From cookstoves to cooking systems: the integrated program on sustainable household energy use in Mexico

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Interest in household energy use and improved cookstoves is growing again, prompted this time by a breadth of concerns that range from local environmental, socio-cultural and, very particularly, health issues to global aspects related to the emissions of greenhouse gases. To face these challenges, improved cookstove programs are evolving from projects narrowly targeting stove construction or sales to more integrated "systemic" approaches. This paper discusses one such approach: a multi-institutional effort directed to improve the sustainability of household energy use in rural Mexico. The program is based in the highlands of central Mexico, and seeks to set up a model that can be scaled up and replicated in other regions. The program has five main components that are highly integrated: technology innovation and market development, a cookstove dissemination package, support to micro-enterprise development, monitoring and evaluation and outreach activities. One of the program's salient features is the development and dissemination of a new efficient wood-burning cookstove named "Patsari". Results of the first year and a half of project implementation and the main challenges and lessons learned by the program are presented and discussed.

1. Introduction

Far from a relatively simple problem with fixed technical solutions, the "biofuel *problématique*'' in developing countries has turned out to be a very complex issue with multiple implications. The patterns of household biofuel use are very heterogeneous, as are also the people, the environment and the cultures that depend on these fuels to solve their essential cooking needs.

After more than a decade of sharp decline, the interest in household energy has emerged again at the international level. A global "crusade" on improved and clean cookstoves is slowly peaking again, pushed now strongly by health concerns [IAP, 2000; Bruce et al., 2000]. The Household Energy Program of the Shell Foundation and the "Partnership for Clean Indoor Air" launched at the World Summit on Sustainable Development in Johannesburg in 2002 illustrate the renewed interest in these issues.

The experience gained from the successes and, particularly, from the failures in the field of improved wood-burning cookstoves has nurtured a new generation of cookstove programs. These new programs challenge the conventional wisdom of the seventies and early eighties. First, rather than being solely designed to save fuelwood, improved cookstoves are beginning to address a comprehensive set of issues ranging from local health and environmental implications to global impacts associated with greenhouse gas (GHG) emissions.

Secondly, experience has shown that a successful cookstove program is more than just building or disseminating cookstoves. The whole "cooking system" needs to be considered through integrated approaches that work simultaneously with technology innovation, creative financing and market development, and the monitoring of actual health and environmental benefits. The programs also foster participatory approaches that seek the involvement of local women to correctly address users' priorities and preferences.

Also, the fuel ladder or "fuel-switching" approach [Barnes and Qian, 1992] has also turned out to be too simplistic to describe the detailed dynamics of household fuel use, particularly within rural and peri-urban households. A mass of evidence now supports an alternative view maintaining that, rather than completely switching to alternative fuels, many households actually follow a "multiple fuels'' strategy, which allows them to get the

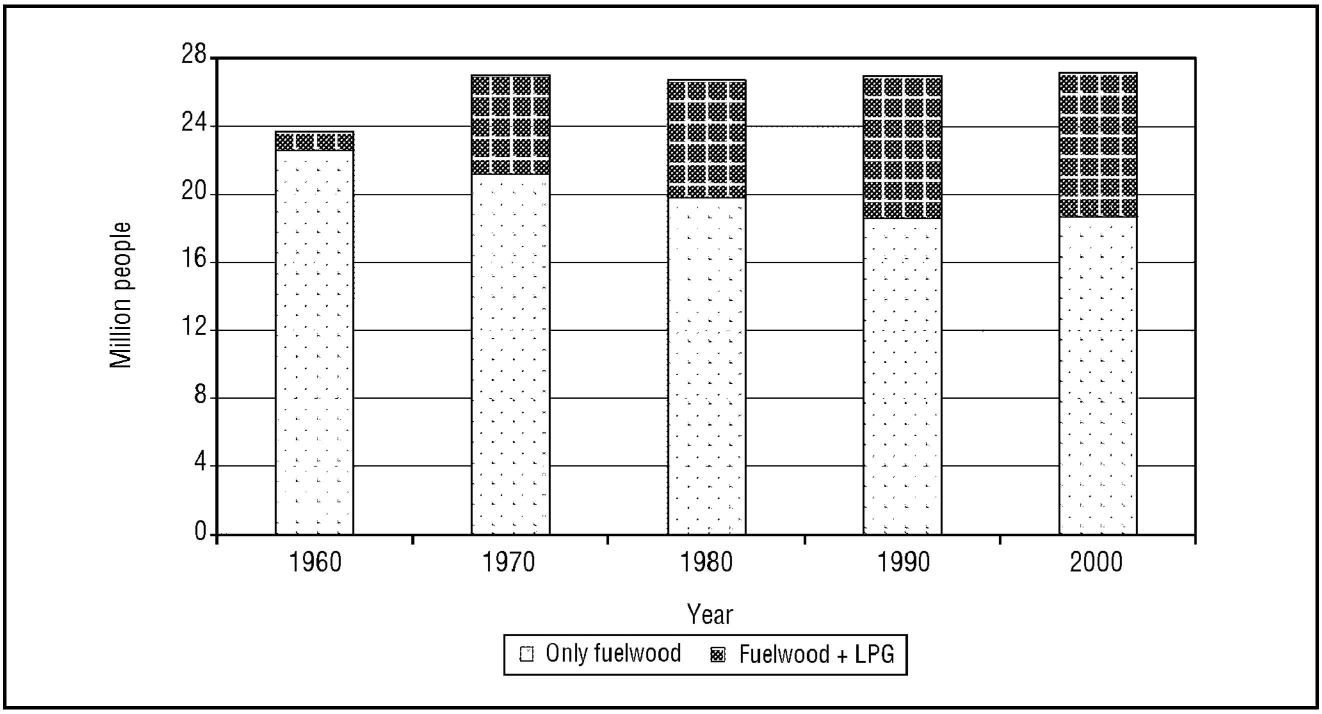


Figure 1. Evolution of fuelwood users in Mexico, 1960-2000

advantages of both traditional and modern fuels. This strategy also helps households to be more resilient to an uncertain and rapidly changing economic environment. Improved cookstoves therefore have also a relevant niche within those households that have already adopted modern fuels [Masera et al., 2000].

This paper discusses one such approach, the integrated program on household energy use in Mexico that is conducted in the state of Michoacan, in the highlands of central Mexico. We begin reviewing the general features of fuelwood use patterns in Mexico. We then provide a general overview of the first year and a half of program implementation.

2. Main features of fuelwood use patterns in Mexico

Currently, about one-fourth of Mexican households (27.2 million people) cook with fuelwood, either exclusively (18.7 million people) or in combination with LPG (8.5 million). Fuelwood use is concentrated within rural and peri-urban households. Fuelwood is still the main residential fuel in Mexico, accounting for approximately 50 % of total energy use and 80 % within rural households [Díaz and Masera, 2003; Díaz, 2000]. Figure 1 shows the evolution of fuelwood use in Mexico from 1960 to 2000, separately for exclusive fuelwood users and users of both fuelwood and LPG. Despite the rapid urbanization process that has taken place in Mexico in the last 30 years the use of fuelwood has remained virtually constant with an increasing share of mixed fuelwood-LPG users in total consumption.

The patterns of fuelwood use are very heterogeneous, as are their associated impacts. Approximately 240 municipalities – representing 10 % of all municipalities and more than 21 % of all fuelwood users – have been determined as high-priority in terms of the number of users, user growth rates, potential negative environmental impacts and resilience of fuelwood consumption [Masera et al., 2003]. Priority municipalities are concentrated in the highlands of central and southern Mexico, often clustered in larger areas determined by cultural, environmental and social conditions. These clusters show an intensive pattern of fuelwood use, which dominates the energy use pattern both in households as well as in thousands of micro-enterprises devoted to pottery, bakeries, brick-making and making tortillas by hand (Figure 2).

The current dominant pattern of household fuelwood use presents several problems. People depend mostly on open fires, leading to very high indoor air pollution (IAP) levels, particularly for women and children. A sample of three studies carried out in rural households belonging to different regions of Mexico report average concentrations of respirable suspended particulates (RSP) ranging between 537 and 995 $\mu g/m^3$ (see Table 1). Per capita fuelwood use averages 2.0 kg/day, with large variations depending on the specific region. Fuelwood is either collected – often by women and children themselves – or increasingly purchased. Access to fuelwood is problematic in many places, either because of its cost or because of the time and effort required to collect it. Households spend up to 15-20 % of their income purchasing fuelwood. Tortilla-making, which accounts for about half of total fuelwood consumption, requires women to spend 2-4 hr/day inhaling the smoke from the fires (up to 8 hr/day for those women devoted to tortilla-making for selling) [Masera, 1995; Díaz and Masera, 2003].

During the past two decades, there has been an increasing penetration of LPG, particularly in the larger urban centers and the higher income levels. LPG has been penetrating these markets as a complementary rather than a substitute fuel with marginal reductions in fuelwood consumption and IAP; high investment costs, the cost of purchasing fuel

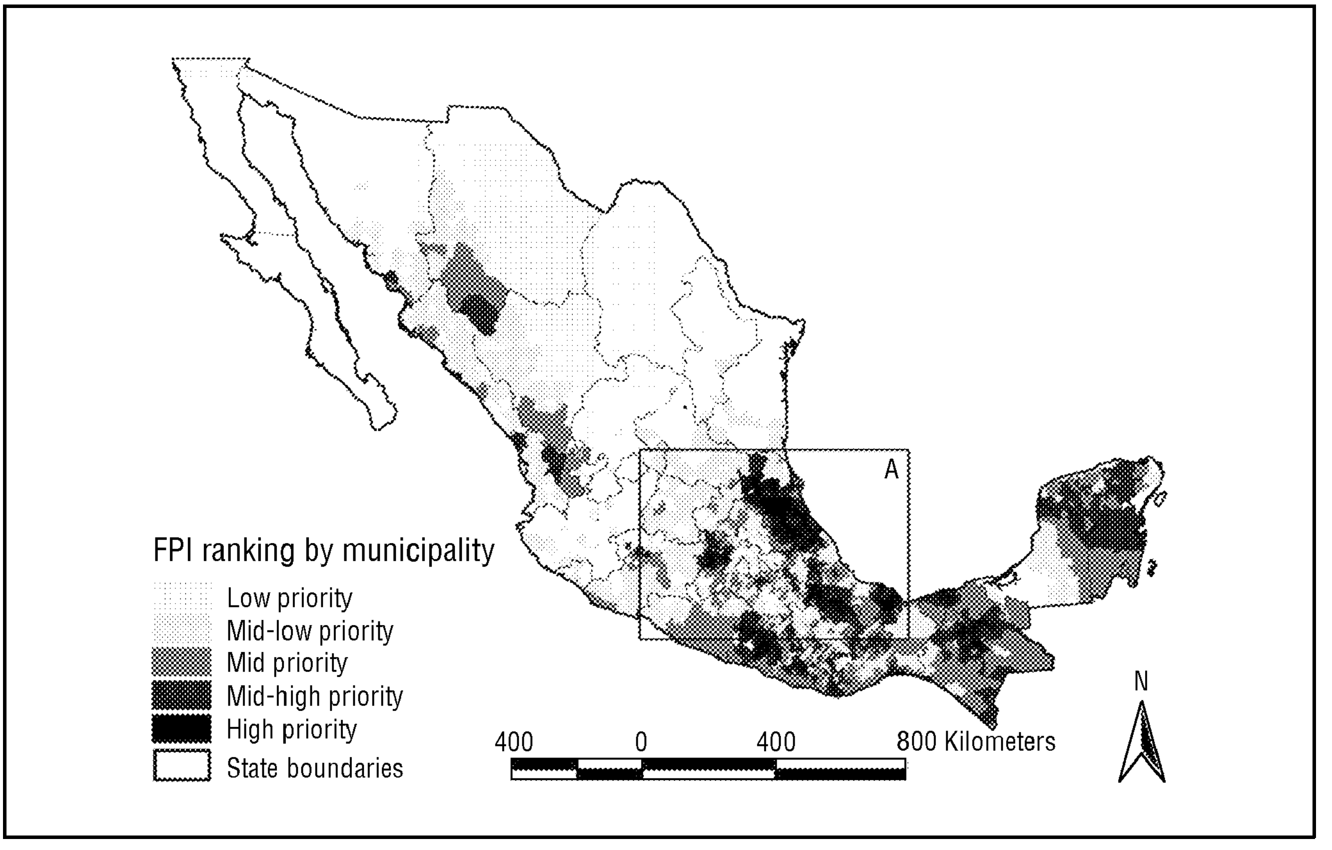


Figure 2a. Priority municipalities in terms of fuelwood use and availability of fuelwood resources, Mexico 2000. Central region detail shown in Figure 2b. Adapted from [Masera et al., 2003]. (FPI = fuelwood priority index)

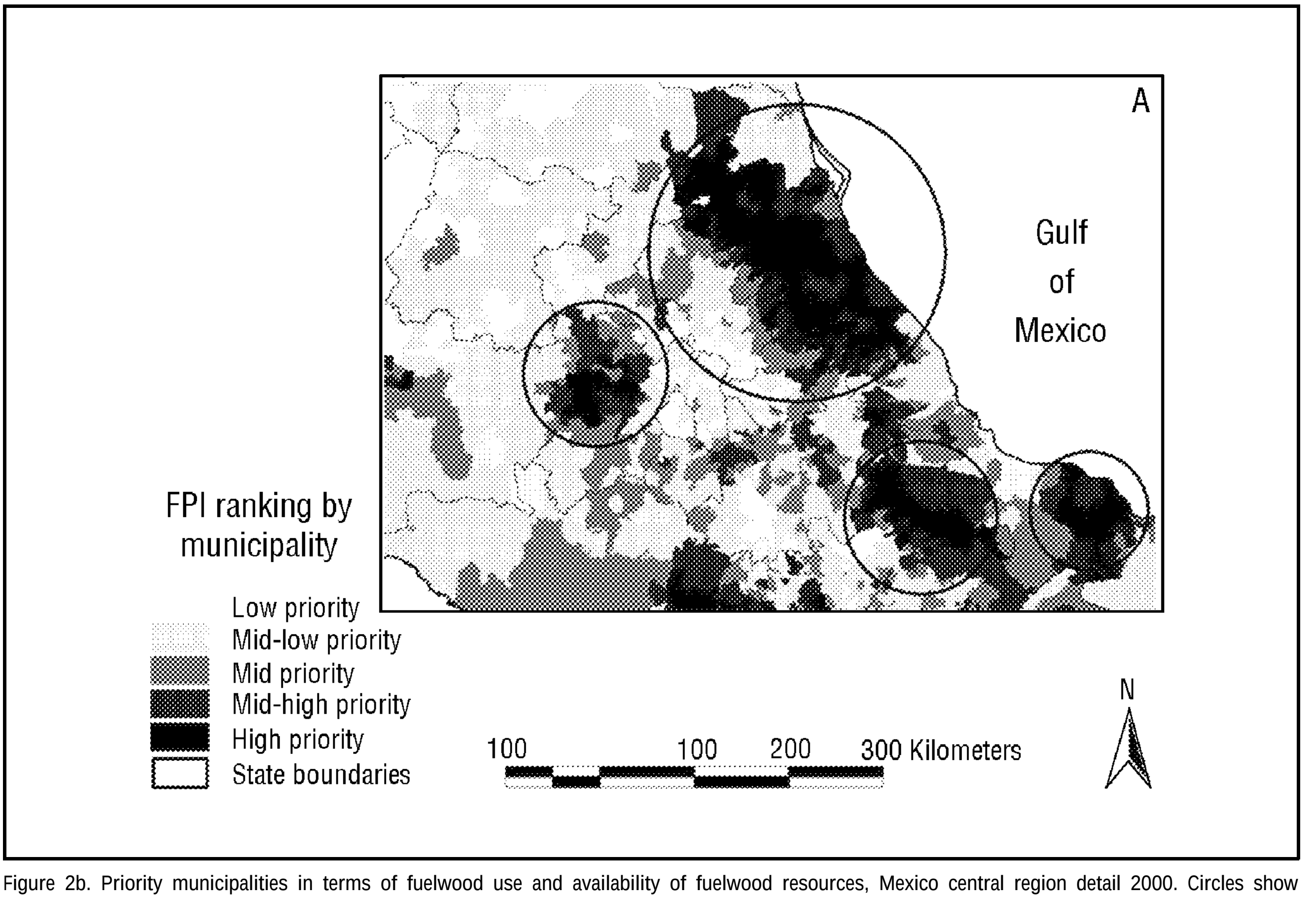


Figure 2b. Priority municipalities in terms of fuelwood use and availability of fuelwood resources, Mexico central region detail 2000. Circles show clusters of high-priority municipalities.

Table 1. Average indoor air pollution levels in Mexican households that cook with open fires

Study location	Authors	Pollutants and the associated concentrations
State of Mexico, central Mexico	Brauer et al., 1996	PM_{10}: 768 μg/m^3 (49-1655)
Chiapas, southern Mexico	Riojas et al., 2001	PM_{10}: 537 μg/m^3 (37-7400)
Michoacán, central México	Saatkamp et al., 1999	Three-stone fire RSP: 655 μg/m^3 CO: 18 mg/m^3 Traditional U-type fire RSP: 995 μg/m^3 CO: 15 mg/m^3

Notes

The concentrations shown are 24-hr averages in the place where children stay. Figures in parentheses are ranges.

(which comes mostly in 30-kg tanks) and an inadequate distribution network hinder a larger impact of LPG. The health and fuel-saving gains from switching to LPG do not materialize because households continue to use fuelwood for the most energy-intensive tasks, such as making tortillas and other traditional dishes. Also, higher incomes do not result immediately in health benefits as the kitchen has a low priority within the family [Masera et al., 2000; Saatkamp et al., 1999].

2.1. Experience with cookstove programs in Mexico

There is limited experience with improved wood-burning cookstove programs in Mexico [Olguín, 1994; Arias and Cervantes, 1994; Navia, 1992; Dutt et al., 1989]. The government launched a large-scale effort at the beginning of the ’80s, with poor results, and basically abandoned the field [Vargas, 1990]. In recent years, a number of initiatives have been started in different regions of Mexico, particularly within the states of Michoacan, Chiapas and Oaxaca, working with a diversity of stove designs and dissemination schemes [RETA, 2004; Cayetano, 1997]. Most groups still work with massive Lorena-type improved stoves, but there are groups now disseminating “Justa” and portable “Rocket” stoves in southern Mexico. Most of the improved cookstove programs are local (village-level) or micro-regional in scope, they are generally part of larger initiatives directed at restoration of local forests or conservation of biodiversity, or they are part of the portfolio of well-established peasant organizations. Efforts are still concentrated on the construction of stoves with little or no follow-up; stoves are entirely or mostly subsidized; there is still emphasis on stoves being constructed by users themselves. Some institutions promoting these stove programs have become more aware of users’ priorities and needs, resulting in higher stove acceptance rates. Last year, the Mexican government again started activities in this area, mostly through the National Forestry Commission (CONAFOR). Health concerns are now a major focus of the new initiatives.

3. The Integrated Program on Sustainable Household Energy Use

3.1. Institutional background

The Interdisciplinary Group on Appropriate Rural Technology (GIRA), a local non-governmental organization, and the Center for Ecosystems Research (CIECO) of the National University of Mexico have been coordinating since the mid-1990s a multi-institutional and long-term program to promote a cleaner and more sustainable pattern of energy use in rural and peri-urban Mexican households, based on the concept of *multiple fuel cooking* [Masera et al., 2000].

Together with the Energy and Resources Group of the University of California, Berkeley (ERG), the Food and Agriculture Organization of the United Nations, and several local institutions, GIRA and CIECO have conducted detailed studies on the patterns of household energy use, and their socio-cultural, economic, health and environmental implications [Masera et al., 1997; Saatkamp et al., 1998; Masera and Navia, 1997]. Primary data on IAP exposure levels and associated health problems derived from the use of traditional devices and the mitigation associated with cleaner devices has been collected. A process of technology adaptation-innovation has led to the development of the smoke-free “Patsari” cookstove that is well adapted to the conditions of local cooking (see below). Undertaking a user-centered approach, with strong emphasis on women’s training on indoor air pollution (IAP) issues, an integrated *multiple-fuel* model is being promoted, which allows users to get the benefits derived both from modern fuels and from cleaner and efficient biomass devices. For a complete list of publications associated with the program refer to the site www.gira.org.mx.

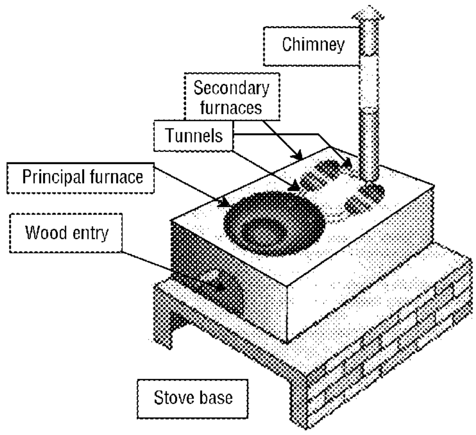
Beginning in 2003, with support from the Household Energy Program of the Shell Foundation and several Mexican institutions, including CONAFOR, the National Commission for Prevention of Health Risks (COFEPRIS), the Institute of Engineering at UNAM, and the National Institute of Ecology (INE), the program has gained major impetus and developed the possibility of having a large-scale impact on Mexican households. During the period 2003-2006 the program seeks to set up an innovative, field-tested, participative, and replicable cooking model centered on rural women to facilitate the transition of poor households and small enterprises from the central Mexican highlands to a cleaner and more sustainable pattern of energy use.

Specifically, the project is working simultaneously with end-users, small entrepreneurs, tortilla-making small enterprises, local NGOs and local authorities to: (1) facilitate the dissemination and adoption of clean and efficient biomass cookstoves, through self-replicating mechanisms; (2) strengthening local micro-enterprises; (3) reducing the health and environmental impacts of present fuelwood consumption and harvesting; and (4) educating local women on the associated health problems of indoor air pollution.

To achieve its objectives the program has five main components that are highly integrated: (1) technology innovation and market development; (2) cookstove dissemination; (3) development of local small enterprises; (4)

Box 1. The Patsari cookstove

The project has developed a new concept of massive wood-burning cookstove called "Patsari", which in the local language means the stove that "takes care" of one's health, environment, economy, etc. [Diaz et al., 2003]. The Patsari departs from a modified Lorena cookstove that was previously disseminated in the region and has the following improvements: (1) optimized design of the combustion chamber and tunnels, (b) custom-designed parts for durability, including a metal chimney support and a ceramic stove entrance (see diagram below); and (3) reduction in construction time and standardized inner dimensions. The cookstove is made in approximately 2 hours with the aid of a metallic mould that ensures that critical dimensions are maintained. The stove also comes with metal *''comales''* – pans to place the pots – that are sealed to avoid leaking of the smoke. Currently two models are disseminated, with one and two wood entries, respectively. The former has one combustion chamber and uses a metal *''comal''* of 52 cm diameter. It is ideal for cooking tortillas and is preferred by mixed fuelwood-LPG users. The second Patsari model has two combustion chambers. The main one usually supports a ceramic *comal* (which is preferred by many users) for making tortillas. The smaller chamber has a metal *comal* of 35 cm diameter designed for cooking other dishes, such as beans, and other tasks, such as boiling water. Both Patsari models include tunnels that conduct the combustion gases to secondary chambers (or furnaces). Each chamber includes baffles to improve heat transfer between the *comal* and the gases. These secondary chambers are used for "low power" cooking tasks, such as keeping food warm or heating water.



The body of the Patsari is made of a mixture of sand and mud and a small amount of cement. All the materials are available locally; the custom-made stove parts are also manufactured by local small industries. External cookstove dimensions are 80 cm by 100 cm (100 cm by 100 cm for the two-entry model), stove height is 27 cm and the distance from the base of the combustion chamber to the *comal* is 20 cm.

The Patsaris have a retail price of US$ 24 including US$ 14 for the labor costs incurred by the stove-builder. The three metal *comales* cost an additional US$ 14. In some villages there is a need to also build a base for the stove, which amounts to an extra US$ 25.

monitoring and evaluation; and (5) program outreach. In the next section we present a critical assessment of the first 18 months of project implementation within each of the main project components.

3.2. Project implementation results

3.2.1. Technology innovation

One of the main program goals is to set up a process of continuous technology innovation. To that end, a field cookstove laboratory has been set up. Here, new cookstove designs and materials are tested. Tests include emission profiles of major pollutants as well as detailed measurements of the cookstove's thermodynamic performance. The cookstove laboratory will be used as a reference – or standard – to test other cookstove models that are currently being disseminated in Mexico. Through a participative process of field trials and feedback, new models are tested in experimental as well as in actual conditions and are finally deployed in the field.

A new efficient massive multi-pot wood-burning cookstove, called "Patsari", has been developed (Box 1 and Figure 3). The Patsari is oriented to mass dissemination; it is built with the help of a mould, and includes several custom-made pieces. The size and geometry of the combustion chamber (primary furnace), the tunnels and the secondary furnaces are designed to increase heat transfer to the pot. Metal flat pans (or *comales)* are tightly adjusted to the furnaces to prevent smoke leakage. The stove comes with a metal chimney, which is inserted into the stove body with the help of a custom-made metal base built in the stove. Currently, two models of Patsari, one with a single entry for fuelwood and a second with two entries, are being disseminated. In the latter case, both a ceramic *comal* and a metal *comal* are used in the primary furnaces. The cost of the cookstove is US$ 38, including a set of high-quality metal *comales.*

Controlled cooking tests for tortilla-making were carried out in both Patsari models and in the two most commonly used open fires (three-stone fires or TSFs and U-type fires). Tortilla-making was chosen because it is the most intensive energy task within households [Masera and Navia, 1997]. The single-entry Patsari scored the best (0.63 ± 0.03 kg fuelwood/kg tortilla), followed by the double-entry Patsari – in this stove tortillas were made over a ceramic *comal* –, the TSF and the U-type fire (Table 2). Savings from Patsari stoves reach 67 % compared to the U-type fire and 59 % compared to the TSF, and were statistically significant at 95 % confidence level (Figure 4). In a pilot study conducted in 11 households (9 with open fires and 2 with Patsari stoves), reductions in indoor air pollution levels associated to Patsari cookstoves and measured in terms of 24-hr concentrations of $PM_{2.5}$ reached 92 % compared to open fires [GIRA, 2004].

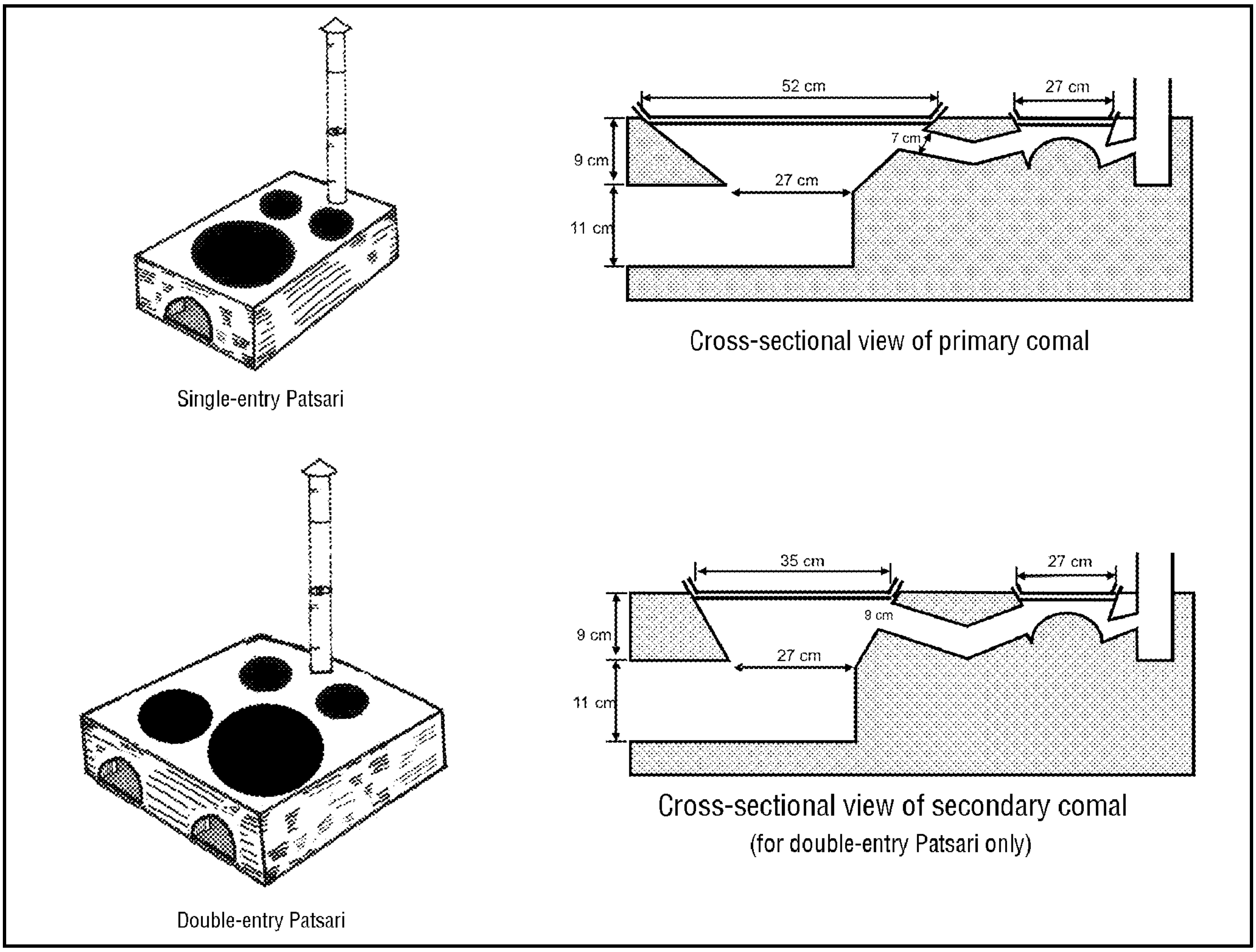


Figure 3. Top view and cross-sectional view of the two Patsari cookstove models

Table 2. Controlled cooking tests for Patsari cookstoves and open fires

Cookstove	n	Fuelwood for tortilla task (kg/kg)	Standard error	Left-over charcoal (g)	Specific fuel consumption (MJ/kg)
Patsari single-entry	6	0.63	0.03	117	12.59
Patsari double-entry	6	0.91	0.08	205	18.30
Three-stone fire (TSF)	6	1.49	0.17	205	29.77
U-type fire	6	1.85	0.17	362	36.98

Notes

We use 20 MJ/kg (oven-dry) and 28 MJ/kg as the heating value of wood and charcoal respectively. Wood heating content is adjusted by the humidity of the fuel according to the standard controlled cooking test protocols.

3.2.2. Cookstove dissemination

The dissemination of cookstoves is based on a user-centered approach that seeks to set up sustainable business operations at the regional level. The goal is having 1,500 households with Patsari cookstoves in 30 villages and a number of successful "stove business operations" established within a period of 3 years. The dissemination of cookstoves is assumed to continue on its own after this period. The main actors in the dissemination process are cookstove builders, end-users, and the manufacturers of stove parts. GIRA and CIECO act as facilitating agents and also conduct the overall monitoring and quality assurance of the dissemination process. Up to this point a total of 600 stoves have been disseminated.

The first step is to establish cookstove builders. To do so, candidate stove-builders are selected following strict criteria (the ability to communicate with people, business initiative, etc.) and through a process that includes a hands-on training course on technical, financial and health and environmental issues related to stove use and maintenance. They are helped by GIRA to generate an initial market of approximately 50 stoves within each village and receive a mould free of charge (at a cost of US$ 200) which they can keep after completing the installation and correct operation of the 50 stoves. To assure the quality of the stoves built, each stove is assigned a serial number

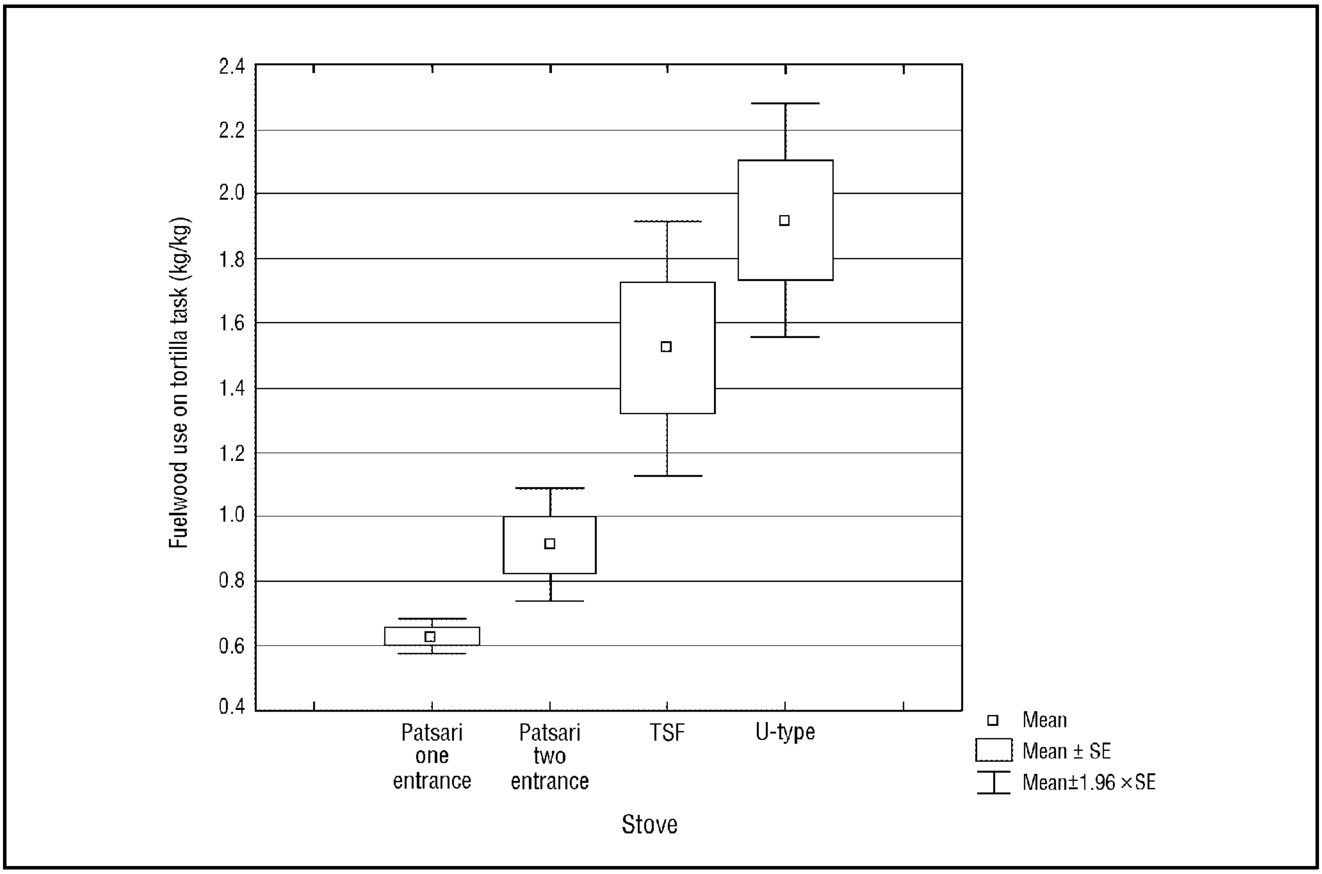


Figure 4. Fuelwood use by different cooking devices for making tortillas

and there is a "technical card" that the builder needs to fill up, with information about stove installation and two subsequent visits (to light the cookstove and after two weeks of operation). The cards are later incorporated into a cookstove digital database that serves for program monitoring and evaluation.

To help develop the market for improved cookstoves the project includes two facilitating mechanisms: (1) user awareness and training workshops (training package) and (2) a financial mechanism (financial package). The first mechanism helps in making local women more aware about the health and other problems derived from the use of open fires. They involve a general presentation of the project in a general assembly of the village and one or two intensive workshops for those women interested in buying a stove. Using participative techniques, users' priorities about fuelwood are expressed, and the workshops also serve to talk about the main features of the Patsari stove. At the end of the workshops, a list of women interested in buying the Patsari stove is drawn up, and a stove committee is formed that also surveys the financing of the stoves.

A financial incentive is critical for a faster adoption of improved cookstoves. We have designed two types of incentives: (1) a 20 % discount on stove costs for the first 50 stoves built within each village; and (2) a "payment in installments" type of micro-finance, that is set up – where needed – to help users to overcome up-front costs (stoves are paid for in 3 installments). The whole operation is run entirely by local women and the local stove builder. To that end, a specific training package on simple micro-financing has been prepared.

A comprehensive set of didactic materials has been prepared expressly for the project. The materials, many of them in Spanish as well as in *Purepecha*, the local language, include a promotional video, posters, a stove leaflet, and a series of graphic materials for the participatory training workshops. Radio spots have been produced that also promote the stoves in the local radio-station.

We conducted a first assessment of the stove dissemination process using the cookstove database and a field survey of a sample of households. Results from the database come from 240 out of 400 households that had Patsari stoves in November 2004. The field survey was applied to a representative sample of 42 households in four villages and was directed to understand women's preferences on the Patsari cookstoves as well as to have users' opinion about the functioning of the dissemination program [Valencia, 2004][1].

A large fraction of households adopting Patsari stoves cook with both fuelwood and LPG (71 % of total households in the sample) and 3 % already had a Lorena cookstove. This result confirms the importance of multiple-fuel users in the market for efficient cookstoves, a fact that was pointed out in previous studies [Masera et al., 2000]. Traditional cooking devices are mostly U-type (62 %) and three-stone fires (29 %). Stoves are placed within the kitchen (70 % of total households), but a significant fraction are installed outside (8 %) or within a small "hut" (22 %). In about half of the cases the kitchen is part of

Table 3. Characteristics of households adopting Patsari stoves

Fuel used for cooking	Number	%
Gas	1	1
Fuelwood	68	28
Fuelwood and gas	170	71
Total	239	100

Type of stove	Number	%
Lorena	6	3
Oil drum	15	6
Three-stone fire	70	29
U-type	147	62
Total	238	100

Cookstove location	Number	%
Outside	18	8
Tejabán[1]	53	22
Kitchen	168	70
Total	239	100

Kitchen location	Number	%
Separated from the house	108	45
Within the house	132	55
Total	240	100

Note

1. Roofed wooden structure

the house (55 %) and in the other half constitutes an independent building (45 %). In these latter cases, it tends to be a precarious wooden structure (Table 3).

Within the households surveyed, women's preferences for buying Patsari cookstoves are heavily related to improving health and kitchen conditions – i.e., the possibility of removing smoke out of the kitchen (28 out of 39 responses), having a clean kitchen (10 responses) and improving health conditions (6 responses). Saving wood was a priority for only 15 households and saving gas for 2 households (Figure 5a). For those women already owning Patsari stoves, the perceived benefits of the cookstoves include health, economic and social aspects. However, the main benefits are the possibility for families to eat together in the kitchen (with the open fires, women usually stay alone in the kitchen while the rest of the family eat in another place), the absence of smoke, and a diverse set of health issues such as avoiding children coughing and avoiding burns (Figure 5b).

Finally, it should be noted that the adoption of improved cookstoves, rather than simply implying changes in the use of fuels, prompts major changes within households. 70 % of the households adopting improved stoves made some type of change or planned on making changes to their kitchen in the near future [Valencia, 2004]. These changes included painting or cleaning the walls, changing the ceiling, buying new dishes and cookware, installing new floors, and even building a new kitchen. Cookstoves are thus seen as households "assets".

3.2.3. Development of local small enterprises

The adequate integration of the "cookstove system" has required the development of local suppliers of custom-made stove parts. We are working with metal workshops for the manufacturing of the mould, the chimney and the chimney base that is attached to the stove and the metal *comales,* and with a pottery workshop that manufactures the ceramic piece that is attached to the stove entrance. Through the interaction with these enterprises we have been able to get important feedback in terms of stove design and durability of alternative materials. Also, working together with these small enterprises has two main advantages: (1) it helps ensure the quality, reliability, and costs of the parts that will enter the cookstove production process, and (2) induces the creation of local employment and income generation alternatives at the regional level.

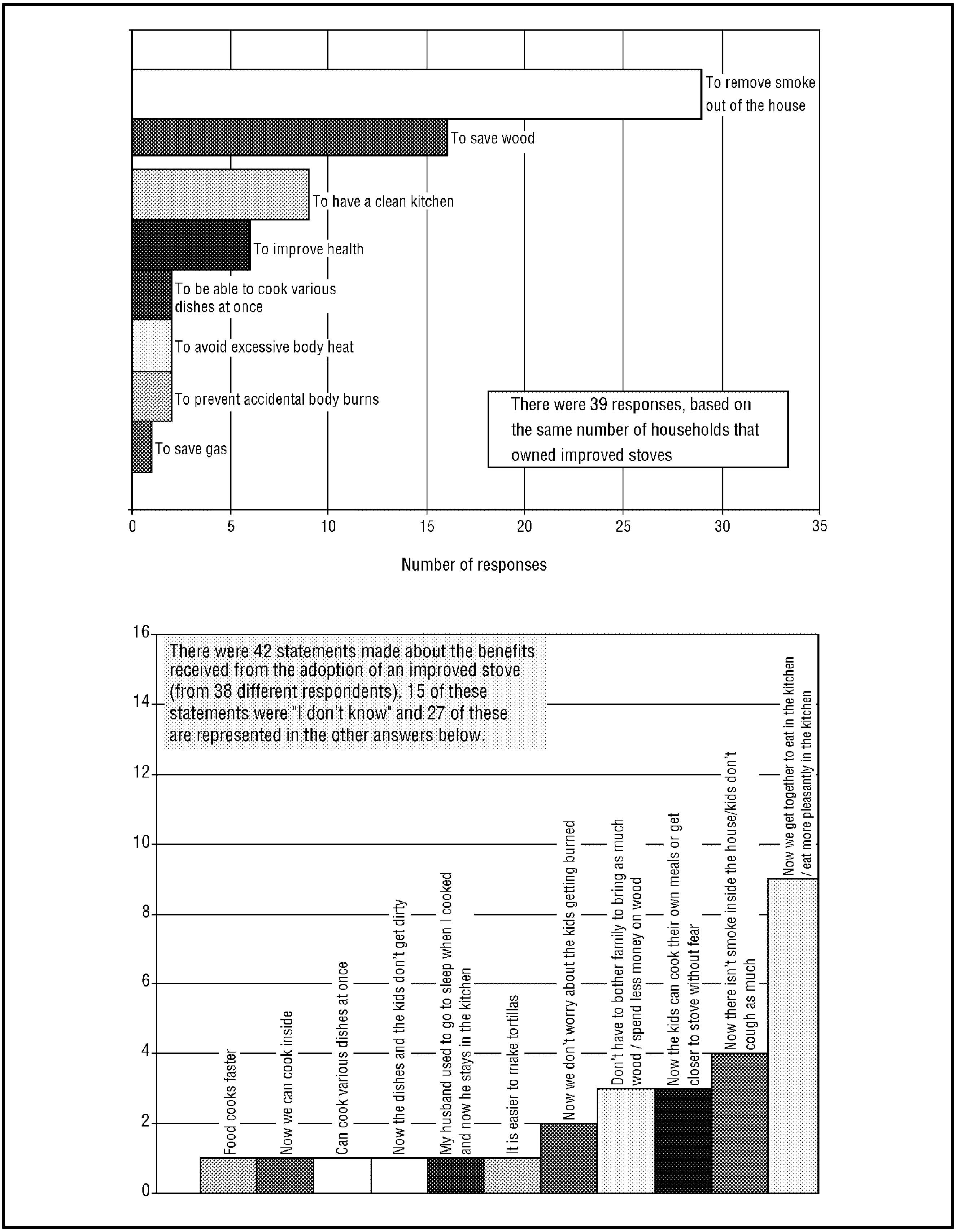
3.2.4. Monitoring and evaluation

A major effort is being made to comprehensively document and monitor the actual benefits achieved by the cookstoves. A "monitoring package" has been designed with the Mexican National Institute of Public Health, the University of California, Berkeley, the University of Liverpool, the Aprovecho Institute, and the Mexican National Institute of Ecology, with support from the Shell Foundation. The program includes the following.

1. Stove performance tests, both in laboratory conditions, such as the water-boiling test (WBT) and the controlled cooking tests (CCT), and in field conditions, such as the kitchen performance test (KPT).
2. Indoor air pollution monitoring, looking at the reduction in the concentration of particles ($PM_{2.5}$) and carbon monoxide associated with the transition from open fires to "Patsari" and from open fires to "Patsari" plus LPG cooking conditions.
3. Health impacts. For this purpose we will conduct a major study (600 households) looking at reduction in respiratory illnesses – particularly ARI – and other sicknesses associated with the inhalation of smoke from wood-burning.
4. Users' attitudes and preferences. This will serve to better understand women's priorities and needs regarding improved cookstoves as well as the changes in time, activities, and socio-cultural issues associated with the adoption of new stoves.

A nested sampling design is being applied to have a maximum simultaneous coverage of critical variables for a set of households. The tests and field surveys began in November 2004.

The program is also assessing two additional aspects. The first is the analysis of the global impact of the dissemination of improved cookstoves, a subject that requires further research work [Bond et al., 2004]. Specifically, we



Figures 5a and 5b. Reasons stated by households to buy an improved cookstove (5a, above) and benefits received by households that adopted the Patsari cookstove (5b, below)

Source: Valencia, 2004.

Notes

The figures show key results from a survey on preferences and attitudes regarding traditional, Patsari and LPG stoves conducted with 42 households. The study is part of the monitoring program on cookstove dissemination.

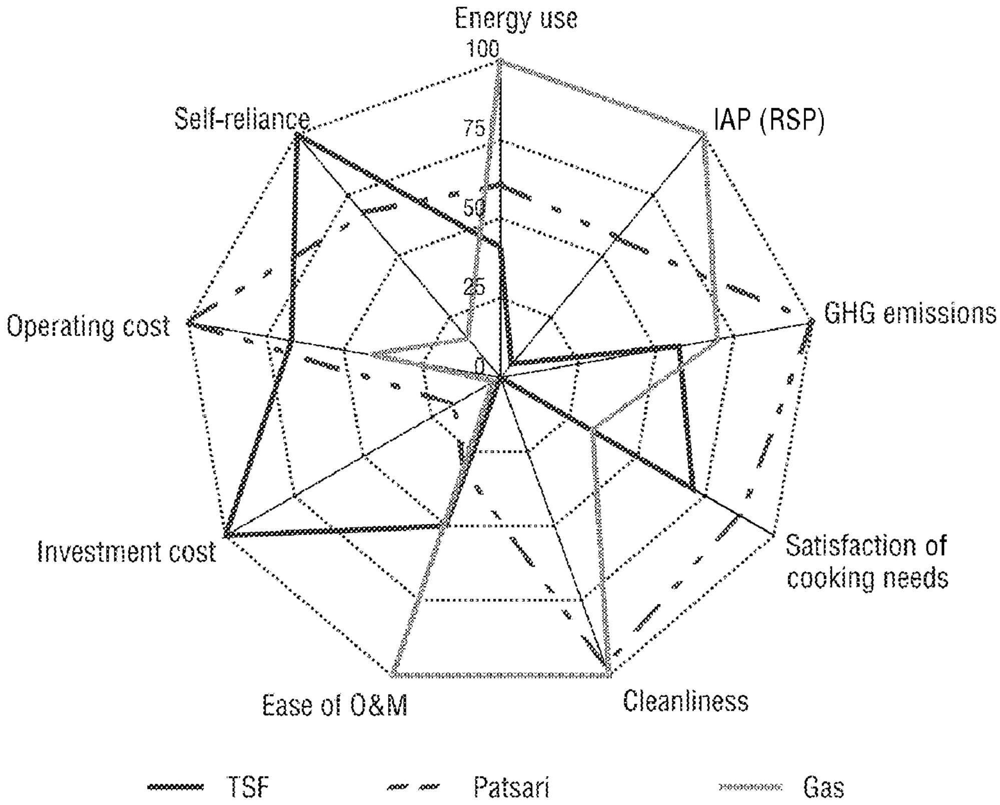


Figure 6. Comparative assessment of three cooking options in Mexico

Source: Adapted from [Galván, 2004]

Note

The figure compares three main cooking options – three-stone fires (TSF), Patsari cookstoves, and gas (LPG) cookstoves – in terms of nine key sustainability indicators. The values of each indicator have been normalized on a 0-100 % scale. The optimum is always 100 %, and can be achieved either by minimizing the specific indicator – such as energy use, IAP, GHG emissions, investment cost, and operating costs -- or by maximizing it -- such as in satisfaction of cooking needs, cleanliness, easiness of operation and maintenance, and self-reliance. The closer to the optimum the corresponding indicators are, the better an option scores. Trade-offs among the different options regarding social, economic and environmental indicators are readily seen; therefore the diagram helps better understand the implications of different choices regarding cooking devices. Refer to [Galván, 2004] for a complete description of the methods used to derive the indicators as well as their specific values in the original units.

will determine the emission factors and annual emissions of the main greenhouse gases – CO_2, CO, CH_4 and non-methane hydrocarbons (NMHC) – associated with the open fires as well as with the Patsari and LPG stoves in both laboratory and field conditions. The second aspect is a holistic assessment of the “sustainability” of different cooking options, integrating economic, environmental, and social indicators into a multi-criteria framework [Galván, 2004]. Using this innovative technique we can identify in a snapshot the main advantages as well as the trade-offs associated with different cooking options in terms of key social, economic, and environmental variables. The results of such an analysis comparing three cooking options – Patsari, LPG cookstove, and three-stone fires – are presented in Figure 6[2]. The radar, or AMIBA, diagram illustrates how the three cooking options score relative to nine indicators that have proved to be critical in terms of stove performance, users’ satisfaction, and overall impacts. The indicators are: energy use, indoor air pollution, greenhouse gas emissions, satisfaction of cooking needs, cleanliness, simplicity of O&M, investment cost, operating cost, and self-reliance. As can readily be seen in the diagram, LPG stoves score the best in terms of fire control, cleanliness, energy use and indoor air pollution. However, they are expensive, are not adapted to key cooking practices, such as tortilla-making, and score low in terms of local or regional self-reliance. TSFs, on the other hand, score highest on costs and traditional cooking practices, but perform badly in terms of energy use, health concerns, and cleanliness. Patsari cookstoves appear as a good compromise, as they perform well for traditional practices while at the same time help to significantly reduce indoor air pollution and greenhouse gas emissions. The main drawbacks are the investment cost and the fact that they involve more skills in terms of operation and maintenance.

3.2.5. Program outreach

Our program ultimately aims at improving the sustainability of household energy use in Mexico. The aim is setting up a center for stove research and dissemination that could catalyze activities in the field of cookstoves within Mexico, acting as a center for training, exchange of experiences, stove-testing, design of interventions and approaches. To that end we have trained 130 technicians and community workers, coming from government, academic and non-governmental organizations. We are developing a model that can be scaled up and replicated in other regions of the country. Three organizations working in the western and eastern parts of Mexico have already decided to use our approach to carry out a large-scale dissemination of Patsari cookstoves.

As part of our outreach activities, we have also started a national network on wood-burning cookstoves in close collaboration with the Mexican Network on Bioenergy. The cookstove network will serve to set a series of technical, safety and health-related standards for improved cookstoves as well as to foster the exchange of experiences and approaches among the different groups. We are also actively working to influence the national policy context on residential fuels. An important barrier is the lack of awareness of indoor air pollution issues and their potential solutions at high political levels. We are currently preparing a series of key documents oriented to decision-makers and multimedia presentations together with the National Forestry Commission and the National Institute of Ecology to begin solving this problem.

4. Lessons learned and current challenges

The experience gained so far has served to confirm that the dissemination of improved cookstoves is not just a "switching" of technologies, but a complex process that needs to be understood in terms of a breadth of technical, socio-cultural and economic issues. Below we discuss the main lessons learned and the associated challenges.

- *Properly designed and disseminated, improved wood-burning cookstoves result in substantial benefits to local households.* Patsari stoves help to achieve more than 50 % fuelwood savings for tortilla-making, which is the most common and intensive cooking task. Preliminary results show that reduction in IAP levels reaches 90 % in field conditions in comparison to open fires. Kitchen performance tests and a comprehensive IAP study are being conducted at the moment in local households to confirm the stated results.
- *Adoption of improved cookstoves implies a learning period that needs to be carefully monitored.* In the case of Patsari cookstoves, local women need to adapt themselves to cook standing instead of kneeling, to tend the fire in a different way, to use smaller pieces of wood, to clean the tunnels and chimney, and to cook with a metal *comal* instead of a ceramic one. All these changes imply an entrance barrier to cookstove adoption; many women take a month to adapt themselves to the new cookstove, a period when cookstove monitoring and user support is essential. We have also seen that cookstove adoption works faster with people who already have LPG stoves, partly because of economic reasons – i.e., these families have usually more cash to buy a new stove – but also because families with LPG stoves have already experienced new ways of cooking.
- *Financial incentives are essential for fast and wide-spread cookstove adoption.* The investment cost of the Patsari cookstove is still too high for most households. There are two reasons for this: (1) improving conditions in the kitchen is seen as a "women's" issue and has a low priority for men, who are those with the economic power within households, even despite an explicit recognition that smoke is a problem; and (2) in the specific case of Mexico, government programs have traditionally highly subsidized or even given away things for free in rural areas. This has also been the case with previous cookstove programs, particularly with regard to the labor costs associated with stove-builders. Thus, users are reluctant to pay the full costs of the new stoves.
- *Once adopted, improved cookstoves are seen as household "assets" and prompt new positive changes within households.* Confirming previous findings [Masera et al., 2000] we have seen that new kitchens are expressly built for the Patsari stove, kitchens are completely retrofitted, or they are integrated together with LPG stoves into a single kitchen where families gather together to eat [Valencia, 2004]. Therefore, when it occurs, adoption of Patsaris is essentially a one-way process; households realize the benefits of a clean kitchen and are very reluctant to go back to the open fire; paradoxically, however, many households prefer to have the kitchen built or modified *first* and thus delay the investment in the Patsari!
- *Multiple fuel users constitute an important market niche for improved cookstoves.* As stated before, mixed-fuel users usually adopt new cookstoves faster than exclusive fuelwood users. Also, the combination of LPG cookstoves with Patsari cookstoves provides families with large and sustained gains in health conditions, versatility in terms of cooking tasks, resilience to fuel price fluctuations, and user satisfaction in terms of traditional cooking practices.

We are currently working on the identified issues and barriers to speed up the adoption process. For example, we are collaborating closely with the local clinics, to reinforce the training and awareness-raising campaign on indoor air pollution. We have also made the cookstove construction-dissemination process more efficient and robust. We are also including the cookstove base and *comales* in the financial package to reduce further the up-front costs of the Patsaris and are working to reduce cookstove costs even further. Further improvements to the current Patsari stoves include increasing stove durability and ease of O&M. At the moment, efforts are concentrated on wood-burning cookstoves, as LPG is slowly entering the household energy pattern by itself. In the coming years, however, we will also explore alternatives to lower the investment cost of using LPG – which mostly comes from the stove and the tank – and facilitate the transition to multiple fuel use within local households.

5. Conclusions

Cookstove dissemination programs are evolving from "projects" narrowly targeting stove construction and fuelwood savings to more integrated "program" approaches looking at providing a set of health, environmental and socio-economic benefits. For them to be successful, systemic and interdisciplinary approaches are needed, including work on technology innovation, users' needs and priorities, market development and innovative financing. Strong and sustained efforts need to be devoted to monitoring stove performance in the field and to ensure the sustainability of the achieved benefits.

Being more complex and ambitious, the new approaches come with a new set of challenges. More than ever, an intense cross-fertilization among groups, both North-South and South-South, is urgently needed. Donors and governments need to realize that *sustained* and long-term efforts rather than the typical two- to three-year projects are needed for setting up the type of integrated approaches described above.

There is a need to support continuous technology innovation, getting research institutions to work hand in hand with local organizations on new stove designs that are more robust, cost-effective and clean. Participatory research is also needed to better understand users' priorities and needs and also to better assess the dynamics of multiple fuel use. Innovative and creative financial mechanisms are required that help users overcome the investment costs of improved cookstoves. Users – specifically women – need to have a strong say in program design and implementation. Finally, to be successful in the medium and long term, cookstove programs need to look at the overall policy context and integrate cookstove programs within larger sustainable rural development strategies. The challenge is substantial, but fostering the current partnership and networks on household energy use and learning from each other's experience will surely pave the way to a larger number of success stories in the near future. ■

Notes

1. Because of space limitations, in this paper we present an overview of the main survey results. Refer to [Valencia, 2004] for a complete description of the survey methodology and for a detailed discussion of users' preferences and attitudes related to both traditional and improved cookstoves.
2. Galván [2004] used the MESMIS framework – an integrated methodology for assessing the sustainability of alternative options – [Masera et al., 1999] and two multi-criteria methods to compare five cooking options: Patsari, Patsari plus LPG, LPG cookstove, LPG plus three-stone fire, and TSF. Indicators were derived for economic issues (such as net present value, investment costs), social issues (related to stove operation and adaptability to local cooking practices), and environmental issues (local and global impacts of fuel use). We refer readers to [Galván, 2004] for a comprehensive discussion of the methodological aspects and results of the evaluation process.

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