1,000	46,000

Source: APFCC (2001)

7 Emission sources and CDM project boundary

This section identifies emissions sources of greenhouse gases and air pollutants and determines the boundary for the CDM project activity.

7.1 Principles for determining the project boundary

For each CDM project a clear boundary needs to be determined. All greenhouse gas emissions within that project boundary are monitored during the project crediting period and compared with baseline emissions. According to the methodology in the Marrakech Accords[1], changes in greenhouse gas emissions outside the project boundary, which are measurable and attributable to the CDM project activity, are considered as *leakage*. Monitored emission reductions should be adjusted for leakage.[2]

The Marrakech Accords further state that "*the project boundary shall encompass all anthropogenic emissions by sources of greenhouse gases under the control of the project participants that are* ***significant*** *and* ***reasonably attributable*** *to the CDM project activity.*"[3] According to this general principal, changes in emissions may therefore not be included in the project boundary if they are very small, or if they cannot be reasonably attributed to the project. In the following, these principles will be applied to the Peruvian boiler case.

The project encompasses only the increase in energy efficiency in the boiler itself. Emission reductions due to fuel switch to natural gas are excluded, as is the distribution of vapour within the company.

7.2 Emission sources

Greenhouse gases (GHG) covered by the Kyoto Protocol are carbon dioxide (CO_2), methane (CH_4), nitrous oxides (N_2O), and fluorinated gases such as hydrofluorocarbons (HFC), sulphur hexafluoride (SF_6) and perfluorocarbons (PFC). Fluorinated gases are not relevant in the case of fuel combustion processes in industrial boilers. Other important air pollutants of industrial boilers are carbon monoxide (CO), nitrogen oxides (NO_X), sulphur dioxide (SO_2) and particulate matter.

According to the Dutch CERUPT tender, emission sources may be classified in the following four categories (CERUPT 2001):

1. **Direct on-site emissions.** These include emissions from fuel combustion and process emissions on the site of the project.

---

1 Paragraph 51 in the Annex to decision 17/CP.7, see FCCC/CP/2001/13/Add.2

2 Paragraph 59 of the Annex to decision 17/CP.7, see FCCC/CP/2001/13/Add.2

3 Paragraph 52 of the Annex to decision 17/CP.7, see FCCC/CP/2001/13/Add.2

2. **Direct off-site emissions.** These involve emissions upstream and downstream of the project, which are directly influenced by the activity of the project. This includes in principle both:
   - One-step *upstream emissions*, for example, those connected with the production, transport and distribution of fuels used for the project. An example is the power generation emission effect of electricity conservation projects.
   - One-step *downstream emissions*, for example, those connected with electricity produced by the project that replaces off-site electricity generation.
3. **Indirect on-site emissions.** Due to the existence of the project, demand for the services provided by the project can change. An example of this is an increase in average indoor temperature after a more efficient heating device is installed. For energy conservation projects this is called the *rebound effect*.
4. **Indirect off-site emissions.** This refers to changes in emission or sequestration activities parallel to the project, which may occur as a result of the existence of the project. An example is where reducing logging in one forestry project leads to an increase in logging in a forest elsewhere.

Indirect emission effects are difficult to estimate in the case of Peruvian industrial boilers. An increase in energy efficiency in one company does not directly influence the behaviour of other companies. However, a CDM programme to improve energy efficiency may have some influence on the market:

Companies participating in the CDM programme increase the energy efficiency of boilers, leading to a reduction in the cost of vapour production. This may make companies in energy intensive sectors more competitive than companies with poor energy efficiency. A competitive advantage on the market may lead to a small increase in production, associated with increased demand for vapour and, possibly, an increase in emissions (rebound-effect). On the other hand, a national CDM boiler programme and a possible increase in the competitiveness of participating companies may also raise awareness for energy efficiency in companies that are not willing to participate or are not eligible for the CDM programme, for example, because of the small size of their boilers. The national CDM boiler programme may indirectly encourage these companies to implement cost-effective energy efficiency measures, which may lead to indirect off-site reduction of emissions. A national CDM boiler programme may also have an effect on the local boiler market, as the demand for boilers is expected to change.

However, it seems difficult to estimate the quantity of such effects and to attribute them appropriately to the CDM project activity. The effects are estimated to be relatively small. It is suggested that possible changes in indirect emissions are not included in the project boundary. Direct emission sources are analyzed in more detail below.

7.3 Direct on-site emissions

The main GHG emission escaping directly from the boiler flue is CO_2, produced by fossil fuel combustion. Boilers mainly operate with oil derivates (PR-6, PR-500 and diesel), which are burnt in the respective burners. CO_2 emissions of industrial boilers in Peru are estimated in Chapter 1. The average CO_2 emission factor of fuels fired in Peru is approximately 79 t CO_2/TJ.

In the oil combustion process, small amounts of CH_4 and N_2O are also emitted. Methane emissions are produced in small quantities due to incomplete combustion and depend, inter alia, on combustion temperature and the size of the boiler. The *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* suggest for oil combustion in *Manufacturing Industries and Construction* a default emission factor of 2 kg/TJ. In the case of *Energy Industries*, a value of 3 kg/TJ is proposed; in the case of the *Commercial / Institutional Sector* the value is 10 kg/TJ (IPCC 1996, Reference Manual, Table 1-7, page 35). The latter emission factor is deemed to be the most appropriate in the case of Peruvian boilers. Taking into account the global warming potential (GWP) of methane (21 times CO_2), the combustion of 1 TJ fuel oil causes methane emissions of about 210 kg CO_2 equivalents. Compared with associated CO_2 emissions of approximately 79,000 kg CO_2, methane emissions are only a very small fraction of CO_2 emissions (0.05-0.27%).

Similar considerations apply for nitrous oxide emissions. Nitrous oxide emissions occur in combustion processes with temperatures above 800 K and below 1200 K. The *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* suggests for oil combustion in all relevant categories a default emission factor of 0.6 kg/TJ (IPCC 1996, Reference Manual, Table 1-8, page 36). Nitrous oxide has a global warming potential (GWP) 310 times that of CO_2. Taking into account this GWP, the effect of nitrous oxide emissions would be relatively small, amounting to approximately 0.24% of CO_2 emissions.

In both cases, for methane and nitrous oxide, emissions uncertainty with respect to appropriate emission factors is high. For this reason, and because of the small quantity of methane and nitrous oxide emissions, it is suggested that methane and nitrous oxide emissions not be estimated. Following this approach, emission reductions of the project are slightly underestimated, as these emissions are reduced slightly with an improvement in energy efficiency.

7.4 Direct off-site emissions

In the case of boilers, direct off-site emissions include, above all, upstream emissions from fuel supply and electricity generation.

7.4.1 Emissions in the fuel supply chain

In the fuel supply chain, carbon dioxide and methane emissions are estimated to be the most relevant. Estimation of carbon dioxide emissions is difficult, as no data on energy demand for exploration, production, transport and refining is available. In the national inventory of greenhouse gases (CONAM 1996), fugitive methane emissions from oil production have been estimated. According to the GHG inventory for the year 1994, these fugitive emissions from oil activities are estimated at 1,190 t CH_4 for 342,135 TJ of refined oil; that is, fugitive emissions amounted to approximately 3.5 kg CH_4/TJ. Consequently, upstream fugitive methane emissions from fuel supply are estimated to be in the same quantitative range as methane emissions associated with the combustion of fuel, and are neglected here.[4]

7.4.2 Electrical generation

Boilers use electric energy to activate fan engines (combustion air, gases), feed water pumps and fuel pumps, and fuel heaters (if they fire PR-6 or PR-500). In an average firetube boiler, fuel accounts for 99% of the total energy consumption (TJ), electric energy consumption being only less than 1%.

To illustrate the above-mentioned, the following example is provided: According to information provided by an important boiler supplier in Peru, a standard boiler of approximately 5 MW consumes a maximum of 142 gal/h residual oil. Electrical engines register different power rates: fan, 12 HP; water pump, 18 HP (continuos operation); oil pump, 1.2 HP; air compressor, 12 HP (when burner can atomize with air or vapour, it atomizes with air only when the boiler is started and then with vapour, when enough pressure is available); oil heater, 13 HP (only at start-up; then it is vapour heated), and the board, 0.6 HP. Taking into account stand-by times and energy consumption values mentioned, it can be stated that electricity demand accounts for 0.41 to 0.73% of fired fuel.

In general terms, it can be expected that electricity demand in boilers will not to be significantly influenced by energy efficiency measures, though electricity consumption does, in fact, reduce slightly when energy efficiency increases.

Thermal-electric power plants release carbon dioxide (CO_2) to the atmosphere. According to the National Energy Balance of 1998 (MEM 1998), the electric energy consumption of power plants amounted to 115,478 TJ (54% hydropower, 19% residual oil, 17% diesel, 9% natural gas and 2% bagasse). Average CO_2 emissions in Peruvian power plants were of the order of 67.7 t CO_2/TJ.

Taking into account the emission factor of 67.7 t CO_2/TJ and electricity demand of up to approximately 0.0073 kWh electricity per kWh of fired fuel in the boiler, CO_2 emissions from upstream electricity generation amount to only approximately 0.5 t CO_2/TJ of fuel, which corresponds to about 0.6% of direct CO_2 emissions.

Taking into account this rather small quantity and the expected low impact of energy efficiency on electricity demand, it is suggested that changes in upstream emissions

4 As above, the increase in energy efficiency leads to a reduction in upstream emissions. Project emission reductions are consequently slightly underestimated.

from electricity production be ignored. In order to get a clearer picture on this effect, it is suggested in the monitoring concept in Chapter 10 that electricity demand for vapour production be monitored in a sample group of 10 boilers.

7.5 Conclusion

For the Peruvian industrial boiler project it is suggested that a rather narrow project boundary be laid down: only CO_2 emissions from fuel combustion in boilers are considered within the project boundary.

In particularly, the following changes in emissions are **not** considered as a result of the project activity:

- Emission effects due to any changes in vapour demand. Such changes may occur as a result of indirect effects, for example, an increase in the competitiveness of the company due to reduced vapour production costs (rebound effect).
- Methane (CH_4) and nitrous oxide (N_2O) emissions resulting from fuel combustion.
- Emissions resulting from upstream electricity generation for secondary boiler equipment (fans, pumps, etc.).
- Upstream emissions resulting from the production, transport and distribution of fuels.
- Upstream emissions associated with the production of technical equipment such as boilers, burners, economizers, etc.

8 Current emissions of industrial boilers in Peru

Below is an estimation of greenhouse gas emissions and emissions of air pollutants (NO_X, SO_2 and CO) and particulate matter of Peruvian industrial boilers. This estimation is mainly based upon the national survey on boilers conducted by MITINCI in 2000, which covered 1,147 boilers around the country, with an accumulated capacity of 5,600 MW (MITINCI 2000).

8.1 Characteristics of combustion in boilers

Emissions released to the atmosphere by boilers are the result of the combustion of different types of fuels. The most common fuels are *residual 500* (PR500) and *residual 6* (PR6), generally fired in boilers with capacities over 1 MW (100 BHP). The remaining boilers mainly use *diesel 2* (PD2), and in some cases *liquefied petroleum gas* (LPG). *Bagasse* is also used in some sugar plants.

Boiler emissions are released directly into the atmosphere through flues. There are few boilers that have cyclones to retain soot (particulate matter); the great majority have no equipment to remove particulate matter or polluting gases.

The combustion products are CO_2, H_2O, CO, NO_X, SO_2, CH_4, N_2O, particulate matter and O_2 and N_2 of excess air. Of these gases, CO_2 is the only important greenhouse gas. Other greenhouse gases, CH_4 and N_2O, are not significant compared with CO_2 emissions (see paragraph 7.3 of this study).

Contaminant gases are CO, NO_X and SO_2. The presence of CO depends mainly on the preparation of fuel, the combustion process (excess air, degree of combination of air and fuel), the maintenance of combustion system components, start-ups and interruptions due to vapour demand. SO_2 emissions depend on the sulphur content of fuels. The sulphur content increases from PD2 to PR500. LPG contains almost no sulphur. NO_X emissions derive from the oxidation of nitrogen in the air as well as the small quantities of nitrogen in the fuel. They depend on significantly on the temperature of the combustion flame. The presence of particulate matter in combustion gases is basically due to the same reasons as the formation of CO.

8.2 Methodology

8.2.1 CO_2 Emissions

The amount of CO_2 emissions in boilers depends on the amount and type of fuel fired and the degree of completion of the combustion process (conversion of fuel into CO_2). In turn, fuel consumption depends mainly upon vapour demand and boiler efficiency.

Below is an estimate of CO_2 emissions in Peruvian industrial boilers obtained through the following steps:

1. Estimation of annual fuel consumption.
2. Application of emission factors with full carbon oxidation.
3. Estimation of the degree of incomplete oxidation.
4. Calculation of GHG emissions.

The quantity of annual CO_2 emissions is calculated for each type of fuel using fuel consumption, the emission factor and the oxidized carbon fraction of the fuel in the combustion process, as follows:

$$Em_{CO_2} = C \cdot EF_{CO_2} \cdot f \quad \text{(Equation 4)}$$

where

Em_{CO2}	*Annual CO_2 emissions (kg)*
C	*Annual fuel consumption (TJ)*
EF_{CO2}	*CO_2 emission factor with full oxidation (kg/TJ)*
f	*Fraction of oxidized carbon of the fuel*

8.2.2 SO_2, NO_X and CO Emissions

SO_2, NO_X and CO emissions also depend on the amount of and type of fired fuel. CO emissions likewise depend on the degree of completion of the combustion process. SO_2 emissions do not depend on the size of the boiler or burner design. NO_X depends on the type of boiler and burner.

To estimate SO_2, NO_X and CO emissions, a similar calculation is made:

1. Estimation of annual fuel consumption.
2. Estimation and application of emission factors inter alia SO_2, NO_X or CO.
3. Calculation of respective emissions.

The amount of annual emissions of such gases is calculated as follows:

$$Em_{gas} = C \cdot EF_{gas} \quad \text{(Equation 5)}$$

where

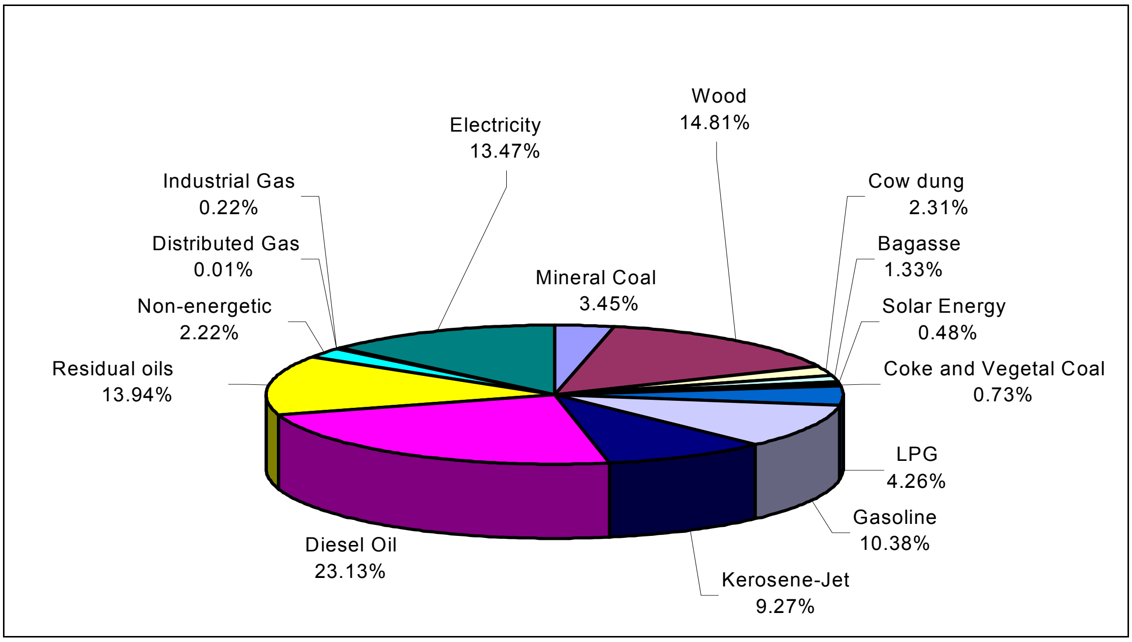
Em_{gas}	*Annual gas emissions; SO_2, NOx or CO (kg)*
C	*Annual fuel consumption (TJ)*
EF_{Gas}	*Gas emission factor; SO_2, NOx or CO (kg/TJ)*

8.3 Fuel consumption in Peru

8.3.1 Peruvian fuel consumption

On the basis of macroeconomic statistical data from the *National Energy Balance of Peru – year 2000, Ministry of Energy and Mines*, overall fuel consumption in Peru is shown in Figure 12. This shows that Peruvian energy users depend strongly on fuel oils such as *diesel* and *residual*.

Figure 12: Energy consumption in Peru in the year 2000

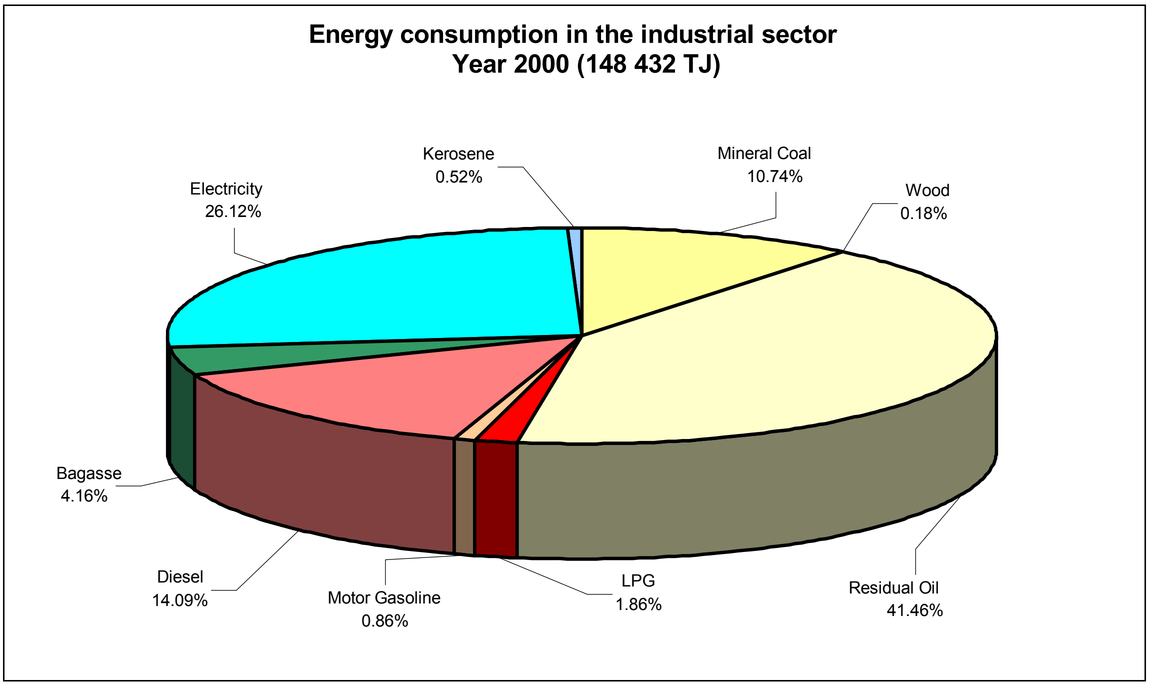


Source: Ministry of Energy and Mines (2001)

8.3.2 Peruvian industry fuel consumption

In the year 2000, energy consumption in the Peruvian industrial sector (which encompasses manufacturing, fish processing, mining & metallurgy and agroindustrial plants), is shown in Figure 13. This figure shows also that the most important fuels in Peruvian industry are residual and diesel oils.

Figure 13: Energy consumption in the industrial sector



Source: Ministry of Energy and Mines (2001)

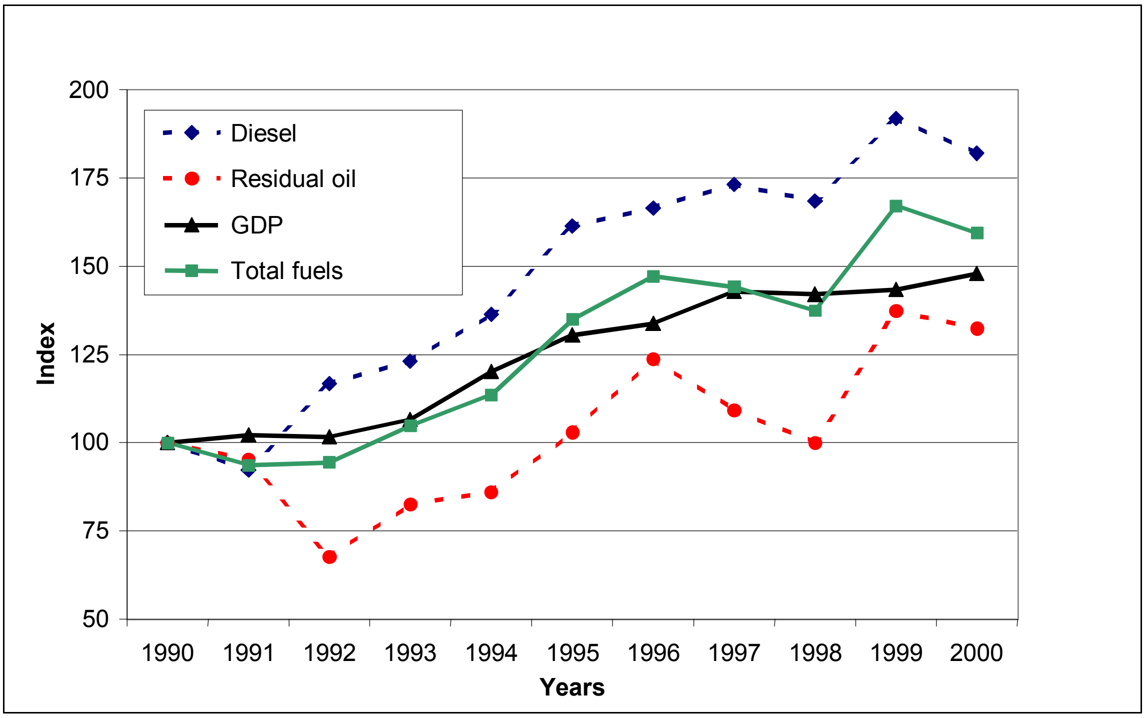
8.3.3 Fuel oil demand and GDP

The development of fuel oil demand and gross domestic product (GDP) in the 1990s in Peru is shown in Figure 14. The figure shows that fuel demand has increased at even higher rates than GDP. GDP increased from 1990 to 2000 by 48%, while the consumption of fuel oils increased in the same period by approximately 60%. Also for the future, it can be expected that energy demand in industry will increase due to economic growth.

8.3.4 Fuel demand trends

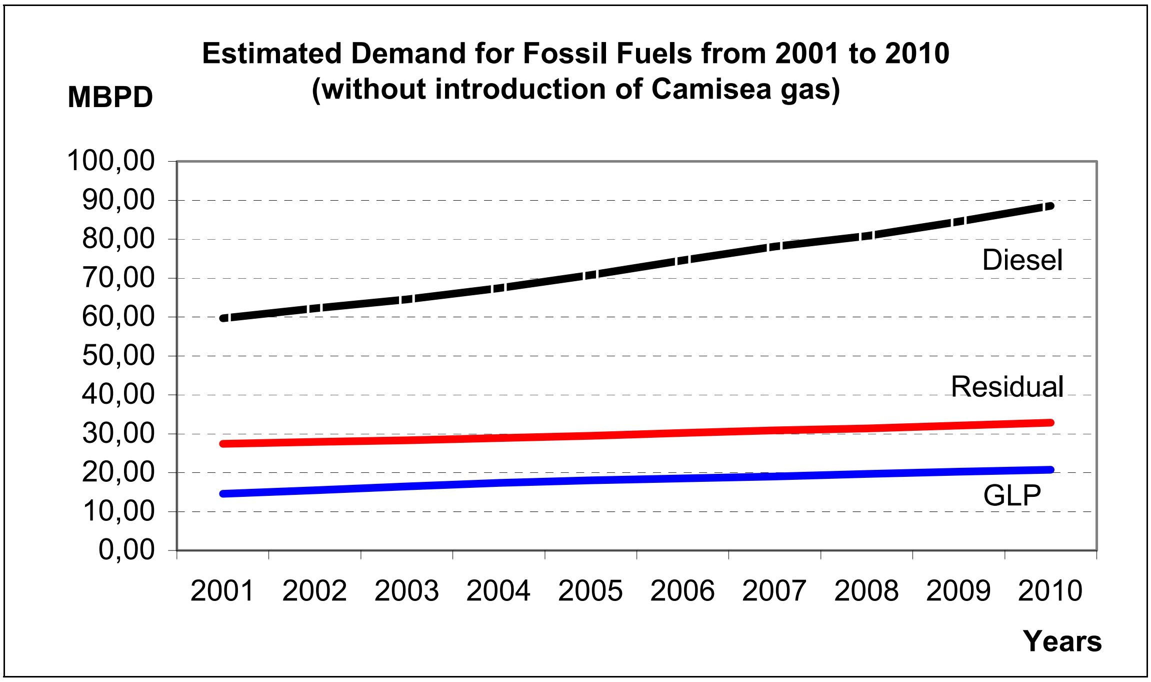
Finally, Figure 15 and Figure 16 show the projected demand for the main fuels to be used in all Peruvian sectors from 2000 to 2010. In the first scenario (Figure 15), the introduction of natural gas is not considered, while in the second scenario (Figure 16) projections about the future fuel switch from fuel oils and LPG to natural gas are reflected.

Figure 14: Development of GDP and oil consumption in Peru from 1990 to 2000



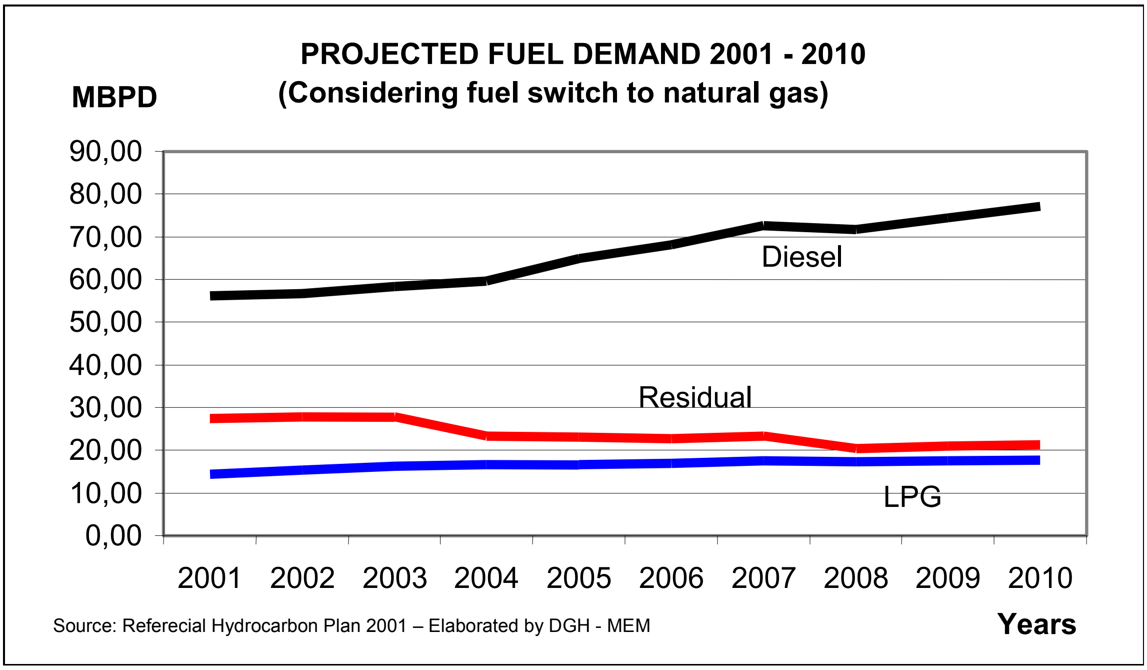
Source: Ministry of Energy and Mines (2001), own calculations

Figure 15: Projected demand for different fuels in 2001 – 2010 in Peru without consideration of a fuel switch to natural gas



Source: Referential Hydrocarbon Plan 2001 – Elaborated by the Ministry of Energy and Mines (2002)

Figure 16: Projected demand for different fuels in 2001 – 2010 in Peru with consideration of a fuel switch to natural gas



Source: Referential plan for hydrocarbons 2001 – Elaborated by the Ministry of Energy and Mines (2002)

8.4 Fuel consumption of industrial boilers in Peru

This section includes an estimation of the fuel consumption of Peruvian boilers, as well as an estimation of the number of existing boilers in the country, on the basis of different sources of information. Such estimation is affected by a degree of uncertainty, since not all sectors dispose of accurate information on the energy consumption of their manufacturing companies.

8.4.1 Results of the National Boiler Survey

In Peru, there is no official statistical information on fuel consumption in industrial boilers, let alone on the number of existing boilers. The most reliable basis available to estimate fuel consumption and the number of industrial boilers is the national boiler survey carried out by the Ministry of Industry, Tourism, Integration and International Commercial Negotiations in 2000 (MITINCI 2000).

It was initially conceived, that *manufacturing companies* included in Section D (Divisions 15 to 37) of the CIIU (International Uniform Industrial Classification), comprising around 18,849 companies, would respond to the survey.

During the process of the survey, additional companies from other sections and divisions, such as hospitals (section N, division 85), hotels (section H, division 55) and dry cleaners (section O, division 93) were included, which had initially not been considered. Sections D, N, H and O together comprise about 19,100 companies.

According to MITINCI, 369 companies took part in the survey, with a total of 1,147 boilers (5,610 MW capacity), including companies from sections D, H, N, O, as shown in Table 26 below:

Table 26: General results of the national survey on boilers

SECTOR	N° Companies	N° Boilers	Boiler capacity (MW)
Manufacturing companies	269	649	2,825
Fish processing companies	66	371	12,628
Hospitals	9	92	131
Hotels and hostels	6	11	7
Dry cleaners	19	24	18
TOTAL	**369**	**1,147**	**5,610**

Source: National survey on boilers by MITINCI (2000)

From Table 26 it can be concluded that manufacturing and fish processing companies total 335 companies (90.8% of the total), 1,020 boilers (88.8% of the total) and 97.2% of the total capacity in boilers.

Considering only *manufacturing companies,* section D (divisions 15 to 37), under the jurisdiction of the MITINCI, the survey reports 269 companies and 649 boilers, with a capacity of 2,825 MW (50.4% of the total).

8.4.2 Projection of fuel consumption and number of boilers

In order to judge the representativeness of the national survey, additional research was necessary using a "bottom-up" approach to estimate both the total consumption of fuels and the number of industrial steam boilers. This additional research was based on statistical data available from the MITINCI, the Ministry of Fishery, INEI (National Institute of Statistics), among others. Special attention was given to manufacturing and fish processing companies, as these are the areas addressed by this study.

In the national survey on boilers, companies reported fuel consumption levels in *gallons* (liquid fuels) and *tonnes* (solid fuels). Such units have been converted to energy units (TJ) using conversion factors and sources included in Table 27. Conversion factors refer to the lower heating value (LHV) of the corresponding fuels.

Table 27: Lower heating value (LHV) and specific gravity of fuels

Fuel	Specific Gravity (1) tonne / m³ (15,5°C)	LHV (2)	
		GJ/gal	GJ/tonne
LPG	0.545	0.09246	44.84
Diesel-2	0.856	0.13790	42.59
Residual-4	0.901	0.14285	41.87
Residual-5	0.934	0.14612	41.35
Residual-6	0.964	0.14903	40.85
Residual-500	0.980	0.15053	40.59
Bagasse (3)			6.28
Firewood (3)			15.06
Sawdust (4)			13.05
Anthracite Coal (4)			29.00
Bituminous Coal (4)			32.40

Sources: (1) PETROPERU (1989)
*(2) LHV for liquid fuels was calculated with the following formula from API TECHNICAL DATA BOOK (1983): LHV (Btu/lb.) = 16796+54.5*API-0, 217*API^2-0.0019*API^3 (where: API = 141.5/S.G - 131.5)*
(3) Factors used in the National Energy Balance (Ministry of Energy and Mines 2001)
(4) IDAE (1983)

8.4.2.1 Manufacturing Companies

In the case of manufacturing companies, research was based on the 18,849 companies registered in the MITINCI in Section D (Divisions 15 to 37) of the CIIU, covering a wide range of companies. However, some of these companies do not have steam boilers.

From that list, companies with boilers were identified as follows:

1. Companies with CIIU codes corresponding to activities not involving the use of steam boilers (e.g. clothing manufacturers, printers, furniture manufacturers, etc.) were eliminated. Some companies, which were likely to use boilers, remain. The number of companies to be analyzed was thus reduced to 9,158.
2. Only companies consuming fuel according to the Bureau of Statistics of the MITINCI were considered. This also reduced the number of companies since companies without boilers would not register fuel consumption in the database of the MITINCI, unless they had furnaces, dryers, diesel groups, freight elevators, etc. As a result of this examination, a list of 627 companies with CIIU data, names and fuel consumption was finally obtained from the MITINCI.
3. From the list of 627 companies registering fuel consumption, those that do not have boilers were eliminated. The selection is based on our knowledge of the processes of each company and of companies in general. For instance, pottery companies, bakeries, brick companies, etc. were eliminated.

The list was finally reduced to 528 companies that have steam boilers, 269 of which participated in the national survey on boilers, that is, 50% of manufacturing companies.

In order to determine the fuel consumption and the number of boilers of the manufacturing companies, the following procedure was followed:

1. **Estimation of fuel consumption in companies that participated in the national survey on boilers.** Based on the 348 boilers for which data on fuel consumption was provided in the national survey on boilers (16,767 TJ/year), fuel consumption of the 649 boilers participating in the survey was projected. The same relation between fuel consumption and boiler capacity was assumed for those companies that did not report their fuel consumption. This assumption implies that companies that did not report their fuel consumption have similar load factors and efficiencies. This linear extrapolation is made for each type of fuel, resulting in an overall fuel consumption of 24,468 TJ/year.
2. **Estimation of fuel consumption in companies that did not participate in the national survey on boilers.** For the 259 companies that did not answer the survey, consumption of 13,922,240 gal/year of diesel and 35,138,002 gal/year of residual oil totalling 7,183 TJ/year is obtained from the statistics of the MITINCI. However, there is no data available on the number of boilers and their corresponding capacities. The capacity of the corresponding boilers is determined in a similar way as above, assuming the same ratio between fuel consumption and boiler capacity as for companies that answered the survey. This way an overall capacity of 1,246 MW was obtained. To estimate the number of existing boilers in companies that did not participate in the survey it is assumed that these companies have similar vapour production characteristics, that is, they have similar fuel consumption per boiler and per company, totalling a number of 501 boilers in those companies.

Finally, the total estimation was made by adding the number of boilers, capacity and fuel consumption of the participating and non-participating companies. This way, a total of 1,150 boilers were estimated in formal manufacturing companies, with an overall capacity of 4,071 MW.

Table 28: Estimation of fuel consumption, number of boilers and boiler capacity in manufacturing companies

Fuel type	Companies with information on their fuel consumption in the national survey			Estimation of the fuel consumption of all companies participating in the national survey			Estimation of the fuel consumption of companies not participating in the national survey			TOTAL ESTIMATION		
	No Boilers	Capacity (MW)	Fuel consumption (TJ)	No Boilers	Capacity (MW)	Fuel consumption (TJ)	No Boilers	Capacity (MW)	Fuel consumption (TJ)	No Boilers	Capacity (MW)	Fuel consumption (TJ)
Total	**348**	**1,967**	**16,767**	**649**	**2,825**	**24,468**	**501**	**1,246**	**7,183**	**1,150**	**4,071**	**31,650**
Residual Oil 500	118	944	7,083	161	1,077	8,074	61	410	3,078	222	1,487	11,152
Residual oil 6	88	572	5,026	135	709	6,232	47	249	2,185	182	958	8,417
Residual oil 5	9	17	199	12	21	245				12	21	245
Residual oil 4	2	2	14	2	2	14				2	2	14
Diesel oil 2	105	192	628	253	378	1,238	392	587	1,920	645	965	3,158
LPG	9	18	71	26	172	667				26	172	667
Bagasse	12	215	3,626	25	326	5,490				25	326	5,490
Coal	0	0	0	0	0	0				0	0	0
Wood	0	0	0	9	30	not estimated				9	30	not estimated
Other	5	5	120	26	109	2,508				26	109	2,508

Source: Own calculations, MITINCI (2000)

8.4.2.2 Fish processing companies

According to the Ministry of Fishery, there is no direct and accurate information available on the fuel consumption of their boilers. A list of companies given by the Ministry of Fishery plus those that additionally participated in the survey totalled 115 existing fish processing companies; all of which are considered to have steam boilers due to the nature of their processes. Hence, the coverage of the companies that participated in the National Survey (66) would account for approximately 57%.

In order to determine the fuel consumption and number of boilers in fish processing companies, the following procedure was followed (see Table 29).

1. **Estimation for the companies that participated in the national survey on boilers.** Following the same procedure as described for manufacturing companies, an estimation of the overall consumption of all participating companies (371) was made on the basis of the 213 boilers for which information was provided on their fuel consumption (9,298 TJ/years). For those companies that did not report their fuel consumption, the same relation between fuel consumption and boiler capacity was assumed. This same linear extrapolation is applied for each type of fuel, obtaining an overall consumption of 15,035 TJ/year.

2. **Estimation for companies that did not participate in the national survey on boilers.** As for the 49 fish processing companies that did not answer the survey, there is information available neither on the number of boilers nor on the corresponding fuel consumption. To estimate the fuel consumption, as well as the number of boilers and their capacity, it is simply assumed that companies that did not answer the survey have the same characteristics as those that did, that is, they have the same relations regarding the number of boilers per company, fuel consumption per boiler and boiler capacity. From such extrapolation, a total number of about 170 boilers were obtained, with a fuel consumption of approximately 6,903 TJ/year and a capacity of about 1,218 MW.

Finally, the total estimation was made by adding the number of boilers, capacities and fuel consumption of companies that both did and did not participate in the survey. As a result, the 115 fish processing companies were found to have about 541 steam boilers with an overall capacity of 3,846 MW.

Table 29: Estimation of fuel consumption, number of boilers and their corresponding boiler capacity in fish processing companies

Fuel type	Companies with information on their fuel consumption in the national survey				Estimation of the fuel consumption of all companies participating in the national survey			Estimation of the fuel consumption of companies not participating in the national survey			TOTAL ESTIMATION		
	No Boilers	Capacity (MW)	Fuel consumption (TJ)	%	No Boilers	Capacity (MW)	Fuel consumption (TJ)	No Boilers	Capacity (MW)	Fuel consumption (TJ)	No Boilers	Capacity (MW)	Fuel consumption (TJ)
Total	**213**	**1,640**	**9,298**	**100.00**	**371**	**2,628**	**15,035**	**170**	**1,218**	**6,903**	**541**	**3,846**	**21,938**
Residual oil 500	155	1,174	6,512	70.04	245	1,752	9,715	122	872	4,835	367	2,623	14,550
Residual oil 6	52	426	2,657	28.57	112	832	5,183	43	316	1,972	155	1,148	7,155
Residual oil 5	0	0	0	0.00	0	0	0			0	0	0	0
Residual oil 4	0	0	0	0.00	0	0	0			0	0	0	0
Diesel oil 2	1	0	1	0.01	6	3	6	1	0	1	7	3	6
LPG	3	23	27	0.29	5	25	29	3	17	20	8	42	50
Bagasse	0	0	0	0.00	0	0	0			0	0	0	0
Coal	2	17	101	1.09	2	17	101	1	12	75	3	29	177
Wood	0	0	0	0.00	0	0	0			0	0	0	0
Other	0	0	0	0.00	1	0	not estimated			0	1		not estimated

Source: Own calculations, MITINCI (2000)

8.4.2.3 Manufacturing and fish processing companies

Table 30 presents a final estimation for the Peruvian productive sector (manufacturing and fish processing companies) obtained by adding the estimations of the number of boilers, their capacities and fuel consumption.

Table 30: Total estimation in manufacturing and fish processing companies

Combustible	No Boilers	Capacity (MW)	Fuel consumption (TJ)
Suma	**1,691**	**7,917**	**51,080**
Petroleo Residual 500	589	4,110	25,701
Petroleo Residual 6	337	2,106	15,572
Petroleo Residual 5	12	21	245
Petroleo Residual 4	2	2	14
Petroleo Diesel 2	652	968	3,164
GLP	34	215	717
Bagazo de caña	25	326	5,490
Carbón	3	29	177
Leña	9	30	not estimated
Otros	27	109	not estimated

Source: Own calculations, MITINCI (2000)

Table 31 shows the total amount of fuel consumption in the Peruvian productive sector in 1999 (the year covered by the national survey) according to the National Energy Balance elaborated by the Ministry of Energy and Mines (MEM).[1]

The table shows that the consumption of fuels in all boilers in manufacturing and fish processing companies equals approximately 51,000 TJ/year. The table also shows that boilers mostly consume residual and diesel oil, their consumption being 44,697 TJ/year (87,5 %).

By comparing the energy consumption of boilers (51,081 TJ/year) with the energy consumption of the productive sector at a national level (112,217 TJ/year) registered in the national energy balance, it can be inferred that steam boilers account for about 46% of total energy consumption in Peruvian industry. As for residual and diesel oils, industrial boilers account for around 66% and 12% respectively in the productive sector.

Table 31: Consumption of fuels in the productive sector in 1999

Sector [(1)]	Consumption of energy (TJ)			TOTAL
	Residual	Diesel	Others[(2)]	
Industry	29,833	8,232	12,854	50,919
Fishery	10,076	7,751	329	18,156
Mining Metallurgy	22,086	7,672	5,516	35,274
Aquaculture/agriculture	1,330	2,076	4,462	7,868
TOTAL (Productive sector)	**63,325**	**25,731**	**23,161**	**112,217**
Relation between boiler consumption / total consumption in the productive sector	65.6%	12.3%	27.6%	

Source: MINISTRY OF ENERGY AND MINES – National Energy Balance - 2000
(1) In MITINCI's nomenclature, Industry, Mining/metallurgy, aquaculture/ agriculture sectors corresponded to manufacturing companies.
(2) Including: coal, bagasse, firewood, LPG, manufactured gas, natural gas and kerosene.

It is important to remark that the consumption of fuels in industrial boilers varies over time due to economic and environmental factors. The most important factor affecting energy consumption is the production level in companies, which in turn depends upon the market in which they perform.

[1] Note that the MEM divides the productive sector into industry, mining/metallurgy, aquaculture /agriculture and fishery. This division does not coincide with the nomenclature provided by the MITINCI, which includes industry and mining/metallurgy in manufacturing industries.

8.4.2.4 Number of industrial boilers

Table 32 below shows the number of boilers in Peruvian industrial companies (manufacturing and fish processing companies) and the scope of the national survey regarding these companies and their steam boilers. It is important to note that the subject of this survey was industrial boilers. Hence, boilers of other sectors (hospitals, hotels, dry cleaners, etc.) are not considered in the survey. There are also informal companies with boilers on which data is not available. However, these companies are rather small and, therefore, their figures would not significantly affect the above-mentioned results.

Table 32: Number of companies and steam boilers in the productive sector

Productive sector	Number of existing companies	Number of existing boilers	Scope of the national survey	
			Participating companies	Participating boilers
Industrial manufacturing companies	528	1,150	51%	56%
Fish processing companies	115	541	57%	69%
TOTAL	643	1,691	52% (1)	60%(1)

(1) Coverage with regard to manufacturing and fish processing companies jointly

8.5 Emission factors

In order to determine emissions of Peruvian industrial boilers and emission reduction of the CDM project, it is necessary to estimate emission factors. For this purpose the following sources of information are evaluated and taken into consideration:

1. SIEE (Economic – Energy Information System) managed by OLADE (Latin American Energy Organization). The Ministry of Energy and Mines of Peru (Technical Bureau of Energy) uses SIEE emission factors, also for the preparation of the Peruvian National Communication. According to official communication from the Ministry of Energy and Mines (Oficio N° 031-2002-EM/OTERG) the emission factors they use are not finalized for SO_2 and particulate matter (they report values for LPG and not for fuel oil, coal and bagasse). For this reason, emission factors from this source were not used in this study.
2. Recommended default emission factors in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (UNEP/OECD/IEA/IPCC 1996, Reference Manual, page 1.13).
3. AP-42 Emission Factors (5^{th} edition, updated 2001) from U.S. EPA -Environmental Protection Agency of United States (http://www.epa.gov/ ttn/chief/index.html).

Of these three sources, AP-42 Emission Factors published by the EPA appear to be the most confident and detailed source applicable to Peruvian fuels, especially because it considers the different types of fuel in Peru. This source of information is chosen for the calculation of emissions in this report. The fuels listed in AP-42 (EPA denomination in parenthesis) correspond approximately to the following fuels in Peru:

- Distillate oil (*diesel 2*)
- Fuel oil 6 (*residual 6*)
- Liquefied petroleum gas (*LPG*)
- Bagasse
- Anthracite coal
- Bituminous coal

Table 33: Emission factors proposed by EPA for different fuels for industrial boilers with a capacity below 3000 BHP (29,400 MW)

Fuel	**Unit**	**CO_2**	**CO**	**SO_2**	**NOx**	**PM**
Diesel 2	lb/1000 gal	22,300	5.00	142 S	20.00	2.00
Residual 5	lb/1000 gal	25,000	5.00	157 S	55.00	10.00
Residual 6	lb/1000 gal	25,000	5.00	157 S	55.00	9.19 S + 3.22
Residual 500	lb/1000 gal	25,000	5.00	157 S	55.00	9.19 S + 3.22
LPG	lb/1000 gal	14,300	3.60	0.09 S	21.00	0.60
Bagasse	lb./ton	1,560	---	---	1.20	15.6
Anthracite coal	lb./ton	5,680	0.60	39 S	9.00	0.8 A
Bituminous coal	lb./ton	6,040	5.00	38 S	11.00	66

Source: EPA (2001). Note: S = sulphur content of fuel. A = ash content of coal

Table 34: Emission factors applied to Peruvian boilers

Fuel	% S	LHV	Emission factors (kg/TJ)					
			CO_2	CO[1)]	CO[2)]	SO_2	NOx	PM
Diesel 2	0.2475	0.1379 GJ/gal	73,351	28.0	16.4	115.6	65.8	6.6
Residual 5	0.715	0.1461 GJ/gal	77,609	30.1	15.5	348.5	170.7	31.0
Residual 6	1.06	0.1490 GJ/gal	76,091	29.5	15.2	506.5	167.4	39.5
Residual 500	1.465	0.1505 GJ/gal	75,334	29.2	15.1	693.1	165.7	50.3
LPG	0.003	0.0925 GJ/gal	70,151	17.7	17.7	0.1	103.0	2.9
Bagasse	0.05	6.28 GJ/ton	112,741	----	----	----	86.7	1127.4
Anthracite coal	1.1	29.00 GJ/ton	88,843	11.8	9.4	671.0	140.8	118.9
Bituminous coal	1	32.40 GJ/ton	84,560	87.5	70.0	532.0	154.0	924.0

Source: EPA (2001), own calculations, PM = particulate matter
1) Emission factor prior to project implementation based on measurements conducted by Jimenez et al. (2001), CENERGIA (2001) and own estimations.
2) Emission factor after project implementation based on standard values contained in AP-42 (EPA 2001).

Table 33 shows the proposed emission factors by EPA in AP-42. From this basis, considering the lower heating value (LHV) and sulphur content of Peruvian fuels, emission factors for Peruvian fuels are determined in Table 34. More detailed information, including underlying assumptions on the applied emission factors, is provided in the following sections.

8.5.1 Carbon dioxide emission factors

Carbon dioxide emission factors depend mainly on the composition of fuels (carbon content). In Peru there is no precise information about the composition of relevant national fuels. For residual and diesel fuels common information includes only data on specific gravity, viscosity, ignition point, sulphur content and heating value. For liquefied petroleum gas (LPG), also only scant information is available. Therefore, for calculations generally, default values from AP-42 are taken for all fuels.

There are no AP-42 emission factors available for CO_2 in the case of *residual oil 5* (API 20) and *residual oil 500* (API 12.9). It is assumed that the emission factors of these fuels are similar to that of *residual oil 6* (API 15.3). For other fuels, the values seem appropriate.

LPG from Talara Refinery in Peru comprises about 40% propane/propylene and about 50% butane/butene/butylene. AP-42 has two emission factors for LPG, one for propane and the other for butane. For calculations, the butane emission factor was taken, due to the predominance of this compound in Peruvian LPG.[2]

Bagasse is a biomass product and consequently CO_2 emissions are not accounted for here.

Coal consumption in Peru is very low compared with oil consumption. The domestic coal is *anthracite coal* while *bituminous coal* is mainly imported from other countries. In practice, a mixture of *bituminous* and *anthracite coal* is used, and the former predominates because of its better combustion properties.

By choosing the default values from AP-42 emissionfFactors, uncertainty is within a relatively small range, since the fuel characteristic varies only slightly in different countries within one type of oil product. The reason for this is that products fulfil quality standards that, in many cases, are the same worldwide (for example: ASTM - American Society for Testing and Materials).

Carbon dioxide emission factors are calculated assuming that a small part of the carbon in fuel is not oxidized in the combustion process and is emitted as CO, hydrocarbons, and particulate matter (soot). The quantity of unoxidized carbon depends on several factors, including fuel type, combustion technology, age of the equipment and maintenance practices.

---

[2] This is an initial estimation, as more precise information is not available. As the number of boilers with LPG is relatively small, the uncertainty associated with the emission factor has no major impact on overall emission estimates.

AP-42 Emission Factors consider different values for the oxidized carbon fraction (*f*); for example, for oil fuels the oxidized fraction is estimated at 0.99%, for gases it varies from 99.5 to 99.9% and for solid fuels from 98 to 99%.

In the case of Peruvian boilers, according to the results of combustion measurements performed in 80 boilers by CENERGIA (2001) and Jimenez et al. (2001), the fraction of oxidized carbon seems to be in the range considered by AP-42 for each type of fuel, though varying significantly from boiler to boiler.

8.5.2 Carbon monoxide emission factors

The rate of carbon monoxide (CO) emissions from combustion sources depends on the oxidation efficiency of the fuel. By carefully controlling the combustion process, CO emissions can be minimized. Thus, if a unit is operated improperly, or not well maintained, the resulting concentrations of CO (as well as hydrocarbons compounds) may increase by several orders of magnitude.

The presence of CO in the exhaust gases of boilers results principally from incomplete fuel combustion. Several conditions can lead to incomplete combustion, including insufficient oxygen (O_2) availability, poor fuel/air mixing, cold-wall flame quenching, reduced combustion temperature, decreased combustion gas residence time and load reduction (that is, reduced combustion intensity). In practice the CO emission rate increases in the following sequence:

LPG $\rightarrow$ Diesel 2 $\rightarrow$ Residuals $\rightarrow$ Solid fuels

The EPA does not propose in AP-42 emission factors for *bagasse* and *residual 500*. In the latter case the same value is assumed as for *residual 6.*

In AP-42, it is presumed that boilers are adequately operated and well maintained. In the Peruvian case this is not the case in practice, for all boilers and real values differ significantly from case to case. Based on an evaluation of measurements in 80 boilers conducted by Jimenez et al. (2001) and CENERGIA (2001), specific CO emission factors for boilers in Peru are suggested, which reflect the current situation prior to project implement. The proposed CO emission factors are listed in Table 35.

Table 35: Proposed emission factors for carbon monoxide (CO)

	Diesel (current situation in Peru)	Residual (current situation in Peru)[1)]	Diesel - EPA	Residual – EPA [1)]
Average CO (ppm)	49	76		
CO Lb/10^3 gal	8.5	9.7	5.0	5.0
CO kg/TJ	28.0	**29.6**	16.4	15.3

Source: EPA (2001), own estimations based on Jimenez et al. (2001) and CENERGIA (2001)
1) Average emission factor for residual 5, 6 and 500

After project implementation and application of good housekeeping measures, the emission factors proposed by EPA in AP-42 are taken into consideration.

8.5.3 Sulphur dioxide emission factors

Sulphur dioxide (SO_2) emissions depend basically on fuel consumption and the sulphur content of the fuel burned in the boiler; it does not depend on boiler size or burner design, or on the characteristics of the combustion process. In the combustion process more than 95% of the sulphur within the fuel is converted to SO_2. About 1 to 5 % of the generated SO_2 is converted to SO_3 due to additional oxidation. SO_3 reacts rapidly with H_2O stemming from the humidity of the combustion gases and forms a sulphuric acid mist. LPG produces very little amounts of SO_2. In Table 36 the sulphur content of different fuels burned in Peruvian boilers is shown.

Table 36: Sulphur content of Peruvian fuels for industrial boilers

Fuel	Sulphur content (%)
Diesel-2	0.248
Residual-5	0.715
Residual-6	1.060
Residual-500	1.465
LPG	0.003
Bagasse	0.050
Anthracite coal	1.100
Bituminous coal	1.000

Sources: PETROPERU (1989) for diesel, residuals and LPG; Information provided by the company Agroindustrial Laredo relating to bagasse; IDAE (1990) for coal

8.5.4 Nitrogen oxides emission factors

Emissions of nitrogen oxides (NO_X) depend on many factors. NO_x is formed in combustion processes either due to thermal fixation of atmospheric nitrogen in the combustion air (“thermal NO_x”), or to the conversion of chemically bound nitrogen in the fuel (“fuel NO_x”). The term NO_x refers to the composite of nitric oxide (NO) and nitrogen dioxide (NO_2). For most fossil fuel combustion systems, over 95% of the emitted NO_x is in the form of NO. Nitrous oxide (N_2O) is not included in NO_x but has recently received increased interest because of atmospheric effects. However, emissions of N_2O are very low and can be neglected here (see section 7.3).

NO_X production increases with flame temperature, oxygen availability, and/or residence time at high temperatures. These trends are generally consistent for all types of boilers. Fuel nitrogen conversion is the more important NO_X-forming mechanism in *residual* oil boilers. It can account for 50 per cent of total NO_X emissions from residual oil firing. Thermal fixation, on the other hand, is the dominant NO_x- forming mechanism in units firing *diesel* oils, primarily because of the negligible nitrogen content in these lighter oils. Emission factors for nitrogen oxides are shown in Table 34 above.

8.6 Emission estimates

Emissions of CO_2, CO, NO_X and SO_2 from fuel combustion in Peruvian industrial boilers are calculated according to the methodology introduced in section 8.2. The basis for calculations is provided by estimations of fuel consumption as listed in Table 31 on page 98 and of emission factors in Table 34 on page 100. The results are summarized in Table 37 below.

Table 37: Emissions of industrial boilers in Peru in 1999

Type of fuel		Fuel consumption (TJ/year)	CO_2 (t/year)	CO (t/year)	NO_X (t/year)	SO_2 (t/year)	Particulate matter (t/year)
Liquid fuels	Residual 500	25,701	1,936,159	750	4,259	17,813	1,293
	Residual 6	15,572	1,184,889	459	2,607	7,887	615
	Residual 5	245	19,014	7	42	85	8
	Residual 4	14	1,087	0	2	5	0
	Diesel 2	3,164	232,083	89	208	366	21
Total liquid fuels		44,696	3,373,231	1,306	7,118	26,157	1,937
Solid fuels	Anthracite coal	0	0	0	0	0	0
	Bituminous coa	177	14,967	15	27	94	164
Total solid fuels		177	14,967	15	27	94	164
Gaseous fuels	Natural gas	0	0	0	0	0	0
	LPG	717	50,298	13	74	0	1
Total gaseous fuels		717	50,298	13	74	0	1
Total fossil fuels		**45,590**	**3,438,497**	**1,334**	**7,219**	**26,251**	**2,101**
Biomass	Bagasse	5,490	618,948	0	476	0	6,189
	Wood	0	0	0	0	0	0
Total biomass		**5,490**	**618,948**	**0**	**476**	**0**	**6,189**
TOTAL		**51,080**	**4,057,445**	**1,334**	**7,695**	**26,251**	**8,290**

Source: Own calculations

From the previous table, the main source of CO_2 and other gases from industrial boilers are again fuel oils (residuals and diesel), which contribute 83% to total CO_2 emissions.

According to the Peruvian Energy Balance published by the Ministry of Energy and Mines in 2001, in the year 1999 total CO_2 emission from the productive sector (industry, mining/metallurgy, aquaculture/ agriculture and fisheries) amounted to about 8,273,000 tonnes. This means that CO_2 emissions from industrial boilers in the same year (4,057,445 tonnes) represent nearly 50% of productive sector emissions.

9 Baseline methodology

9.1 General approach

In CDM projects, the amount of emission reductions is determined with the help of a baseline. This baseline represents the emissions that would have occurred in the absence of the project. The establishment of a baseline is meant to construct a *scenario* that shows the future development of emissions in the absence of the project. The amount of reduced emissions results from the difference between project emissions and baseline emissions (see Equation 1). Hence, baseline emissions are the basis for the calculation of reductions to be certified.

For each year during the crediting period, project emissions will be subtracted from baseline emissions, the result being the emission reductions to be certified:

$$\text{RedEm} = \sum_{\substack{\text{Tiempo}\\ \text{de crédito}}} \left(\text{Em}_{\text{Linea Base}} - \text{Em}_{\text{Proyecto}}\right)$$ (*Equation 6)*

where

RedEm *Total project emission reductions (t CO_2)*

$Em_{Baseline}$ *Level of annual baseline emissions (t CO_2)*

$Em_{Project}$ *Level of annual project emissions (t CO_2)*

9.2 Disaggregation of baseline into activity level and emission factor

For many types of projects – such as energy efficiency projects – it is useful to disaggregate the baseline into two parts: the activity level and the emission factor.

The *activity level* describes the amount of production. In the case of electricity generation, the activity level could be the amount of electricity generated (in MWh). In the case of cement production this level could be the amount of cement (in tonnes), and in the case of industrial boilers in Peru it is the volume of vapour production in MWh coming out of the boilers.[1]

The *emission factor* describes the process quality with regard to GHG emissions. In the case of cement production, it would be the equivalent CO_2 emissions per tonne of cement. In the case of industrial boilers, it is defined as the equivalent CO_2 emissions per

[1] As vapour distribution has not been included in the project, it is the quantity of produced vapour coming out of the boiler.

MWh of vapour production (t CO_2/MWh).

The baseline emission level, as well as the project emission level, can be determined by multiplying the activity level by the emission factor:

$$E_{Baseline} = AL_{Baseline} \cdot EF_{Baseline} \quad \text{(Equation 7)}$$

$$E_{Project} = AL_{Project} \cdot EF_{Project} \quad \text{(Equation 8)}$$

where

$E_{Baseline}$	*Annual baseline emission level (t CO_2)*
$E_{Project}$	*Annual project emission level (t CO_2)*
$AL_{Baseline}$	*Baseline activity level (MWh)*
$AL_{Project}$	*Project activity level (MWh)*
$EF_{Baseline}$	*Baseline emission factor (t CO_2/MWh)*
$EF_{Project}$	*Project emission factor (t CO_2/MWh)*

The differentiation between activity level and emission factor is made primarily to calculate and separate the factors that influence emissions.

9.2.1 Activity level

In many types of projects, the baseline activity level corresponds to the project activity level. In the boiler project, two cases can be identified:

In the case of an *increase in energy efficiency* of industrial boilers the emission factor is lowered by the project, but vapour demand is not directly affected. In this case the baseline activity level corresponds to the project activity level.[2]

In the case of boiler replacement, the output capacity of the new boiler may be increased due to plans to expand production in the company. Therefore, not only would the replacement of the boiler as a CDM project activity affect the emission factor, it would also indirectly increase vapour production. In the absence of the project the company may in this case

a) acquire an additional boiler which covers the additional capacity needed,

b) replace the current boiler by a new boiler with a higher capacity or

[2] In industrial sectors where energy supply forms an important part of overall production costs the improvement of energy efficiency may enhance the competitiveness of the company, which could result in an increased level of production and corresponding vapour demand (see Chapter 7). However, in the case of Peruvian industrial boilers this effect would probably be relatively small.

c) continue to produce vapour with the existing boiler and with limited production.

The last case seems hardly realistic, since economically healthy companies would not limit their production in the medium term due to limited energy supply. The second case corresponds to the CDM project activity, and additionality should be addressed carefully since, on the one hand, it is economically more attractive to replace an existing boiler when expansion of vapour supply is needed anyhow, and on the other hand, some barriers impeding the acquisition of new boilers would not apply (see section 9.9 with respect to additionality).

The first case would probably apply in many situations in Peruvian industry, since it is common practice to operate boilers as long as possible. It therefore seems appropriate, that only a part of vapour production is attributed to the project activity. It is suggested that vapour production be divided into two parts: one part attributable to replacement of the existing boiler, and one part attributable to expansion of capacity. The activity level of the project would correspond to the part that is attributable to replacement of the existing boiler, and it could be estimated proportionally to existing and new capacity, as follows:

$$AL = \frac{C_{actual}}{C_{nuevo}} \cdot VapProd \qquad (\textit{Equation 9})$$

where

AL	*Activity level (MWh)*
$C_{current}$	*Current installed capacity of the boiler (kW)*
C_{new}	*New installed capacity of the boiler (kW)*
VapProd	*Annual vapour production with the new capacity (MWh)*

The activity level depends mainly upon economic factors that are not influenced by the project. Demand for vapour of a company, sector or country depends on factors such as GDP and the prices of products on the domestic and international market. However, climatic factors, such as the Niño phenomenon, also influence the production level in the fishery sector. This implies that part of the estimated baseline – the activity level – is always “dynamic”, that it changes throughout the project lifetime and cannot be exactly projected before project implementation. This kind of uncertain operation is a key feature of some CDM projects and cannot be completely avoided.

9.2.2 Emission factor

The emission factor is defined basically by emissions per output unit or unit of produced vapour in t CO_2/MWh. In the case of industrial boilers, the emission factor depends upon the emission factor of the fuel and the energy efficiency level. The emission factor of the fuel refers to the volume of CO_2 per heat unit (LHV = lower heating value) emitted by fuel combustion. As different fuels have different compositions of C, H and other elements, this factor depends upon the type of fuel.

The emission factor can be calculated by:

$$EF = \frac{EF_{Fuel}}{\varepsilon} \qquad \textit{(Equation 10)}$$

where

EF	*Emission factor (t CO_2/MWh)*
EF_{Fuel}	*Emission factor of the fuel (t CO_2/MWh)*
ε:	*Energy efficiency of the boiler*

The emission factors of different fuels have been estimated in section 8.5 of this study (see Table 34 on page 100). Energy efficiency (ε) considers the different sources of loss, including those losses per fraction of fuel non-oxidized in the combustion process.

This study does not consider fuel switch to natural gas as a CDM activity. Therefore, the amount of emission reductions in a boiler will result basically from the difference between baseline energy efficiency and project energy efficiency. Thus, the following equation can be determined:

$$\Delta E = AL \cdot EF_{Fuel} \cdot \left(\frac{1}{\varepsilon_{Baseline}} - \frac{1}{\varepsilon_{Project}} \right) \qquad \textit{(Equation 11)}$$

where

ΔE	*Emission reduction (t CO_2)*
AL	*Activity level (MWh)*
EF_{Fuel}	*Emission factor of the fuel (t CO_2/MWh)*
$\varepsilon_{Baseline}$	*Baseline energy efficiency of the boiler*
$\varepsilon_{Project}$	*Project energy efficiency of the boiler*

Thus, the key factor distinguishing project emissions and baseline emissions is energy efficiency. In the CDM boiler project energy efficiency is improved, thus reducing the GHG emission factor.

9.3 A dynamic baseline approach

As described above, baseline emissions depend upon:

a) energy efficiency,

b) vapour demand (activity level) and

c) type of fuel.

To establish a baseline, it is necessary to estimate these three factors. The main difference between them is that whereas the level of vapour demand and the type of fuel are not influenced by the project activity, energy efficiency is improved. Thus, vapour demand and the type of fuel can be verified during the project activity as part of the monitoring. In contrast, the energy efficiency of the baseline has to be estimated *before* implementation of the measures.

In order to reduce uncertainty with respect to emission reductions, it is proposed to develop a *dynamic baseline* that will be adjusted partly in the course of the project. With this approach, changes in the demand for vapour, or in the type of fuel, can be considered *ex post* in an appropriate manner. Following this approach, the baseline is adjusted each year prior to verification of emission reductions, taking account of actual demand for vapour and the fuel types actually used in that year. The baseline would then be calculated using collected and/or calculated information about fuel types and vapour production.

In this context it is important to note, that the estimation of energy efficiency is crucial for the environmental integrity of the baseline, while the ex ante estimation of the demand for vapour and fuel types used serves mainly to provide a realistic scenario for investors concerning the potential volume of the project. However, a realistic estimation of the demand for vapour and the proportions of fuel types helps reduce uncertainties and associated risks.

With the dynamic approach considered here, baseline emissions will be determined in the course of the project as illustrated in the following three steps:

1. ***Ex ante* estimation of baseline emissions.** Prior to the start of the project, baseline emissions are estimated, including assumptions about the number of participating companies, their respective vapour demand and fuel types used, as well as an estimation of business-as-usual energy efficiency.

2. ***Ex post* collection of information during the monitoring process.** During the monitoring process information on vapour demand, fuel types and improved energy efficiency in participating companies is collected for the purpose of calculating project emissions.

3. ***Ex post* calculation of baseline emissions.** Real baseline emissions are calculated with the help of the estimated energy efficiency in Step 1 and the collected information on fuel types and vapour demand under Step 2.

In this study, baseline emissions are estimated (Step 1) and detailed concepts for the collection of data and ex post calculation of real baseline emissions are elaborated. Following this dynamic approach, baseline emissions are not determined finally when the project is presented to the Executive Board for approval, but will be determined during the monitoring process before verification and issuance of CERs.

9.4 Bundling many boilers into one CDM project

According to the analysis in section 8.4.2.4 of this study, there are about 1,700 industrial boilers operating in Peru (see Table 32 on page 99). Most of the boilers have a relatively small capacity ranging from 200 kW to 10 MW. The refurbishment or replacement of a single boiler as a CDM project would lead to considerable transaction costs. In most cases transactions costs would probably exceed revenues from generating certified emission reductions (CERs).

According to the Bonn Decision (FCCC/CP/2001/L.7) and the decision on mechanisms in the Marrakech Accord, the Executive Board for the CDM shall develop **simplified modalities and procedures for small-scale CDM projects**. Small-scale projects are defined by threshold values for different project categories. In the case of energy efficiency improvement projects, annual energy savings must be below 15 GWh.

In nearly all Peruvian boilers, projected annual energy savings are expected to be below 15 GWh.[3] Nevertheless, it seems inappropriate to establish separate CDM projects for each boiler refurbishment. Even if procedures and modalities for small-scale projects were to be simplified significantly, it can be expected that bundling of many boilers into one CDM project will allow a large reduction in transaction costs for the following reasons:

- **Simplified project development, validation and approval.** Several procedures in the CDM life cycle have to be implemented to get a project working and generating CERs. This relates, firstly, to project development, including the participation of relevant stakeholders, environmental impact assessment, baseline study, draft of the project design document, etc. Secondly, this concerns official procedures, such as the validation of the project by an independent operational entity and approval by the host government and the Executive Board. All or most of these procedures will only have to be carried out once if many boilers are bundled into one CDM project.[4]
- **Simplified monitoring and verification.** Data collection for monitoring and verification purposes can be managed and evaluated centrally. Uncertainty with respect to data quality can be reduced through standardized procedures, consistency checks

[3] For illustration: Annual energy savings of 15 GWh would be achieved with the improvement in efficiency from 70% to 85% in a 10 MW boiler operating 6000 hours per year.

[4] The issue of bundling is not directly addressed in the decisions on mechanisms in the Marrakech Accord. However, in discussions during the negotiation process the possibility to bundle projects was raised by several parties. It can be expected that the Executive Board will allow the bundling of similar activities into one CDM project.

and experiences gained with data collection in different companies. Transaction costs for monitoring, verification and issuance of CERs can be reduced considerably.

- **Attractive size for investors.** A small-scale CDM project that reduces energy consumption by 15 GWh annually would mitigate CO_2 emissions by approximately 4,000 tonnes per year. Financing such small projects, which generate a limited number of CERs, would involve relatively high transaction costs for investors. Bundling many boilers will make the project volume more attractive for investors.[5]
- **Reduced risks for investors.** Several risks for investors can be reduced and managed easier when different types of boilers are bundled. The risk of lower vapour demand is reduced due to the increased number of companies participating and the involvement of different industrial sectors. The same applies to other relevant risks, such as that of higher investment costs or lower efficiency improvements.

Consequently, bundling all boilers into one CDM project can lower transaction costs to a great extent and has advantages with respect to uncertainties, risks and quality of data.

9.5 Baseline aggregation level

In projects where similar project activities in different locations are bundled, a baseline can be constructed on different aggregation levels. The following three aggregation levels could be considered in the case of the boiler project:

1. **Aggregated baseline scenario.** The baseline is developed on an aggregated level, assuming similar characteristics for all participating boilers. The same baseline assumptions would apply to all boilers.
2. **Partly aggregated baseline scenario.** Boilers with similar characteristics are grouped into different categories. For each boiler category a baseline is defined reflecting the specific characteristics of that group. Overall baseline emissions are obtained by summarizing the baseline emissions of all categories.
3. **Disaggregated baseline scenario.** A separate baseline with specific assumptions is defined for each of the participating boilers. Overall baseline emissions are obtained by totalling the baseline emissions of all boilers.

As described above, there are three factors that influence the baseline emissions of boilers: energy efficiency, quantity of vapour production and fuel type. Theoretically, all or some of these three factors could be estimated on an aggregated or disaggregated level, but more aggregated estimations will involve greater uncertainties.

---

[5] In the Dutch public tender for CDM projects from November 2001 the minimum amount to be purchased from any one contractor is 100,000 CERs (CERUPT 2001).

For the purpose of the ex ante estimation of baseline emissions, data is gained at an aggregated or partly aggregated level, using statistical material and specific models, since it is not yet clear which companies will be participating in the CDM project.

For the purpose of the ex post calculation of baseline emissions for the boiler project, uncertainty of results can be considerably reduced if the three factors of influence rely on boiler-specific data collection and calculations. The baseline will therefore be recalculated at a disaggregated level for each boiler, but with a common methodological approach. Table 38 gives an overview of the aggregation level applied in the different stages of the project.

Table 38: Aggregation level of data collection and calculations

	Ex ante baseline *estimation*	Monitoring	*Ex post* baseline *calculation*
Efficiency	models / benchmarks	-	boiler specific / category
Fuel type	aggregated	boiler specific	boiler specific
Vapour production	aggregated	boiler specific (verification with macroeconomic data if applicable)	boiler specific

Source: Öko-Institut

9.6 Methodological Approaches in the Marrakech Accord

With the adoption of the Marrakech Accord at the Seventh Session of the Conference of the Parties (COP 7) in November 2001 the modalities and procedures for the CDM have been put into more concrete forms (Annex to decision 17/CP.7). However, the elaboration of specific guidance on many issues is left to the Executive Board for consideration by the COP or COP/MOP.

According to the modalities and procedures for the CDM in the Annex to decision 17/CP.17 project developers can choose a baseline methodology from among three approaches:

(a) existing actual or historical emissions, as applicable; or

(b) emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment; or

(c) average emissions of similar project activities undertaken in the previous five years, in similar social, economic, environmental and technological circumstances, whose performance is among the top 20 per cent of the respective category.

While the first two methodological approaches will be evaluated in more detail, option (c) does not seem to be applicable for Peruvian boilers. Little experience with boiler refurbishment has been collected so far in countries with social, economic, environmental and technological circumstances similar to those in Peru. Projects realized under AIJ (Activities Implemented Jointly) include district heating systems or the switch to less carbon-intensive fuels. Furthermore, most of the projects are conducted in Eastern Europe, where technological and social circumstances are quite different. The activities known up to now in this field do not allow the pursuance of this methodological approach.

9.7 Options for baseline energy efficiency

9.7.1 Option 1: actual energy efficiency

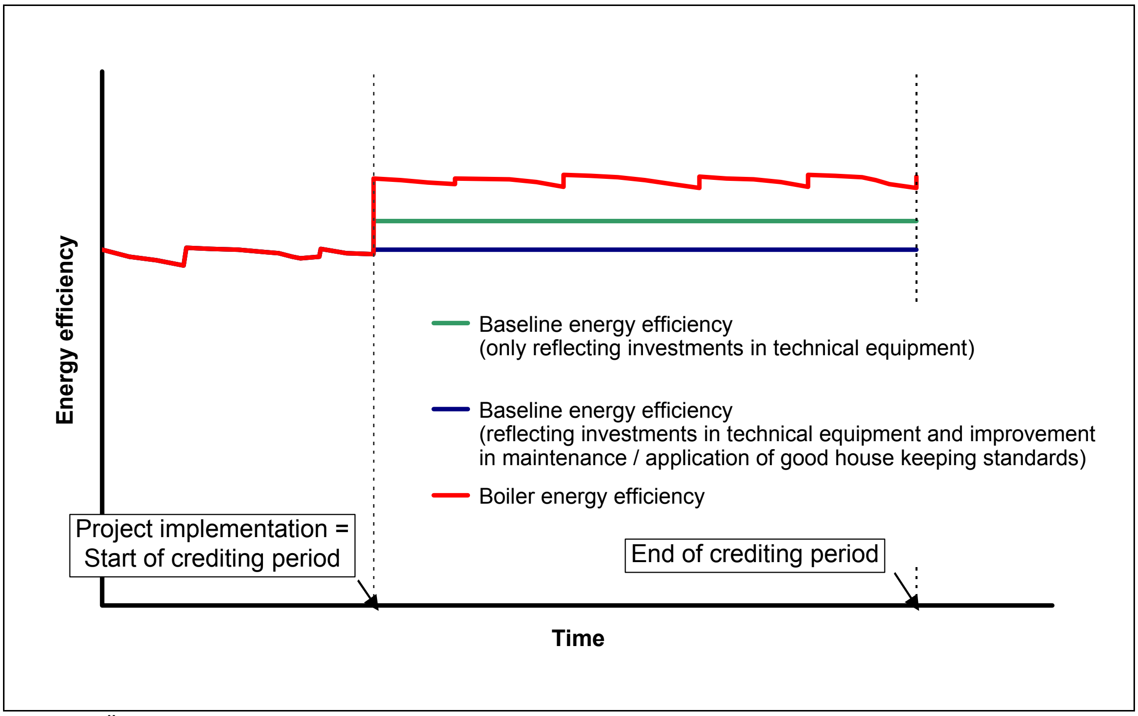
In the case of energy efficiency improvement projects, the continuation of the current situation is a common approach for the baseline. This approach corresponds to methodology (a) proposed in paragraph 48 of the modalities and procedures of the CDM (decision 17/CP.7, see section 9.6). In this approach it is assumed that the current energy efficiency of each boiler would not have changed during the project crediting period in the absence of the project. It is technically possible to operate boilers over a long time span with the same energy efficiency, if maintenance practices are applied consistently and no investments in energy efficiency improvement occur. The efficiency improvement of a boiler can be differentiated between an efficiency improvement effect resulting from changes in installed technical equipment and an improvement effect resulting from improved maintenance efforts. Both effects have to be considered in the boiler baseline. In the Peruvian case, maintenance of boilers is generally poor and does not even reflect good housekeeping standards[6]; thus the introduction of good housekeeping standards for maintenance will already result in an efficiency gain. It is questionable whether the introduction of good housekeeping standards, which do not involve large investments, which are profitable without any CDM activity and which mainly reflect appropriate management of a plant, should qualify for credits under the CDM. The following approach therefore differentiates two cases: in the first case, both effects are regarded as project effects to be credited, and the baseline reflects continuation of the current situation (without good housekeeping); in the second case, only the change in technical equipment is regarded as the project effect, which should be credited, and the improvement of maintenance is a side-effect that improves efficiency but does not generate certified emission reductions. This results in a project baseline at a higher level of energy efficiency than the actual project.

Figure 17 presents the baseline option of continuation of the current situation for both cases. The energy efficiency of the boilers varies depending on maintenance intervals and equipment changes.

---

6 Of course there are exceptions with appropriate maintenance for boilers.

Figure 17: Baseline with continuation of actual energy efficiency



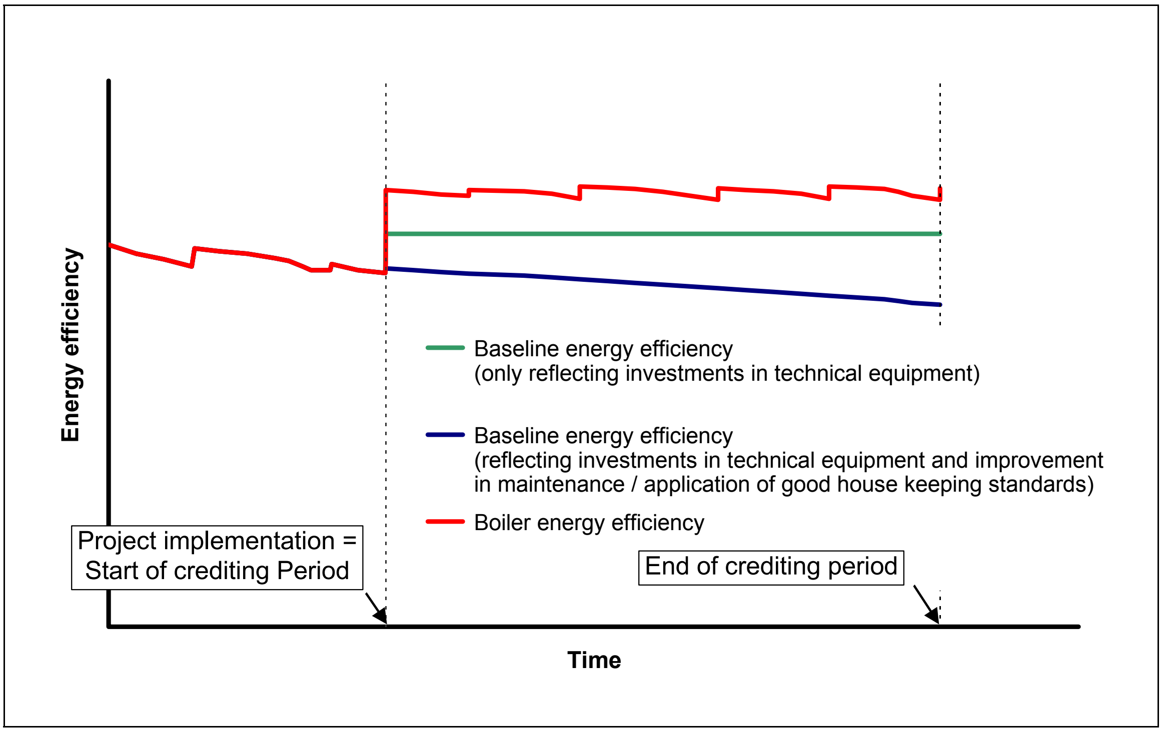
Source: Öko-Institut

9.7.2 Option 2: Decreasing energy efficiency

In this baseline approach it is assumed that the energy efficiency of Peruvian boilers decreases over time. As Option 1, this approach would also correspond to the methodology (a) proposed in paragraph 48 of decision 17/CP.7. The baseline approach is illustrated in Figure 18.

As described above, it is necessary to conduct appropriate maintenance activities in order to maintain energy efficiency at the same level. Otherwise, energy efficiency would decrease over time. If this is the case, in the absence of the CDM project the current trend of decreasing energy efficiency might continue. However, this trend would only apply to the baseline where credits accrue from both maintenance improvement and investments in technical equipment, as it can be expected that energy efficiency could be kept approximately constant with implementation of good housekeeping activities.

Figure 18: Baseline with decreasing energy efficiency



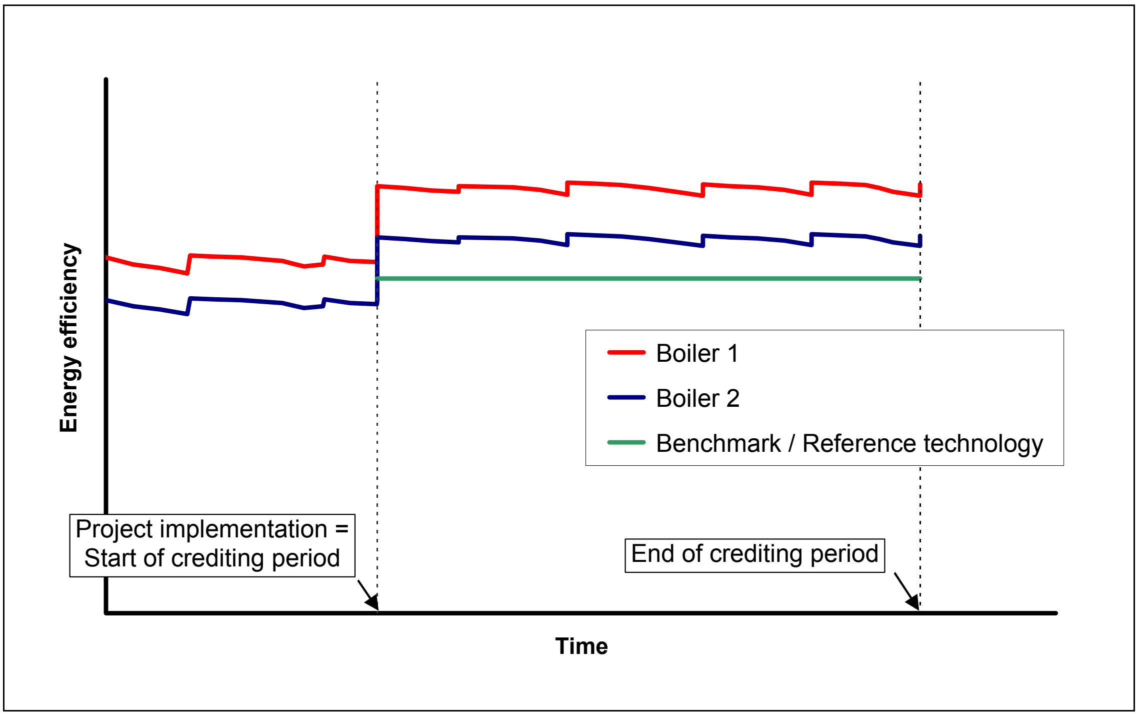
Source: Öko-Institut

9.7.3 Option 3: Energy efficiency of a reference technology

According to methodology (b) in paragraph 48 of the modalities and procedures for the CDM, baseline energy efficiency could be the efficiency of an economically attractive reference technology under consideration of barriers to investment. In this approach a *benchmark* for baseline energy efficiency could be considered.

In baseline options 1 and 2, baseline energy efficiency is determined at a totally disaggregated level. In this approach, a reference technology with corresponding energy efficiency might be proposed for all boilers or for different fuel types or capacity ranges. The typical reference technology in Peru would be a boiler with an average efficiency of approximately 82% (see section 5.4). This overall benchmark would apply to all boilers, independent of actual energy efficiency before implementation of improvement measures. The general approach is illustrated in Figure 19.

Figure 19: Baseline with reference technology



Source: Öko-Institut

9.7.4 Selection of baseline approach

Among the three baseline options presented above, actual energy efficiency without crediting good housekeeping activities (Option 1) is proposed as the most appropriate baseline methodology. Option 2 might be appropriate if sufficient reliable data is available. Option 3 involves several difficulties and should not be chosen.

In Option 3, benchmark energy efficiency is derived from a reference technology. This approach seems inappropriate for a number of reasons. Firstly, it is difficult to define a reference technology, which is typical for the Peruvian situation. The equipment of boilers varies: whereas many boilers do not have automated combustion control systems, others do have such a system. Secondly, it is difficult to derive benchmark energy efficiency from a defined technology in the Peruvian case, as energy efficiency varies even among boilers with similar technological performance, mainly due to different maintenance practices.

Taking into account these variations in energy efficiency, the benchmark baseline option would bear the danger of creating incentives to overestimate emission reductions. In the case of Boiler 1 in Figure 19, emission reductions would be overestimated, as the benchmark energy efficiency is even below the energy efficiency before implementation of the project. In the second case, Boiler 2, emission reductions would be underestimated, as the energy efficiency before implementation of the project is considerably lower than the benchmark technology. When the benchmark energy efficiency is fixed after approval of the project, project participants would have an incentive to consider above all boilers of type 1 in Figure 19, because those boilers already have relatively good energy efficiency and would deliver more emission reductions than boilers of type 2. Consequently, if more boilers of type 1 would be selected than boilers of type 2, emission reductions would be overestimated. As a consequence, the benchmark approach seems generally inappropriate in the case of bundled projects, where the current situation varies significantly within the bundled group.

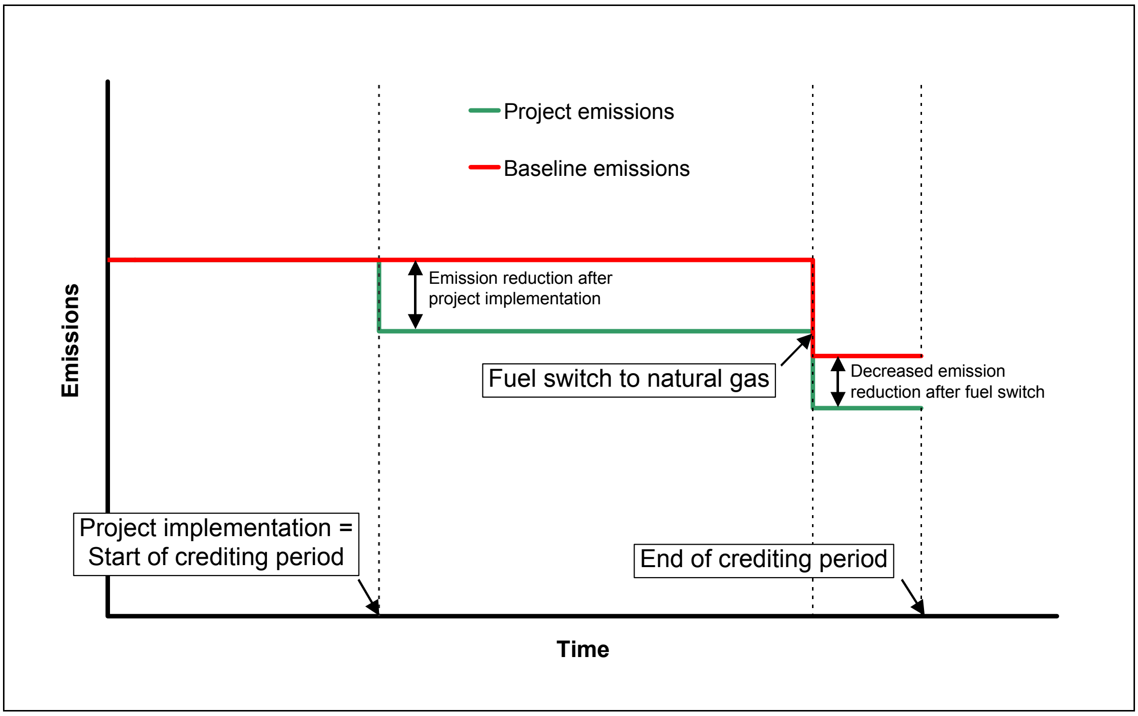
In Option 2, a baseline trend of decreasing energy efficiency over time is proposed. In Peru, no reliable time series data on the energy efficiency of boilers is available, which would allow verification of this trend. On the contrary, an analysis of boiler age and energy efficiency did not show any significant correlation between these parameters (see Figure 8 on page 68). It therefore seems more appropriate to assume that energy efficiency does not vary over time (Option 1), taking also into consideration that the assumption of constant baseline energy efficiency is the more *conservative approach*, as emission reductions are higher with decreasing energy efficiency.

9.8 Impact of the Camisea gas project on baseline and project emissions

As described in section 4.3 of this study, natural gas from the Camisea gas field will be exploited and transported to the Lima region. It can be expected that several companies with boilers will switch from residual and diesel fuels to natural gas. This is likely to also affect boilers participating in the CDM programme. The fuel switch to natural gas generates additional emission reductions, since natural gas has lower carbon content than oil fuels and energy efficiency may be increased due to replacement of the burner. However, these emission reductions are not accounted for as part of the CDM project activity (see chapter 9.9).

On the contrary, certified emission reductions will be lower, if boilers change to natural gas after project implementation. As natural gas has lower carbon content, the same energy savings generate less emission reductions. In cases where companies change to natural gas only after implementation of energy efficiency improvements, the same baseline energy efficiency is assumed, since additional energy efficiency improvements due to the fuel switch to natural gas cannot be attributed to the project activity. However, in the calculation of project and baseline emissions, the lower carbon content of natural gas needs to be considered. Figure 20 illustrates how baseline and project emissions develop over time in such a case.

Figure 20: Change of project and baseline emissions in case of fuel switch



Source: Öko-Institut

9.9 Additionality

According to the Kyoto Protocol and the Marrakech Accords, project participants have to demonstrate that anthropogenic emissions of greenhouse gases are below those that would have occurred in the absence of the CDM project activity. The Marrakech Accords do not provide specific guidance on how this principle can be implemented.

The main question with respect to additionality is whether the same or similar activities would also take place if the CDM project would not be implemented. Analysis of the potential and of the mitigation costs of measures to improve energy efficiency in Chapter 11 below shows that there is a significant potential to increase energy efficiency with negative abatement costs. Consequently, many of the proposed measures are economically attractive and could be implemented without any additional cost. However, in practice these measures are currently not implemented, mainly due to several barriers to investments that are described in chapter 4. The CDM project activity aims at overcoming some of these barriers by setting up an institutional framework, which allows for implementation of specific measures addressing existing barriers. These include inter alia:

- The negotiation of a green credit line with a local bank, which facilitates access to capital with lower interest rates and lower transaction costs for companies.
- Technical advice with respect to the identification of abatement options.

- Capacity building for companies' personnel for the implementation of good housekeeping activities in order to maintain high energy efficiency of boilers.

Without these specific measures, which are part of the proposed CDM boiler programme, it seems very unlikely that energy efficiency improvements would occur, even though such measures appear in many cases economically attractive.

However, there are two issues, which are of particular concern for the project and which are briefly analyzed below: the treatment of good housekeeping activities and possible windfall effects. Additionally, participation requirements to exclude non-additional cases in the CDM programme are introduced below.

9.9.1 Treatment of good housekeeping activities

As part of the CDM project, two type of activities are conducted:

- **Good housekeeping activities.** In Chapter 5 it was shown that there is currently only very poor maintenance in respect of many boilers in Peru. Energy efficiency could be increased by several percentage points merely by good housekeeping measures. These measures have short-term benefits and need to be continuously implemented in order to maintain an appropriate level of energy efficiency. The achieved improvements may change over time depending on the extent to which good housekeeping measures are continuously implemented. This exacerbates the monitoring of such emission reductions.
- **Investments.** Significant additional energy efficiency improvements are only possible through investment in boilers, which may include the replacement of boilers or certain equipment, or the installation of additional equipment (for example, control of excess air). Investments usually have long-term environmental benefits if the equipment is operated in an appropriate manner.

In the context of good housekeeping activities as CDM measures it is also stated that the associated transfer of technology is limited to maintenance practices and that no “real” investments occur. Other arguments are that good housekeeping activities should always be implemented, and that considering such activities as a CDM activity could have undesirable repercussions: in the case of the boiler project, those companies, which have not implemented good housekeeping measures, would be rewarded and acquire additional income through the CDM boiler programme, whereas companies, which have already implemented good environmental practices, would not be rewarded.

As a conservative approach, it is suggested that good housekeeping activities be conducted as part of the CDM project, but that only emission reductions that occur due to investments be accounted. However, this approach may be revised, depending on decisions of the Executive Board for the CDM on this issue. In the analysis of the potential and of mitigation costs of emission reductions in Chapter 11 below, emission reductions due to investments and emission reductions due to good housekeeping measures are estimated and illustrated separately.

9.9.2 Windfall effects in bundled projects

When bundling several small activities into one CDM project, the problem of the additionality of emission reductions in conjunction with possible *windfall effects* is an important issue. For many boiler-operating companies it can be expected that energy efficiency improvements occur only due to the additional incentives of the CDM project activity. In other cases, however, companies, which strive to increase energy efficiency for their own business reasons, or which need to replace old boilers, could participate in the CDM programme and might only implement business-as-usual measures. In this case, emission reductions are not additional and should not be certified.

General difficulties in assessing additionality are slightly different in the case of bundled projects. In normal projects with one project activity at one site – for example, a renewable energy plant – additionality can be assessed under careful consideration of the specific economic, institutional and environmental circumstances of that project. When many small-scale activities are bundled, a detailed assessment for each project participant is not practicable.

There seem to be two different approaches to addressing additionality and windfall effects in bundled projects:

1. Development of eligibility criteria for participation in the bundled CDM project on a boiler-specific level to distinguish additional from non-additional measures (*micro level approach*).
2. Assessment of the range of possible windfall effects at a macro level and respective adjustment of calculated emission reductions (*macro level approach*).

How these methodological approaches can be implemented depends on the type of project activity. In the case of a project for efficient lighting (which, in effect, is a big bundling project) it is obviously not possible to carry out an assessment at a micro level if a consumer would also have bought compact fluorescent lamps (CFLs) in the absence of the project. Neither is it possible to exclude those consumers from the project in practice; though, at a macro level, the historical and possible future diffusion of CFLs can be assessed and emission reductions adjusted accordingly.

In the case of the boiler project, time series information is not available on the improvement of energy efficiency, making the estimation of the range of windfall effects difficult at a macro level. The proposed procedure is a double approach: firstly, simple eligibility criteria are developed on a boiler specific level in order to exclude those boilers whose participation in the project seems unlikely to be clearly additional; and secondly, emission reductions are estimated conservatively by choosing relatively short crediting periods.[7] In the following section eligibility criteria resulting from additionality requirements are proposed.

---

[7] This latter approach could be considered as an indirect adjustment of emission reductions, as the effect of choosing shorter crediting periods is similar to discounting emission reductions. See rules for boilerspecific crediting periods in section 9.10.2.

9.9.3 Eligibility criteria for participation

In the development of eligibility criteria to address additionality on a boiler specific level it is helpful to differentiate between

- the *installation of additional equipment* and
- the *replacement of existing equipment*.

Where new additional equipment is installed, such as equipment for automatic control of excess air, or an economizer, the development of specific eligibility criteria seems difficult, as such equipment is currently used in some companies, in others not. However, no specific characteristics for those companies that use such "additional" equipment could be identified. Therefore, for the installation of additional equipment it is suggested that eligibility criteria be not applied at a boiler level, but that possible windfall effects be dealt with by making conservative assumptions for the crediting period (see Section 0).

Where existing equipment is replaced, more careful consideration of additionality is necessary. The main risk is that very old equipment, or boilers, which need to be replaced anyhow, would participate in the programme. To avoid every replacement of a boiler or burner being eligible to participate in the CDM programme, simple applicable criteria need to be defined. First of all, the boiler or equipment should be not out of order, but able to operate. Secondly, it should be possible to run the equipment or boiler for at least a number of years. This should be evaluated by straightforward technical assessment, assuming that only regular maintenance activities are carried out and no major investments occur. A simple criterion for the usefulness of existing equipment is the economic value of the equipment if it would be sold.

Table 39: Eligibility criteria for replacement of equipment or boilers

- The equipment or boiler to be replaced should not be out of order, but *able to operate.*
- The replacement of a boiler or equipment is eligible for participation in the CDM programme only if a simple technical assessment conducted by the project operator, or a subcontractor, suggests that the equipment or boiler can be expected to operate for at least three more years under normal circumstances, assuming that only regular maintenance activities and no major investments occur.
- Boilers to be replaced should not be older than *35 years*.
- Burners to be replaced should not be older than *20 years*.

Additionally, a threshold for the age of current equipment is proposed. Equipment, which has exceeded its usual technical life, should not be considered to operate for many more years. Most boilers in Peru are not used longer than 35 to 40 years.[8] Therefore, for a boiler to be replaced, a maximum age of 35 years is proposed. In the case of burners, a maximum age of 20 years is proposed. The proposed eligibility criteria are summarized in Table 39.

9.10 Crediting period

The crediting period is the time span during which *certified emission reductions (CERs)* are generated. Generally, the crediting period should reflect the time span in which achieved emission reductions can be attributed to the CDM project activity.

In the case of bundled projects, it has to be differentiated between the crediting period of the overall project and the crediting period of a single participant. For a single boiler, CERs may be generated only for a couple of years, while the project activities continue on other plant sites. The overall project crediting period encompasses the time span of all single activities and is therefore longer than the crediting period of any one single activity. Furthermore, the crediting period of single activities may differ from plant to plant, reflecting the specific circumstances of the activity. Following this approach, a specific crediting period is determined for each participating boiler, applying a common methodology. As a consequence, the *overall project crediting period* can be estimated and proposed *ex ante* in this study, while *boiler-specific crediting periods* will be established *ex post* during the course of the project, but, however, following clear rules as elaborated in section 9.10.2 below.

To establish clear rules for the crediting period of each boiler, in a first step energy efficiency improvement measures are classified and different approaches for the definition of the boiler-specific crediting period are proposed. With the help of this classification, rules for the definition of boiler-specific crediting periods are established. Finally, the general approach for the overall project crediting period is introduced.

9.10.1 Classification of energy efficiency improvement measures

When determining the crediting period for energy efficiency improvement projects it is helpful to distinguish between two types of activities:

1. ***Early implemented standard activities.*** These refer to the implementation of technically well-established measures, which increase energy efficiency to the standard level for new boilers. These activities can be characterized as investments that are implemented earlier than would have been the case without the project activity – for example, they would only have been implemented after failure of the equipment. Typical activities for this category, in the context of the

[8] Some boilers are 70 years old. See more detailed analysis in chapter 1.

boiler project, would be the replacement of a boiler or the installation of equipment for automatic control of excess air.

2. ***Advanced activities.*** These include investment activities, which increase energy efficiency above a level that represents the technical standard for new equipment. This would be the case if it could not be expected that the improvement of energy efficiency would occur even at a later stage in the absence of the project. In the case of the Peruvian boiler project, this would apply for example to the use of economizers, as they are rarely used in Peru, even when installing new boilers.

The approach for the boiler-specific crediting period depends on the characteristics of the activity. In both cases two time frames should be considered:

- **Technical lifetime of improvement measures.** The crediting period cannot be longer than the technical lifetime of the installed equipment. The crediting period ends whenever the installed equipment fails before reaching the end of its predicted technical lifetime.
- **Remaining lifetime of existing equipment.** If current equipment (for example, a burner within the boiler, or the boiler itself) is in bad condition, it is probable that it would be replaced within a certain time frame. The crediting period is consequently limited to the probable remaining lifetime of existing equipment.

In case of *advanced activities*, the *technical lifetime of newly- installed equipment* is the more important factor. Even if the existing boiler is very old, it seems not very likely that with a new boiler a very high efficiency standard would be realized. However, in the case of *early-implemented standard activities* the *technical lifetime of existing equipment* is the more important factor, because the CDM project advances the investment, but does not lead to an energy efficiency level that could not be achieved at a later stage.

Table 40: Technical lifetime and classification of measures to improve energy efficiency in Peru

Proposed measure	**Approximate technical lifetime**	**classification**
Automatic control of excess air	10 years	standard
Replacement of the burner	15 years	standard
Automatic control of boiler blowdown	10 years	advanced
Replacement of the boiler	35 years	standard
Installation of an economizer	10 years	advanced

Table 40 shows the most important energy efficiency improvement measures, their estimated technical lifetime and the proposed classification, reflecting the current Peruvian situation.

In practice, a precise distinction between the two approaches is difficult, because in many cases several measures to improve energy efficiency are proposed for one boiler. These different measures for *one* boiler may be of different types (standard / advanced) and may have different technical lifetimes. However, the establishment of different crediting periods for different activities within one boiler would be very complicated and practically impossible to monitor, as the measured efficiency improvement in the monitoring process could not be attributed to single improvement measures. Where measures of different types and lifetime are mixed, an appropriate crediting period for the boiler has to be chosen which covers all measures and reflects the principle that baselines be established in a transparent and conservative manner. In this case it is suggested that an average value be calculated, which is weighted with the estimated contribution of each measure to the expected overall energy efficiency improvement.

9.10.2 Rules for the determination of boiler-specific crediting periods

In the box below, rules are summarized for the determination of the boiler-specific crediting period and further requirements for participation in the CDM programme. A distinction is made between the implementation of standard measures, advanced measures and a combination of standard and advanced measures.

It is generally suggested that the crediting period be limited to a maximum of 80% of the typical technical lifetime of the equipment. Additionally, a maximum threshold value for the crediting period is introduced, depending on the type of the proposed measure (boiler replacement, standard efficiency improvement, advanced efficiency improvement). This approach is chosen to reflect the additionality considerations outlined in section 9.9.

Considering only 80% of the technical lifetime for the purpose of crediting is a conservative approach, taking into account that in some cases companies would implement such measures also in the absence of the project, at the same time or at a later stage (see windfall effects in Section 9.9.2). According to data obtained from Jimenez et al. (2001) and CENERGIA (2001), only a small proportion of about 10-20% of boilers are operated appropriately. It is therefore assumed that possible windfall effects may be covered by considering only 80% of the technical lifetime of the equipment.

Advanced measures to improve energy efficiency are less sensitive with respect to additionality. The technical lifetime of the equipment is usually 10 years. Therefore, CERs might be generated up to 8 years. In case of *standard measures* to improve energy efficiency, additionality is more difficult to assess, as it seems more likely that the measure would have been implemented in the absence of the project. Consequently, the crediting period is limited to a shorter time span, namely, a maximum of six years.

A. Standard Measures

Energy efficiency improvement:

- The crediting period is limited to a maximum of *six years,* or *80% of the expected technical lifetime* of the energy efficiency improvement measure, whichever is lower.

Boiler replacement:

- The boiler to be replaced needs to be *able to operate*.
- The boiler replacement is only eligible for participation in the CDM programme, if a simple technical assessment conducted by the project operator, or a subcontractor, suggests that the boiler can be expected to operate for at least three more years under normal circumstances, assuming that only regular maintenance activities and no major investments occur.
- The boiler to be replaced should not be older than *35 years*.
- The crediting period is calculated by subtracting the age of the existing boiler from 40 years, and is limited to a maximum of eight years.[9]

B. Advanced Measures

- The crediting period is limited to a maximum of *8 years,* or *80% of the expected technical lifetime* of the energy efficiency improvement measure, whichever is lower.

C. Combination of several measures

- If several measures with different technical lifetimes are applied, an average value for the crediting period should be taken into account. The average should be weighted with the estimated contribution of each measure to the expected overall energy efficiency improvement, making conservative assumptions with respect to the range of uncertainty.

The *replacement of a boiler or equipment* might be a sensitive measure with a significant potential for free riding, as most boilers are replaced sooner or later. Usually old boilers are replaced when a major technical failure occurs, which makes major maintenance investments necessary. Such cases are excluded from the project, as boilers need to be capable of operation, and a straightforward technical assessment should confirm

[9] Examples: Replacement of a 34-year-old boiler: 6-year crediting period. Replacement of a 30-year-old boiler: 8-year crediting period.

that the boiler could be expected to operate for several more years under normal circumstances. For the same reason, boilers that have exceeded the usual technical boiler lifetime of about 35-40 years in Peru should not be eligible to be replaced within the CDM project. For the crediting period, an approach is proposed that considers the age of the replaced boiler: the crediting period is limited to the time span for operation of the existing boiler, assuming a potential technical lifetime of 40 years.

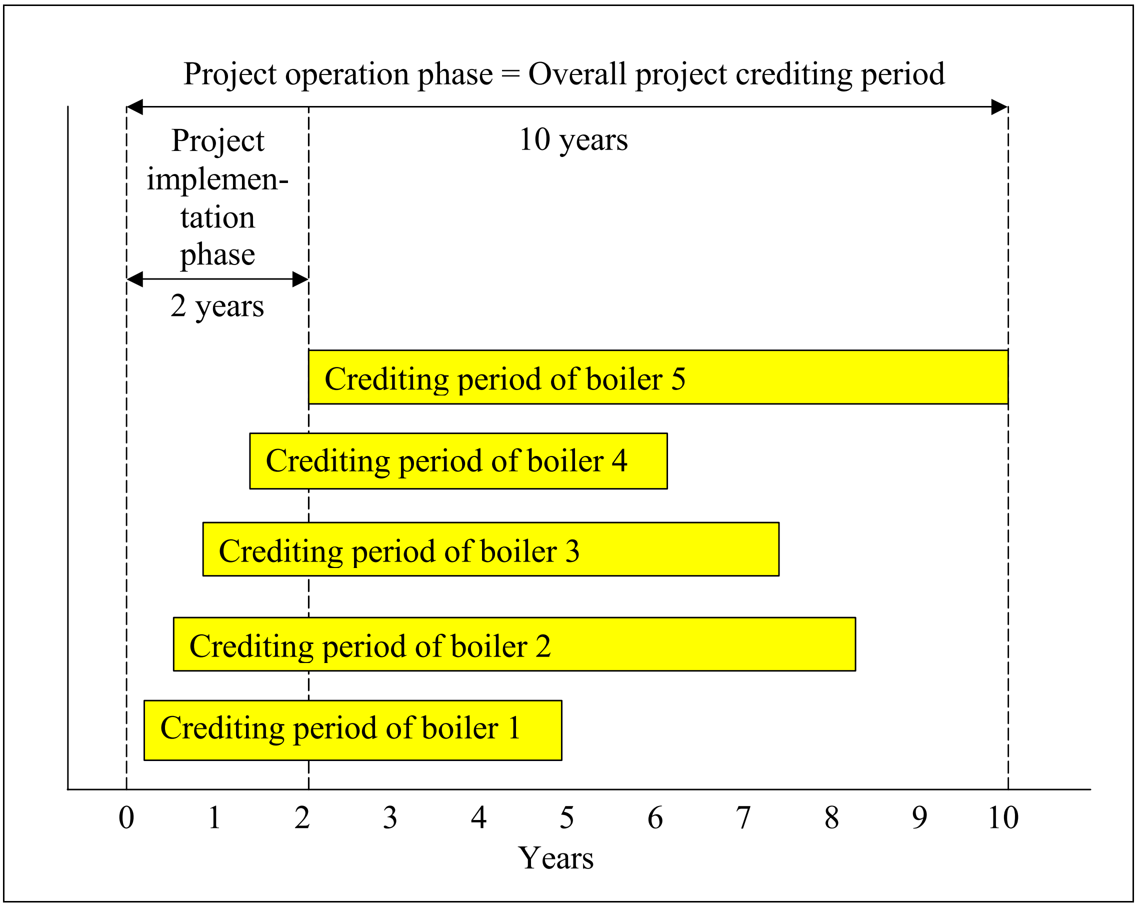
9.10.3 Overall project crediting period

In accordance with paragraph 49 of the modalities and procedures of the CDM (Annex to decision 17/CP.7) project participants can choose between two approaches for the determination of the crediting period:

(a) a maximum period of seven years, which may be renewed twice, at the most, provided that for each renewal a designated operational entity determines and informs the Executive Board that the original project baseline is still valid or has been updated taking account of new data where applicable; or

(b) a maximum period of ten years without renewal.

Figure 21: Crediting period of single boilers and overall project crediting period



Source: Öko-Institut

For the Peruvian boiler project the second approach is proposed, with a maximum crediting period of ten years. An overall crediting period of ten years seems sufficient, as single measures might have a crediting period of up to eight years and a project implementation phase of two years is suggested (see Figure 21). If a measure would be implemented at the end of the two-year implementation phase, CERs for that boiler might still be generated for eight years without exceeding the overall crediting period of ten years.

9.11 Leakage effects

According to paragraph 51 of the modalities and procedures of the CDM (Annex to decision 17/CP.7), leakage is defined as "the net change of anthropogenic emissions by sources of greenhouse gases which occurs outside the project boundary, and which is measurable and attributable to the CDM project activity." Furthermore, according to these modalities and procedures the achieved emission reductions shall be adjusted for leakage effects. In the case of the proposed Peruvian boiler project, positive leakage effects may occur, and this means that additional emission reductions will occur outside the project boundary. Therefore, emissions reductions might be scaled up slightly. However, in practice it is difficult to adequately quantify emission reductions outside the project boundary. It is therefore suggested, that emission reductions not be adjusted for leakage, as a conservative approach.

10 Monitoring plan

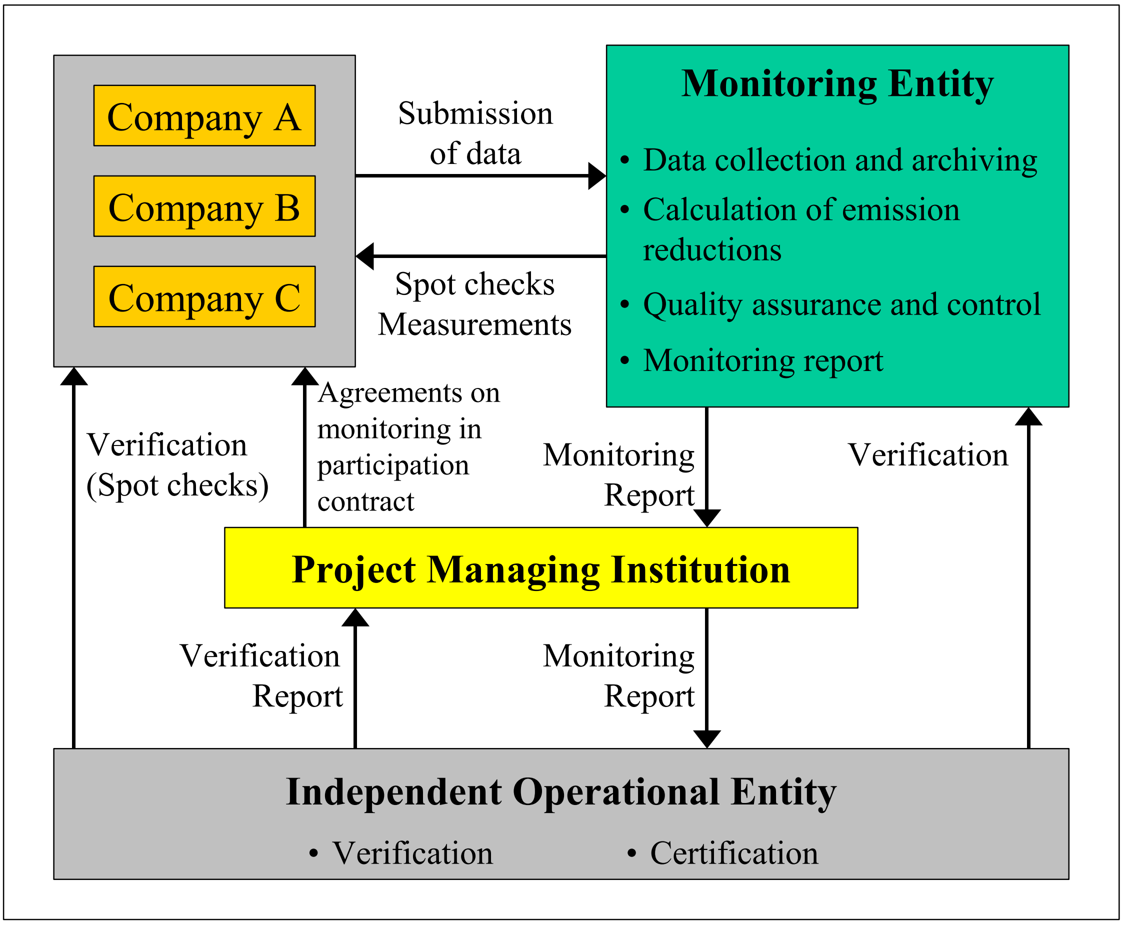
10.1 Multi-project monitoring and verification

In the monitoring process, the achieved GHG emission reductions are measured and calculated. According to the modalities and procedures for the CDM (Annex to decision 17/CP.7, paragraphs 53 to 60) project participants shall provide a **monitoring plan,** which provides for the collection and archiving of all relevant data for determining emissions within and outside the project boundary, as well as baseline emissions. Furthermore, procedures for the calculation of emission reductions and procedures for quality assurance and control shall be provided. All necessary steps have to be documented. Emission reductions are periodically estimated in accordance with the monitoring plan and presented in a **monitoring report** to an operational entity for the purpose of verification and certification.

In the Peruvian boiler project, a **multi-project monitoring and verification process** is proposed. With this approach, the monitoring process will be conducted *centrally* for all companies by one **monitoring entity**. The monitoring entity will be responsible for the appropriate collection and archiving of all data from all companies, the calculation of emission reductions and leakage effects, the implementation of quality assurance and control procedures and the drafting of the **monitoring report** for the purpose of verification and certification by an independent operational entity. The monitoring entity may be an independent company, contracted for this purpose by the project managing institution, or the project managing institution itself.

The overall monitoring process comprises several steps. The tasks and relationships between differing participating institutions are illustrated in Figure 22. As a first step, the participating companies periodically submit relevant information about the operation of boilers. The monitoring entity collects and archives the submitted information, checks its consistency and conducts company inspections to verify the correctness of the information provided. Additionally, measurements of the energy efficiency of boilers are conducted to provide necessary information for the calculation of emission reductions. For the measurement of energy efficiency the monitoring entity may take on subcontractors. With the information provided, the monitoring entity calculates current emissions of boilers, baseline emissions and emission reductions. The results and all the necessary information are documented in the monitoring report, which will be used by the project managing institution to control whether participating companies have fulfilled their contractual commitments and achieved the expected energy efficiency improvements. The monitoring report will also be evaluated by an independent operational entity for the purpose of verification and certification. The independent operational entity will be contracted by the project managing institution and will review the monitoring report, control the institutions involved and determine whether reported emission reductions have occurred. The independent operational entity may therefore conduct on-site inspections at participating companies. Finally, a verification report will be published by the independent monitoring entity.

Figure 22: Multi-project monitoring and verification



Source: Öko-Institut

For the purpose of achieving sufficient and reliable information for monitoring, participating companies will be contractually obliged to co-operate in the monitoring process, including

- the obligation to submit relevant data,
- granting permission to the monitoring entity or a third party to check the correctness of submitted data,
- granting permission to the monitoring entity or a third party to conduct inspections at the plant side,
- granting permission to the monitoring entity, subcontractors of the monitoring entity or third parties to conduct measurements at boiler plants in co-operation with the company's management, or to install permanent measurement equip-

ment (which may automatically submit operation data via electronic data transfer systems).

The centralized approach to the monitoring process has several advantages. Firstly, it allows a significant reduction in transaction costs. Secondly, by standardized procedures the quality of data can be improved and uncertainty reduced by comparing data from different boilers and conducting spot checks. And thirdly, the verification and certification process is simplified, since the independent operational entity has one centralized system and one counterpart to check the consistency of data collection and calculations.

10.2 Methodological Approach

As described in chapter 9 concerning baselines for the estimation of achieved emission reductions, it is necessary to determine the current emissions of the project and to calculate the *ex-post* emissions of the dynamic baseline. Emission reductions are calculated by subtracting current emissions from baseline emissions. For the *ex-post* calculation of emission reductions, **energy efficiency**, **fuel consumption** and **fuel type** need to be monitored. According to the monitoring methodology proposed below, the activity level – the vapour production – need not to be monitored directly, since there is a direct link between vapour production, energy efficiency and fuel consumption, and vapour production can be calculated from energy efficiency and fuel consumption. For the purpose of continuous control of energy efficiency, however, vapour-metering equipment will be installed in most companies. The procedures and modalities of data metering and collection and the calculation of emission reductions are described in more detail in the following sections.

In the approach followed here, emission reductions are determined at a disaggregated level for each boiler and subsequently added up to show the overall emission reduction. The detailed evaluation of 80 boilers in two studies conducted by Jimenez et al. (2001) and CENERGIA (2001) demonstrates that there are not many boilers with similar performance and characteristics that would allow common assumptions to be made for certain boiler types. Vapour production and energetic efficiency vary considerably from boiler to boiler, even between boilers of the same age, size and fuel, or within one industrial sector. It is therefore necessary to consider energy efficiency and the quantity of vapour production for each boiler.

In the monitoring process data from participating companies and technical data of the boilers has to be collected and archived. Technical personal of participating companies will be instructed on the use of this equipment in a capacity-building unit when efficiency improvement measures are implemented.

It is suggested that data collection be principally carried out on an *annual basis*. A shorter interval would increase transaction costs and complicate quality assurance and control procedures, as data comparison of different seasons is more difficult. Verification and certification by an operational entity may, however, be conducted on a biannual basis in order to reduce transaction costs.

10.3 Energy Efficiency

Correct monitoring of energy efficiency improvements obtained by the project activity is crucial for the environmental integrity of achieved emission reductions. However, measurements of energy efficiency bear a certain degree of uncertainty. In the case of the boiler project, uncertainty can be reduced by standardized procedures for the measurement and calculation of energy efficiency improvements, as well as by quality assurance and control procedures. Additionally, the impact of isolated errors in measuring energy efficiency is mitigated by the large number of boilers.

Measurements of energy efficiency will be conducted at three different stages of project implementation:

1. Prior to implementation of energy efficiency improvement measurements.
2. Directly after implementation of energy efficiency improvement measurements.
3. During operation, continuously or at regular intervals.

The first two measurements are necessary to verify achieved energy efficiency improvements. Measurements during project operation aim at quantifying the extent to which energy efficiency may decrease over time due to wear and tear of the installed equipment. Measurements of energy efficiency may be performed by personnel of the monitoring entity itself, or by subcontractors.

10.3.1 Technical standards

Procedures and technical standards for the measurement of energy efficiency are contained in several technical guidelines. In Peru, the *Commission for Technical and Commercial Regulations* is currently elaborating a technical standard for energy efficiency measurements in industrial boilers. A first draft version has been published in August 2002.[1]

The *Manual of Energy Efficiency of Industrial Boilers* published by *Instituto de Investigación Technológica Industrial y de Normas Técnicas* provides instructions on the measurement and calculation of energy efficiency (ITINTEC 1991).

The *Performance Test Code for Fired Steam Generators* (PTC 4-1998), published by the *American Society of Mechanical Engineers* (ASME 1998), is a very comprehensive standard for all kinds of steam generators, which allows energy efficiency to be determined very accurately. The British Standards *Methods for assessing thermal performance of boilers for steam, hot water and high temperature heat transfer fluids* (BS 845),

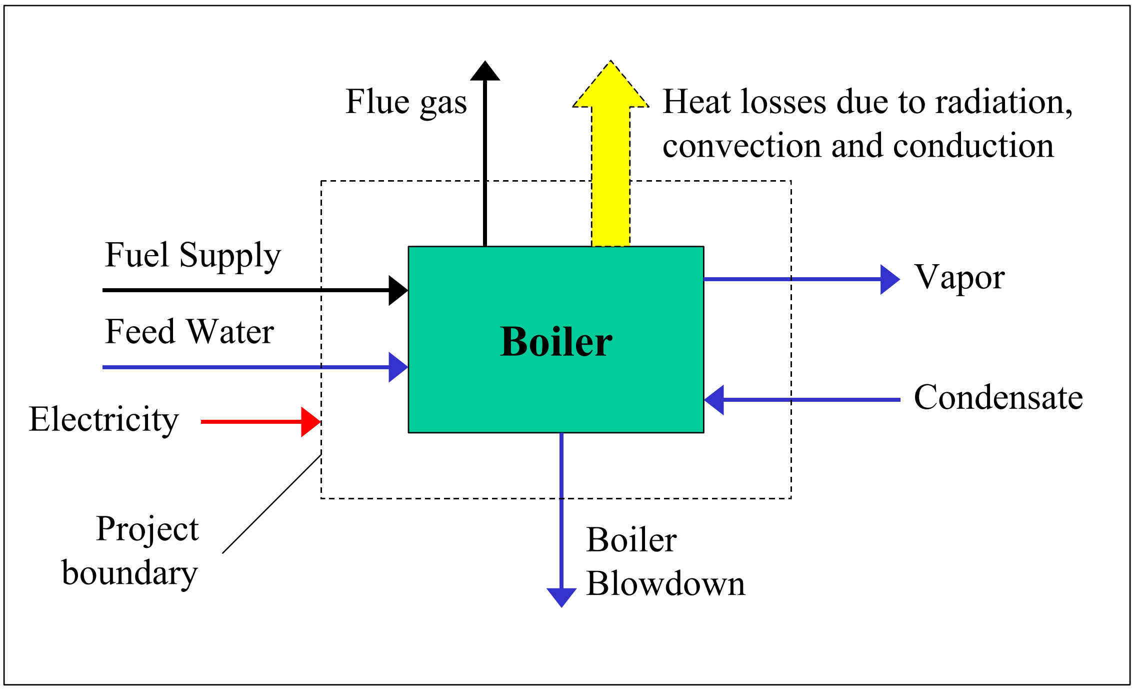
[1] Project de Norma Técnica Peruana (PNT 350.300): Calderas Industriales. Procedimento para la Determinación de la Eficiencia Térmica de Calderas Industriales. 1ª Edición, Lima, August 2002

published by the *British Standards Institution* (1987), encompasses two procedures: a concise straightforward procedure for standard boilers (BS 845-1) and a comprehensive procedure for more complex boilers (BS 845-2). The *German Industry Norm* (DIN 1942) also provides detailed instructions for measurements and calculations, including exemplary calculations. Most of these technical guidelines have been developed for the thorough assessment of energy efficiency in large steam generators. In the case of oil- or gas-fired boilers up to 10 MW some simplifications seem appropriate, which significantly reduce measurement costs and increase uncertainty only moderately. In order to acquire consistent and reliable data, all measurements in the course of the project should be performed in the same way applying the same technical standard.

10.3.2 Energy balance method and input-output method

Energy efficiency can be measured using two different methods (ASME PTC 4-1998): the **energy balance method** (indirect method) and the **input-output method** (direct method). The energy balance of the boiler can be divided into energy input as fuel supply, energy output as vapour production and losses (see Figure 23).

Figure 23: Energy balance and project boundaries of a boiler



Source: Öko-Institut

With the input-output method, fuel supply and vapour production are measured and energy efficiency is calculated by dividing the energy in vapour output by the energy supplied with the fuel:

$$\varepsilon = \frac{Q_{Vapor}}{Q_{Fuel}}$$ *(Equation 12)*

where

ε	*Energy efficiency of the boiler*
Q_{Vapour}	*Vapour production during measurement (MWh)*
Q_{Fuel}	*Fuel supply during measurement (MWh)*

For the input-output method, primary measurement requirements[2] in the case of gas- or oil-fired boilers are

- the flow rate of the fuel, feed water and all secondary streams such as boiler blowdown[3],
- pressure and temperature of the feed water and the vapour output, and
- the lower and/or higher heating value of the fuel.

The energy balance method determines energy efficiency indirectly through measurement of the various losses of energy. Energy efficiency is calculated by subtracting the various losses from 100%:

$$\varepsilon = 1 - L_{FG,dry} - L_{FG,vapor} - L_{rcc} - L_{ug} - L_{cm} - L_{blowdown}$$ *(Equation 13)*

where

ε	*Energy efficiency of the boiler*
$L_{FG,\,dry}$	*Loss due to sensible heat in dry flue gas (%)*
$L_{FGvapour}$	*Loss due to enthalpy in water vapour (%)*
L_{rcc}	*Loss due to radiation, convection and conduction (%)*
L_{ug}	*Loss due to unburned gases (%)*
L_{cm}	*Loss due to combustible matter in flue gases (%)*
$L_{blowdown}$	*Loss due to boiler blowdown (%)*

[2] Further measurements are required to determine energy efficiency more accurately. However, further measurements have usually a minor effect on the results.

[3] Instead of measuring the flow rate of feed water and all secondary streams, it may be possible to meter the flow rate of the vapour. However, flow-rate measurements of vapour are usually associated with greater uncertainty than measurements of liquid streams.

For the energy balance method, primary measurement requirements[4] in the case of gas- or oil-fired boilers are

- the chemical analysis of the flue gas,
- air and flue gas temperatures, and
- the lower and/or higher heating value of the fuel

Table 41: Advantages and disadvantages of energy balance method and input-output method

	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 • Uncertainty of test results is often lower than with the input-output method • 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 • Few measurements are necessary
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) • Requires more measurements	• Fuel flow, fuel heating value, steam flow rates and steam properties have to be measured very accurately to minimize uncertainty • Sources of inefficiency are not identified

Source: ASME PTC 4-1998, considerations of Öko-Institut

Advantages and disadvantages of the input-output and energy balance methods are listed in Table 41. 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 the determination of major losses. 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 have to be estimated. Furthermore, the input-output method allows determination of

[4] Further measurements are required to determine energy efficiency more accurately. However, further measurements have usually a minor effect on the results.

average operational efficiency at a greater interval of time, 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.

Technical standards recommend use of the method that involves less uncertainty. In cases where fuel supply measurements are difficult, the energy balance method is usually recommended. This applies in practice especially to coal-fired steam generators, where fuel properties may change over time. The German Industrial Norm recommends for smaller gas- or oil-fired boilers the input-output method, since losses due to radiation, convection and conduction are significant in small units and the measurement of oil- and gas-flow rates can usually be performed accurately (DIN 1942, 1994, page 6), whereas the concise procedure of *British Standard 845* (BS 845-1) uses the energy balance method. The *Performance Test Code for Fired Steam Generators*, published by the *American Society of Mechanical Engineers* (ASME PTC 4-1998), does not provide specific recommendation for small gas- and oil-fired boilers, but "*recommends the energy balance method when corrections to standard or guarantee conditions are required. In other cases, the choice between the methods should be based upon available instrumentation and expected text uncertainty.*"

10.3.3 Influence of load factor and maintenance activities on energy efficiency

The energy efficiency of boilers depends not only on the general performance of the boiler, but also on the actual load factor[5] and the current status of maintenance of the boiler. It may therefore change considerably over time. Usually, the highest efficiency is achieved directly after maintenance activities (such as combustion adjustments and the cleaning of tubes) have been conducted and at load factors of 60-70%. This complicates the comparison of energy efficiency before and after implementation of energy efficiency improvement measures. The following approaches seem feasible:

- Energy efficiency is determined before and after implementation of measures in a steady-state reference operation situation. The reference operation situation may be at fuel firing rate and within a limited period after completion of regular maintenance procedures.

  Small boilers (< 1 MW) usually have burners that allow only one firing position at full firing rate (type On-Off). In the case of burners with two possible firing positions (High-Low-Off), measurements should be conducted in both firing positions. An average value may be taken for the determination of energy efficiency, except that one of the firing positions is generally applied during operation. In the case of burners that allow modulation of the firing rate it is suggested that two to three measurements be conducted at different firing rates.

- Energy efficiency may be determined as average efficiency at a greater interval of time (for example, 1 to 4 weeks) before and after implementation of the

[5] The load factor is defined as the actual load of the boiler divided by the maximum possible load (capacity) of the boiler. An actual load factor of 0.5 means that the boiler is operating at 50% of capacity.

measures. In this way an average energy efficiency would be determined that includes other losses due to stand-by or discontinuous boiler blowdown.

In the first case, the energy balance method and the input-output method could be used, while in the latter case only the input-output method is applicable. The latter approach has the disadvantage that measurement results depend on the operational characteristics of the respective time-interval. The production activity, and consequently the characteristics of vapour demand in the company, may vary significantly between the two measurement periods before and after implementation of measures to improve efficiency.

It is therefore suggested, that the first approach be followed for the purpose of verification of efficiency improvements, and that measurements be conducted before and after implementation of the project activity at steady-state operation. Maintenance activities should have been conducted in an appropriate manner within the previous week.

In order to exclude good housekeeping activities from accounting of emission reductions (see section 9.9.1), it needs to be ensured that the measurement for baseline determination, which takes place prior to project implementation, is conducted in a situation where appropriate maintenance and good housekeeping activities are applied. If this is not the case, it is suggested that the measured energy efficiency be adjusted to reflect achievable energy efficiency with appropriate maintenance and good housekeeping.

10.3.4 Two-track approach in the case of Peruvian boilers

In Peru, the energy balance method is used much more than the input-output method. Among the 80 boilers that were analyzed, in only two boilers had vapour measurement equipment been installed. Companies apparently flinch from spending money on efficiency control equipment. In the studies carried out, it proved difficult to use the input-output-method, since the portable equipment could not be installed properly in some companies and the measurements would have implicated considerable uncertainties. Measurements were therefore conducted using the energy balance method. However, even the measurements conducted with the energy balance method by Jimenez et al. (2001) and CENERGIA (2001) proved to be very uncertain with respect to some losses, especially losses due to combustible matter in flue gases, where losses of up to 12% were determined, which seems to be unreasonable.

Taking into account the difficulties experienced in the measurement of energy efficiency in Peru, it is proposed to apply a two-track approach for the CDM programme involving both methods, the energy balance method and the input-output method. The energy balance method should be principally used to verify efficiency improvements achieved through the implemented measures, whereas the input-output method should be principally used to monitor possible changes in energy efficiency during the project operation. The energy balance method has several advantages with respect to the determination of efficiency improvements:

- The main advantage is that the energy balance method can be expected to yield a lower degree of uncertainty taking into account the circumstances in Peru. The primarily required measurements of flue gas composition and temperature are relatively easy to conduct, and they allow calculation of the major sources of inefficiency.

- The energy balance method allows identification of the sources of inefficiency. Test results can be used to propose measurements for the improvement of energy efficiency.
- The identification of sources of inefficiency with the energy balance method helps, when it proves necessary to choose a different efficiency as baseline, in order to exclude good housekeeping from the CDM activity.

For the purpose of monitoring energy efficiency during project operation, it is proposed to install permanent fuel and vapour flow-metering equipment, which allows the continuous determination of energy efficiency during operation of the boiler. Though the installation of such equipment involves significant costs, ranging from US$ 3,000 to US$ 5,300 in Peru, it seems helpful to monitor energy efficiency continuously for different reasons:

- To maintain a high level of energy efficiency it is helpful to meter energy efficiency continuously during boiler operation. This allows for possible decreases in energy efficiency due to wear and tear of the boiler or other equipment to be ascertained during operation. Maintenance intervals and activities can be optimized. Practical experience shows, that in this way a higher level of energy efficiency can be sustained and overall vapour production costs lowered.
- When boiler operators are enabled to monitor energy efficiency continuously, awareness of the importance of energy efficiency can be enhanced.

However, in some cases of relatively small boilers the cost for fuel- and vapour-flow metering equipment may be too high. In these cases, energy efficiency during operation may be monitored through regular measurements applying the energy balance method.

10.3.5 Special case: Monitoring of energy efficiency enhancement from measures related to boiler blowdown and boiler insulation

Applying the energy balance method, losses due to radiation, convection and conduction, as well as losses due to discontinuous boiler blowdown, cannot in practice be measured appropriately. The amount of these losses in relation to overall losses depends on specific circumstances such as the quality of insulation of the boiler, the manner of operation (load factor, number of start-ups) and boiler-blowdown control equipment. Common approximation methods in the case of the energy balance method, as suggested in the German Industry Norm (DIN 1942) or the British Standard 845 (BS 845-1), estimate losses due to radiation, convection and conduction as a standard percentage of output capacity, depending on the boiler type. However, with these typical values, or standard formulae, improvements in boiler insulation cannot be considered.

Therefore, in cases where measurements are proposed, which decrease losses related to boiler blowdown or boiler insulation, the input-output method has to be applied for the purpose of verification of energy efficiency improvements. In these cases, additional measurements applying the energy balance method will be carried out simultaneously, enabling identification of the amount of these specific losses before and after implementation of energy efficiency improvement measures.[6] Whenever the input-output method is applied to verify efficiency improvements, because of the greater uncertainty of the input-output method secondary measurements should be conducted using the energy balance method.

10.3.6 Uncertainty in the determination of energy efficiency

Errors in the determination of energy efficiency significantly affect the calculation of overall emission reduction. For example, if energy efficiency in a boiler is improved by 5% from 75% to 80%, and energy efficiency is measured after implementation of improvements with an error of 1%, emission reductions may be overestimated by 20%.

Typical equipment for measurements of energy efficiency in Peru is listed in Table 42 and Table 43.

Table 42: Equipment typically used in Peru for the measurement of energy efficiency with the input-output method

Measurement equipment	Typical accuracy	Typical repeatability
1) Fuel oil		
Gear type (main)	0.1 – 0.5 % of reading	0.1 % of reading
Mutating disc (less used)	1.5% over full range	0.5 %
2) Steam flow		
Orifice plate (main)	0.6 % of maximum flow	
Vortex type (less used)	0.75 – 1.5 % of flow rate	0.2% of flow rate
3) Steam pressure		
Bourdon manometer	1% of full scale	
4) Steam temperature		
Electronic thermocouple (type J or K)	0.5% max. value	-
5) Water temperature		
Bimetallic thermometer	1.5%	-

6 The energy balance method allows the identification of all losses apart from losses due to boiler blowdown and losses due to radiation, convection and conduction. Comparing the results of measurements applying the input-output method and the energy balance method, the proportion of these specific losses can be estimated. However, in this comparison it should be kept in mind that metering uncertainty is higher in the case of the input-output method.

Table 43: Equipment typically used in Peru for the measurement of energy efficiency with the energy balance method

Measurement equipment	Typical accuracy
1) Gas analyzer	
O_2 cell	0.2 %vol.
CO cell	5 % max. vol. (2000 ppm)
2) Gas temperature	
Electronic thermocouple (type J or K)	0.5% max. value
3) Air temperature	
Electronic thermocouple	0.5%
Bulb thermometer	
4) Steam pressure	
Bourdon manometer	1% of full scale

However, smaller inaccuracies in the measurement of energy efficiency will have only a minor effect on the emission reductions accounted for:

1. Isolated *accidental* metering failures have only a minor overall impact, as in a project with a huge number of boilers one failure has only little effect and some failures may be statistically levelled out to some extent.
2. If the same *systematic* error is committed in the measurements the impact may be limited, as the effect of that error applies to measurement prior to *and* after project implementation. This applies if losses are underestimated or energy efficiency overestimated by error. In this case, if losses were underestimated in both cases – prior to and after project implementation – related emission reductions would also be underestimated.

10.4 Fuel consumption

In Peruvian industry there is in most cases no or relatively poor metering equipment to quantify the fuel consumption of boilers. Some companies have fuel-level meters for oil tanks that are relatively inexact; others use volumetric flow meters. The existing equipment in most cases provides relatively inaccurate information on fuel consumption.

For the purpose of continuously metering energy efficiency, in most of the participating companies fuel-flow meters will be installed. This equipment can also be used to monitor fuel consumption. Companies will be obliged to report on meter-reading data to the monitoring entity. On-site checks by the monitoring entity will be conducted to verify the reported data (see section 10.8 on quality assurance and control procedures).

In the case of small boilers, where the installation of fuel-flow meters involves too high transaction costs, it is suggested that information on fuel consumption be collected using fuel purchase invoices. The quantity of purchased fuel is indicated in invoices, usually with relatively reliable quality, as the fuel meters of fuel supplying companies in Peru are under official control and the quantity purchased is determined with sufficient precision. In this case, the purchased quantity of fuel may be different in the short term from the quantity fired in the boiler, since there is a certain residual amount of fuel in the oil tank. This may lead to small differences at the beginning of the crediting period, when efficiency improvement measures are implemented or the boiler replaced, or at the end of the crediting period. The content of the oil tank, initially and at the end of the crediting period, may be estimated

(a) by quantifying the content of the oil tank, where possible, when the project is being implemented and at the end of the crediting period, or

(b) by linear interpolation, taking into account average annual fuel purchases and the date when efficiency improvements or boiler replacement occur.

However, if in such companies fuel is also used in boilers that do not participate in the CDM project, or for other purposes, such as gas turbines, dryers, emergency power generation, the installation of fuel-flow meters proves to be necessary.

10.5 Fuel type

Reporting on the type of fuel is necessary for the application of the correct corresponding emission factor. Companies should demonstrate the type of fired fuel to the monitoring entity by means of invoices for fuel purchases. If different fuel types have been fired, an average emission factor will be estimated by linear interpolation weighted with the respective quantities.

10.6 Execution of measurements

For the purpose of measuring energy efficiency it is suggested that in the case of the energy balance method the concise procedure laid down in British Standard 845-1 (BS 845-1) be used, which provides certain simplifications and reduces measurement requirements, but still yields reliable and relatively certain results. Measurements should be carried out in three runs, with a minimum time interval of 10 minutes between each measurement, and at steady-state operation conditions. In the case of modulating burners or burners with two possible firing positions, three measurements at different positions should be carried out.

In the case of the input-output method it is suggested that the general approach be used as described above. The comprehensive ASME PTC 4-1998 may provide advice in the case of doubts about measurements. Stream measurements may include either fuel and vapour flows or fuel and all secondary stream flows. If the boilers are not operating continuously, measurements should be conducted over a period of 15 days as a minimum requirement. If the boiler is operating continuously (24 hours), measurements should be conducted over a period of one week.

Considering the measurements to be performed for the determination of energy efficiency with each method, the following minimum instrumentation equipment is suggested[7]:

(a) Energy balance method:

- Gas analysis: Electronic analyzer (cell type), Orsat, compact absorption type. All of these analyzers can measure O_2 and CO_2. Electronic analyzers can also measure CO, SO_2, NO_x and hydrocarbons in the flue gas exhaust.
- Flue gas and ambient air temperature: Thermocouple (type J or K), mercury thermometer and resistance thermometer.
- Smoke density test kit to measure opacity in flue gases. This can be correlated with soot concentration in order to determine loss of unburned material.
- Approximate determination of the firing rate.
- Air humidity: electronic hygrometer.
- Steam pressure: Bourdon gauge.
- Fuel flow (oil, gas): positive displacement, orifice, nozzle, venturi, Pitot tube, vortex and turbine.
- Appropriate methods to measure boiler blowdown under the circumstances prevailing in Peru need to be identified.

(b) Input-output method:

- Fuel flow: positive displacement type meter (in line). For example, gear type.
- Steam flow: vortex or orifice plate type meter (in line).
- Steam pressure: Bourdon gauge (locally-used measurement instrument).
- Steam temperature (for superheated steam): thermocouple (type J or K).
- Feed water temperature: thermocouple (type J or K) or temperature gauge.
- Secondary stream flows (including boiler blowdown).

The measurements may be performed either by personnel of the monitoring entity or by independent companies, but not the company that is involved or any related company.

[7] Appropriate methods to measure boiler-blow down under the circumstances prevailing in Peru need to be identified.

10.7 Calculation of emission reductions

10.7.1 Project emissions

Project emissions after implementation of energy efficiency improvement measures are related directly to the amount and type of fuel fired in the boilers. This information is collected from companies, and emissions are calculated as follows:

$$E_{Project} = \sum_{boilers} C \cdot EF_{Fuel} \qquad \textit{(Equation 14)}$$

where

$E_{Project}$	*Project emissions during a monitoring period (t CO_2)*
C	*Fuel consumption during a monitoring period (MWh)*
EF_{Fuel}	*Emission factor of the fuel (t CO_2/MWh)*

10.7.2 Baseline emissions

Dynamic baseline emissions are calculated by multiplying the activity level for each boiler – which corresponds to the vapour demand – by the baseline emission factor:

$$\begin{aligned} E_{Baseline} &= AL \cdot EF_{Baseline} \\ &= AL \cdot \frac{EF_{Fuel}}{\varepsilon_{Baseline}} \end{aligned} \qquad \textit{(Equation 15)}$$

where

$E_{Baseline}$	*Baseline emissions during a monitoring period (t CO_2)*
AL	*Activity level (= vapour production) during a monitoring period (MWh)*
$EF_{Baseline}$	*Emission factor of the baseline (t CO_2/MWh)*
EF_{Fuel}	*Emission factor of the fuel (t CO_2/MWh)*
$\varepsilon_{Baseline}$	*Energy efficiency of the boiler in the baseline*

The activity level is then calculated indirectly from fuel consumption and actual energy efficiency as follow:

$$AL = C \cdot \varepsilon_{Project} \qquad \textit{(Equation 16)}$$

where

AL	*Activity level (= vapour production) during a monitoring period (MWh)*
C	*Fuel consumption during a monitoring period (MWh)*
$\varepsilon_{Project}$	*Energy efficiency of the boiler after project implementation*

With equations 15 and 16 emissions of the baseline of all boilers can be calculated as follows:

$$E_{Baseline} = \sum_{Boilers} C \cdot EF_{Fuel} \cdot \frac{\varepsilon_{Project}}{\varepsilon_{Baseline}} \qquad \textit{(Equation 17)}$$

where

$E_{Baseline}$	*Baseline emissions during a monitoring period (t CO_2)*
C	*Fuel consumption of the boiler during a monitoring period (MWh)*
EF_{Fuel}	*Emission factor of the fuel (t CO_2/MWh)*
$\varepsilon_{Project}$	*Energy efficiency of the boiler after project implementation*
$\varepsilon_{Baseline}$	*Energy efficiency of the boiler in the baseline*

10.7.3 Emission reductions

Taking into account equations 14 and 17 the emission reduction can finally be determined as follows:

$$\Delta E = \sum_{Boilers} C \cdot EF_{Fuel} \cdot \left(1 - \frac{\varepsilon_{Project}}{\varepsilon_{Baseline}}\right) \qquad \textit{(Equation 18)}$$

where

ΔE	*Emission reductions during a monitoring period (t CO_2)*
C	*Fuel consumption of the boiler during a monitoring period (MWh)*
EF_{Fuel}	*Emission factor of the fuel (t CO_2/MWh)*
$\varepsilon_{Project}$	*Energy efficiency of the boiler after project implementation*
$\varepsilon_{Baseline}$	*Energy efficiency of the boiler in the baseline*

10.8 Quality assurance and quality control procedures

Quality assurance and quality control procedures include consistency checks of the reported data, spot checks at the plant site and additional measurements conducted by the monitoring entity or subcontractors.

10.8.1 Energy efficiency

In the case of the determination of energy efficiency the following procedures are proposed for quality assurance and quality control purposes:

- The monitoring entity should conduct automatic consistency checks of all measurement results.[8]
- Calculation of energy efficiency from the measurement results should be conducted automatically with the help of software. This ensures that calculations are transparent and simply verifiable.
- On random selection additional secondary measurements of energy efficiency should be carried out in some boilers. The measurements should be conducted by different teams from different companies or institutions. However, the same methods and the same type of instrumentation should be used. These additional measurements should provide supplementary information on the uncertainty of measurements. It is proposed that additional parallel measurements be conducted in 10% of the measurements carried out in the course of the project.
- Measurement results using the energy balance method should be cross-checked with results obtained from continuous metering of efficiency using the input-output method. If measurement results show significant deviations the metering equipment should be checked and, if necessary, additional measurements carried out.

10.8.2 Fuel consumption and fuel type

In order to identify possible errors in data reporting or data archiving, the following automatic consistency checks can be performed very easily for each boiler:

- The average annual load factor can be calculated from the capacity of the boiler, actual energy efficiency and reported fuel consumption. If the load factor is larger than 100%, some of the reported data must be wrong.
- The load factor or fuel consumption may change from year to year at certain intervals due to changes in the production process or in the level of production. As a general consistency check, the reported data should be compared with the data submitted the previous year. If reported fuel consumption has changed signifi-

[8] There is a link between the different measurement results, which enables their consistency to be checked. This applies, for example, to flue gas composition where concentrations of O_2, CO_2, CO, NO_x and SO_2 are linked.

cantly (for example, more than 10%) compared to the previous year, the monitoring entity may seek clarification concerning the correctness of the reported information. In cases of doubt the company may be asked to make available additional information, such as the annual business report, which provides information on the level of production.

The monitoring entity should select some companies at random, where spot checks can be conducted. In the course of spot checks it should be verified that reported information on the energy supply system and on meter reading of fuel consumption is correct. It is proposed that spot checks be conducted at initially 30% of participating companies each year. If results show a high reliability of reported data, this percentage may be lowered in subsequent years.

10.9 Leakage effects

Emissions outside the project boundary occur principally as indirect upstream emissions. These emissions are mainly related to the extraction, processing and transport of fuels and the generation of electricity for boiler fans and pumps. Furthermore, some emissions occur upstream in the production and transport of energy efficient technologies. It is suggested that such emissions outside the project boundary be estimated approximately with the help of the Environmental Manual,[9] and that available data be added to this system where necessary. Altogether, it can be assumed that overall GHG emissions outside the project boundary will be reduced by the project activity.

The influence of the project activity on the electricity demands of boilers should be evaluated by means of a small control group of approximately 10 boilers of representative capacity. In the case of this control group of boilers portable electricity meters should be temporarily installed prior to and some time after implementation of energy efficiency improvement measures. The electricity demand per unit of vapour production should be used as an indicator to compare the specific electricity demand before and after implementation. If electricity demand decreases, as assumed, relevant emission reductions outside the project boundary should be neglected, being probably small. If electricity demand unexpectedly increases and is significant, the electricity supply will be introduced in the project boundary and additional measurements conducted.

10.10 Overview of the process of boiler baseline determination, monitoring and certification

The process of baseline determination, monitoring and certification includes several steps, which are described in a general way below. More detailed provisions need to be elaborated when the project is implemented.

[9] Download at: http://www.oeko.de/service/em

1. **Pre-evaluation of the boiler.** Based on information provided by the company, and possibly by a short spot check, it is assessed whether energy efficiency improvements seem appropriate and whether the boiler fulfils the participation requirements as laid out in the section on baseline methodology.
2. The **project participation contract** between the company and the project managing institution needs to be signed.
3. The project manager provides **technical assistance** and related capacity building to the company. The company applies good housekeeping measures and appropriate maintenance activities. Where appropriate, measurement equipment is installed for the determination of energy efficiency with the direct method.
4. The **monitoring entity** conducts measurements of energy efficiency for the purpose of **determination of baseline energy efficiency**. In doing so, the energy balance method is applied, and, where appropriate, direct method measurements are conducted during the course of one month.
5. **Measures** to improve energy efficiency are **implemented**. The boiler-specific crediting period is determined and commences.
6. The **monitoring entity** determines **project energy efficiency** directly after implementation of energy efficiency improvements (**monitoring**).
7. **Continuous monitoring process.** Measurements are conducted continuously by the monitoring entity on a random basis. Measurements are generally conducted on an annual basis. Companies provide annual data on fuel consumption and fuel type.
8. **Calculation of emission reductions.** The monitoring entity collects all relevant data and calculates the emission reductions of the project.
9. **Verification.** An independent operational entity controls the monitoring entity and the companies, and verifies emission reductions. Spot checks and additional measurements may be conducted by the independent operational entity.
10. **Certification and issuance of CERs.** After verification by the independent operational entity, certified emission reductions (CERs) can be issued and sold.

11 Potential and abatement costs of the CDM project

In this chapter, the potential and costs of GHG emission reductions in the boiler project are estimated. Estimations are conducted with the help of a combined bottom-up and top-down approach. In the bottom-up approach, a representative sample group of boilers is evaluated with respect to possible GHG mitigation measures and associated costs. From the results of this evaluation a marginal abatement cost curve is constructed. In the following step, the calculated potential and mitigation costs of the sample group are extrapolated to all those Peruvian boilers that have been identified in chapter 8. In the following top-down approach, some boilers are excluded, since they fire renewable fuels or are too small or too old to be considered in the CDM programme. Furthermore, a boiler participation rate in the CDM programme is estimated, taking into account several barriers in this sector. As a result, an overall marginal GHG mitigation cost curve is approximated and the potential of a Peruvian CDM boiler project is assessed.

In the following, the methodology for the calculation of CO_2 abatement costs is at first introduced and key economic influence factors are estimated. In Section 11.3 mitigation potential and abatement costs are calculated for the selected sample group. In section 11.4 results of the sample group are extrapolated and the potential and CO_2 abatement costs of a Peruvian boiler CDM programme are estimated.

11.1 Methodological approach

11.1.1 Assessment of energy efficiency improvement options

The assessment of possible options to improve energy efficiency in Peruvian boilers is based on the technical analysis in chapter 6. Options to improve energy efficiency are assessed individually for each of the boilers within the sample group. Generally, three different options are considered:

- Application of good housekeeping measures.
- Replacement of the boiler or the burner.
- Increase of energy efficiency by additional investments.

In assessing energy efficiency improvements, a *two-step approach* is followed: The starting point of the analysis is current energy efficiency, as has been measured. Based on this technical assessment, in a first step it is estimated to which extent energy efficiency could be increased by implementation of *good housekeeping* measures. In a second step, possible *investments* to improve energy efficiency are identified and the respective improvement in energy efficiency for each of the proposed investments is estimated. Alternatively, in the case of boiler replacement the efficiency of the new boiler is considered. This two-step approach is conducted in order to separately assess the effect of good housekeeping measures and of measures involving investment. By estimating costs and energy efficiency improvements for *each* measure, it is possible to determine CO_2 mitigation for each measure and to identify economically feasible options.

11.1.2 Calculation of marginal CO_2 mitigation costs

Marginal mitigation costs are calculated on a dynamic basis. The methodology is illustrated in Figure 24. All costs and proceeds associated with the project activity are transformed into average annual GHG mitigation costs during the crediting period.

The proposed methodology comprises the following three steps:

1. **Determination of the net present value of all relevant costs and proceeds.** For the improvement of energy efficiency in boilers, investment costs, additional costs for operation and maintenance are considered, as well as avoided costs from achieved energy savings. Transaction costs for companies arising from participation in the programme, or other transaction costs (for example, for capacity building or monitoring) are not taken into account in the estimation of GHG abatement costs.

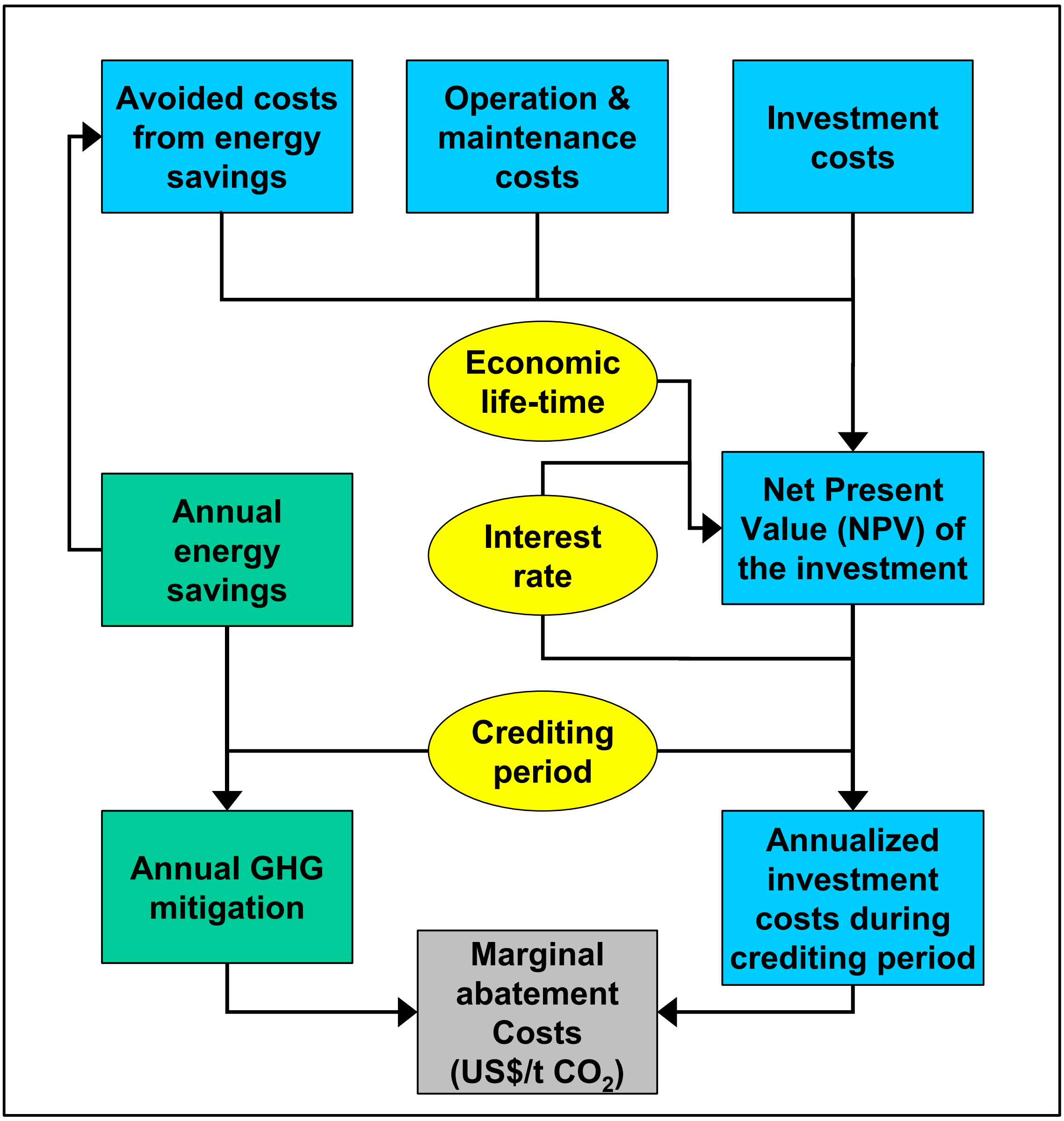
   In calculating net present value, the technical and economic life of the mitigation measure and appropriate interest rates are selected that reflect the Peruvian financial market and the project design. Other barriers, such as irrational cashflow return expectations or limited access to capital are not reflected in the calculation of GHG abatement costs. Consequently, net present value reflects the economic feasibility of energy efficiency improvement measures without taking other barriers into account.

2. **Transformation of net present value into average annual abatement costs.** The net present value is annualized in annual abatement costs during the crediting period. The same interest rate as used in the calculation of net present value is considered, but costs are annualized over the crediting period, instead of over the economic life, since CERs are only generated during the crediting period.

3. **Marginal Abatement costs.** Marginal abatement costs are calculated by dividing annual abatement costs by annual GHG emission reductions.[1]

[1] In the case of boiler energy efficiency, project emission reductions of one boiler are estimated to be constant over time, since the activity level is projected as constant and energy efficiency in the baseline and the project activity is expected to be constant. However, if emission reductions change during the crediting period, for the purpose of calculation of GHG abatement costs an average annual value can be determined by calculating the net present value of emission reductions and transforming this net present value into an annuity during the crediting period.

Figure 24: Methodology for the calculation of marginal abatement costs



Source: Öko-Institut

11.2 Key economic factors of influence

11.2.1 Fuel prices

In Peru, there are no official national price projections available for domestic fuel types, such as diesel 2, residual 500 and residual 6. Official documents concerning future fuel prices refer only to international prices. In this study, therefore, national price projections are derived from analysis of the correlation between international oil prices and domestic fuel prices in the past, assuming the same correlation for the future. Future national prices for domestic fuel types are then calculated from projections for future international oil prices.

Current and future prices of the most important fuels (diesel 2, residual 500 and residual 6) are estimated on the basis of two official Peruvian documents: the *Hydrocarbon Referential Plan 2001*[2] and the *Statistical Hydrocarbon Annual 2000* of the Ministry of Energy and Mines (MEM). The price of WTI crude oil (West Texas Intermediate) is taken as the base price to estimate the price of hydrocarbons sold in Peru, since crude WTI is an internationally known indicator. The analysis conducted by MEM assumes steady prices from 2002 to 2010. It analyzes projections made by different specialized publications, particularly by the study presented in the International Energy Outlook 2001 elaborated by the Energy Information Administration (EIA) of the United States.

Table 44: Projection of crude oil prices and oil derivates sold in Peru (US$/bbl)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002 - 2010
WTI	18,42	17,18	18,41	22,13	20,60	14,40	19,25	30,29	25,00	22,00
Crudo Exp.	11,89	12,40	14,39	17,38	14,93	8,70	14,02	22,85	18,84	16,23
Crudo Imp.	16,01	15,43	16,90	20,33	17,46	11,17	16,78	27,12	22,39	19,50
Gasolina	21,34	20,03	21,29	25,07	24,65	17,43	22,00	35,03	28,87	25,50
Diesel	22,56	22,56	20,41	25,16	23,10	18,68	20,04	34,04	27,88	24,78
Kero/Turbo	22,22	20,62	20,71	25,45	23,48	19,96	21,46	35,63	28,89	25,72
Residuales	14,63	14,40	15,05	17,90	16,45	13,50	14,64	25,99	20,67	18,17
GLP	14,07	13,38	14,43	18,44	17,07	14,85	15,79	21,04	18,57	17,08

Source: MEM

The prices of crude oil and fuels sold in Peru are estimated against the background of their historical relation to the price of WTI crude oil and the prices of crude oils and similar or equivalent fuels that are sold on the international market.

Table 45: Estimated future fuel prices in Peru in the national currency (soles)

Year	**Price with VAT in nuevos soles per gallon**		
	Diesel 2*	**Residual 6**	**Residual 500**
2001	6.31	2.33	1.94
2002-2010	5.91	2.18	1.82
Year	**Price without VAT in nuevos soles per gallon**		
	Diesel 2	**Residual 6**	**Residual 500**
2001	5.35	1.97	1.64
2002-2010	5.01	1.85	1.54

Source: Calculations conducted by FONAM. In the case of diesel, a commercial margin and a selective excise tax are assumed.

2 www.mem.gob.pe/wmem/publica/ssh/planrefe2001.asp

Table 46: Estimated future fuel prices in Peru US$

Year	Sales price in US$ per gallon with VAT		
	Diesel 2	**Residual 6**	**Residual 500**
2001	1.80	0.66	0.55
2002-2010	1.69	0.62	0.52
Year	**Price in US$ per gallon without VAT**		
	Diesel 2	**Residual 6**	**Residual 500**
2001	1.53	0.56	0.47
2002-2010	1.43	0.53	0.44

Source: Calculations conducted by FONAM. Prices are calculated assuming a constant correlation of 3.5 soles per US$.

The results on the projection of prices as of 2010 are summarized in Table 45 and Table 46. For the project period, real prices are estimated to be constant, as the official documents available in Peru suggest constant prices. Energy prices for the calculation of GHG abatement costs include energy taxes, but not value-added tax (VAT).

11.2.2 Capital costs

In this section, the weighted average cost of capital (WACC) is assessed for investments in energy efficiency by Peruvian companies.

The access to capital of Peruvian companies depends on several factors. One important factor is the size and type of the company. Peruvian firms can be disaggregated into microenterprises, small and medium-sized enterprises (SME) and corporate enterprises.

Table 47: Classification of companies in Peru

Firm class	Sales per year	Employees
Microenterprises	US$ 5,000	Two people
Small enterprises	Up to US$ 1 million	Less than 100 people
Medium-sized enterprises	Up to US$ 30 million	Less than 100 people
Corporate enterprises	Over US$ 30 million	Over 100 people

Source: Finanzas Ambientales

Microenterprises are firms regarded as a subsistence activity, mostly in the commercial sector, run by one or two people with revenues of around US$ 5,000 per year.

Small enterprises are mainly found in the commercial sector, employ less than 100 people and are mostly family-owned and managed, average annual revenues amounting to less than 1 million US$.

Medium-sized industrial firms produce revenues of between 1 Million US$ and 30 Million US$ and they employ less than 100 people. Carbon dioxide emission reductions of such companies are still relatively low. The participation of these companies seems only economically attractive in the carbon market if several boilers are bundled as proposed in this study.

Furthermore, regardless of their financial situation, access to the capital market is restricted to local commercial banks, where credit conditions are not competitive compared with the international market (interest rates for loans nominated in US$ may range from 15% to 24% per year).

The revenues of local corporate or international enterprises are above 30 million US$ per year. These firms have access to capital markets, commercial banks, international funding, as well as to international and local inter company loans.

Each type of industry, for each size of enterprise, has its own related risk, and thus its own expected rate of discount. An approximation of the range of discount rates might be ascertained using the Capital Asset Pricing Model (CAPM)[3]:

$$\mathrm{R_C} = \mathrm{R_f} + B \cdot \left(R_m - R_f\right) \qquad \textit{(Equation 19)}$$

where

R_C:	*Discount rate*
R_f:	*Market interest rate*
R_m:	*Risk free rate*
B:	*Parameter to assess industry risk based on data from the stock market*

In the Peruvian case, the market interest rate is about 9.48%, and the difference between the market interest rate and the risk free rate is about 5.5%. The parameter B is the result of the Lima Stock Market Exchange standard deviation divided by the Standards and Poor indicator standard deviation:

3 "Emerging Markets Discount Rates". Goldman Sachs calculated the Latin America discount rate as the highest. Goldman Sachs Investments, November1999.

$$\frac{\text{gamma BVL}}{\text{gamma S \& P 500}} = \frac{1.89}{1.03}$$ *(Equation 20)*

The final discount rate R_C amounts to 19.57%. The estimated discount rate might be applicable only for corporate enterprises that have access to the local capital market; but considering that medium-sized enterprises are riskier than larger ones, and assessing the risk with the standard deviation of its stock's quotes, we could assume[4] higher discount rates of about 500 basis points, resulting in a 24.57% discount rate for medium-sized enterprises.

Table 48: Estimated capital discount rates and interest rates for different firms

Kind of firm	Capital discount rate	Interest rate
Local and International corporate firms	19.57%	9% in US$
Medium-sized firms	24.57%	17% in US$
Small firms	28.00%	20% in US$

Source: Finanzas Ambientales

The financing of fixed assets in the Peruvian banking system (standard practice) requires a 20% to 30% down payment from eligible companies, so the required financing might amount to between[5] 70% and 80% for each kind of firm with standard banking loans, nominated in US$. The cost of capital would be a weighted average discount rate for the project as illustrated in Table 49 below.

Table 49: Capital costs for different types of companies in Peru

Kind of firm	Capital discount rate	Down-payment	Interest rate	Loan	Weighted Average Cost of Capital (WACC)
Local and international corporate firms	**19.57%**	20%	7%	80%	**10.93%**
Medium-sized firms	**24.57%**	30%	17%	70%	**21.10%**
Small firms	**28.00%**	30%	24 %	70%	**25.20%**

Source: Finanzas Ambientales

Under these circumstances, investments in energy efficiency must show marginal savings, and discounted WACC rates must be higher than zero (positive net present value).

4 There is no indicator for calculating discount rates for SME using CAPM methodology.

5 Willingness to finance non-preferred equipment, such as industrial boilers, may be a lower percentage.

According to banking practices, companies must show that replacing boilers is a profitable investment that will improve their competitiveness.

11.2.3 Technical and economic life of investments

When investments in new boilers or in the improvement of energy efficiency in boilers are evaluated economically, two different periods of time have generally to be taken into account for the calculation of mitigation costs: the fiscal depreciation period and the technical life of the boiler.

Peruvian tax regulations[6] set the fiscal depreciation period for boilers at ten years. Companies could request a shorter depreciation period, but they must prove that the technical life is in each case shorter. The average technical life of boilers in Peru amounts to about 35 to 40 years[7], so the depreciation period for fiscal consideration is 10 years for new boilers. The technical life of most measures to improve energy efficiency is about 10 years. In this case, the technical life and depreciation period would be equivalent.

It is important to mention that, for fiscal matters, the shorter the depreciation period the better the cash flow, due to tax shields if net income is positive. Nevertheless, depreciation would lessen net income, and cash flow would be higher and therefore increase the value of the company. From an overall cash flow perspective, the typical technical life of the investment has to be taken into account, considering, where relevant, necessary overhaul expenses.

For the purpose of calculating marginal CO_2 abatement costs, the **technical life** of boilers is considered for the amortization of the investment. In cases where boilers are replaced by new and more efficient boilers before the technical life of existing boilers has expired, a different approach is followed. In these cases, only a fraction of the investment is attributable to the project activity, as the existing boiler would have had to be replaced in any case some years later. In the early years, the investment is additional, as existing boilers would have continued to operate. These early years correspond to the crediting period. After this period the investment would have occurred anyhow. Therefore, only a fraction of the total investment is attributable to the project activity and thus considered for the purpose of calculating CO_2 abatement costs. In this study a simple approach is chosen, assuming a linear correlation between the crediting period and the technical life:

$$\text{Project investment} = \frac{\text{Crediting period}}{\text{Technical life (35 years)}} \cdot \text{Overall boiler investment} \qquad \textit{(Equation 21)}$$

6 Income tax regulation, Articles 22 and 39

7 Some boilers are operated even as long as 70 years. However, MITINCI (2000) showed that the average age of the boiler park is about 20 years, and that most boilers are operated for 35 to 40 years.

11.3 Potential and mitigation costs: sample group

11.3.1 Selection of the sample group

The sample group of boilers comprises 41 boilers selected among the 80 boilers analyzed by Jimenez (2001) and by CENERGIA (2001). From the original 80 boilers, 39 are excluded for various reasons:

- Boilers with a size less than 1.47 MW (150 BHP) could not be considered, since possible measures to improve energy efficiency proved to be highly uneconomic due to limited energy savings.
- Some of the analyzed boilers fire renewable energy fuels such as cane trash, and energy efficiency improvements would thus not lead to a reduction in CO_2 emissions.
- Some measurements are performed inaccurately, and measurement results could not be considered for boiler evaluation.
- In seven cases, current energy efficiency proved to be reasonably high and no measures to improve energy efficiency are proposed.

The sample group comprises boilers with different fuels (residuals and diesel), of different sizes ranging from 1.47 MW (150 BHP) up to 49 MW (5000 BHP), with different technologies and from 5 to 34 years old. The overall installed capacity of the sample group amounts to 263,000 MW (26,800 BHP) with an average size of 6,400 MW (650 BHP).

11.3.2 Evaluation of boilers

All boilers of the sample group are evaluated individually, and measures to improve energy efficiency are proposed after analysis of the specific circumstances of each boiler. In all cases, energy efficiency, as determined by Jimenez et al. (2001) and CENERGIA (2001), is recalculated using the original measurement results. This seemed to be necessary, because some losses were determined imprecisely. According to recalculations, the current average energy efficiency of the sample group amounts to 83.1% weighted by the number of boilers and 82.8% weighted by capacity.

For the group of 42 boilers, 83 investment measures to improve energy efficiency are proposed, including

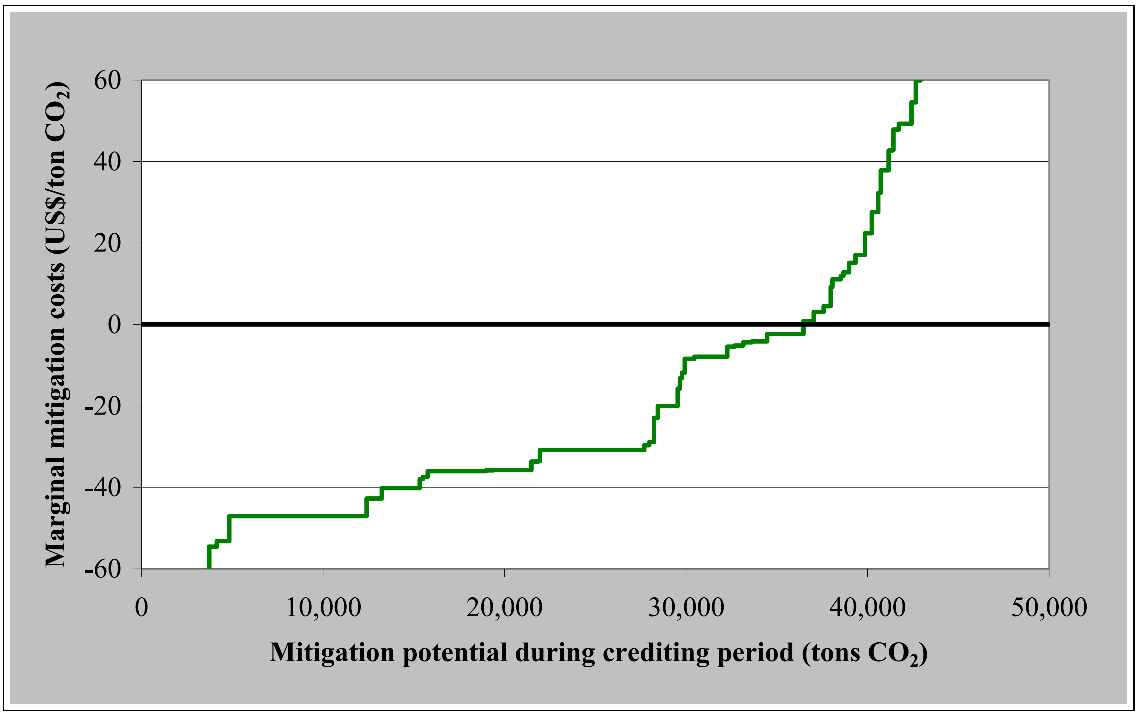
- automatic control of excess air,
- automatic control of boiler blowdown,
- replacement of the burner,
- installation of an economizer and
- replacement of the boiler.

For each of the proposed 83 measures investment costs, additional costs for operation and maintenance as well as the improvement in energy efficiency are estimated.

With application of the proposed measures and good housekeeping practice an average energy efficiency of 89.0% weighted by the number of boilers and 89.3% weighted by capacity could be achieved. Possible energy efficiency improvements thus amount to about 6 - 6.5%. As in many cases, maintenance practices are poor, and energy efficiency improves significantly only through application of good housekeeping. According to the analysis performed, the effect of good housekeeping amounts to about 3.5%, while the improvement due to the measures proposed above amounts to about 3%. With application of good housekeeping measures, energy savings of about 105,000 GJ annually and CO_2 emission reductions of about 8,000 tonnes can be obtained within the sample group. Another 85,000 GJ of energy savings and about 6,500 tonnes of CO_2 emission reductions can be achieved with implementation of all proposed investment measures, not considering their economic viability.

The economic viability of the proposed investment measures is analyzed by calculating the CO_2 abatement costs and the total mitigation potential during the crediting period for each of the 83 measures. From these calculations, a marginal CO_2 abatement cost curve is constructed (Figure 25). Measures to apply good housekeeping are not considered in the estimation of the potential, and transaction costs are not considered in the calculation of abatement costs.

Figure 25: Marginal CO_2 abatement cost curve for the sample group of 43 boilers without consideration of measures to improve housekeeping



Source: Calculations conducted by Öko-Institut

The results in Figure 25 show that some of the measures are economically very attractive with negative abatement costs, while other measures are economically very unattractive with CO_2 abatement costs above 50 US$/t. During the crediting period, approximately 43,000 tonnes of CO_2 could be mitigated if all measures proposed for the sample group would be applied.

However, measures with abatement costs above a certain level should not be considered for the CDM programme, as they will probably not be economically feasible with the expected market prices for certified emission reductions (CERs). At the moment, there are many different price projections, and future prices may change.[8] Here it is suggested that only those measures be considered that can be realized with abatement costs below 5 US$ per tonne of CO_2. When this threshold value is applied for the estimation of CDM potential, the number of feasible measures diminishes from 83 to 36, and the potential decreases from 43,000 to 35,000 tonnes of CO_2. In 14 of the 41 boilers no measures can be implemented at all. However, a significant part of the improvements (more than 80%) is obtained by a relatively limited number of measures (about 45%). The results of the evaluation of the sample group of boilers are summarized in Table 50.

Table 50: Theoretical and cost-effective GHG mitigation potential of the sample group

		Current situation	Application of Good House-keeping	Implemention of additional CDM investment	Total
Theoretical potential (All proposed measures)					
Number of boilers	-				41
Total capacity of boilers	MW				263,006
Energy efficiency	-	82.8%	86.4%	89.3%	
Annual energy savings	GJ/a		104,900	85,362	190,263
Annual CO_2 mitigation	t/a		7,963	6,463	14,426
Energy savings during crediting period	GJ		673,558	567,392	1,240,950
CO_2 mitigation during crediting period	t		51,148	42,947	94,095
Cost-effective potential (Implementation of measures with costs below US$ 5/ton)					
Number of boilers	-				27
Total capacity of boilers	MW				201,203
Energy efficiency	-	82.6%	86.3%	88.7%	
Annual energy savings	GJ/a		95,861	69,337	165,198
Annual CO_2 mitigation	t/a		7,281	5,252	12,533
Energy savings during crediting period	GJ		630,334	466,052	1,096,386
CO_2 mitigation during crediting period	t		47,889	35,289	83,177

Source: Own calculations

8 see Den Elzen (2001), Grüttner (2001), Vrolijk (2002)

11.4 Potential and mitigation costs: CDM boiler project

In the following, the potential and abatement costs are estimated for a national CDM boiler programme. The estimation follows a combined *bottom-up* and *top-down* approach in two steps. In the first step, results from the analysis of the sample group are taken as the basis and extrapolated to all boilers in Peru (*bottom-up approach*). With this bottom-up approach, the economic potential for all boilers in Peru is determined, without consideration of any barriers to a CDM boiler programme that reduce the number and potential of participating boilers. In the second step, the proportion of companies and boilers that under realistic circumstances may participate in the CDM programme is estimated and applied to the overall potential (*top-down approach*).

With the bottom-up approach, in the first step an economic mitigation potential of 700,000 tons of CO_2 during the whole project lifetime is determined, which is 20 times higher than the potential identified for the sample group of about 35,000 tonnes.[9] Another 950,000 tonnes of CO_2 emissions would be reduced by good housekeeping activities, resulting in total savings of 1,650,000 tonnes of CO_2.

However, the real potential of the CDM programme is considerably smaller, as the following restricting factors have to be taken into account in the top-down approach:

- **Boiler size.** In boilers with a small capacity, efficiency improvements will generate a correspondingly small amount of CERs. Even if investment costs are low, there are considerable transaction costs independent of the size of the boiler. Due to these transaction costs GHG abatement costs are relatively higher for small boilers than for large boilers. As a minimum requirement, the income from selling CERs generated by energy efficiency improvements should exceed the boiler-specific transaction costs of the 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. In the analysis conducted by Jimenez et al. (2001) and CENERGIA (2001), efficiency improvement in boilers of about 1.5 MW reduced CO_2 emissions by 10 to 50 tonnes annually. Assuming a price of around 5 US$ per tonne of CO_2 and an average crediting period of seven years, income from selling CERs would amount to approximately 350 – 1,750 US$ and approximated boiler-specific CDM transaction costs are estimated to be covered.

- **Technological performance.** Energy efficiency in Peruvian boilers varies considerably (see analysis in Chapter 5). The energy efficiency improvements realized in the CDM programme should lead to a certain amount of energy savings

9 Fuel consumption is taken as the basis for extrapolation. Fuel consumption of the sample group amounts to 2,569 TJ annually, whereas fuel consumption of all boilers amounts to about 51,080 TJ annually. In this bottom-up approach only economically feasible measures with a price below 5 US$ per tonne of CO_2 are considered, as also above for the determination of the economic potential of the sample group.

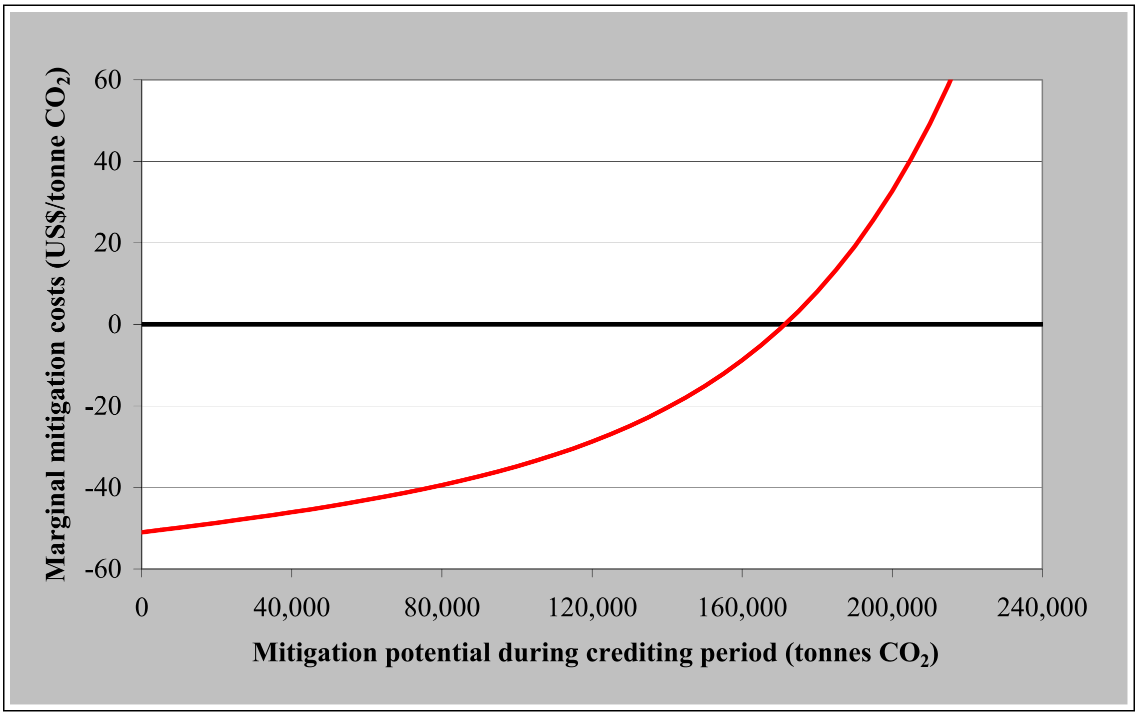
for each boiler to cover investment and transaction costs. In some cases, boilers already have a relatively high technical performance. Consequently, efficiency improvements are not possible, or would only generate insignificant energy savings even if boilers were above the proposed capacity threshold of 1.5 MW. Secondly, in some cases boilers operate at a low annual load factor, and, in consequence, energy savings are insignificant 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.

In the energetic evaluation of 80 boilers conducted by Jimenez et al. (2001) and CENERGIA (2001) only a few boilers already have relatively advanced energy efficiency. In a detailed analysis based on this data it is estimated that this applies only to 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 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, as 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 as 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 36 years old are eligible for replacement in order to meet the established additionality criteria (see section 9.9.3). In practice, energy efficiency improvements at the end of the lifetime of a boiler would also generate energy savings only for a few years, which in most cases is not economically attractive. Therefore, boilers older than 35 years are generally not considered in the estimation of the CDM potential.
- **Financial and economical viability of companies.** According to the Peruvian SBS, some sectors of Peruvian industry, such as the fishing industry, have considerable debts. A number of companies are under regulation of a law (Ley de Reestructuración empresarial), which limits their access to capital. According to information from the SBS, 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.
- **Other barriers.** Experiences with energy efficiency programmes show that in practice only a part of potentially qualified companies participate in projects due to lack of information or other barriers. In this case, it is assumed that 50% of

technologically and economically qualified companies would participate in the CDM programme.

Figure 26: Marginal mitigation cost curve of the CDM boiler programme



Source: Calculations by Öko-Institut

Taking into account these assumptions, the economic potential of a CDM boiler programme decreases to about *170,000 tonnes of CO_2* during the project lifetime, which is approximately five times the economic potential of the sample group and a quarter of the potential of all Peruvian boilers. Another 230,000 tonnes of CO_2 are reduced by implementation of good housekeeping activities. Figure 25 shows the approximate marginal cost curve for the whole CDM boiler programme, and Table 51 summarizes the main results.

Considering that natural gas will come from Camisea to the Lima region, the potential decreases slightly more. Since natural gas has lower carbon content, the same energy savings achieved by the project generate less CO_2 emission reductions if the proportion of natural gas in the fuel mix increases. In section 4.3 of this study it is estimated that a fuel switch to natural gas may affect 15% of boilers in 2010. Considering a linear increase for natural gas from 2004 until 2010, and in the following years a more moderate increase, the total economic potential of the CDM programme would amount to about 166,000 tonnes of CO_2, which is only 4,000 tonnes less than the estimated potential without consideration of the Camisea gas project. Emission reduction from good housekeeping activities would be reduced correspondingly to about 225,000 tonnes of CO_2. Consequently, the impact of the Camisea gas project on the amount of emission reductions is quite low compared to other uncertainties in the estimation of the potential.

Table 51: 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 mitigation		
CDM measures	tonnes/a	25,396
Good housekeeping	tonnes/a	35,209
Total	tonnes/a	60,605
Average annual energy savings		
CDM measures	GJ/a	335,278
Good housekeeping	GJ/a	463,536
Total	GJ/a	798,814
CO_2 mitigation during crediting period		
CDM measures	tonnes	**170,638**
Good housekeeping	tonnes	231,566
Total	tonnes	402,204
CO_2 mitigation during crediting period (with Camisea gas)		
CDM measures	tonnes	**166,188**
Good housekeeping	tonnes	225,528
Total	tonnes	391,716

Source: Own calculations

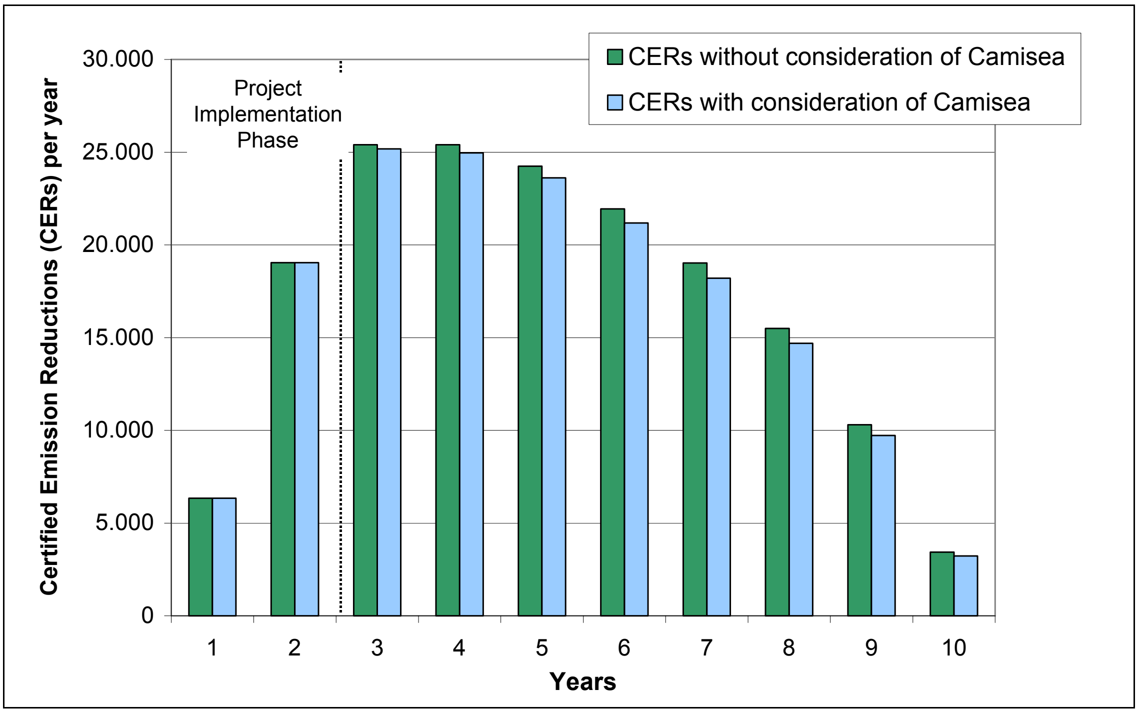
11.5 Certified emission reductions (CERs)

Certified emission reductions (CERs) are generated throughout the overall project crediting period of ten years. During the first two years, the project is being implemented by way of investments in energy efficiency improvements or boiler replacements. The generation of CERs is projected in Figure 27 over the project lifetime, taking into account the project implementation phase and the different crediting periods for each boiler. The projection is based on estimations in this chapter; actual emission reductions can only be determined ex-post during the monitoring process and depend on several factors, such as the number of participating boilers, the economic situation of the relevant sectors, the energy efficiency of participating boilers, etc. The results of the projection in Figure 27 show how the estimated project potential of about 170,000 CERs is estimated to be spread over the crediting period of ten years.

Two cases are considered in Figure 27. With the left bar the effect of natural gas coming to the Lima region through the Camisea project is not considered; with the right bar the Camisea Gas Project is considered and, as a result, certified emission reductions (CERs) are slightly reduced due to the decreased emission factor of natural gas. The figure shows that the effect of the Camisea gas project on the amount of certified emission reductions is expected to be relatively low.

During the project implementation phase, emission reductions are expected to be lower, as boilers join successively during the first two years. The highest potential can be achieved in the following years, whereas the potential decreases during the later years, when some boilers start reaching the end of their individual crediting period.

Figure 27: Generation of CERs during the ten-year overall crediting period



Source: Own calculations

11.6 Conclusions

In Peruvian industry there is a significant potential to reduce GHG emissions at negative marginal mitigation costs. Taking into account only measures with abatement costs under 5 US$ per tonne of CO_2 and considering the various barriers, such as a total participation rate of 50% of boilers, the **feasible potential** for a CDM boiler programme in Peru is estimated to amount to about **170,000 tonnes of CO_2**. Assuming a price of US$ 5 per tonne of CO_2, additional income of about US$ 850,000 could be achieved through the CDM project activity.

Although most of the proposed measures are economically feasible and have negative implementation costs, they are currently not implemented due to different barriers. The income of CERs in this multi-boiler project serves mainly to acquire additional revenue, which is required to overcome these barriers.

12 Evaluation and risk management

This chapter identifies and evaluates the economic, financial, technical and environmental risks as well as measures for managing and minimizing their effects. Such risks are associated with the achievement of estimated reductions and would affect project implementation and profitability.

12.1 Risks in the project development phase

Acceptability on the part of the host country

If CONAM, the environmental authority in Peru, does not approve the project, it cannot be submitted to the executive board of the CDM and cannot generate CERs under the Kyoto Protocol.

MITINCI (Ministry of Industry, Tourism and International Negotiations) has decided to support this project, since it allows the modernization of the Peruvian industrial boiler park. On the other hand, CONAM is also greatly interested in the project. Furthermore, the project has several positive effects on the sustainable development of the country (for example, the reduction of polluting emissions) and improves the competitiveness of participating companies. Therefore, approval of the project by the Peruvian government can be expected.

Acceptability on the part of the investing countries

If the investing country were not to approve the project, the foreign buyer (for example, a company) would not buy CERs because it would not be accepted in its respective country. This can be dealt with through additional criteria on the part of each country to prioritize a certain sector or activity.

Eligibility criteria have been clearly established and each signatory country of the Kyoto Protocol will define in advance its own criteria. This will significantly reduce the risk. The development of this study intends to identify all relevant aspects that can be crucial for the approval of the Parties included in Annex I. In general, energy efficiency improvement projects in small installations seem to be well accepted by Annex I Parties. Additionally, conservative assumptions have been made in the feasibility study so as to guarantee the environmental integrity of the project.

Acceptability on the part of the Executive Board of the CDM

If the Executive Board of the CDM does not approve the project, CERs cannot be generated under the Kyoto Protocol. A reason for this rejection could be non-observance of the international regulation for CDM projects to be developed by the Executive Board and the COP.

The development of the project tries to comply with the Marrakech decisions (decision 17/CP.7) and with all necessary requirements, in general, taking advantage of other experiences gained through other projects. There is, nonetheless, a degree of uncertainty with respect to the project's approval by the Executive Board, given that clear norms on aspects such as baselines have not yet been established. However, conservative criteria are proposed, especially with regard to the baseline (for example, the exclusion of good housekeeping measures or the assumption of relatively short crediting periods). Therefore, the risk of disapproval by the Executive Board can be expected to be relatively low.

12.2 Risks during the project elaboration phase

The number of eligible companies could be lower than estimated in this study

Of all technically viable companies, only a small number can participate in the programme. This reduces the expected amount of CERs. One of the reasons for this might be that only companies that are eligible for credits in the banking system can participate. Other reasons are that the volume of CERs is too small to participate, that the company decides not to participate for internal reasons, or that the company lacks capital. In addition, there is uncertainty concerning the estimation of the quantity of boilers in Peru. In practice, project potential will depend particularly upon whether companies with large boilers participate in the programme. If the number of companies is smaller in practice, less CERs than projected are generated and, consequently, transaction or marginal mitigation costs are increased.

The study has taken into account a conservative number of boilers, thus reflecting financial eligibility and other barriers. Two local banks have already confirmed financing for such clients. It is recommended to sign pre-contracts with a number of companies in an early stage of the project delevopment to mitigate this risk. In total, this risk is deemed relatively important.

Estimated energy efficiency improvement might not be achieved

If emission reductions resulting from energy efficiency improvements are overestimated, the amount of CERs avoided each year will be less than projected. This could be due to technical problems related to implementation. The biggest risk arises after implementation of technical measures, as technical staff might fail to implement the necessary measures to maintain high energy efficiency levels. In addition, energy efficiency improvements may be overestimated in this study due to little valid information being available in Peru.

The capacity building of the company will play an important role in the reduction of this risk. Additionally, there will be an economic incentive to maintain the energy efficiency level through the planned bonus payment. Other factors to be taken into account could be careful selection of technology suppliers to overcome possible technical implementation problems, or requests for guarantees on boiler performance from suppliers. In selecting the appropriate measures to improve energy efficiency, the uncertainty on the actual efficiency improvement should be taken into account.

Investment costs higher than estimated

If investment costs are higher than estimated, CO_2 mitigation costs will increase and project potential will decrease. Consequently, some companies will not be eligible to replace their boilers and the projected amount of CERs will therefore be reduced. As a result, the bank could ask for more guarantees and set additional conditions the company might not be able to meet.

It is recommended to include a contingency item in the budget, to talk to companies about their cash flow and to work jointly with banks to define maximum additional credit lines.

Transaction costs higher than estimated

If transaction costs are higher than estimated in this study, the project could turn out to be not economically viable. Transaction costs can involve general costs of the project, such as registration costs in Peru, commission payments to the adaptation fund, payments to external operational entities (for example, for monitoring and validation activities), sales commissions to brokers, expenditure on project co-ordination, and costs for monitoring and project verification. Legal expenses for contracts and the granting of guarantees to banks will also be important. Transaction costs could constitute an important barrier to project participation.

This study analyses in detail every item of cost involved in each project phase and designs an institutional set-up meant to reduce transaction costs as much as possible. The magnitude of transaction costs should be carefully assessed in the business plan for the project. International donors or the Peruvian government may help in meeting these costs.

Delays in setting up the Project Managing Institution

The start of operations of the Project Managing Institution that co-ordinates the whole project may be delayed. Reasons for this could include the lack of financing or trained staff, administrative delays and delays by the stakeholders in formalizing its participation.

It is recommended to discuss with all the actors involved in the project the definition of the necessary institutional set-up and a timetable of activities and goals to set minimum and maximum deadlines. A workshop is foreseen under the participation of the key actors, to determine roles, responsibilities, risks and timetables before commencement of the programme.

12.3 Risks during project operation

Reduced heat demand in Peruvian Industry

Reduced demand for heat, due to a decrease in Peruvian economic activity, would reduce the quantity of CERs to be generated. This relates to each economic sector and each company. It is recommended to diversify participating boilers among different economic sectors in order to reduce the risk of concentration. Estimates in this study have been kept conservative, since it is assumed that the actual level of vapour demand does not increase during the next decade, which is feasible given economic growth levels.

Insolvency of companies participating in the CDM project

A relevant risk is departure from the market of a number of companies due to insolvency, bankruptcy, and so forth. The effects of this risk are a reduction in the volume of CERs that could be issued annually, the failure to repay credits granted by banks, and an increase in average transaction costs for project management. For this reason, it is recommended to carefully select eligible companies in collaboration with the banks involved in the project.

Fuel switch from oil to natural gas

Beginning in 2003, the Camisea project is supposed to deliver gas to the Lima region. Several companies may in future switch their vapour production from fuel oils to natural gas. Due to the lower carbon content of natural gas, energy savings achieved through energy efficiency improvements lead to lower reductions in carbon dioxide. Depending on the rate of gas distribution, the amount of CERs may in future be reduced. The future penetration of natural gas may be other than anticipated in this study due to different factors, namely: changes in relative prices (in favour of natural gas and to the detriment of oil) made by political decision, a strong financial-commercial campaign by the Camisea consortium to increase demand for its product, higher profitability due to the change, etc.

Both in the baseline study and in the projection of future emission reductions, the possible effects of the Camisea gas project have been considered. It is estimated that in 2010 natural gas will have a market penetration of 35% among industrial boilers in Lima. On the other hand, companies can be interviewed before setting the project in motion, and co-ordination established with the consortium in charge of the Camisea project to raise awareness of its operational plans.

Decreasing energy efficiency of participating boilers

Improved energy efficiency levels resulting from the replacement of boilers can decrease due to bad maintenance. This could be due to financial problems in companies, changes in technical staff, new budget priorities on the part of new stockholders, and so on. It is recommended to include provisions regarding this matter in the contract signed with banks and to sign agreements with the company and the technical supervisor at the beginning of the project.

12.4 Risks during the CERs trading phase

Reduction in international carbon prices

A fall in the price of carbon on the international market is beyond the Peruvian Government's control. The future carbon price will depend on several factors, including the volume of domestic action as against the use of flexible mechanisms in Annex I Parties, the issuance of Removal Units (RMUs) from land-use, land-use change and forestry activities, and the development of the key driving forces of greenhouse gas emissions in the coming years. Russia will also play a central role on the GHG market, since it will have a large amount of surplus allowances ("hot air") during the first commitment period. A possible solution is to sign a long-term purchase agreement with the PCF, CAF, The Netherlands, among others, to eliminate the price risk.

12.5 Risk matrix

The following table summarizes the risks and possible measures to manage them. It shows that most of the risks of the project are manageable. The major risks are

- uncertainty related to the number of companies and the size of the respective boilers that will participate in the CDM programme,
- possible delays and difficulties with the establishment of the Project Managing Institution,
- difficulties in keeping energy efficiency at a high level due to poor implementation of good housekeeping measures in the participating companies, and
- uncertainty about the future price for CERs.

Table 52: Risk matrix

Project Phase	Type of risk	Solution	Final risk level
Development of the project design	Approval of the host country	To comply with the CDM criteria To secure the involvement of very solid local actors (for example MITINCI)	Very low
	Approval of the Executive Board of the CDM	To comply with CDM criteria. To explain additionality.	Low
	Approval of the investing country	To comply with CDM criteria. To explain additionality,	Low
Investment	Reduction of the number of eligible companies	To select the companies jointly with the financial agent	Medium
	Overestimation of eco-efficiency	Qualified suppliers, supplier's warranty, sensitivity analysis	Low
	Investment costs higher than estimated	Contingency budget item. To work jointly with banks.	Low
	Higher transaction costs	Donations for additional costs, partners with financial capacity. To negotiate a group tariff with banks.	Medium
	Delays in the establishment of the PMI	Work plan with the stakeholders in the PMI	Medium
Integral Operation	Lower vapour demand	Sector diversification of companies	Low
	Company insolvency – bankruptcy	To include a percentage in the business plan.	Low
	Fuel change from diesel to natural gas	To include it in the baseline. Co-ordination with the Camisea Consortium	Low
	Lower boiler eco-efficiency	To ensure the good maintenance of boilers through the signing of agreements.	Medium

Carbon sales	Fall in the international price	Future sales with pre-fixed prices	Medium

Source: Finanzas Ambientales, Öko-Institut

13 Project contribution to sustainable development

In this chapter, the project contribution to the national priorities of sustainable development is assessed. Such priorities have been set out in the 27 State Policies recently approved[1] in the historical National Agreement signed by 7 political parties, 7 social organizations with representatives from all over the country and the Peruvian Government. The National Agreement is the set of state policies aiming at four main objectives:

1. Democracy and a constitutional State
2. Equity and social justice
3. Competitiveness
4. An efficient, transparent, and decentralized State.

Extracts from the National Agreement, deemed to contribute to the implementation and development of the CDM Boiler Project, are cited and summarized below.

1. **Eighth State Policy: Political, economic and administrative decentralization to enhance integral, harmonic and sustained development in Peru.**

   "*The government (g) will incorporate the necessary mechanisms to improve management, competitiveness and efficiency in private and public entities, as well as in companies and production chains at the national, regional and local levels".*

   When implemented, the boiler project will have a significant impact on the process of decentralization of the economy, for it will incorporate companies of 61 codes CIIU[2] revision 3, located in 21 of the 24 political departments in Peru (MITINCI 2000). In turn, this will encourage the reactivation of production activities in more efficient and competitive conditions, especially in the fish processing and foodstuff (oils and greases, sugar, and canned vegetal products) sectors, the textile sector and in hospitals. The highest number of boilers is concentrated in the departments of Lima (36.7%), Ancash (13.4%) and La Libertad (7.5%).

   "(j) access to capital at a regional and local level will be facilitated particularly for micro-, small and medium-sized companies."

   One major contribution of the boiler project is the proposal for a financing scheme that would allow entrepreneurs to overcome strong current financing barriers that make it difficult to access capital. These companies, especially SMEs, are either not eligible to participate in the local financial system, or are subject to an inadequate interpretation of risks. More specifically, guarantees and down payments are two of the limitations an entrepreneur would have to face in applying for a credit to invest

[1] National Agreement signed on Monday, 22 July 2002.

[2] CIIU stands for Uniform International Industrial Classification.

in CDM projects related to boilers. Even though the local banking system has shown a certain disposition to process the credit risk, it would request a down payment from the company to reduce that risk. If boiler depreciation is taken into account, such a payment could be so high as to force the entrepreneur to give up the idea of a credit. As an answer to this problem, the financial scheme included in the project is presented as the best solution: an average down payment, a "preferred guarantee" (collateral security), and a "guarantee of flows of CERs". Considering CERs as a guarantee for loans calls for the establishment of an institution that would trade them in the carbon market. In other words, emission reductions would become valuable assets. For this to happen, CERs of each company should be "secured", so that they could be used not only as financing guarantees, but also to generate additional cash flow. The project would then generate a new type of guarantee, thus greatly facilitating the access of companies to capital.

2. **Fourteenth State Policy: Access to full, dignified and productive employment**

   "... the State: (a) will promote agreement between government, industry and education to encourage research, innovation and scientific, technological and productive development that allows an increase in public and private investment, in the added value of our exports and in employment capacity. All this implies the continuous development of personnel, technical and professional capacities and the development of working conditions . . ."

   In accordance with the financing scheme proposed for this project, a Project Managing Institution (PMI) (see chapter 3) will manage the CDM project. The Project Managing Institution will have several roles and responsibilities, one of them being to render technical assistance to companies for the improvement of energy efficiency. This includes the creation of capacity building units for technical staff, requiring the employment of experts whose technical assistance could assure quality and increase energy efficiency in boilers through the implementation of technical, operative and replacement measures. Thus, the project contribution to employment generation, as well as to continuous development of personnel, technical and professional capacities and working conditions, is evident.

3. **Eighteenth State Policy: Seek competitiveness, productivity and formalization of the economic activity**

   "Improvement of the competitiveness of all entrepreneurial forms, including small and microcompanies is an effort to be undertaken by all members of society, especially by entrepreneurs, workers and the government"

   The boiler project is expected to contribute to improving the productivity and competitiveness of participating companies. Technological options for emission mitigation – both the replacement of boilers and energy efficiency improvement measures (with and without investment) - will have a significant impact on operational costs and fuel consumption savings, along with positive effects on the organization and the staff of companies. The increase in energy efficiency levels reduce vapour generation costs in companies. In some cases, savings in costs of over 10% are projected. While vapour generation costs are an important factor in production costs, a reduction of such costs will increase the competitiveness of those companies in the market. Based on the calculations made in this study, it is estimated, for instance, that annual average energy savings of about 335,278 GJ/year are to be achieved through CDM mitigation measures, and savings of 463,536 GJ/year through good housekeeping measures (that are not to be financed by the CDM Project[3]). By increasing entrepreneurial competitiveness, the boiler project may contribute to dynamizing the market for complementary services. In future, this may lead to a growing demand for consultancy services and follow-up activities concerning energy efficiency and the maintenance of boilers.

4. Nineteenth State Policy: Sustainable Development and Environmental Management

"The government.... (d) will encourage the application of environmental management instruments, privileging instruments of prevention and clean production; (f) will promote environmental investment and technology transfer for the generation of cleaner and more competitive industrial, mining, transport, sanitation and energy activities. It will also promote the sustainable development of forestry resources, biotechnology, biocommerce and tourism; (g) will promote and continuously assess the efficient use, preservation and conservation of soil, subsoil, water and air, avoiding negative environmental externalities; (m) will comply with international agreements addressing environmental management and will facilitate participation in and support of international co-operation in order to recover and maintain the ecological balance";

Without a doubt, the main project contribution is the reduction of the most important GHG emissions (CO_2, CH_4, and N_2O), as well as the reduction of emissions of other gases, such as carbon monoxide (CO), sulphur dioxide (SO_2) and nitrogen oxides (NO_X), which adversely affect public health and the economy. The project mitigation potential has been estimated at as much as 400,000 tonnes of CO_2, resulting from the implementation of several technological mitigation options applicable to the prospective 100 to 130 participating boilers.

For further details on the internal risks of contaminant gas emissions such as NO_X, CO, SO_2 and dust, their effects could be categorized as follows:

- **Exposure of the population to air contamination.** Air contamination has negative impacts on health and cause severe health problems, even death. Contamination of the air could reach especially high levels near industrial sites. Given that industrial boilers in Peru are mainly located in urban areas, emission reductions are of particular importance for the reduction of health risks.

---

[3] As explained in previous chapters, this type of good housekeeping measure is not eligible according to the CDM project scheme as it is considered to be part of the company´s regular managerial practices. Therefore, reductions resulting from this practice could not be considered to be additional.

- **Exposure of materials, buildings and cultural legacy to air contamination.** Many buildings, including historical monuments and construction materials, suffer deterioration due to air contamination, thus causing great economic damage.
- **Acidification.** Precipitation containing emissions resulting from industrial boiler combustion leads to a series of problems usually known as acidification, which damages ecosystems, agriculture, and forestry.
- **Instances of photochemical smog**. NO_X emissions from industrial boilers, along with emissions from other sources, such as vehicles, can cause high ozone levels that damage both health and vegetation.

These negative impacts of air emissions illustrate that the reduction of such emissions through the CDM boiler project has positive effects on people's health, Peruvian cultural legacy, and the economy.

5. **Twentieth State Policy: Development of science and technology**

"We are committed to strengthening the ability to generate and use scientific and technological knowledge in order to develop human resources and improve the management of natural resources and competitiveness of companies in Peru."

The project will allow technological innovation in vapour generation through the installation of automatic systems of burners, control panels, water treatment and so forth. Furthermore, new technology and international standards will facilitate boiler production of high energy efficiency and the application of security and quality norms in the domestic fabrication of boilers.

On the other hand, the need for technical assistance to maintain new equipment in boilers will increase the need for trained experts. This will lead to the establishment of technical service companies that will, in turn, require labour.

In conclusion, the boiler project positively contributes to:

- Decentralization, since it comprises participating companies located outside Lima.
- Improving access to capital, due to an innovative financing proposal that would allow current barriers to be overcome.
- Providing access to honest and productive work sources generated by technical assistance, consultancy, and training services required by the project.
- Investment by companies in capacity building, due to their evident need to guarantee effective and sustained certifiable project emission reductions.
- Seeking competitiveness, productivity and regularization of companies due to the technological options for energy efficiency improvement applicable to the boilers participating in the project.

- Mitigation of GHG emissions, as a goal of CDM projects to meet commitments set out in the Kyoto Protocol.
- Significant reduction in pollutant emissions that affect people's health and damage economic, cultural, and environmental assets.
- Development of technology, due to the modernization of boiler equipment and the adoption of international operational standards.

14 Conclusions

In this study, the feasibility of a CDM project to improve energy efficiency in industrial boilers in Peru is assessed. Technologies for and costs of investment in energy efficiency are identified, the baseline methodology is elaborated, a monitoring plan is provided, the potential and abatement costs are estimated and a proposal for the institutional set-up of the project is put forward.

The most important feature of the project is the way that about 100 small boilers are bundled into one CDM project. On the one hand, bundling many boilers makes the project more complicated compared with other CDM project activities: participation contracts between the project managing institution (PMI) and companies have to be concluded, technical assistance and capacity building have to be provided to a large number of companies, the baseline will only be fixed after project implementation and will depend on the number and characteristics of the participating companies, and monitoring involves measurements in many companies. All these tasks are likely to lead to significant transaction costs and will require highly competent management of the project.

On the other hand, the participation of many companies provides several opportunities and is expected to have important **positive effects regarding Peru's key sustainable development objectives**. The proposed CDM project would facilitate access to capital, in particular for small and medium-sized enterprises, which could hardly set up a similar CDM project by themselves due to high transaction costs and a lack of expertise. In this way, the bundled CDM project helps companies to invest in the urgently needed modernization of outdated boilers. Improvements in energy efficiency will decrease the cost of vapour supply and thereby increase the competitiveness of companies. Technologies, such as economizers, which are currently only used by very few companies in Peru, may spread throughout the country. The proposed measures do not only reduce CO_2 emissions, they also lead to the reduction of other important air pollutants, which cause serious health problems, destroy historical monuments, and produce severe losses for the economy. As part of the project, capacity building will be provided to companies' personnel, broadly enhancing technical and environmental knowledge of boilers and energy efficiency in relevant industrial sectors and the country. In particular, because of these **secondary benefits** of the proposed CDM programme, the project is expected to have important positive impacts on the sustainable development of Peru.

The total **potential** of the project amounts to about 170,000 tonnes of CO_2, due to investments in energy efficiency improvements, and another 230,000 tonnes of CO_2 due to application of good housekeeping measures. This potential is clearly smaller than the potential of large CDM projects, such as hydro-power-plants, but it seems sufficient to place the project in the future CDM market. With an assumed price of US$ 5 per tonne of CO_2, and excluding good housekeeping measures, an income of about US$ 850,000 may be generated through the project activity.

The **GHG abatement costs** of most of the proposed measures are negative, which means that these measures can be implemented at no additional economic cost. However, there exist serious barriers to their implementation, which impede implementation of measures to increase energy efficiency. The project aims at overcoming these barriers through a package of measures, including technical advice, capacity building and a special credit line to facilitate access to capital. In this regard, in spite of negative GHG abatement costs for the proposed measures, the project and associated GHG emission reductions are assumed to be additional in relation to the eligibility criteria for the CDM. However, the overall economic performance of the project can be assessed only after thorough analysis of all costs and revenues in a business plan.

In the determination of baseline methodology, elaboration of the monitoring plan and estimation of potential and mitigation costs, a "**conservative approach**" has been followed. This means that underlying assumptions are carefully made in order not to overestimate emission reductions, and monitoring provisions include several measures to obtain reliable and repeatable measurement results.

The implementation of the project is associated with some **uncertainties and risks**. The main uncertainty relates to the transaction costs of the project and the quantity and size of boilers that can be acquired for participation. An important step will therefore be to assess carefully all transaction costs on the basis of this study and to acquire a minimum number of companies with large reduction potentials.

Of particular concern for the future implementation of the project is also the **monitoring** of greenhouse gas emission reductions. During the feasibility study it was evident that the advisory institutions involved had serious difficulties in determining energy efficiency with an acceptable degree of accuracy. Measurements were partly not conducted in accordance with internationally recognized principles and standards, leading to unreliable results. Since the measurement of energy efficiency is a key requirement for monitoring and certification of emission reductions, particular attention should be paid to appropriate capacity building for the institution that will be responsible for monitoring and calculating emission reductions.

Because of these difficulties and the unknown extent of transaction costs, it may also be a viable option to implement the project without using the CDM. This would considerably facilitate management of the project and reduce transaction costs, in particular with regard to monitoring requirements and other costs of the CDM cycle. Implementation of the project without using the CDM would not make possible the important secondary benefits described above. It is therefore suggested, that a **two-track approach** be followed when the next steps are taken to forward the project: the option of not using the CDM should be compared with the option as a CDM project, without bias. In particular, related costs should be assessed carefully.

To sum up, implementation of the project seems feasible, viable and promising, in particular because of large benefits for small and medium-sized enterprises and its contribution to several of Peru's sustainable development objectives. The following steps are proposed to assess the final viability of the project and to get it started:

1. The **Project Managing Institution** has to be established and responsibilities clearly assigned among the institutions involved. One existing institution should be designated with the leadership of the project. This institution should have overall responsibility for the project and manage the different activities. The leading institution needs to function as the project's motor, involving all relevant stakeholders in Peru and building up the necessary international contacts. The chances of the project will depend significantly on successfully setting-up the project managing institution.
2. A sound **business plan** for the project has to be elaborated. The business plan should estimate all costs and revenues on the basis of this study, including transaction costs that have not yet been estimated. Transaction costs will encompass expenditures for, inter alia, acquisition of companies, technical advice for companies, capacity building, negotiations with local banks, validation of the project as well as monitoring and verifying greenhouse gas emission reductions. It is recommended that the efficiency and cost-effectiveness of the project be assessed with and without the use of the CDM.
3. **Acquisition of companies.** Prior to negotiations with donors and banks, it is suggested that promising companies be contacted with a view to signing **letters of intent** or **preliminary agreements** containing all important elements of co-operation (responsibilities, capacity building, allocation of CERs to the Project Managing Institution, payment of bonuses, etc.). This would enable the Project Managing Institution to assess more thoroughly the possible number and size of boilers as well as the willingness of companies to participate in the CDM programme. Letters of intent or preliminary agreements will also facilitate negotiations with donors and banks.
4. **Negotiations with donors, banks and purchasers of CERs.** These negotiations will be carried out on the basis of this study, the elaborated business plan and the letters of intent or preliminary contracts with a number of companies. On this basis, the Project Managing Institution should start negotiations with donors and banks on financing the initial costs of the project and on the establishment of a special credit line with favourable interest rates and facilitated access to capital. The Project Managing Institution may sell CERs to the market after project implementation, or close a deal prior to project implementation to purchase CERs in the future at a fixed price.
5. Finally, after completion of the previously mentioned steps and a positive evaluation of the chances as a CDM project, the necessary steps for the **approval of the CDM project by the Executive Board** can be taken. This includes elaboration of the project design document, the involvement of relevant stakeholders, validation of the proposal by an independent operational entity and, finally, approval by the Executive Board for the CDM.

References

Asociación Peruana de Fabricantes y Comercializadores de Calderas (APFCC) 2001. Information provided for the purpose of this study.

Arroyo, V. 2001. *Resultados de la evaluación del mantenimiento y ajustes del sistema de combustión en 50 calderas industriales*. Presentation at *Primer Congreso Internacional de Mantenimiento*. Lima, Peru, 25 to 27 October 2001

ASME 1998. *Performance Test Codes. Fired Steam Generators.* ASME PTC 4-1998. The American Society of Mechanical Engineers. New York, USA.

British Standards Institution 1987. *British Standard Methods for Assessing Thermal Performance of Boilers for Steam, Hot Water and High Temperature Heat Transfer Fluids.* BS 845, UK

CENERGIA 2001. *Evaluación ambiental y energética de 40 calderas en 5 departamentos.* Final report for the Ministry of Industry, Tourism, Integration and International Commercial Negotiations (MITINCI). San Borja, August, 2001

CERUPT 2001. *Netherlands Certified Emission Reduction Unit Procurement Tender. Terms of Reference.* Senter International. www.carboncredit.nl The Netherlands, November 2001

CONAM 1996. *First National Communication of Peru submitted to the UNFCCC.*

Den Elzen, M.G.J,. de Moor, A.P.G. 2001. *The Bonn Agreement and Marrakech Accords: an updated analysis.* RIVM report 728001017/2001. Bilthoven, the Netherlands, 2001.

EPA 2001. *Compilation of air pollutant emission factors*. AP-42 5th edition, Volume I: stationary point and area sources. EPA, USA 2001. www.epa.gov/ttn/chief/ap42/index.html

Grüttner, J. 2001. *The GHG Market after Bonn.* Andwil, Switzerland. October 2001

IDAE 1983. *Manual Técnico y de Instrucción para Conversación de Energía*. España, 1983.

IDAE 1987. *Uso eficiente de energía en calderas y redes de fluidos*. Spain, 1987.

IPCC 2001. *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, UK and New York, NY, USA, 881pp.

ITINTEC 1991. *Manual of Energy Efficiency of Industrial Boilers.* Published by Instituto de Investigación Technológica Industrial y de Normas Técnicas (ITINTEC). 1991

Jimenez et al. 2001. *Evaluación Energético-ambiental de una Muestra de 40 Calderas Industriales.* Prepared for the Ministry of Industry, Tourism, Integration and International Commercial Negotiations (MITINCI). Elaborated by the Energy and Environment Analysis Service (SAEA-PUCP). Report No 2001-06-09.

Ministry of Energy and Mines (MEM) 2001. *Balance Nacional de Energía 2000*. Lima, Peru 2001.

Ministry of Energy and Mines (MEM) 2002. *Plan Referencial de Hidrocarburos 2001*. Lima, Peru 2002.

MITINCI 2000. *Estudio de factibilidad para la creación de un fondo de finanicamiento para la renovacíon y optimización del parque nacional de calderas industriales. Encuesta Nacional de Calderas Industriales.* Report on the data provided by the boiler-user companies. Lima, Peru, October, 2000.

Nakamura, J. 2001. *Análisis Comparativo de Metodologías de Medición de Eficiencia Energética*. Realizado por encargo de MITINCI. Lima, Peru, April 2001

Latin American Energy Organization (OLADE) 2001. *Sistema de Información Económica – Energética*.

PETROPERU 1989. *Análisis Típicos de Productos*. Lima, Peru 1989.

Taplin, H. 1991. Boiler Plant and Distribution System Optimization Manual. Mr. Fairmont Press. United States, 1991.

UNEP/OECD/IEA/IPCC 1996. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*.

Vrolijk, Ch. 2002. *A New Interpretation of the Kyoto Protocol. Outcomes from The Hague, Bonn and Marrakech.* Royal Institute of International Affairs (RIIA). Briefing Paper No 1. April 2002