Case Study

BEHIND THE BRICKS:
an experience in the integrated management of the informal sector
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Case study
BEHIND THE BRICKS: An experience in the integrated management of the informal sector

Table of contents

PREFACE

SUMMARY

3 REASONS FOR THE CASE STUDY AND METHODOLOGY 6
3.1 Background 6

4 THE SITUATION BEFORE THE INTERVENTION 7

4.1 Baseline information 8
4.1.1 Location 8
4.1.2 Fuels 8
4.1.3 Materials, inputs and mixtures 10
4.1.4 Technology 11
4.1.5 Organisation of the production 13
4.1.6 Management and commercialisation 14
4.1.7 Selling mechanisms 16
4.1.8 Environmental aspects 16
4.1.9 Gender approach 19

4.2 Stakeholders 20
4.2.1 National level 20
4.2.2 Arequipa 21
4.2.3 Cusco 22

5 JUSTIFICATION FOR THE INTERVENTION AND RELATION TO THE STRATEGY OF PRIVATE SECTOR DEVELOPMENT (PSD) OF SWISSCONTACT 23

5.1 Development strategy for the private sector 24
5.1.1 Intervention with market stakeholders and the government 24
5.1.2 Changes in economic systems relevant to the poor 75
5.1.3 Achieving economic pro-poverty growth 25
5.1.4 Leading the way to poverty alleviation 26
5.1.5 Interrelation with other Swisscontact projects 26

6 DESCRIPTION OF THE INTERVENTION 27

6.1 Clean production audit 27
6.2 Socioeconomic diagnosis of brick manufacturing in Arequipa and Cusco 28
6.3 Preparation and dissemination of the Guide of good practices for brick manufacturing 28
6.4 Implementation of improvements in traditional pilot kilns of Arequipa 29
6.5 Implementation of technical improvements in conventional kilns in Arequipa 30
6.6 Implementation of the pilot vertical shaft kiln in Arequipa 33
6.7 Promoting the use of coal in Cusco 34
6.7.1 Coal as an alternative fuel 34
6.7.2 Demonstrative firing 34
6.7.3 Coal revolving fund 38
6.8 Improvement of the clay mixture 38
6.9 Business management workshops
6.10 Regional interchange
  6.10.1 Visit to Nepal
  6.10.2 Exchange workshops of Bolivia and Peru
  6.10.3 International Clean Technology Fair for Small Producers of Artisanal Bricks and Tiles
6.11 Promoting gender and family issues

7 EFFECTS OF THE INTERVENTION ACCORDING TO THE PSD STRATEGY
7.1 Results
  7.1.1 Fuels
  7.1.2 Technology
  7.1.3 Organisation and management of the production
  7.1.4 Materials, inputs and mixtures
  7.1.5 Institutional management
  7.1.6 Environmental aspects
  7.1.7 Social aspects
  7.1.8 Contribution to the mitigation of climate change

7.2 Swisscontact strategy
  7.2.1 Intervention with market stakeholders and the government
  7.2.2 Changes in economic systems
  7.2.3 Achieving economic pro-poor growth and poverty alleviation

8 DISCUSSION OF SUCCESSES, FAILURES AND POSSIBLE REASONS
8.1 Successes
8.2 Failures
8.3 Lessons learned

9 DISCUSSION OF FINDINGS AND RELATION WITH OTHER STUDIES
9.1 Plura and Ayacucho (Peru)
9.2 India, Vietnam and Nepal

10 HINTS FOR FURTHER ACTIVITIES
10.1 System diagnosis
10.2 Institutional strengthening
10.3 Business management
10.4 Technical aspects
10.5 Social aspects

REFERENCES
1 Preface

The Clean Air Regional Programme (PRAL) is financed by the Swiss Agency for Development and Cooperation (SDC). It started in 2004 and ends in December 2009. Its mission is to execute actions aiming to improve air quality and to reduce air pollution effects on the health of Peruvian population - especially in Cusco and Arequipa - through an agreement among the Ministry of the Environment (MINAM), Swisscontact and the Association of Communicators' Calandria.

Initially, Clean Air Plans were prepared for the cities of Cusco, Arequipa and Trujillo and consulted with the population. According to the prioritisation established in the consultations, the activities of these plans are being implemented in Cusco and Arequipa with the support of PRAL. The purpose is to enable participating institutions to manage self-sustainable activities and transfer air quality management models to other cities of the country through the national environmental authority. Besides, citizen participation is actively encouraged by the programme in concerns of air quality management processes at the local level and in the surveillance of the fulfilment of national standards. Since PRAL is a Clean Air Program the Demand side of Bricks was not part of the project activities.

One of the interventions prioritised in the Clean Air Plans is the reduction of smoke emitted by brick factories located in the periurban zones of the cities since they're the second most important source of contamination after motor vehicles. Accordingly the intervention of PRAL in artisanal brick factories aims at reducing smoke and gas emissions using cleaner fuels and introducing more efficient technologies. It’s expected that these actions will increase energy efficiency, diminish the production of greenhouse gases and improve the health of brick manufacturers, their families, and the people in the surrounding cities.

The intervention begins with actions geared towards cleaner production and energy efficiency incorporating later training in production management. Workshops on gender issues are carried out as well as workshops to sensitize children and young people on the health effects of contamination. Regional and local governments are also involved to institutionalise the models and provide the regulative framework for the operation of small brick factories. That way an integrated intervention model is applied for artisanal brick factories. The present document systematises this experience.

The intervention model has proved that it's possible to effectively integrate social, economic and legal aspects when adopting cleaner technologies, simultaneously contributing to fight climate change and poverty. We hope that this study will help the implementation of future interventions targeted at small brick manufacturing enterprises in Peru and other countries where artisanal brick-makers are not considered in the public policies of the state, even if they are important employment sources for local and national economies.
2 Summary

The situation before the intervention: In Peru bricks and tiles are usually manufactured by small informal family-based enterprises and migrant agricultural labourers that start this activity helping other small brick manufacturers. Most of the brick-makers have limited knowledge of business management, their working conditions are precarious and they live in extreme poverty. These factors influence the use of cheap but highly contaminant fuels and low-efficiency technologies. Therefore artisanal kilns release high amounts of smoke and air pollutants contaminating the air next to the kilns, adjacent to settlements and surrounding cities. This situation is similar to other parts of the country, the region and the world.

Justification for the intervention and relation to the strategy of Private Sector Development (PSD) of Swisscontact: As Swisscontact aims at contributing to poverty reduction through the promotion of a sustainable private sector that can be beneficial to the poor, PRAL’s intervention in the brick manufacturing sector is under the scope of Swisscontact objectives. The target population of this intervention are the low-income brick-makers that participate in the informal private sector.

The intervention: The main activities carried out by PRAL in the brick sector were: a) clean production audit for the artisanal brick-makers of Arequipa and Cusco; b) socioeconomic diagnosis of the artisanal brick sector in Arequipa and Cusco; c) implementation of technical improvements in traditional kilns; d) implementation of a pilot vertical kiln; e) promotion of coal use to replace contaminant fuels; f) kiln improvement to reduce greenhouse gas emissions and promote energy efficiency; g) training in business management through workshops; and h) promotion of gender and family issues. To adapt the interventions to the specific characteristics of the sector different studies have been made about the sector, among others a socioeconomic characterization of the sector and an evaluation of the cost structure of the brick production.

Intervention results

Fuels: In Arequipa the contaminating fuels have been replaced in a notorious way and now approximately 80% of the producers are using coal (coal is a sound alternative until a natural gas system is installed in the zone). In Cusco no coal has been used when the Programme started and now it’s estimated that the artisanal brick factories consume 60 to 80 tons of coal monthly.

Institutional strengthening: The Regional Government of Cusco through the Regional Directorate of Production has developed a public investment project of two millions of soles (US$ 660,000) to provide technical assistance and implement clean technologies in artisanal brick factories of the region. The Municipality of San Jerónimo in Cusco actively contributes to improve the production of local brick-makers. Local universities are committed to do research and implement improvements for artisanal brick factories.
**Business management:** Due to the business management workshops, a change has been observed in the approach of those producers that attended the training activities, especially in the analysis of their costs and the marketing of their products.

**Technical aspects:** The introduction and evaluation of alternative technologies like the vertical kiln of continuous production has had some organisation difficulties in its operation, but brick-makers have realised that there are other technological options. The implementation of improvements in traditional kilns, as well as the recommendation of good practices, have shown positive results; for instance, less days needed for the firing phase, lower use of fuel, optimal firing temperatures, clay mixture tempering according to Peruvian national standards, better quality of the final product and significant reduction of air emissions. Brick manufacturers are aware that the replacement of contaminant fuels with coal brings benefits in terms of a reduction of air emissions and also economic profits through the reduction of the variable production costs.

**Social aspects:** Awareness raising campaigns and gender workshops helped the brick-makers to realise the need to improve environmental conditions and the living standard for themselves and their families.

**Lessons learned:** This case sets the basis to propose future interventions. It has been seen that the brick industry is a complex sector. Therefore a comprehensive approach is needed that includes different aspects as the reduction of air pollutants and greenhouse gas emissions, the support to improve technological processes, a cross sectional social component including gender and family issues, training in business organisation and production management, and the participation of relevant stakeholders and institutions. It’s important to have a comprehensive vision of the value chain of brick production. Also the sector must be included in the public policies. Regarding technological improvements it has been shown that it’s more viable to focus on adapting existing techniques than to introduce completely new technologies.
3 Reasons for the case study and methodology

3.1 Background

In Peru, artisanal bricks and tiles are usually manufactured by small informal enterprises and migrant agricultural labourers who start this activity helping other small brick manufacturers. Later on they build their own kilns and expect that their independence will improve their socioeconomic condition.

Artisanal kilns are an important source of air pollution. The use of firewood, discarded tires, plastics, used oils and other residues as fuels to fire and operate the kilns releases high amounts of air pollutants that contaminate the air next to the kilns, nearby settlements and surrounding cities.

This case study systematizes the experience made in Arequipa and Cusco with brick manufacturers within the framework of the Clean Air Regional Programme (PRAL). It presents the evolution of the Programme approach, its results and the lessons learned along the four years that this intervention was carried out.

The present case will be the basis to propose future interventions in the sector as it has integrated the reduction of air emissions, the support to improve technological processes, a cross sectional social component, better organisation and management in the production, and the participation of relevant stakeholders and institutions.

The methodology to prepare this document corresponds to a systematization of the experience with brick manufacturers and is based on the Programme documentation.
4 The situation before the intervention

In the action plans for the prevention of air pollution of Arequipa and Cusco, mobile sources were identified as the first most important source of air pollution. Artisanal brick kilns that operate in the cities' surroundings were considered as the second source. Hence, PRAL developed an intervention focused on the reduction of air pollutant emissions from small brick kilns in both cities.

In the past years the promotion of social programmes for infrastructure development and improvement of the economic situation of the population has increased the demand of building materials and has boosted the production of bricks and tiles. Although there are no official statistics on this issue, it is considered that nationally artisanal brick enterprises supply around 50% of the market demand and almost 100% in Cusco. Most of them are informal family-based enterprises.

The main problems of the artisanal brick producers in Peru are related to the low efficiency of their kilns, the use of unsuitable fuels, the low quality of their final products and their ineffective commercialisation processes. As a consequence the economic situation of these producers is precarious.

![Diagram of the artisanal brick sector]

**Figure 1. Diagnosis of the artisanal brick sector**
4.1 Baseline information

The intervention of PRAL was focused on reducing the pollution effects of artisanal brick production in the atmospheric basins of Arequipa and Cusco, as specified in the Clean Air Plans of each city. As part of the intervention, an initial diagnosis was made and the following information was collected.

4.1.1 Location

Generally artisanal brick kilns are built in the surroundings of cities where raw materials are readily available. In these areas there’s enough land for the kiln and the production areas; also the market to sell the final products is close.

Arequipa

The small artisanal brick manufacturers of the province of Arequipa are distributed mainly in the districts of Moyobamba (71%), Socabaya (14%), Characato (3%), Yarabamba and Paucarpata (2%); Cayma, Cerro Colorado and Yura (less than 1%). The intervention of PRAL was focused on the district of Socabaya, especially in Pampa Primero de Mayo (part of the atmospheric basin).

Cusco

In the district of San Jerónimo – the focus area of the PRAL intervention – the largest number of brick and tile producers are concentrated, disseminated in the communities of Sucso Aucaylle (65%), Pillao Matao (28%) and Picol Orcompujo (7%). Overall there are 192 families.

4.1.2 Fuels

Fuels represent approximately 30% of the brick production costs. Given its importance in the cost structure, low-cost fuels with high calorific values as discarded tires, plastics and used oils are used. But these fuels are of low quality and highly pollutant.

It’s important to highlight that discarded tires are used because of their low costs and also because of their high calorific value that reduces the time of the firing process. In Arequipa, the use of tires reduces the firing period from two weeks to one week compared to other fuels. But it has to be mentioned that using tires as fuel also results in minor product quality.

Arequipa

Generally, fuels to fire the brick kilns are discarded tires, used oils, plastics, organic residues (animal manure) and other waste products.
Table 1. Type of fuels used in the kilns of Arequipa

<table>
<thead>
<tr>
<th>Fuels</th>
<th>% enterprises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used gasoline and oil</td>
<td>55%</td>
</tr>
<tr>
<td>Organic wastes</td>
<td>30%</td>
</tr>
<tr>
<td>Gasoline/coal/oil</td>
<td>10%</td>
</tr>
<tr>
<td>Coal</td>
<td>3%</td>
</tr>
<tr>
<td>Other combinations</td>
<td>2%</td>
</tr>
</tbody>
</table>

Figure 2. Use of discarded tires and polluting air emissions

Cusco

The mostly demanded fuels to fire the kilns were sawdust, eucalyptus branches, coffee husk (during the harvest season) and used tires.

Eucalyptus branches and fresh leaves or firewood are used to light up the kiln and for the firing. They have a medium calorific value and are highly pollutant. Its uncontrolled use is one of the causes for deforestation, soil erosion and reduction of rainfall.

Figure 3. Firing bricks with eucalyptus
Sawdust and eucalyptus branches are used to start the firing process and also along the process itself. The small particles of sawdust help lighting up the fire rapidly. Sawdust has a medium heating value and its use produces clouds of fine particles that contaminate the environment.

![Sawdust](image)

**Figure 4. Lighting up of the kiln using sawdust**

### 4.1.3 Materials, inputs and mixtures

The manufacture of products in an empirical and disorganised way, without knowledge of the chemical composition of the raw materials and their effects in the firing process, leads to a final product that lacks homogeneity and that hasn’t the required mechanical resistance, density or adequate weight. As a consequence, there is a high percentage of loss in every firing process and less quality in the final product, which in turn reduces its selling value.

**Arequipa**

The materials used in the manufacture of bricks are clay, soil and water. The clay used in Arequipa comes from far away quarries, which implies additional freight charges and water is scarce so that producers need to buy it from tank trucks.

<table>
<thead>
<tr>
<th>Raw material/Input</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black clay and soil</td>
<td>Chiguata, Pocsi, Yarabamba</td>
</tr>
<tr>
<td>Clay</td>
<td>Pocsi, Yarabamba</td>
</tr>
<tr>
<td>Water</td>
<td>Characato, Cerro Colorado</td>
</tr>
<tr>
<td>Used oil and gasoline</td>
<td>Gas stations, mining enterprises, rail stations, auto repair shops</td>
</tr>
<tr>
<td>Coal</td>
<td>Trujillo</td>
</tr>
<tr>
<td>Tires</td>
<td>Auto repair shops</td>
</tr>
<tr>
<td>Firewood and others</td>
<td>Socabaya, Characato, Chiguata</td>
</tr>
</tbody>
</table>
Cusco

Raw materials used for bricks and tiles are clay and sand. Soil is used as a third component in artisanal enterprises. The quarries of clay are close to the kilns so that the freight is minimal.

Table 3. Location of raw materials and inputs used in Cusco

<table>
<thead>
<tr>
<th>Raw material/input</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay</td>
<td>Communities of Sucuso, Aucaylca, Picol and Pillao, Matao</td>
</tr>
<tr>
<td>Sawdust</td>
<td>Sawmills and timber mills of Cusco city</td>
</tr>
<tr>
<td>Eucalyptus branches</td>
<td>Anta, Mollepata, Limatambo, Paucartambo, Andahuaylllas</td>
</tr>
<tr>
<td>Coffee husk</td>
<td>Province of La Convención</td>
</tr>
<tr>
<td>Tires</td>
<td>Tire and auto repair shops in Cusco city</td>
</tr>
</tbody>
</table>

4.1.4 Technology

Arequipa

The kilns are used all year round, although more intensely during the dry season and they don’t operate in a continuous way. The design has a rectangular base without columns and two sections; the lower part is wider compared to the upper part. In general, the walls are thin and don’t have insulation, the wide horizontal area for firing isn’t efficient as it has a negative influence on the firing period and the product quality; this deficiency is compensated using highly polluting fuels but with high calorific values. Usually, they are built with bricks or adobes. An average kiln has a production capacity of 30 thousand bricks for every firing; others produce between 20 and 70 thousand bricks for each load. The kiln usually has a large-size opening to feed the fuel.

Figure 5. Brick kiln in Arequipa

Cusco

Artisanal kilns are made of bricks and clay without any lining, in cylindrical or square shapes with a natural draft and semi-opened to the atmosphere. They produce between

Case study

BEHIND THE BRICKS: an experience in the integrated management of the informal sector  Page 11
7 and 10 thousand bricks and between 4 and 8 thousand tiles with each load. Both the artisanal producers (bricks made by hand in moulds) as well as the mechanised manufacturers (bricks produced by extruders) use the same type of kiln. Generally, every manufacturer has at least one kiln and in the whole area 215 kilns have been registered.

The kilns in Cusco, as in Arequipa as well, have thin walls without insulation and poor ventilation that leads to a lack of oxygen and large amounts of particulate matter and gas emissions to the air.

Figure 6. Brick kiln in Cusco

Regarding the equipment used for the production (extruders, shovels, wheelbarrows, etc.) most of it is produced in local workshops, although some of the bigger enterprises import their machinery from Brazil.

Table 4. Equipment used by artisanal producers and mechanised manufacturers in Cusco

<table>
<thead>
<tr>
<th>Artisanal production</th>
<th>Mechanised production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheelbarrows</td>
<td>Wheelbarrows</td>
</tr>
<tr>
<td>Shovels</td>
<td>Shovels</td>
</tr>
<tr>
<td>Pickaxes</td>
<td>Pickaxes</td>
</tr>
<tr>
<td>Moulds</td>
<td>Diggers</td>
</tr>
<tr>
<td></td>
<td>Processors</td>
</tr>
<tr>
<td></td>
<td>Extruders</td>
</tr>
<tr>
<td></td>
<td>Crushers</td>
</tr>
<tr>
<td></td>
<td>Blowers</td>
</tr>
<tr>
<td></td>
<td>Cutters</td>
</tr>
</tbody>
</table>
4.1.5 Organisation of the production

Arequipa

Artisanal enterprises are basically family-based. The participation of the family members in the different phases of production is shown in Table 5.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tempering of the mixture and material</td>
<td>Undertaken mainly by the father, elder sons, brothers or brothers in law because great physical effort is required to make the clay, soil and water more workable and easier to mould the next day.</td>
</tr>
<tr>
<td>Moulding</td>
<td>Carried out by the wife, sons or children older than 10 years, who help in the production in the morning and go to school in the afternoon.</td>
</tr>
<tr>
<td>Brick drying and scraping</td>
<td>Mainly children help in the task of turning the bricks around for a uniform drying. Once the bricks are dried, children help scraping the bricks to get a smooth surface.</td>
</tr>
<tr>
<td>Brick fitting and fuel feeding in the kiln</td>
<td>Both tasks are carried out by the husband and wife, brothers, grandparents and other members of the family.</td>
</tr>
<tr>
<td>Transferring the bricks from the drying bed to the kiln</td>
<td>Task usually carried out by women with the help of wheelbarrows.</td>
</tr>
<tr>
<td>Firing the kiln</td>
<td>Task carried out by the father.</td>
</tr>
<tr>
<td>Unloading the bricks to sell them</td>
<td>This activity is carried out by the middlemen that buy the bricks using the practice “put in the kiln.”</td>
</tr>
</tbody>
</table>

The manpower is mainly composed by the members of the family that run the operative unit; specialized workers are hired temporarily if required. Table 6 shows the number of direct jobs (1,391) generated by the brick manufacturing sector of Arequipa, which are mainly distributed in the districts of Mollebaya (70%) and Socabaya (14%).

<table>
<thead>
<tr>
<th>Nº enterprises</th>
<th>Nº kilns</th>
<th>Manpower</th>
<th>Total of employment</th>
</tr>
</thead>
<tbody>
<tr>
<td>107</td>
<td>1</td>
<td>5</td>
<td>535</td>
</tr>
<tr>
<td>89</td>
<td>2</td>
<td>8</td>
<td>712</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>12</td>
<td>144</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>1,391</td>
</tr>
</tbody>
</table>
Cusco

As in Arequipa, most microenterprises are family-based. Production technology is at an early stage and there's neither control of processes nor product development. Generally, manpower isn't qualified or is semi-qualified.

Mechanised manufacturers carry out an average of three firings every week (12 firings monthly). Each firing produces between 7 and 8 thousand bricks. However, the artisanal producers carry out an average of two firings monthly and each firing produces between 8 and 10 thousand bricks. These firings are usually carried out conjointly among artisanal producers.

4.1.6 Management and commercialisation

Arequipa

There are 208 enterprises registered in the Regional Directorate of Industries; probably the motivation of most of them to be registered has been the possibility to receive support after the earthquake of June 2001. All of them — with the exception of two — are microenterprises installed mainly in Mollebaya (71%), Socabaya (14%), Characato (3%), and others. On the other hand, only 34 of the microenterprises are registered in the National Office of Tax Administration (SUNAT) and have a taxpayer registry identification (RUC).

The majority of the informal brick-makers doesn't know efficient production processes due to a lack of business management skills and they sell their products in the market through intermediaries.

Regarding their level of partnership, 97% of the manufacturers are associated in one of the seven brick craft unions of the zone: ALCOSA (24%), CUDELASUR (22%), Cooperativa Virgen de Chapi (17%), Cooperativa Señor de los Milagros (16%), Primero de Mayo (9%), Pampa Santa Ana (5%), and Alto San Martín (4%). It's important to note that the main motivation to be associated is related to their expectations of receiving support from public and private institutions to improve their technological conditions, environmental control, training, capabilities to negotiate and commercialise and to have access to land.

Cusco

There is an ongoing trend towards informality. Only 13% of the artisanal brick manufacturers have a taxpayer registry identification (RUC) and 3% have a license to operate.

The value chain includes the suppliers (mainly fuel), the manufacturers - either mechanised or artisanal - up to the final selling that can be directly or through middlemen.
Among artisanal producers, 98% doesn't have an appropriate cost structure. Regarding to this they don’t consider the costs of some raw materials nor direct inputs, don’t take manpower into account (operative or directive) and there are several hidden costs that are not included (food, security, transportation, depreciation, water, tips for family members). It has been identified that some producers have no profits at all, especially when the price of the fuels increases.

Cusco’s brick-makers may be classified in three large groups:
- Family-based artisanal producers
- Family-based mechanised producers
- Commercial producers.

<table>
<thead>
<tr>
<th>Production system</th>
<th>Level of entrepreneurial organisation</th>
</tr>
</thead>
</table>
| 1. Family-based artisanal producers   | The producers:
   | 1. They don’t have any long-term vision and don’t set short-term objectives or goals.               |
   | 2. They don’t consider themselves as entrepreneurs.                                               |
   | 3. They don’t forge strategic alliances to optimise productive or commercial processes.           |
   | 4. Their production is based on the existence of clay quarries as raw material.                     |
   | 5. Their main concern is to cover their basic needs with their low income.                          |
   | 6. They don’t promote their products.                                                              |
| 2. Family-based mechanised producers   | The producers:
   | 1. They have short-term vision but don’t fulfil their objectives and goals.                        |
   | 2. They don’t consider themselves as entrepreneurs.                                                 |
   | 3. Their strategic alliances to optimise productive or commercial processes are very limited.      |
   | 4. They don’t analyse opportunities to develop agreements with institutions involved in brick manufacturing. |
   | 5. Their income allows them to invest in the brick sector.                                          |
   | 6. The promotion of their products is on the basis of a person-to-person approach.                  |
| 3. Commercial producers                | The producers:
   | 1. They have medium-term entrepreneurial vision.                                                    |
   | 2. Many of them consider themselves as entrepreneurs and are registered legally.                   |
   | 3. They have developed a value chain that optimises their productive processes and commercialisation.|
   | 4. They promote their products with a brand name, which allows a better positioning.                |
   | 5. They use mass media and dissemination means to promote their products.                           |
4.1.7 Selling mechanisms

The main methods to sell bricks and tiles are the following:
- Indirect selling: Products are sold to middlemen that unload the bricks from the kiln once the cooling period has concluded. Like this there are no costs related to distribution (transportation and loading) for the producers.
- Direct selling: The producers sell directly their products to the final consumer eliminating the distribution points. Distribution costs are bared by the producer if the products are put in a selling point or by the client if he goes to the factory and buys the bricks directly.

4.1.8 Environmental aspects

There are three significant environmental impacts related to artisanal brick production:
1. Local air pollution by contaminants generated in the combustion process.
2. Emissions of greenhouse gases as a consequence of the inefficient energy use.
3. The deterioration of the landscape and agricultural lands due to the removal of material from the quarries of clay and sand, and the final disposal of discarded materials.

Air quality: Firing is the phase that releases the biggest amount of emissions, especially when lightning up the kiln. Generally, discarded tires or plastics are used to produce the flames that will light up the materials used as fuel. Fuel burning in kilns with direct fire generates fugitive emissions. The burning of sawdust, used tires and used oil in a compartment with poor ventilation and incomplete combustion releases high concentrations of particulate matter that are clearly visible as clouds of dense and visible smoke.

The affected population includes the workers of the brick factories up to the people living in the surrounding cities (Arequipa and Cusco).

Figure 7. Contamination caused by brick firing
**Table 8. Contaminants released along the brick manufacturing phases**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Activities that release contaminants</th>
<th>Type of contaminants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraction of clay and soil</td>
<td>Extraction with manual tools.</td>
<td>Few suspended particles Changes in the morphology of the ground</td>
</tr>
<tr>
<td></td>
<td>Extraction with heavy machinery.</td>
<td>High volume of suspended particles Changes in the morphology of the ground Use of agricultural land</td>
</tr>
<tr>
<td>Mixing</td>
<td>Screening and selection. Mixing clays with water and sand.</td>
<td>Suspended particles</td>
</tr>
<tr>
<td>Moulding</td>
<td>Doesn’t produce contaminants.</td>
<td>None</td>
</tr>
<tr>
<td>Drying</td>
<td>When moulds are exposed to the open air for drying only water vapour is released. Defective moulds are recycled in the moulding phase.</td>
<td>None</td>
</tr>
<tr>
<td>Kiln loading</td>
<td>Dry brick accommodation resuspends particles from the ground and due to friction between bricks.</td>
<td>Dust</td>
</tr>
<tr>
<td>Firing</td>
<td>Fuels used in the firing of bricks and tiles: tires, used oil, sawdust, coffee husk, firewood, eucalyptus branches and coal.</td>
<td>Suspended particles Sulphur dioxide Nitrogen oxides Carbon monoxide Volatile organic compounds</td>
</tr>
<tr>
<td>Classification</td>
<td>Discarding broken bricks, bricks with a crack or those that don’t have been fired properly.</td>
<td>Inert solid wastes</td>
</tr>
<tr>
<td>Preparing the bricks for selling</td>
<td>Discarding broken products.</td>
<td>Inert solid wastes</td>
</tr>
</tbody>
</table>
Table 9. Effects of the contaminants according to the fuel

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Effect of the air contamination</th>
<th>Additional effect in the surroundings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used tires</td>
<td>Very high, carcinogen</td>
<td>Black smoke, blackening of the surroundings, soil, houses, etc.</td>
</tr>
<tr>
<td>Plastics (bags, bottles, etc.)</td>
<td>Very high, carcinogen</td>
<td>Not estimated</td>
</tr>
<tr>
<td>Branches and leaves of fresh eucalyptus</td>
<td>High, the large volumes of dense smoke make visibility difficult</td>
<td>Deforestation owing to indiscriminate use, soil erosion, less rains</td>
</tr>
<tr>
<td>Dry firewood of eucalyptus or other wood species</td>
<td>Medium</td>
<td>Deforestation owing to indiscriminate use, soil erosion, diminution of rainfalls</td>
</tr>
<tr>
<td>Coffee and rice husk</td>
<td>Medium</td>
<td>Use of residues</td>
</tr>
<tr>
<td>Sawdust</td>
<td>Medium</td>
<td>Use of residues</td>
</tr>
<tr>
<td>Liquid fuels (diesel, residual)</td>
<td>Medium</td>
<td>Soil contamination risk owing to spills</td>
</tr>
<tr>
<td>Coal (anthracite)</td>
<td>Low</td>
<td>Not representative</td>
</tr>
<tr>
<td>Gas (LPG, NPG)</td>
<td>Very low</td>
<td>Not representative</td>
</tr>
</tbody>
</table>

According to the inventory of air emissions carried out in 2003 by National Environmental Council (CONAM)\(^1\) in Arequipa, the brick industry (including mechanised and informal brick factories) is the main source of stationary pollutant emissions, representing 40% of the total emissions.

![STATIONARY SOURCE EMISSIONS](image)

Figure 8. Proportion of contaminants in the atmospheric basin of Arequipa

---

\(^1\) CONAM was the environmental authority before the creation of the Ministry of the Environment.
Table 10. Contaminant contribution of the brick manufacture in Arequipa, ton/year

<table>
<thead>
<tr>
<th>Stationary source emissions (t/year)</th>
<th>TSP</th>
<th>SO₂</th>
<th>NOₓ</th>
<th>CO</th>
<th>VOC</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick factories</td>
<td>8,860</td>
<td>187</td>
<td>32</td>
<td>216</td>
<td>45</td>
<td>9,340</td>
</tr>
</tbody>
</table>

As well CONAM determined that the brick and tile industry in Cusco was the major source of stationary contaminant emissions, representing 31.4% of the total of CO emitted by all sources in 2004.

Figure 9: Proportion of contaminants in the atmospheric basin of Cusco

Table 11. Contaminant contribution of the brick manufacture in Cusco, ton/year

<table>
<thead>
<tr>
<th>Stationary source emissions (t/year)</th>
<th>PM₁₀</th>
<th>SO₂</th>
<th>NOₓ</th>
<th>CO</th>
<th>VOC</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick factories</td>
<td>1,067.30</td>
<td>7.96</td>
<td>55.75</td>
<td>5,575.44</td>
<td>1,831.93</td>
<td>8,538.38</td>
</tr>
</tbody>
</table>

Loss of soils and landscape deterioration: Owing to the lack of territorial planning and control, the exploitation of quarries to extract raw material for brick manufacturing additionally to the alteration of the landscape, enhances deforestation and leads to the loss of topsoil and erosion. Another factor affecting the landscape is the production of inert solid wastes composed of ceramic wastes from deficient products that may represent up to 15% of each firing.

4.1.9 Gender approach

Arequipa

Based on the diagnosis by Calandria in the Asociación Primero de Mayo, the following aspects were identified:

- Women working in brick factories perceive themselves as housewives. At home they maintain their traditional gender roles with few changes in the redistribution of roles on the part of men and women as well. The precarious economic situation and the eagerness that their children have a good education motivate women to work in the manufacture of bricks. But their status compared to men is
unfair because their work is assumed as a help only and their participation as workers is invisible meaning that they don’t have rights in the productive process.

- Men generally assume their role as heads of their families and providers, reproducing a vertical relation of authority with their partners and children. In many households the absence of the father has been observed, which represents an additional burden for the wife.
- Women and men perceive that they have harsh working conditions that affect their health.
- The women’s participation in decision making is restricted with exception of some leaders. In spite of their proposal capability to improve the productive process and commercialisation, generally they aren’t empowered to fulfil those proposals.
- Women are in a disadvantaged position in their relation with their partners due to their inferior status and power imbalance. It has been observed that gender relations are asymmetrical, both in the reproductive aspect as well as in the productive field.
- Women need capacity building in order to have access to the management, commercialisation and use of clean technologies in the brick manufacturing sector. They perceive the strategic need to improve their position in the power relationship with their partners to be able to implement better their proposals.
- A special mention needs to be given to the fact that an important number of women – most of them widows, orphans or single mothers – are owners of communal concessions for soil use, making them leaders in the production process and also active participants of communal assemblies.

### 4.2 Stakeholders

#### 4.2.1 National level

**Ministry of Production**

On the one hand, the Subsector of Domestic Industry supervises the manufacturing activities and among them is the “manufacturing of clay and refractory ceramic for structural use”. The subsector is in charge of the standardisation, surveillance and promotion of said activities. On the other hand, the Directorate of Industrial Environmental Issues coordinates all the environmental aspects related to the sector and their core strategies are the preventive intervention, efficiency in the production and the use of clean technologies.

The purpose of the National Environmental Plan of the industrial manufacturing sector is to establish a national strategy to develop sustainable manufacturing activities enabling competitiveness, technological innovation and an environmental policy duly articulated with a fair participation of relevant stakeholders of the private and public sectors. The objective is to develop an environmental management focused on the prevention of contamination and the use of clean technologies to protect the environment, and enhance productivity and competitiveness among enterprises, thus, improving their positioning in the market.
Ministry of the Environment (formerly National Environmental Council)

The Viceministry of Environmental Management through the General Directorate of Policies, Standards and Tools for Environmental Management supervises that sectoral, regional and local bodies adopt effective measures to prevent, mitigate and control environmental pollution and its components derived from economic activities under its scope of work.

4.2.2 Arequipa

Regional Directorate of Production (DIREPRO) of Arequipa

The Regional Directorate of Production is a deconcentrated body of the regional government that depends on the Regional Management of Economic Development and is responsible for preparing, leading, guiding, executing and supervising sectoral regional policies related to industries and fishery according to national policies. The Directorate of Industry is responsible for proposing, implementing and supervising the sectoral policy, pursuing the development of regional industrial and manufacturing activities and surveilling the fulfilment of the environmental protection regulation.

Arequipa Province Municipality

The Municipality has forbidden polluting industrial activities within the urban perimeter of the city; for that reason, brick manufacturers have moved to Mollebaya, in the Socabaya district.

Socabaya District Municipality

Through its Directorate of Community Issues the Municipality provided the materials for the construction of the pilot vertical kiln. It also sponsored the workshops for technological exchange targeted at artisanal producers and gender workshops.

National University of San Agustín (UNSA)

Through the Faculty of Engineering students and teachers have been involved in the development of more efficient technologies to improve the quality of artisanal bricks.

Asociación Primero de Mayo

This association was created as a result of a participating process that selected 15 artisanal manufacturers that signed an agreement for the operation of a demonstrative project to build a vertical shaft kiln of continuous production.
4.2.3 Cusco

Regional Directorate of Production of Cusco

The Regional Directorate of Production of Cusco has the same functions as the Directorate in Arequipa (see above).

Cusco Province Municipality

Through the Submanagement for the Environment – of the Management for Tourism, Education, Health and Environment – it’s in charge of promoting the culture of prevention based on education to protect the environment, developing interventions to protect the health of the population and environmental quality, and participate in the preparation of the local development and environmental management plan and its tools within the framework of the national and regional environmental management system. In that sense, the Municipality led the development of the Clean Air Plan for Cusco.

San Jerónimo District Municipality

Most brick factories are located in the district of San Jerónimo. The Municipality of San Jerónimo, through the Subdirection of the Environment, has been involved in the introduction of efficient technologies and clean fuels among artisanal brick manufacturers of the district. The Subdirection also helped to improve the roads in the sector and implemented controls to ban the use of tires as fuel.

Associations of producers in San Jerónimo

- The Asociación de Productores de Ladrillos y Tejas - Propietarios de Sucso Aucaylle is a group of 80 owners (30%) and producers. They have a medium production capacity (between 15 thousand bricks by small artisanal and 200 thousand by bigger enterprises by month) and use intermediate technologies and traditional kilns. Their main fuel is firewood, sawdust and coffee husk. They generate small profits.
- The Asociación de Productores de Picol is a group of 40 associates, all of them artisanal, few are mechanised due to lack of electricity, which has recently been solved by the installation of an energy supply line.
- The Asociación San Agustín is a group of 80 artisanal producers that lease the land. All of them are informal manufacturers and have kilns of low capacity. As fuel, they use tires and plastics and make profits barely to survive. They have to pay to the landowners one thousand bricks for each firing.
- Additionally, there are six large entrepreneurs that don’t belong to any association.
5 Justification for the intervention and relation to the strategy of Private Sector Development (PSD) of Swisscontact

The Clean Air Regional Programme (PRAL) started its intervention in 2004, focused on the cities of Arequipa, Cusco and Trujillo, in Peru. The main goal was to promote the sustainability of air quality management programmes by strengthening local institutions, developing technical capacities and promoting citizen participation. The programme, besides considering national policies, focused its intervention in finishing and implementing the local air quality plans of the three cities.

Arequipa and Cusco have clearly identified artisanal brick manufacturers as the second source of air contamination in their atmospheric basins, after the mobile sources. Consequently, air emission reduction from brick producers was included as an objective of the “Cleaning the Air” Plan of these cities. In this regard, PRAL incorporated an action line in that sector. Initially, the intervention was focused on direct support for technical issues, but after the first steps it was evident that an integrated support was necessary to complement the technical support with social and managerial aspects if better results in environmental issues were expected.

The initial diagnosis identified small brick manufacturers as a population in extreme poverty living of a subsistence economy, with strong traditional production techniques passed down through generations and limited knowledge about management and business organisation.

As Swisscontact aims at contributing to poverty reduction through the promotion of a sustainable private sector that can be beneficial to the poor, the PRAL intervention in the brick manufacturing sector is under the scope of Swisscontact objectives. The target population of this intervention are the low-income brick-makers that participate in the private sector. The capacity building of the brick-makers and the institutions involved will be the basis to improve the sector and be a requisite to implement better techniques to accomplish the environmental objectives that have been proposed.
5.1 Development strategy for the private sector

Taking as a reference the impact chain of the public sector development (PSD) strategy, advanced by Swisscontact, the intervention in the artisanal brick manufacture sector included:

**Impact chain for the private sector development**

![Diagram](image)

The components of the PSD strategy of SC are:
- The main key elements
- Those elements that have an impact on the individuals, the families and the enterprises

Figure 10: Impact chain for the private sector development

5.1.1 Intervention with market stakeholders and the government

Artisanal brick manufacturers are considered within the productive sector of the country. Their development requires that relevant public institutions (Municipalities and the Ministry of Production) identify them as productive actors. As well, the development of the sector requires the definition of framework policies to set guidelines promoting formalisation and market growth.

The intervention was carried out involving the participation of the principal institutions; at the regional level PRAL activities were coordinated directly with the Municipalities and the Regional Government, as well as with the National Environmental Council (now Ministry of the Environment), looking for the internalisation and institutionalisation of this topic.
5.1.2 Changes in economic systems relevant to the poor

Scarce resources and the lack of knowledge about the harmful effects and the available alternatives limit the possibilities to use more efficient fuels. The emissions due to the use of inadequate fuels have a direct impact on the producers and affect the air quality of the atmospheric basins where these brick factories operate.

Technological improvements of the kilns and fuel replacement for more efficient alternatives have direct environmental benefits in the above mentioned aspects. As well, they enhance the quality of the products and therefore they can be sold under better conditions.

However, for the implementation of these technological improvements and fuel replacement it must be dealt with social and cultural barriers. As well, training needs to be integrated with business management issues and institutional strengthening. Besides, brick manufacturers should be seen as part of a complete system composed of suppliers in the initial stage up to the final consumer (PRAL only included the producers).

5.1.3 Achieving economic pro-poverty growth

The small scale manufacturers of the artisanal brick production have a subsistence production with minimal or no profits and many management deficiencies. The intervention was focused on the producers themselves, strengthening them as part of the productive chain and facilitating the introduction of efficient technologies and clean fuels. It was expected that any change could imply an improvement in the conditions of brick manufacturers in economical terms and in their working environment.
5.1.4 Leading the way to poverty alleviation

The objective of the PRAL intervention in the brick sector was to reduce the emissions from artisanal kilns that affect the air quality of Arequipa and Cusco. Very soon it was evident that the artisanal brick sector is a complex system where the main actors are low income families with poor standard of living that lack managerial skills to run their business.

For this sector, to be poor not only means to have a very low income but also not to have access to basic services, such as infrastructure, sanitation, education and health, and few possibilities to reach a better living standard. Any intervention should keep in mind that the problem has several angles that must be dealt with an integrated approach in order to achieve objectives such as reducing poverty and improving living conditions, and as a consequence achieve a reduction of air pollution.

In this regard, the PRAL intervention included training in business management, gender and family issues, and technological support to create the conditions that will enable the necessary changes that will make it possible to reduce contaminant emissions.

5.1.5 Interrelation with other Swisscontact projects

The success of the implementation of a diversity of measures necessary to improve a sector was possible due to the expertise of Swisscontact in fields such as small and medium enterprises and financial services. Specifically, the project “Mi Empresa” (My Business) provided training in business administration and the project SERFI (Financial Services) promoted the link between brick producers and credit and savings cooperatives.
6 Description of the intervention

The main activities carried out by PRAL as part of the intervention in the brick sector were:
1. Clean production audit to the artisanal brick manufacturers of Arequipa and Cusco
2. Socioeconomic diagnosis of the artisanal brick sector in Arequipa and Cusco
3. Implementation of technical improvements in traditional kilns
4. Promotion of the use of coal to replace contaminant fuels
5. Training workshops in business management
6. Improvement in the tempering of the brick mixture
7. Promotion of the gender and family approach
8. Implementation of a pilot vertical shaft kiln

6.1 Clean production audit

The first step of the intervention was to carry out a clean technology audit to the artisanal brick manufacturers of Arequipa and Cusco. From the technological point of view it was determined that the firing is the main process and the kiln is the most important technological component. The manufacturers use low-efficiency kilns because the design is based on cheap fuels of high calorific power (tires or plastics), its walls are thin and don’t have sufficient insulation and the burning area is very large. All these factors imply a higher energy consumption.

The diagnosis identified the following improvement opportunities:

<table>
<thead>
<tr>
<th>Area</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuels</td>
<td>Replace tires and plastics using less contaminating fuels such as coal.</td>
</tr>
<tr>
<td>Processes and technology</td>
<td>Modifications in the kiln design</td>
</tr>
<tr>
<td></td>
<td>Improvements in the preparation of the clay mixture to mould bricks</td>
</tr>
<tr>
<td></td>
<td>Mould standardisation</td>
</tr>
<tr>
<td></td>
<td>Use of tools to control the process variables</td>
</tr>
<tr>
<td>Safety and occupational health</td>
<td>Introduce the use of personal safety equipment</td>
</tr>
<tr>
<td></td>
<td>Eliminate hazardous working conditions</td>
</tr>
<tr>
<td></td>
<td>Training</td>
</tr>
<tr>
<td>Management, commercialisation and</td>
<td>Introduce formalisation and partnerships</td>
</tr>
<tr>
<td>processes</td>
<td>Training in managerial capabilities and processes, costs and commercialisation</td>
</tr>
<tr>
<td>Social</td>
<td>Improve gender relations</td>
</tr>
</tbody>
</table>
6.2 Socioeconomic diagnosis of brick manufacturing in Arequipa and Cusco

Two consultancies were carried out to prepare a socioeconomic diagnosis of the brick sector in Arequipa and Cusco. The objective was to identify the operating conditions of artisanal brick manufacturers.

The diagnoses included:
1. Socioeconomic characterization of the environment
2. Identification of social organizations
3. Value chain analysis of the brick manufacturing sector
4. Description of the productive process
5. Evaluation of costs and finance
6. Analysis of the brick and coal markets.

The principal conclusion of the studies was that the brick sector is mainly composed by family-based microenterprises that produce just to survive, lack business management capabilities and have limited knowledge of the costs involved in the productive system; which leads to minimal profits and even economic loss.

The main barriers for improving their production are: their activity is not recognised by the state; they have limited access to the financial system because of the lack of a formal property registry; due to their informality the producers are excluded from social, educational, health and infrastructure systems, including public electric service and communications. Besides, they aren’t incorporated in the value chain and depend on intermediaries.

6.3 Preparation and dissemination of the Guide of good practices for brick manufacturing

A guide of good practices was prepared to improve the sector’s performance and address the reduction of emissions, considering that an implementation of coercive measures as maximum permissible limits for emissions wasn’t suitable because there was no technical standard for kilns; hence emissions can’t be compared to a standard and as the majority are informal producers it’s difficult to apply regulations and penalties.

The preparation of the guide was in charge of an external consultant. The purpose was to support small brick manufacturers to identify practical measures of common sense to minimize production costs, increase productivity and improve commercial management implementing productive processes of low environmental impact.

The document is based on the premise that artisanal brick manufacturers have a good knowledge of their activity and that they have a set of paradigms which is necessary to acknowledge and respect. Their knowledge should be taken into account to improve existing technologies and combine them with new and better ones.
The guide, besides proposing better technical options to optimise kiln operation, includes recommendations on how to manage the production and commercialisation; the possibilities to improve the quality of their products, and the enlargement of the market to obtain higher profits.

Once the guide was concluded and validated, the dissemination process started. The document was first presented to the officials of the Regional Directorate of Production of Arequipa and Cusco and the Municipalities. Then, it was introduced to the brick-makers of Socabaya and San Jerónimo. The original document was summarized in technical notes and booklets of easy reading to be distributed in the city of Cusco. With the support of the Cusco Regional Directorate of Production the document has been disseminated in informative workshops and a contest of good practices has been organised with the participation of artisanal brick manufacturers of this region. At present, the guide is being disseminated in Arequipa. Also, a general guide was presented to the Ministry of Production for nationwide dissemination.

6.4 Implementation of improvements in traditional pilot kilns of Arequipa

Based on a kiln developed by the University of San Agustín, a traditional pilot kiln was implemented with the following characteristics:
- Two chambers for independent firing, one opened and the other one vaulted. The latter one has a vent installed in the vault.
- Vertically, it has two bodies, a lower one of 2.4 m and an upper one of 2.8 m.

![Figure 13. View of the traditional pilot kiln in Arequipa](image)

The implementation of the kiln was realized following this procedure:
- PRAL financed the technical assistance and the manpower to build the kiln, as well as the material and fuel.
- Professors, ex-alumni and alumni of the University of San Agustín participated in building the kiln and supported the follow up and control of the tests.
- Additionally, several tests were conducted to find the most appropriate formula according to the type of clay and working conditions.
- The kiln was fired with dried pieces of eucalyptus and the firing process was fuelled with coal.
The following improvements were suggested:
- Modify the vents to allow better entrance of air
- Reduce the height of the firing chamber
- Increase the space between bricks
- Rationalize the distribution of coal
- Fire the kiln in the first hours of the day
- Control the temperature inside the kiln at different points.

The tests allowed the reduction of the firing period from seven to four days and the quantity of fuel used was reduced as well.

6.5 Implementation of technical improvements in conventional kilns in Arequipa

The improvements proposed in the Guide of good practices for a conventional kiln comply with the following criteria:

a. The dimension of the kiln must be in accordance with the production capacity (see table):

<table>
<thead>
<tr>
<th>Kiln capacity</th>
<th>Length (L)</th>
<th>Width (w)</th>
<th>Height (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 thousand</td>
<td>3.00 m</td>
<td>4.70 m</td>
<td>3.00 m</td>
</tr>
<tr>
<td>30 thousand</td>
<td>5.20 m</td>
<td>4.30 m</td>
<td>4.50 m</td>
</tr>
<tr>
<td>70 thousand</td>
<td>7.50 m</td>
<td>6.30 m</td>
<td>5.00 m</td>
</tr>
</tbody>
</table>

Table 12: Recommended dimensions according to the kiln production capacity

![Figure 14. Structure of the artisanal kiln](image)

Figure 14. Structure of the artisanal kiln
b. The structure has an upper and lower body built with adobes or bricks, following the recommended dimensions according to the production capacity.

In the lower body, the height and width will be $\frac{1}{2}$ and $\frac{1}{5}$ of the total height, respectively. In the upper body, the width will be $\frac{1}{3}$ of the width of the lower body.

![Figure 15. Recommended characteristics to build kilns in Arequipa](image)

c. Firing chamber: Should be built following the longitude of the floor level and oriented towards the predominant wind direction. The shape of the windows of the firing channel should be as similar as possible as shown in the following figure, maintaining in the vertical plane the height proportion of the bricks to be cooked and the horizontal distance between the internal walls. The firing channels vary according to the kiln size and should keep the relationship shown in Figure 16.

![Figure 16. Characteristics of the firing chamber for kilns in Arequipa](image)

To apply the recommendations of the Guide of good practices (GGP) for conventional kilns, it was selected a kiln which had a firing chamber and dimensions according to the GGP recommendations.
Figure 17. View of the improvements in the traditional kiln

Four firing processes for monitoring were carried out with the participation of several manufacturers of the Asociación Primero de Mayo. The results are shown in Table 13.

Table 13. Comparison of the results before and after the burnings

<table>
<thead>
<tr>
<th>Conventional kiln</th>
<th>Improved kiln</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kilns with larger dimensions don’t allow a uniform cook of the bricks</td>
<td>Kilns with smaller dimensions allow a uniform firing of the bricks</td>
</tr>
<tr>
<td>Kilns with thin walls lose heat and use more fuels</td>
<td>The width of the wall (0.80 cm) retains heat and improves the firing of the products</td>
</tr>
<tr>
<td>Consumes 4,2 tons of coal for 27 thousand bricks</td>
<td>Consumes 3,9 tons of coal for 27 thousand bricks</td>
</tr>
<tr>
<td>The dimensions of the firing chamber are reduced and don’t allow an easy inlet of air into the kiln</td>
<td>The wide dimension of the firing chamber allows a better inlet of air into the kiln</td>
</tr>
<tr>
<td>The brick cooking period is 12 days</td>
<td>The brick cooking period is 9 days</td>
</tr>
<tr>
<td>Sometimes there are deficiencies in the firing process in some parts of the kiln</td>
<td>There are no deficiencies in the firing process of the kiln</td>
</tr>
</tbody>
</table>

A comparison of the fixed and variable costs was made for both kilns; the improved kiln allowed a saving of 198 soles because less coal is consumed.

Table 14: Comparison of production costs in Peruvian soles (1 USD = 3 New Soles)

<table>
<thead>
<tr>
<th>Items</th>
<th>Conventional kiln</th>
<th>Improved kiln</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed costs</td>
<td>2750,00</td>
<td>2750,00</td>
</tr>
<tr>
<td>Total labour capital for one burning</td>
<td>6006,37</td>
<td>5880,37</td>
</tr>
<tr>
<td>Total costs</td>
<td>8776,37</td>
<td>8600,37</td>
</tr>
</tbody>
</table>

The results show that the GGP recommendations are valid to achieve more efficiency and profitability in brick production.
6.6 Implementation of the pilot vertical shaft kiln in Arequipa

As part of the recommendations suggested by the diagnosis made at the initial stage of the intervention, the implementation of a demonstrative project was carried out to show how the introduction of good practices and improved low-cost technologies generates profits for the entrepreneurs and reduces environmental impacts in the surroundings. To this end, it was proposed to build a vertical shaft kiln of continuous production based on the vertical shaft kilns that are widely used in Asia.

The general characteristics of the kiln are:
- Continuous production
- Bricks are loaded in the upper part, are fired in the middle section and are unloaded at the lower part.

The pilot kiln was built at the end of 2005. During 2006 several tests were carried out to optimise its operation. It was built and operated with the Asociación Primero de Mayo that consists of 15 producers.

After the first months of its operation, several operating problems were detected, as loss of heat, deficient evacuation of gases and inconveniences in the system of loading and unloading that resulted in brick damaging. To improve the operation of the kiln, Swisscontact implemented some technological changes such as the use of refractory bricks to improve thermal efficiency and a new system to load the bricks.

Once the improvements were implemented, a test was carried out and the technical feasibility of the kiln could be proved. After that, the kiln was handed over to the Asociación Primero de Mayo for its use.

![Figure 18. Improvements in the pilot vertical shaft kiln](image-url)
6.7 Promoting the use of coal in Cusco

6.7.1 Coal as an alternative fuel

The use of national coal available in the Peruvian market was promoted as a substitution for firewood, discarded tires and used oil. The main coal mines that are exploited in artisanal way and that sell coal at a reasonable price are located in the region of Trujillo, in the department of La Libertad.

At present, the coal used by the brick sector in Arequipa and Cusco contains approximately 0.7% of sulphur, according to the analysis made in Corporación Mexicana de Investigación en Materiales S.A - COMINSA\(^2\) laboratories, México. This is a reduced percentage and as such it doesn’t represent an environmental hazard.

During the combustion process, coal produces carbon dioxide \((\text{CO}_2)\) and carbon monoxide \((\text{CO})\), and the presence of nitrogen and sulphur in its contents contributes to acid rains. The most important element that determines the contaminant capacity of coal is its sulphur \((\text{S})\) content. The steel industry demands coal with a maximum of 1.5% of sulphur because sulphur in combination with oxygen will create \(\text{SO}_2\) along the process, which is a toxic and highly contaminant gas; for that reason the least amount of sulphur in coal is recommended. The presence of \(\text{CO}\) can diminish when combustion has the required oxygen. Maximising combustion process efficiency reduces emissions.

Natural gas isn’t provided as a public service in the cities of the southern part of Peru yet. Meanwhile, coal is the most convenient fuel, available for brick kilns.

6.7.2 Demonstrative firing

Twenty-seven firings of bricks were carried out in conventional kilns to promote the use of coal in order to replace other fuels. This was made for both artisanal and mechanised kilns.

This two types of production, artisanal and mechanised, have both the same productive process, but brick manufacture, the use of carbon and the time allotted to the processes of preheating, lighting up and firing are different.

In artisanal traditional factories, bricks are made directly by the workers and solid bricks called king kong are produced, as well as tiles.

\(^2\) Final report of carbon analysis, folio 1889.
In the mechanised production, bricks are made by extruder machines producing different types of bricks, as king kong, hollow bricks with 15 holes, extruded bricks, etc.

Brick firing involves the following processes in both cases:
   a) Loading and coal covering inside of the kiln
   b) Lighting up of the kiln to cook the products
   c) Cooling
   d) Unloading.

Brick loading is carried out building chimneys, which are the spaces left among bricks of approximately 8 to 10 cm. In the lower part of the kiln the number of chimneys is larger and the number decreases as the higher part of the kiln is being loaded, as shown in the following figure:
The following table shows the similarities and differences of the production processes for artisanal and mechanised brick manufacturing with kilns of similar production (7 to 11 thousand bricks).

<table>
<thead>
<tr>
<th>Artisanal production</th>
<th>Mechanised production</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Loading and coal covering:</strong> Arrangement of raw bricks sprinkling them with coal.</td>
<td><strong>Loading and coal covering:</strong> Arrangement of raw bricks sprinkling them with coal.</td>
</tr>
<tr>
<td>• The first 7 rows without coal.</td>
<td>• The first 5 rows without coal.</td>
</tr>
<tr>
<td>• The following rows with coal in increasing amounts, from 8 to 25 kg.</td>
<td>• The following rows with coal in increasing amounts, from 11 to 25 kg.</td>
</tr>
<tr>
<td>• Chimneys are built.</td>
<td>• Chimneys are built.</td>
</tr>
<tr>
<td>• Total of coal used: 300 kg.</td>
<td>• Total of coal used: 400 kg.</td>
</tr>
<tr>
<td><strong>Lighting up of the kiln:</strong> With eucalyptus branches and sawdust, in some cases coffee husk (depending on the season). In the preheating phase, combustion must start slowly and the temperature should increase gradually to avoid losses due to ruptures.</td>
<td><strong>Lighting up of the kiln:</strong> With eucalyptus branches and sawdust, in some cases coffee husk (depending on the season). In the preheating phase, combustion must start slowly and the temperature should increase gradually to avoid losses due to ruptures.</td>
</tr>
<tr>
<td>• Preheating: 5 hours</td>
<td>• Preheating: 4 hours</td>
</tr>
<tr>
<td>• Lighting up: 15 hours</td>
<td>• Lighting up: de 12 hours</td>
</tr>
<tr>
<td>• Total approx.: 20 hours</td>
<td>• Total approx.: 16 hours</td>
</tr>
<tr>
<td><strong>Cooling:</strong> Once the cooking has finished, the products should rest the necessary time to lose temperature.</td>
<td><strong>Cooling:</strong> Once the cooking has finished, the products should rest the necessary time to lose temperature.</td>
</tr>
<tr>
<td>• 72 hours</td>
<td>• 48 hours</td>
</tr>
<tr>
<td><strong>Unloading:</strong> Preparing the bricks for selling them.</td>
<td><strong>Unloading:</strong> Preparing the bricks for selling them.</td>
</tr>
<tr>
<td>• Once the cooling has concluded, the unloading phase starts.</td>
<td>• Once the cooling has concluded, the unloading phase starts.</td>
</tr>
</tbody>
</table>
The intervention was carried out mainly with artisanal brick-makers that used up to 50% of coal in the upper part of the kiln and that are still using eucalyptus branches and sawdust. The results were the following:

Table 16. Comparison between a kiln that uses coal and another one that doesn’t

<table>
<thead>
<tr>
<th>Artisanal production</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Without coal</strong></td>
<td><strong>With coal</strong></td>
</tr>
<tr>
<td><strong>Brick loading</strong></td>
<td></td>
</tr>
<tr>
<td>Seven thousand bricks are loaded.</td>
<td>Seven thousand bricks are loaded; the first 7 rows without coal, the following contain coal.</td>
</tr>
</tbody>
</table>

**Lighting up:**
- Fuel used: eucalyptus branches and sawdust.
  - Preheating: 5 hours
  - Lighting up: 17 hours
  - Total approx. 22 hours
- Fuel used: eucalyptus branches and sawdust and coal.
  - Preheating: 5 hours
  - Lighting up: 12 hours
  - Total approx. 17 hours

**Cooling**
- 72 hours

**Unloading**
- Brick unloading to sell them.

When using coal, a saving of 5 hours is achieved. This also means a saving in manpower and less gas emissions. As well, the product gets a better colour and sound and is known by brick-makers for its quality.

Tests of the lighting up process carried out separately with 100% firewood or coal, in coordination with the Universidad Nacional San Antonio Abad del Cusco, demonstrated that the use of coal reduces 80 times the amount of particles generated; and CO₂ emissions diminish about more than 10%.

Table 17. Comparison of burning emissions using firewood and coal

<table>
<thead>
<tr>
<th>Description</th>
<th>Firewood</th>
<th>Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate matter</td>
<td>1,19147 g/m³</td>
<td>0,0149 g/m³</td>
</tr>
<tr>
<td>• Total emissions per firing</td>
<td>10,7232 g/firing</td>
<td>0,1344 g/firing</td>
</tr>
<tr>
<td>CO</td>
<td>0,07125 mg/L</td>
<td>0,20938 mg/L</td>
</tr>
<tr>
<td>CO₂</td>
<td>0,01351 mg/L</td>
<td>0,012 mg/L</td>
</tr>
</tbody>
</table>

The cost comparison made regarding fixed and variable costs for both firings showed a saving of 200 new soles in the firing process with coal.

Table 18. Comparison of production costs in artisanal kilns in Peruvian soles
<table>
<thead>
<tr>
<th>Items</th>
<th>Kiln without coal</th>
<th>Kiln with coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed costs</td>
<td>1700</td>
<td>1700</td>
</tr>
<tr>
<td>Total work capital for one burning</td>
<td>1504</td>
<td>1304</td>
</tr>
<tr>
<td>Total costs (S/.)</td>
<td>3204</td>
<td>3004</td>
</tr>
</tbody>
</table>

Finally, to promote the use of coal, a contest of good practice was held as part of the 1. International Fair of Clean Technologies in the production of bricks and tiles with the participation of 86 local brick-makers, who use coal in the firing process. Three producers with the best experiences were rewarded.

6.7.3 Coal revolving fund

Through the Asociación de Productores de Tejas y Ladrillos de San Jerónimo a coal revolving fund was implemented so that brick manufacturers could have rapid and sustainable access to this resource. It was identified that one of the barriers to change the fuel was the lack of access to financial sources. PRAL offered the initial fund and the operation was entrusted to the association. Coal is brought from Trujillo and the fund has opened a market that wasn’t available previously.

6.8 Improvement of the clay mixture

Both in Cusco and Arequipa, in coordination with local universities, tests were carried out to improve the clay mixtures for brick production.

In Arequipa, with the participation of the Universidad Nacional de San Agustín, the thesis “Improving the mixture formula with coal addition” was written. The hypothesis was that the addition of a small percentage of coal in the mixture leads to degreasing and enhances the mechanical resistance.

The conventional formula for artisanal bricks is 88% of soil and 12% of clay. In the research, 1% of coal was added to the mixture.

![Figure 22. Clay](image)

For other tests, only soil and clay in different proportions were mixed. Compression resistance tests were carried out for all the mixtures in Servicio Nacional de Capacitación
para la Industria de la Construcción (SENCICO)³ laboratories and the following results were obtained:

<table>
<thead>
<tr>
<th>Mixture formula</th>
<th>Resistance to compression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional artisanal brick (88% soil - 12% clay)</td>
<td>3748 kgf/cm²</td>
</tr>
<tr>
<td>Artisanal brick with coal (Addition of 1% of coal)</td>
<td>49.4 kgf/cm²</td>
</tr>
<tr>
<td>Brick with recommended formula (80% soil - 20% clay)</td>
<td>90 kgf/cm²</td>
</tr>
</tbody>
</table>

The formula of the recommended mixture is 80% of soil and 20% of clay for Arequipa; the mixture accelerates the brick cooking process and increases two and a half times the resistance to compression. According to the national technical standard of Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual (INDECOPI)⁴, the resistance to compression for this brick—type I— must be 60 kgf/cm².

![Figure 23. Bricks manufactured with the recommended formula](image)

In Cusco, with the advisory of the professors of the Faculty of Chemistry, Universidad San Antonio Abad del Cusco, it was proposed to improve the quality of bricks in the district of San Jerónimo, developing a formula with the addition of waste of cooked bricks to improve mechanical resistance, and so its quality. Several tests led to the optimal formula: clay 90%, sand 7%, brick waste 2% and clay loam 1%. The national technical standard of INDECOPI establishes that resistance to compression for this brick—type V—is 180 kgf/cm².

<table>
<thead>
<tr>
<th>Mixture formula</th>
<th>Resistance to compression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional artisanal brick</td>
<td>164.2 kgf/cm²</td>
</tr>
<tr>
<td>Improved brick</td>
<td>182.4 kgf/cm²</td>
</tr>
</tbody>
</table>

³ It is a public superior technical school in Peru.
⁴ Technical standard ITINTEC N° 331.018
This new formula also contributes to the reduction of solid waste contamination as it uses broken and crashed bricks (Spanish: chamota).

6.9 Business management workshops

In Arequipa, training in marketing, management, costs and formalisation of the enterprises was provided to the sector of Primero de Mayo.

![Figure 24. Brick-makers with their certification as participants in the training courses](image)

The following workshops were held in Cusco:

- Market and marketing workshops: The objective was that the participants understand some marketing strategies so that they can apply market and marketing concepts in their businesses.

| Table 21. Methodology, contents and group dynamics in the market and marketing workshops |
|---------------------------------|-----------------|-----------------|-----------------|
| Topics                          | Contents                         | Methodology                | Group dynamics |
| Marketing                       | Introduction What is a market? What is marketing? | Participative Working groups | Role play Two groups were formed |
| Market research                 | Demand The correct price Attitude follows multitude What do you need to know about your market? | Participative Group analysis | Brainstorming Show drawings to the participants |
| Marketing formula               | Product Price Position Promotion | Participative               | Brainstorming Show drawings to the participants |

Case study

BEHIND THE BRICKS: an experience in the integrated management of the informal sector
As a result of the workshops, producers learned the concepts of marketing, market and marketing formula to apply them in their respective businesses.

- Cost workshops: The purpose was that the participants understand and calculate the different costs (direct and indirect) of their businesses.

### Table 22. Methodology, contents and group dynamics in the cost workshops

<table>
<thead>
<tr>
<th>Topics</th>
<th>Contents</th>
<th>Methodology</th>
<th>Group dynamics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost calculation</td>
<td>Direct costs</td>
<td>Explanatory group work</td>
<td>Two working groups:</td>
</tr>
<tr>
<td></td>
<td>- Direct costs of materials</td>
<td></td>
<td>Group of artisanal tiles and group of</td>
</tr>
<tr>
<td></td>
<td>- Direct costs of qualified and non-qualified</td>
<td></td>
<td>artisanal bricks</td>
</tr>
<tr>
<td></td>
<td>manpower</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indirect costs</td>
<td>Explanatory group work</td>
<td></td>
<td>Working in the same groups</td>
</tr>
</tbody>
</table>

At the end of the workshops, 90% of the participants were able to establish the difference between direct and indirect costs.

The workshops on business management have provided new concepts to the producers. Although not all of them apply the recommended guidelines, changes have been observed in the approach of the producers that attended the training activities, especially in the analysis of their costs and the marketing process of their products.

### 6.10 Regional interchange

#### 6.10.1 Visit to Nepal

The consultant in charge of the vertical kiln development in Arequipa made a visit to Nepal together with the local coordinator of the brick manufacturers of Arequipa, and an officer from the Regional Directorate of Production from Cusco to get to know the structure and operation of this type of kilns. With SDC support, vertical kilns of continuous production, originally developed in China, have been introduced successfully in medium and large enterprises of India, Vietnam and Nepal. However, the situation in Peru is quite different and the experience can’t be replicated without making the corresponding adaptations.

#### 6.10.2 Exchange workshops of Bolivia and Peru

PRAL organised in Arequipa a workshop to exchange experiences between brick manufacturers of Bolivia and Peru. Representatives of universities and public officials involved in this subject also participated. The workshop included a field visit to pilot kilns (traditional and vertical) of Arequipa. The representatives of Cochabamba presented
their experiences with kilns using natural gas. As a complement, communication and public campaigns carried out in both countries were also discussed.

6.10.3 International Clean Technology Fair for Small Producers of Artisanal Bricks and Tiles

The international fair was held in Cusco at the end of 2008 and was promoted and organised by PRAL, the Regional Directorate of Production (Cusco) and the District Municipality of San Jerónimo. The fair was attended by delegations of Peru, Bolivia, Argentina and Nepal – mostly artisanal brick manufacturers – and representatives of public institutions and universities. The objective was to offer a platform where brick manufacturers and institutions could exchange useful information on technical processes, business management, occupational health and environmental topics. The Good Practices contest was also held within the framework of the fair.

At the end of the fair, the manufacturers prepared a manifest to draw attention to the need of public policies on economic, social and environmental issues related to this sector, and the importance of encouraging and formalising contacts for future commercial agreements.

6.11 Promoting gender and family issues

As part of the educational programme “Women, Family, Work and Air Quality Management” a diagnosis focused on gender issues was prepared to facilitate the participation of women working in brick factories of Arequipa and Cusco. Along with this, workshops were held with female brick workers to discuss their situation and family topics, encouraging their participation in the process of getting better working conditions while protecting air quality.

Workshops carried out in Socabaya, Arequipa, improved the participation of women in the productive activities and increased their awareness regarding their own situation and how they can contribute to reduce air pollutant emissions that will bring health benefits. Women also expressed their demand to be recognized for the important role they play in the productive process and they recalled the importance of the relationship between air pollution and health.

In San Jerónimo, Cusco, women were sensitized about their position and power in their couple relationships. Participants debated about their possibilities of change to improve the gender situation in the domestic and productive spaces. Efforts were coordinated between the institutions taking part in the workshops and a driving group denominated “Women for Air Quality” (“Mujeres por la Calidad del Aire”) was created, supported by the Regional Directorate of Production, the Municipality of San Jerónimo and PRAL.
7 Effects of the intervention according to the PSD strategy

One of the main results of the intervention has been the awareness created among the artisanal brick producers regarding the problems they have to face. During a workshop, they identified the following aspects as the most important:

- Indiscriminate use of contaminant fuels in the firing process
- Non-standardised products
- Non-qualified labourers
- Lack of knowledge about the market characteristics
- Inadequate cost structure
- Difficult access to finance mechanisms
- Individual work without coordination
- Disarticulation and disagreements among associations
- Short-term vision
- Informal status of most manufacturers
- Not being recognized as part of the economic system
- Not being taken into account in the governmental public policies.

7.1 Results

Regarding the different topics on which the PRAL intervention has focused, the main results for each of them are presented.

7.1.1 Fuels

Arequipa

Used tires have been replaced in a notorious way and now approximately 80% of the manufacturers are using coal.

Cusco

There has been a significant increase in the use of coal. When the programme started, coal was not used in the brick sector of Cusco. Nowadays, it is estimated that brick manufacturers consume 60 to 80 tons of coal monthly (50% of the fuel).

It has been observed that young manufacturers are more willing to accept changes and improvements and they want to have more alternatives. Conversely, older people show resistance to any change.

7.1.2 Technology

Arequipa

Continuous vertical shaft kiln: The implementation of the continuous vertical kiln has been a complex experience. From the technological point of view, it is an energy-efficient kiln that generates less contaminants than the traditional kilns. It has been possible to
precise different factors related to its operation and gradually the amount of coal has been reduced as well as the number of days to fire the bricks.

It's important to mention that the operation of this type of kiln requires a radically different organisation compared to the traditional way of working. Artisanal brick manufacturers had organisational problems in the implementation of the vertical kiln because the members of the association had to change their shifts and get used to continuous production. The experience has shown that this type of kiln is more suitable for medium and large producers. It's worthwhile to mention that the experience with the vertical kiln has allowed the adjustment of coal use, which was replicated in the conventional kilns.

Conventional kiln: The implementation of improvements should be based on a known technology; for brick manufacturers it's easy to adapt technological improvements starting with their own kiln, as they don't need to change to new production ways. The comparative tests before and after the improvements in the thickness and height of the walls reported a reduction in the use of coal and in the number of days to fire the bricks because energy was better maintained inside the kiln and better distributed in the firing chamber. As well, cost reduction in the production is achieved because less amount of coal is used in the improved kilns.

The lighting up tests, comparing the contamination levels using firewood and coal, showed that the use of coal reduces the generation of particles up to 80 times and CO₂ emissions are reduced more than 10%. Besides, the use of coal saves a significant amount of money taking into account that the artisanal brick manufacture is only economic survival.

7.1.3 Organisation and management of the production

Arequipa

No major changes have been observed in the organisation of the production among manufacturers using traditional kilns. The experience in the implementation of the vertical kiln demonstrated that partnerships among small brick manufacturers are difficult because it implies significant changes in the way they organise their work as they aren't used to share responsibilities.

Cusco

Training implementation in business management has been reflected positively in economic results. Managerial aspects have been a novelty for brick manufacturers and were well accepted. However, not all of them have put into practice what they've learned because they consider that the present mechanisms allow them to survive. It has been estimated that 10% of the manufacturers have implemented at least one business management mechanism offered in the training workshops done by the programme.
7.1.4 Materials, inputs and mixtures

The formula of the mixture is a practice that every brick-maker performs according to his experience. Both in Cusco and Arequipa comparative studies were made to compare clay composition and characteristics. A more suitable mixture of the input materials and additives has been tested by graduate students from local universities to optimize production. A formula to prepare the mixture for more resistant bricks has been found. It fulfills the technical standards established for the type of bricks produced in Socabaya, Sucso Aucaylle and Picol; the results are being disseminated.

7.1.5 Institutional management

Cusco
In the context of the intervention of PRAL, including the tests of lighting up using coal, management training courses, and workshops on gender issues in the brick factories of San Jerónimo, The Regional Directorate of Production prepared in 2007 the public investment profile implementation and technical assistance in clean technologies for the brick and tile industry of the districts of San Jerónimo, Andahuaylillas, Sicuani and Santa Ana of the Cusco region. This project estimates an investment of two millions of soles, with a cost-effective ratio of S/. 1’305 for every beneficiary. The purpose is to enhance a culture of business production and partnerships, increase combustion efficiency using coal, implement good practices in the manufacture, and improve regulation tools for clean production.

The Regional Government finances the project with funds from the mining licence fees, royalties and customs taxes and is under execution by the Cusco Regional Directorate of Production.

7.1.6 Environmental aspects

One of the principal results is the use of coal that replaced the use of tires, plastics, used oil and firewood which is responsible for the significant reduction of visible smoke in Arequipa and also in Cusco.

Arequipa
Regarding the traditional kiln, the implementation of good practices in brick production, especially the kiln firing with wood and the use of coal in the firing phase determined that significant particle emissions occurred only in the firing phase. Whereas, the operative phase using coal reduced considerably particle emissions and there were no significant contributions to air contamination in the surroundings.

Cusco
The research done by the National University San Antonio de Abad to compare the use of firewood and coal determined that particle emissions from coal represent less than 2% of firewood emissions.
7.1.7 Social aspects

Cusco

On the one hand, manufacturers and the population living nearby have identified health problems derived from fuel combustion, therefore they're now more willing to implement measures to reduce contaminant emissions.

On the other hand, journalists and mass media are including environmental issues in their agendas more frequently.

7.1.8 Contribution to the mitigation of climate change

The improvement of energy efficiency in brick kilns has a direct effect in reducing the emissions of greenhouse gases. This in turn contributes to the mitigation of global climate change. Improving the technology of traditional brick kilns, implementing good practices and the use of coal can contribute to 20% of energy savings in the sector.

7.2 Swisscontact strategy

The economic activities that should be improved in the brick factories are those in which poor people participate most, for that reason the relationship among the strategies of the Programme and Swisscontact is very direct.

7.2.1 Intervention with market stakeholders and the government

The structure of the intervention of PRAL combines institutional strengthening, citizen awareness and technical support strategies; so the brick factories intervention followed this scheme from the beginning.

At the institutional level, the governmental agency included has been the CONAM, both at the central and regional levels in Arequipa and Cusco, the Ministry of Production (PRODUCE) and its decentralised offices; the Regional Directorates of Production (DIREPRO) in Arequipa and Cusco. The Municipalities as local authorities also played a very important role.

Regarding the response of Arequipa and Cusco at the institutional level, it was evident that the involvement of local institutions was different in each case:

- In Arequipa, from the beginning the emphasis of the intervention was on the technical support. Coordination was established with local institutions.
- The implementation of the vertical shaft kiln and the adoption of the model was difficult due to the need of continuous operation and because the brick producers didn’t feel a sense of ownership.
- The improved traditional oven is successful because it adapt better to the operating process of the producers.
- The implementation of the guide of good practices at the national level is currently in process.
In Cusco, where the intervention started later, the emphasis was focused on institutional capacity building and development of managerial skills obtaining a better response from institutions and authorities.

The manufacturers are the key actors of the market in the brick factories intervention. Both in Arequipa and Cusco, brick manufacturers were convened directly to improve the technology of their traditional kilns and to introduce changes in the use of fuels. In Arequipa a pilot project for a vertical shaft brick kiln was introduced. There was a local specialist operating as the linkage between the programme and artisanal brick manufacturers. It was important to have a local specialist as a resource person because brick manufacturers felt at ease talking to him and gave their opinions freely about the intervention, and made contributions and suggestions.

7.2.2 Changes in economic systems

In the four years that lasted the intervention, changes in the following systems have been achieved:

- Brick manufacturers: They have been trained in business management.
- Coal market in Cusco: There is a dynamic coal market in Cusco, which is brought mainly from the region of La Libertad. Coal is offered as “fine powder” to brick factories.
- Along this same line, manufacturers have access to a revolving fund to buy coal. PRAL started the fund and at present the brick producers association manages it and has its own regulation.
- The Regional Government is implementing the project Implementation and technical assistance in clean technologies for the brick and tile industry of the districts of San Jerónimo, Andahuaylillas, Sicuani and Santa Ana of the Cusco region. It has been approved by the National System of Public Investment (SNIP) for two millions of soles (US$ 660,000).

7.2.3 Achieving economic pro-poverty growth and poverty alleviation

Improvement of the production conditions in brick factories directly contributed to improving the standard of living of kiln workers that belong to the lowest socioeconomic stratum.

The intervention has given the first steps to raise awareness about the environmental conditions that brick workers and their families have to endure. A strong component of the intervention has aimed at providing business management skills to brick manufacturers so that they can see their business from another perspective taking into account the associated costs of the production and commercialisation, looking for alternatives to optimise productivity and increase their profit margins and life quality.
8 Discussion of successes, failures and possible reasons

8.1 Successes

General aspects
- The preparation of the initial diagnosis and the clean production audit in brick factories allowed the identification of priorities that the intervention had to tackle to improve the environmental and social conditions of brick labourers. This first effort was the basis of the intervention that was focused on the most relevant activities to meet the specific needs of Arequipa and Cusco.
- Also, the effort opened the artisanal brick manufacturing sector to the interventions of governmental institutions, universities, non-governmental organizations, among others, in a sector where previous efforts and interventions were scarce.

Institutional strengthening
- The Ministry of Production, through the Office of Environmental Management, assumed the commitment to boost the Guide of good practices at the national level.
- The Regional Government of Cusco through the Regional Directorate of Production has developed a public investment project of two millions of soles (660,000 dollars), to provide technical assistance and implement clean technologies in artisanal brick factories of the region.
- There is a high commitment of the local universities to research and implement improvements for artisanal brick factories. The search for alternatives allows the involvement of local professionals who contribute with their knowledge to upgrade the conditions of the zone.

Business management
The business management workshops have provided new concepts to the manufacturers. Whereas not all of them apply the guidelines that were recommended, a change has been observed in the approach of those producers that attended the training activities, especially in the analysis of their costs and marketing of their products. The methodological guidelines that have been prepared contribute to the dissemination of the topic in other regions.

Technical aspects
- The introduction and evaluation of alternative technologies like the vertical kiln of continuous production has had some organisation difficulties in its operation, but has demonstrated continuous production options as an alternative for medium and large brick-makers.
- The implementation of improvements in traditional kilns, as well as the recommendation of good practices, have given positive results, for instance less number of days in the firing phase, minor use of fuel, optimal firing temperatures,
better quality of the final product, reduction of variable costs in the production and significant reduction of air emissions and greenhouse gases.
- Brick manufacturers are aware that the replacement of contaminant “fuels” with coal brings benefits in terms of air emissions reduction and also economic profits. As long as gas is not available, coal is a feasible fuel option with obvious environmental benefits.

**Social aspects**
- Awareness raising campaigns have helped the brick workers to realise the need of improving the environmental conditions and also the living standard for themselves and their families.
- Women have been empowered and are leading technological and environmental changes.

### 8.2 Failures
- Regarding institutional participation and involvement the public institutions of Arequipa (Province Municipality, District Municipality of Socabaya, Regional Directorate of Production) were less receptive to the project and activities related to brick factories.
- There were difficulties in the introduction of technologies that require a radical change in the brick production system, as is the case of the vertical kiln of continuous production. This production system is more adapted to medium and large producers; small producers would require solid organisation and partnerships and they still don’t have these abilities. Training is needed as well as a manufacturer profile with larger production and investment capacities.

### 8.3 Lessons learned
- Artisanal brick-making is a complex sector where social, entrepreneurial, technical and environmental aspects are mutually interrelated. The objective of reducing air contaminant emissions will be feasible only if the other aspects are also tackled and managed in a comprehensive approach.
- The initial diagnosis, including both a clean production audit of the artisanal brick sector and a socioeconomic diagnosis to identify barriers should be the starting point of every intervention.
- The implementation of changes in technological processes will be easier if they are focused on adapting techniques and processes that the manufacturers are used to. For this reason, it’s important to encourage the active participation of local institutions, universities and the producers themselves starting from the identification of needs to the development of measures to be implemented according to the reality of the intervention zone.
- It’s essential to have a comprehensive vision of the value chain that supports the production of brick manufacturers. The intervention must deal with all aspects of the value chain, offering tools to improve managerial and organisation skills. As well, it’s indispensable to introduce improvements that will bring economic benefits, whether direct as less use of fuel or indirect as less incidence of diseases.
and accidents, and offer them the possibilities to upgrade their production and create better conditions for their families.

- The informal brick manufacturing sector is not recognised by the government as part of the economy; thus, it’s not included in public policies. This leaves the producers without access to basic public services.

- The formal recognition of land ownership with their respective titles could represent a limitation for the producers, making it difficult for them to access the financial system. As well, the lack of planning in the zone could represent a risk for the development of the activity, since producers might be displaced from their working zone.

- The regional Clean Air Project didn’t analyze the marked demand (this wasn’t part of the objectives). But further interventions should take the demand into account.

- New designs of bricks, especially hollow bricks have an important potential to reduce the use of raw materials and energy for firing which could result in an important reduction of greenhouse gases.
9 Discussion of findings and relation with other studies

The situation of Arequipa and Cusco artisanal brick factories is similar in other parts of the country, the region and the world. From the management standpoint, they’re family-based microenterprises that operate mostly in an informal way that have limited knowledge of business management. Their working conditions are precarious and they live in extreme poverty. These factors influence the use of highly contaminant fuels and low-efficiency technologies that generate air contamination, affecting the manufacturers as well as their families and surrounding populations.

These same conditions have been reported in the artisanal brick sector of Piura and Ayacucho by ITDG; in Cochabamba, Bolivia by the Clean Air Programme; and in India, Vietnam and Nepal by SDC, among others.

9.1 Piura and Ayacucho (Peru)

As part of the project on energy efficiency in small-scale production of bricks, in 1998 ITDG made an evaluation of brick firing in Ayacucho and Piura to promote the replacement of firewood with more efficient fuels. They also wanted to develop a technological transfer methodology to optimise the sector. One of the principal conclusions of the experience was that it’s necessary to substitute firewood with coal both for economic and environmental reasons and, as a complement, manufacturers should receive training in technological, managerial and commercialisation issues (Mayorga and Sánchez, 1998).

9.2 India, Vietnam and Nepal

Since 1992 SDC has developed an intervention to improve brick production in Asia, installing continuous vertical kilns originally built in China and extended to India, Vietnam and Nepal. The difficulties that these continuous kilns present were overcome through business management training and in India child care units were created to improve working conditions. An environmentally friendly technology that is feasible from the economic point of view has been adopted and a team has been strengthened to manage technical, economic and social questions posed by 500 kilns. For this experience to expand much more time and efforts are needed to facilitate changes in the regulations, finance access to a coal rotating fund, and capacity building in business management and self-sustainability. The Asian experience with technology adapted to local conditions (social, governmental and technological) could be a reference to be followed by Latin America.
10 Hints for further activities

The following priorities and possible next steps to support artisanal brick factories have been identified:

10.1 System diagnosis

- Conduct an initial socioeconomic diagnosis and a clean production audit in brick factories to identify the problems, barriers and priorities an intervention has to tackle to improve the environmental and social conditions of brick labourers.

10.2 Institutional strengthening

- Promote the Guide of good practices for brick manufacturing as an official document making adaptations according to the type of kiln used in every zone.
- Strengthen capacity building in relevant sectoral institutions so that they could be able to incorporate in their functions the promotion of clean production in brick factories.

10.3 Business management

- It’s essential to have a comprehensive vision of the complete value chain that supports the production of brick manufacturers. The intervention must deal with all aspects of the value chain, offering tools to improve managerial and organisation skills.

10.4 Technical aspects

- Improve the technology of conventional kilns making them more energy-efficient, saving fuel and reducing contaminant air emissions. Reducing greenhouse gases is an important issue and should be considered from the beginning. It’s important to involve local universities, as well as the commitment of the manufacturers in this process to ensure that the improvements are feasible for the zone.
- Continue the substitution of contaminant fuels (tires, plastics, used oils and firewood) with coal, and introduce the use of gas (LPG or natural gas) as soon as it will be available.
- Disseminate technological alternatives that have been proven and validated.
- New brick designs require market investigation but could significantly contribute to reduce GEI.

10.5 Social aspects

- Raise awareness among brick manufacturers, women and children regarding the occupational risks that brick factories pose to their health.
- Promote measures to improve their working and environmental conditions.
- Promote the eradication of child labour and encourage children’s attendance to school.
11 References

- Calandrini, Programa de Capacitación “Género, Familia, Trabajo y Gestión
Regional Clean Air Program - PRAL

PRAL is a SDC program executed by MINAM, Swisscontact y Calandria