Bensch, Gunther; Peters, Jörg

**Conference Paper**

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# Combating Deforestation? – Impacts of Improved Stove Dissemination on Charcoal Consumption in Urban Senegal

Gunther Bensch and Jörg Peters

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**JEL Classification:** O13, O22, Q41, Q56

**Abstract:**

The dissemination of improved cooking stoves (ICS) is frequently considered an effective instrument to combat deforestation. This paper evaluates the impacts of an ICS dissemination project in urban Senegal implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (German Agency for International Cooperation, or GIZ). Based on a survey among 624 households, we examine the effects of the intervention on charcoal consumption. Given a complex cooking behavior in urban Africa with simultaneous usage of different fuel and stove types, the virtue of our data set is that it provides for detailed information on individual stoves and meals. This allows for estimating charcoal savings by accounting for both household characteristics and meal specific cooking patterns. On average, households using an ICS save around 25 percent of charcoal per stove utilization. In total, around 6.1 to 6.9 percent of the Dakar charcoal consumption is saved due to the ICS dissemination project.

**Correspondence:** Dr. Jörg Peters, Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI), Hohenzollernstr. 1-3, 45128 Essen, Germany. Phone: 0049 (0)201 8149-247, email: peters@rwi-essen.de.

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## 1. Introduction

In many developing countries, biomass is the most important source of energy. Today 2.5 billion people use traditional biomass as their primary fuel for cooking (IEA 2009). The reliance on biomass for cooking purposes – essentially wood and charcoal – is particularly high in Sub-Saharan Africa. With 81 %, the proportion of people relying on these fuels is higher than in any other region (UNDP/WHO 2009). Considering the low conversion rates of raw wood into charcoal, total wood consumption for cooking continues to grow in Africa, not least due to an increased usage of charcoal as a result of ongoing urbanization processes (FAO 2008, IEA 2006).

The dominant usage of wood-based fuels is particularly problematic, since it contributes to deforestation as the wood tends to be harvested unsustainably. This in turn is closely related to local and global environmental issues such as land degradation, loss of biodiversity, and air pollution. In the case of West African Senegal, the deforestation issue has a particularly high relevance. Two approaches can reduce deforestation pressure on the demand side: The usage of more efficient, so-called, *improved cooking stoves* (ICS), or switching to non-wood fuels such as liquefied petroleum gas (LPG) or kerosene. In Senegal, both strategies have been pursued for several decades, leading to a situation in which LPG is dominantly used in urban areas, with charcoal representing the primary wood-based cooking fuel. While a national subsidy and promotion program to foster LPG usage was launched already in the 1970's, first ICS distribution and dissemination efforts date back to the 1980's. Since then, the international donor community and national governments have put much effort into disseminating ICS in Senegal same as in other developing countries.

Rigorous impact evaluations of these development interventions, however, are rare (for exemptions, see DUFLO, GREENSTONE, AND HANNA 2008a, 2008b; DIAZ ET AL. 2007, SMITH-SIVERTSEN ET AL. 2004, BAILIS 2009). Evidence for Africa is completely lacking. This paper therefore focuses on the robust evaluation of the impacts of ICS usage on charcoal consumption related to a dissemination project by *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ) in urban Senegal. It starts out from the findings on ICS adoption in the intervention regions presented in BENSCH, PETERS, AND ZIMMERMANN (2011). These support the validity of the identification strategy followed in this paper of conducting a cross-sectional comparison of ICS owners and non-owners.

The research project was assigned by the Independent Evaluation Unit of GIZ. Based on a survey among 624 urban households conducted between August and September 2009 in the cities of Dakar and Kaolack, we examine the potential reduction in charcoal consumption induced by the usage of ICS. Beyond the direct environmental impact, savings in the consumption of charcoal are decisive for all potentially following impacts. These range from health to gender and poverty through reductions in emissions of harmful pollutants (indoor air pollution) and in terms of financial or work-load burdens. Hence, by rigorously assessing charcoal consumption, we implicitly also examine the plausibility of impact assumption on these indicators. To the extent to which charcoal is economized, one can, for example, assume that people's exposure to harmful particles is also reduced. The virtue of our data is that it contains detailed information on cooking behavior and fuel usage on a per dish basis. A dish here refers to the warm food prepared on a single stove as part of a typical meal preparation. In our context, a typical meal is composed of two dishes, mostly rice and sauces. Having this data at hand, we are able to estimate charcoal savings per dish in an Ordinary Least Squares (OLS) equation accounting for household-specific characteristics, as well as dish and meal specific cooking patterns such as the number of persons cooked for and the type of dish that is cooked. Ultimately, we can estimate the total charcoal savings induced by the GIZ project.

The remainder of the paper is organized as follows: Section 2 reviews the country and project background, Section 3 presents the research design, followed by a discussion of the identification assumption in Section 4. In Section 5, we show the results. Section 6 concludes.

## 2. Country and project background

Urban cooking in Senegal is dominated by LPG. Already in the 1970's, the butanisation program, a subsidy and promotion program to foster LPG usage was launched. LPG continues to be subsidized[1] lifting Senegal among the countries with the highest LPG consumption per capita in the region (World Bank/WLPGA 2001). In 2002, around 71 % of urban households in Senegal and even 88 % of households in Dakar used LPG as primary cooking fuel (ANSD 2006). Nevertheless, charcoal is used by most households as a complementary fuel. Charcoal demand tends even to rise, partly due to a constant population growth of 2.6 % per year (AfDB 2010). In urban areas, where the charcoal is mostly used, the population grows even at 3.1 % per year (CIA 2010).

According to data gathered by the National Union of Forest Workers (UNCEFS) in 2010, the capital city of Dakar alone consumed 94,000 tons of charcoal per year, which corresponds to one fifth of the national consumption (SIE 2007). This demand can only be met using wood sources extracted several hundred kilometers away from the capital. The charcoal is often produced in the neighboring country, Gambia, or in the Casamance region in Southern Senegal. These more humid areas produce much more biomass than the dry regions in Central Senegal.

Outside the Casamance, Senegal is a dry country. While it still counts a relatively high share of primary forests, these forests mainly consist of small trees and shrubbery. Deforestation leads to annual losses of forests of 0.5 %, which comes close to the average of West African countries (FAO 2007, FAO 2005a, WDI 2009, FAO 2005b). FAO figures on Africa and Senegal indicate that agricultural land clearance has been the predominant cause of deforestation (WEC/FAO 1999 and FAO 2005b). TAPPAN ET AL. (2004) support this view, but also emphasize the role of charcoal production in the decline in the level of woody cover in the remaining forests in Senegal. According to their surveys, charcoal

[1] While direct fuel subsidies have been removed in June 2009 under the ongoing pressure of IMF, the government at the same time uses different indirect subsidies to avoid that international price increases pass through. For example, LPG is exempted from customs duties and VAT (LAAN, BEATON, AND PRESTA 2010, MEB 2009, APS 2010).

production has led to a degradation of 28 % of Senegal's wooded savannas and woodlands (TAPPAN 2000). For two main reasons the deforestation effect of charcoal can be considered as even worse than for firewood: First, the charcoal production process is intensive. It thereby puts more pressure on the forest resources than fuelwood collection, which is rather extensively carried out by rural populations (KAMMEN AND LEW 2005). Second, the production process tends to be inefficient. Cooking with charcoal therefore requires roughly twice the amount of raw wood that is needed when cooking with fuelwood.[2]

Against this background of deforestation and woodfuel scarcities, GIZ is active in the Senegalese energy sector with a wide range of interventions put together under the umbrella of the energy program PERACOD (Programme pour la promotion des énergies renouvelables, de l'électrification rurale et de l'approvisionnement durable en combustibles domestiques). One of PERACOD's components addresses the supply of charcoal via promoting sustainable forest management and charcoal production approaches. On the demand side, PERACOD promotes the dissemination of ICS via its sub-component *Foyers Améliorés au Sénégal* (FASEN). The FASEN ICS intervention is the focus of the present paper.

The ICS promoted by FASEN is called *Jambar*. The Jambar is a simple stove, composed of a metal casing and an insert of fired clay. Thanks to simple design improvements, the fuel burns more efficient, the heat is better conserved and much more focused towards the cooking pot than with traditional stoves.[3] Different ICS models exist to be fuelled with firewood or charcoal. The latter is the relevant one for urban Senegal, where charcoal is virtually the only used woodfuel. The traditional counterpart is the so-called *Malagasy* here, a simple pyramidally shaped single-pot metal charcoal stove. In so-called Controlled Cooking Tests, in which local women cook typical meals under day-to-day conditions with both stove types, the Jambar stove saved 40 % of charcoal compared to the Malagasy.

[2] Around 5 kg of wood yield 1 kg of charcoal while the caloric content of charcoal is only twice that of wood (KAMMEN AND LEW 2005, GTZ 2009).

[3] See BRYDEN ET AL. (2006) and GTZ (2009) for further information on ICS.

FASEN followed a strategy to focus first on urban areas. It started its activities in Dakar in June 2006 and extended them to Kaolack in 2007. While the metropolitan area of the capital Dakar counts some 2.5 million inhabitants, Kaolack has roughly 200.000 inhabitants making it the fourth largest city in Senegal. Kaolack is an important peanut trading and processing center and is situated 190 kilometres South-East of Dakar in the heart of the Bassin Arachidier, Senegal's major agricultural region.

The FASEN dissemination strategy was intended to learn from the inability of predecessor projects to create a sustainably functioning market for ICS in Senegal. Firstly, the project does not directly subsidize ICS production or purchase. Instead, on the supply side potters and whitesmiths are trained in producing ICS fulfilling pre-defined quality requirements. They are also supported through specific financing mechanisms and in the marketing of their products. On the demand side, women groups and retailers are supported to market ICS towards the households. For example, cooking demonstrations are organized as social events, in which cooking with the traditional Malagasy stove is compared to preparing a dish with an ICS.

As part of the outcome-oriented Dutch-German Energy Partnership *Energising Development* (EnDev) implemented by GIZ, FASEN has to report how many people in the project's intervention areas have acquired an ICS and, hence, have benefited from the FASEN development measure. For this purpose, the number of disseminated ICS is meticulously monitored at the level of the whitesmiths. Around 40 of them are constantly working with FASEN and are visited by a FASEN staff member two times a month. The figures collected at whitesmiths are cross-checked at potters, women groups and retailers. In total, around 78,500 ICS have been disseminated by the end of 2009, 71,600 in Dakar and 6,900 in Kaolack. Beyond the direct benefits of the intervention – disseminating the ICS – FASEN intends to induce indirect benefits: Contributing to the combat against deforestation, but also achieving impacts on health, gender and poverty. According to

Rehfuess/WHO (2006), for example, indoor air pollution causes the premature death of 1.5 million people annually, among them some estimated 6,300 in Senegal (WHO 2009).

## 3. Data and research design

### 3.1. Identification Strategy

The primary objective of this evaluation is to identify how much woodfuel is in fact saved in households using ICS. In general, savings rates for ICS can be obtained in so-called Controlled Cooking Tests (CCT). In a CCT, a cooking woman prepares the same meal on both a traditional stove and an improved stove in order to compare the woodfuel consumption of the both stove types. They thereby provide for an idea of how much woodfuel can be saved when switching from the first to the latter. The test yielded a reduction of 40 % in Dakar. The effective savings, however, most probably deviate from these results for the following reasons: first, the actual day-to-day cooking habits are more complex, which, for example, implies the simultaneous use of different cookstoves (e.g. LPG and charcoal stoves) and different savings rates for different dishes. Second, the CCT may be biased from what is known as the Hawthorne effect. This refers to the effect on the performance of subjects triggered by the sheer fact of being observed and – as in our case – even measured. The behavior of a cook in the CCT can therefore hardly be expected to exemplify her behavior in the preparation of a business-as-usual meal at home. A third reason are potential adjustment processes after acquisition of a more efficient stove. The household might prepare more hot meals or the number of persons the meals are prepared for can change. Fourth, the CCT cannot account for the heterogeneity of households in terms of socio-economic characteristics that might affect fuel consumption such as income or education. Finally, the cook should be equally habituated in cooking with the different stove types in order to properly compare the fuel consumption for the different stove types, which typically cannot be the case in CCTs. Conducting the ICS evaluation based on a survey among a large sample of households, we are able to capture the diversity and dynamics of real life cooking practises and can thereby overcome or at least mitigate all these deficiencies of the CCT.

Certain methodological considerations have to be accounted for in such an evaluation, in order to rigorously examine fuel savings that result from the replacement of traditional stoves by ICS. RAVALLION (2008) and FRONDEL AND SCHMIDT (2005) comprehensively familiarize with these considerations related to development interventions and environmental programs, respectively. Ideally, one would have to compare the impact variable after a household received the treatment, here the acquisition of an ICS, to the counterfactual situation of not having received it. This mean effect of treatment on the treated $M$ is the difference of conditional expectations $E$ of the impact variable $Y$ expressed as follows:

$$M = E(Y^{T=1} \mid X, T = 1) - E(Y^{T=0} \mid X, T = 1) \quad (1)$$

where $X$ refers to a set of household characteristics that determine the outcome beyond treatment $T$. Obviously, we can never observe both situations for the same household, since it either receives the treatment or not. In order to overcome this fundamental evaluation problem, we have to formulate identification assumptions that allow replacing the unobservable and, hence, non-computable counterfactual outcome.

Since the FASEN project under investigation has already been underway for over three years at the time of survey preparation and no baseline study has been conducted, before-after comparison proved to be impossible. Instead, we resorted to a cross-sectional comparison group that serves to simulate the counterfactual. We basically examine households that chose to buy an ICS and compare them to non-owners.

The two fundamental identification assumptions needed to estimate woodfuel savings in this setup are the following: First, the non-owning control households behave like the owning households would do if they had not bought an ICS. This would allow us to replace the right-hand side of equation (1) by the conditional expectation of the impact variable for the control group, which would read in functional form:

$$E(Y^{T=0} \mid X, T = 1) = E(Y^{control} \mid X, T = 0) \qquad (2)$$

so that equation (2) plugged into equation (1) becomes

$$M = E(Y^{T=1} \mid X, T = 1) - E(Y^{control} \mid X, T = 0) \qquad (3).$$

This implies that we assume that there are no systematic differences in the $X$ between the owners and non-owners that affect both the decision to buy a stove and impact variables at the same time. It is, however, likely that such systematic differences exist. Typically, certain characteristics make households more inclined to obtain the treatment, here the ICS, than others. For example, one might expect that better educated households are more likely to buy an ICS, because they better understand its advantages or financial benefits. At the same time, the better education might make them being more capable to employ any woodfuel stove more efficiently. As a consequence, a simple comparison of ICS owners and non-owners would ascribe at least parts of the difference in the woodfuel consumption impact indicator values to ICS ownership, even though they are, in fact, induced by differences in the education level. The education level would confound the impact assessment.

Yet, this factor is to a sufficient degree observable via the level of education of the household members. We therefore account for this and similar characteristics such as household income in our analysis. In contrast, some of the heterogeneity among ICS owning and non-owning households may be hard to capture and remains unobserved. Examples of a potentially unobserved difference that might violate the identification assumption is the womens' intrinsic propensity to save resources or their astuteness. These are hardly measurable and may affect the decision to buy an ICS as well as charcoal consumption. In order to assess the appropriateness of our identification assumption, we examine the question of which type of households buy an ICS and why in Section 4. It will become clear that we do not expect unobservable characteristics to drive the decision to buy an ICS that would bias our impact assessment. Hence, there is some hope that the effect of ICS ownership can be isolated – holding other household characteristics constant.

In addition, our cross-sectional evaluation has to fall back on the level of stoves, not only the level of households, in order to obtain unbiased results. This is required, because a myriad of different fuel and stove choice patterns exists among households, mostly involving LPG and charcoal. For example, households prepare the breakfast on an LPG stove and the lunch on two different stove types, an LPG and a charcoal stove, either traditional or improved. The stove-related second identification assumption therefore implies that a dish cooked with an ICS would have been cooked on a Malagasy stove had there been no FASEN intervention. The functional representation thereby becomes:

$$M = E(Y^{T=1} \mid X, Z_j, T = 1) - E(Y^{Control} \mid X, Z_j, T = 0) \qquad (4).$$

In comparison to equation (3), a set of dish-related characteristics $Zj$ is added where j refers to the different dishes throughout the day. Such a characteristic is, for example, the distinction between main and side dish, which are mostly rice and sauce respectively in our context, or the meal the dish is cooked for. In addition, our identification assumption implies that $T = 1$ more specifically refers to a dish being cooked with an ICS while $T = 0$ stands for a dish cooked on a Malagasy stove.

Similar to the household-related first assumption, findings presented in Section 4 underpin that this identification assumption can be expected to hold. As outlined in the following section, we meet the need to account for the stove level by gathering detailed information on individual stoves used for meal preparation.

### 3.2. The Data

In light of the methodological considerations presented in the previous section, we based our observational study on survey data collected among ICS owning and non-owning households. Before survey implementation, the share of ICS owners in the intervention areas of the project was expected to amount to around 20 to 30 %. We therefore considered simple random sampling as the most appropriate sampling approach to reach both representativeness and a sufficient number of ICS owning households in the sample for the intended statistical analysis. During fieldwork preparations in August 2009, we then selected 16 quarters of Dakar and 4 quarters of Kaolack, in which FASEN had been active, to be included in the survey. Enumerators were recruited among students from the *Ecole Nationale d`Economie Appliquée* (ENEA), a faculty specialized in the education of rural development agents familiar with field and survey assignments. After enumerator training and pre-tests in collaboration with local researchers, the survey started in early September 2009 and ended a month later. The enumerators have been accompanied during the whole survey by a researcher from our team. In total 624 households were interviewed – 508 in Dakar and 116 in Kaolack.

The major survey tool was a structured questionnaire covering virtually all socio-economic dimensions that characterize the household's living conditions. A particular focus of the questionnaire is on cooking energy, cooking behavior and patterns of fuel provision. The core impact determinant, the amount of charcoal consumed per stove used for meal preparation, was elicited from the person responsible for cooking. She was asked to mention all stoves used for meal preparation throughout a typical day as well as information on the cooking duration and the number of persons cooked for. In case the stove was fuelled with wood or charcoal, she was further asked to specify the amount of fuel used with the specific stove for the specific dish. The enumerators were equipped with weigh scales to weight this fuel. Yet, households most often were able to indicate the weight of the fuel in kilogram themselves. This is due to the fact that households usually buy charcoal for each meal individually in terms of kilograms. For this reason, they are very familiar with quantifying the amount they use. These statements can therefore be expected to be accurate.

In addition to cooking-related questions, the questionnaire also covers income, income sources, time use, and gender related issues. The interviews took, on average, around 45 minutes. The structured questionnaire delivers data for quantitative analysis and is complemented and cross-checked by qualitative information from semi-structured interviews among selected key informants such as women groups, ICS producers, or "chefs du quartier".

## 4. Cooking behavior and living conditions in the survey regions

This section's objective is first, to discuss the comparability of the ICS owners and non-owners. It is crucial to learn to what extent we will be comparing the comparable and, hence, whether our identification assumption is appropriate. For this purpose, it will be assessed to what extent differences in household characteristics are observable. In addition, we scrutinize in how far unobservable differences may play a role. The second objective of this section is to present the setting of the evaluation – the living conditions in the survey regions, the households' structure, activities, financial situation, and, in particular, the cooking behavior.

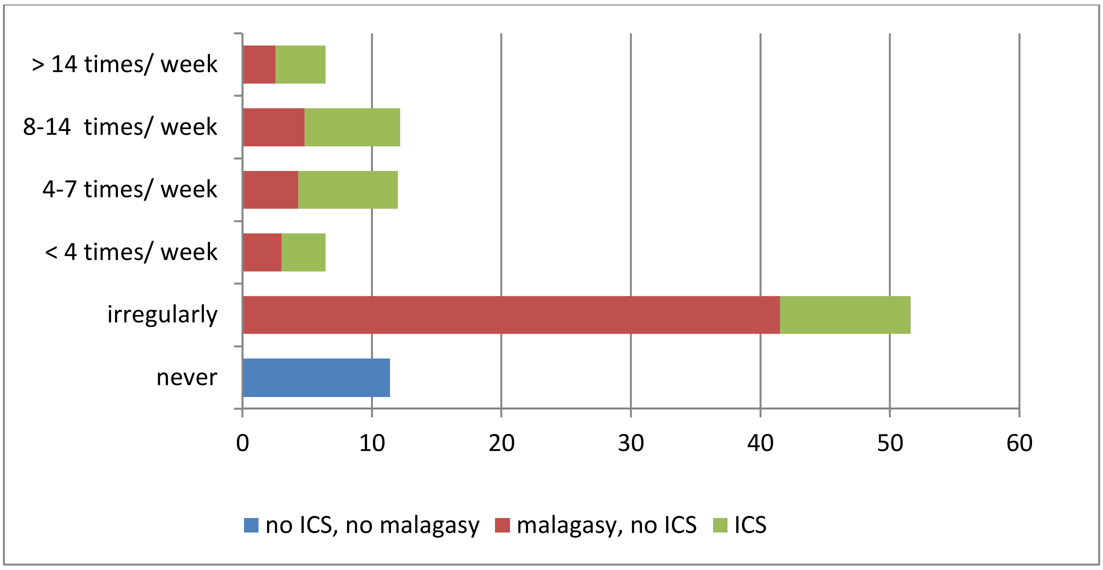
### 4.1. Cooking behavior

The dominant cooking fuel in Dakar and Kaolack is LPG. Around 93 % of interviewed households in Dakar and around 53 % in Kaolack state that their principal cooking stove is a LPG cooker. They appreciate LPG as a clean, fast and easily manageable cooking fuel. The remaining households use principally charcoal. Firewood is almost never used in urban Senegal. Only 2 % of the surveyed households use firewood at all, which is why we focus our analysis on LPG and charcoal. 92 % of households own more than one stove and – with few exceptions – stoves for the different fuel types.

There are four principal reasons why households do not use LPG alone: First, people sometimes prefer the taste of meals cooked on a charcoal stove. Second, LPG is not constantly available. Supply shortages occur frequently, but unpredictably. Households then resort to charcoal. Third, although LPG is not more expensive than charcoal on a per dish basis, households have to "invest" in an LPG bottle, which lasts for around ten days. The price of a 6 kg bottle was at 2700 FCFA in Dakar and 3400 FCFA in Kaolack at the time of the survey. Households with little and unstable income prefer charcoal that can be purchased in small quantities on a day-to-day or even meal-to-meal basis. Fourth, even if people are able to buy the LPG bottle, they are likely not to have more than one. Yet, the typical Senegalese meals that are also prevailing in the survey regions are based on two dishes, mostly rice and sauces, for which two stoves are required.

Figure 1: *Frequency of charcoal stove use per week*

Share of households in percent.

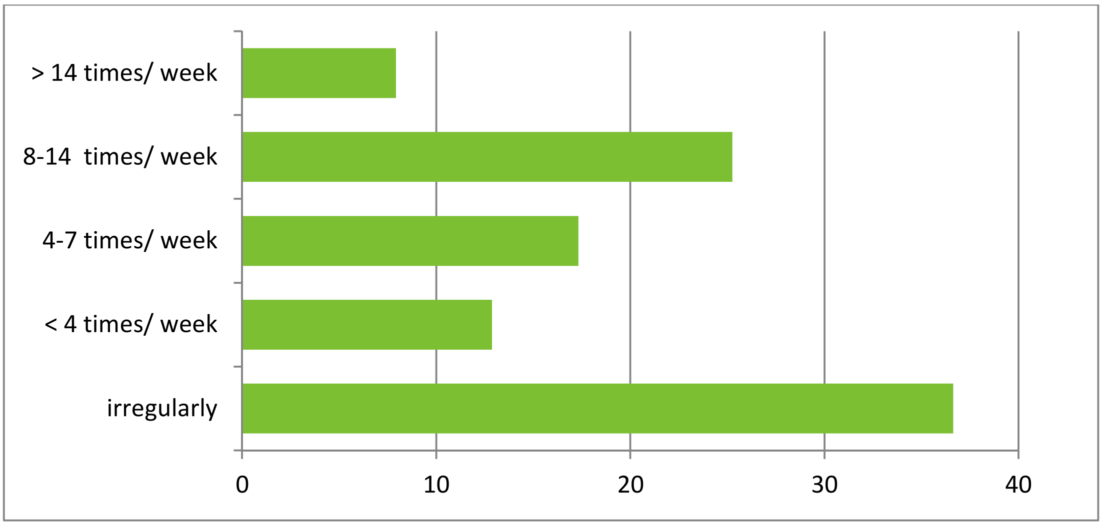



With particular respect to charcoal usage, we can see from Figure 1 that 11 % of our sample households do not have a charcoal cooker and therefore never use charcoal. Another 53 % predominantly use LPG in their every-day life and use charcoal only occasionally, for example for celebrations, specific dishes, or in case of LPG shortages.

Even among the ICS owners, a considerable share of 37 % does not use the ICS regularly (Figure 2). Since this has implications for the following impact analysis of ICS ownership, we distinguish between two groups: (1) the *LPG always* users that employ charcoal never or only in exceptional cases and (2) the *simultaneous LPG and charcoal* users, who use LPG but also charcoal on a regular basis.

Figure 2: *Frequency of ICS use among ICS users*

Share of households in percent




Among the *LPG always* households with ICS, we cannot expect strong impacts, since they simply do not use the ICS on a regular basis. In addition, their irregular ICS usage implies that we do not have data at hand on the every-day cooking fuel consumption. For these reasons, we will in the following focus the comparability assessment on the *simultaneous LPG and charcoal* users and calculate stove and meal specific charcoal savings based on this subsample only.

### 4.2. Comparing the comparable?

Virtually all households are connected to the electricity grid and water access is widely available as well. Most of the households (83 %) even dispose of a private tap at home. Housing conditions, the composition of households, and their financial situation suggest a better status of ICS owners. We perform t- and chi-square tests to find out whether in fact statistically significant differences between our two comparison groups exist. These can only be found in the number of rooms inhabited – even in spite of a slightly lower household size for ICS owning households – and bank account ownership, which is a common proxy for both the regular reception of income and access to credits. Table 1 also shows the primary occupation of the household heads constituting the decisive income source. Again, no substantial differences between ICS owners and non-owners can be seen. This supports qualitative findings from our field work, suggesting that income is not a decisive variable in driving the decision to obtain an ICS.

Table 1: *Housing conditions and household composition*

| Variable | Charcoal and LPG | | Significance level |
|---|---|---|---|
| | ICS owner | No ICS | |
| **Number of observations** | 118 | 92 | - |
| **Housing Conditions** | | | |
| Average Number of rooms inhabited per household | 5.8 (2.8) | 5.0 (2.5) | 5% |
| Share of households that share kitchen | 29.8% | 37.2% | - |
| **Household composition** | | | |
| Average household size | 8.0 (2.9) | 8.3 (3.3) | - |
| Share of female heads of household | 21.4% | 22.8% | - |
| **Financial situation** | | | |
| Share of households that receive remittances | 30.2% | 28.3% | - |
| Average monthly household income per working age household member (in 1,000 FCFA, excl. students) | 80.5 | 74.6 | - |
| Average monthly household income (in 1,000 FCFA) | 273.3 (235.6) | 237.9 (170.0) | - |
| Share of households that hold a bank account | 37.3% | 23.9% | 5% |
| **Primary occupation of household head** | | | - |
| Managers, professionals, technicians | 21.2 % | 16.7 % | |
| Services and commerce | 23.0 % | 28.9 % | |
| Agriculture and crafts | 23.0 % | 23.3 % | |
| Elementary occupations | 7.1 % | 8.9 % | |
| Emigrant (not further specified) | 4.4 % | 0 % | |
| Household, child care and retirement | 17.7 % | 16.7 % | |
| Unemployed | 3.5 % | 5.6 % | |

Note: The grouping of employed heads of households into the top four occupation categories is based on an adaptation of the ILO occupation classification ISCO-88 by Elias and Birch (1994) according to so-called skill levels. Stand errors in parentheses. Differences between the two groups at a significance level of a least 10 % tested by means of t- and chi-square tests are pointed out in the very right column.

Beyond income, it is frequently argued that the probability of ICS adoption depends on the ability of a household to understand the advantages of ICS usage. Among the observable variables, this can best be grasped by the educational level of the women. Table 2 therefore contains information on the education of the household's mother. In fact, we find some differences between ICS owners and non-owners in terms of both years of schooling and highest level of education.

Table 2: *Gender-related variables*

| Variable | Charcoal and LPG | |
|---|---|---|
| | ICS owner | No ICS |
| **Highest Education of Mother in the household** *** | | |
| no education | 33.0% | 55.6% |
| up to secondary school | 65.2% | 43.3% |
| University | 1.7% | 1.1% |
| Years of schooling of Mother in the household *** | 4.7 | 2.9 |
| Any household member responsible for cooking has at least secondary school level | 44.3% | 34.8% |

| Variable | Charcoal and LPG | |
|---|---|---|
| | ICS owner | No ICS |
| **Household member responsible for household budget** | | |
| father | 55.1 % | 53.3 % |
| mother | 30.5 % | 28.3 % |
| both | 14.4 % | 18.5 % |

*, *, ** and *** indicate differences between the two groups at a significance level of 10 %, 5 % and 1 %, respectively (tested by means of t- and chi-square tests)

Apart from these observable differences between ICS owners and non-owners one might suspect unobservable differences that could also bias a cross-section comparison. If one assumes that some kind of astuteness is required to grasp the benefits of ICS or to arrange the small investment into an ICS and this astuteness cannot be captured by the educational level, this would induce problems if this astuteness also affects the outcome of woodfuel consumption. A similar reasoning applies for a potential intrinsic propensity to save resources. During the field work, we put much effort on understanding the process underlying the decision to purchase an ICS by many open and qualitative interviews. The insights and results are extensively presented and discussed in BENSCH, PETERS, AND, ZIMMERMANN (2011). The basic message is that no clear indication for a distorting effect of the unobservable variables astuteness and intrinsic propensity to save resources could be found. Overall, ICS adoption seems to be mainly driven by personal relations: If a neighbor or a friend buys an ICS, this clearly affects the inclination to buy one. Social proximity to women groups that market the ICS also plays a role. While these network characteristics are difficult to grasp, we do not have reason to believe that these factors also affect our outcome variable charcoal consumption. Only if this were the case, our impact assessment would be biased.

Also based on qualitative findings from the field work, the patterns of charcoal stove usage can be identified as a major driver of the decision to buy an ICS: Households that prefer to use a charcoal stove for the main dish are more likely to buy an ICS than those that use it only for side dishes like sauces. This is due to two reasons: First, households that use charcoal stoves for main dishes use it more often than those that use charcoal for side dishes. Second, the main dish requires longer cooking time and, hence, bears higher potentials for charcoal savings. Since we have detailed data on the usage of each stove individually, we can easily control for this factor.

## 5. Impact Assessment

### 5.1. Charcoal consumption per dish

The descriptive survey results presented in Section 4 have revealed that households in urban Senegal in principal use LGP and charcoal simultaneously and employ different stoves for different meals with different frequencies. An appropriate assessment of the efficiency of ICS effectively in use can therefore not be carried out on the household level. Instead, we account for these features of cooking customs in our analysis by examining the charcoal consumption per meal on stove level. Basically, we compare the usage of Malagasy stoves to ICS, thereby assuming that, if there was no ICS, Malagasy stoves would be employed. Before we analyze the impact of ICS usage using Ordinary Least Squares regressions, we first examine the mean values of charcoal consumption for these two stove types.

We account for three basic particularities that affect charcoal consumption for meal preparation and, consequently, the savings potentials: First, the different dish types prepared as main and side dish respectively. Second, we account for the number of people a meal is prepared for and, third, whether it is a breakfast, dinner, or lunch meal. Accordingly, Table 3 shows charcoal consumption per dish and per capita for the different meals to determine the efficiency gain.

Table 3: *Charcoal consumption per dish and savings rates*

| Variable | Malagasy Stove | | ICS | | Savings Rate (in %) |
|---|---|---|---|---|---|
| | Number of observations | Average charcoal consumption per capita (in kg) | Number of observations | Average charcoal consumption per capita (in kg) | |
| **Breakfast** | | | | | |
| all dishes | 15 | 0.078 (0.04) | 14 | 0.072 (0.06) | 7.5 |
| **Lunch and dinner** | | | | | |
| main dishes | 61 | 0.228 (0.12) | 110 | 0.157 (0.07) | 31.3 |
| side dishes | 77 | 0.201 (0.15) | 68 | 0.156 (0.08) | 22.4 |
| all dishes | 138 | 0.213 (0.14) | 178 | 0.156 (0.07) | 26.8 |
| **All Meals** | 153 | 0.200 (0.14) | 192 | 0.150 (0.08) | 24.8 |

Note: Stand errors in parentheses.

The savings rate is highest if the ICS replaces the Malagasy for main dish at lunch. Here, almost 37 % of the charcoal is economized, which confirms the results from the Controlled Cooking Tests. Yet, the average savings rate across all applications is only 24.8 %. For preparation of a dinner main dish the savings rate amounts to only around 27 %. For breakfast, the savings rate even goes down to less than 8 %. This has to do with the fact that for breakfast, people usually do not prepare a complete meal but – if they use a stove – rather prepare porridge. Because of a very short cooking duration charcoal savings cannot materialize.

Employing Ordinary Least Squares (OLS) regression, we regress charcoal consumption per dish on ICS usage and control for household-, meal- and dish-specific characteristics in order to further increase the accuracy of our impact assessment. The central variable is a dummy variable taking the value one if the respective dish is prepared on an ICS and zero otherwise.

Concerning stove-level control variables, we first control for the number of persons the meal is cooked for. Different from Table 3, we do so in terms of *adult equivalents* in order to account for differences in household size and composition – consumption needs of young children, for instance are less than those of prime age adults.[4] Since adult equivalents can be expected to influence charcoal consumption in a non-linear decreasing way, they also enter the equations in squared terms. Furthermore, we include a dummy taking the value one if the charcoal stove is used for a *main dish*. We also differentiate between breakfast, dinner, and lunch meals by including two dummies (*lunch* and *dinner*). In addition, we add another dummy indicating whether the respective meal is prepared on *multiple stoves* or on one single stove only. Sometimes Senegalese households just warm up a meal; we control for this by including a *quick cooking* dummy in order to account for the fact that ICS first need some time to heat up and cannot realize their efficiency advantage in such quick meals.

[4] The scale used to determine adult equivalents is one that distinguishes between age categories and sex. For Senegal and neighbouring countries no such scale is available, which is why we used one applied in Eastern Africa (MCKAY AND GREENWELL 2007).

Table 4: *OLS results for charcoal consumption per dish*

| Variable | Coefficient |
|---|---|
| **Stove variables** | |
| Dish is cooked on ICS | -0.355*** |
| | (0.071) |
| Number of people the meal is cooked for (in terms of adult equivalents) | 0.078** (0.038) |
| Squared number of people the meal is cooked for (in terms of adult equivalents) | -0.003 (0.002) |
| Main dish | -0.111 |
| | (0.124) |
| Lunch | 0.505*** |
| | (0.110) |
| Dinner | 0.161 |
| | (0.110) |
| Multiple stoves | -0.170 |
| | (0.120) |
| Short cooking (< 30 min) | -0.598*** |
| | (0.103) |
| **Household variables** | |
| Female head of household | -0.066 |
| | (0.092) |
| Educational level of cooking person | 0.078 |
| | (0.062) |
| Household income (log) | -0.044 |
| | (0.044) |
| Bank account ownership | 0.119 |
| | (0.076) |
| Tiled floor in household | -0.053 |
| | (0.074) |
| Dakar | 0.184*** |
| | (0.067) |
| *Constant* | 1.491 |
| | (0.493) |
| Observations used for estimation | 307 |
| Adjusted R-squared | 0.439 |
| F-Test | 20.47*** |

Note: Only charcoal stoves used at least one time per week are included. Standard errors in parentheses. *, ** and *** indicate significance levels of 10 %, 5 % and 1 %, respectively.

In addition, we incorporate household level control variables, which of course do not change from one meal to another[5]. First, the sex of the head of household is accounted for as well as the education of the woman responsible for cooking. Furthermore, we include the household's income, a dummy for bank account ownership reflecting the household's access to credits and ability to pay, housing conditions represented by whether the floor in the household is tiled and a dummy indicating whether the household is located in Dakar or Kaolack. The results depicted in Table 4 show a highly significant effect of using an ICS on the charcoal consumed for the respective dish. The coefficient for the ICS utilization variable can be transferred to absolute terms by inserting 1 and 0 for this variable for ICS and Malagasy usage respectively while setting the covariates in this regression at their average value. Accordingly, a Malagasy stove consumes 1.41 kg of charcoal and an ICS only 1.05 kg per stove utilization, which yields a savings rate of 25.2 %. The comparison with the savings rate detected in Table 3 shows that controlling for further potential influences in a regression model only leads to a marginal increase in the rate.

Among the meal-specific variables, the household size expressed in terms of adult equivalents significantly affects charcoal consumption. Even though non-significant, the negative sign of the squared term suggest that the positive effect is decreasing in the number of household members. Also in line with expectation is the strongly significant positive influence of the lunch dummy and strongly negative influence of a short cooking duration. Table 4 furthermore shows that most household variables do not have a significant influence. Only whether the household is located in Dakar or Kaolack is strongly significant.

Altogether, with regard to the effective efficiency increase reflected by the charcoal savings per dish, we confirm the existence of a strong and significant reduction of around 25 percent if the household switched from a traditional charcoal stove to an ICS. However,

[5] Accounting for the fact that we sometimes have several observations for different stoves but the same household, we cluster the standard errors by household.

the savings are lower than one would expect if the results from Controlled Cooking Tests were transferred to all meals prepared in reality.

### 5.2. Total charcoal savings

At the end of the day, the decisive question with regards to most impacts, most importantly the impact on deforestation is how much charcoal is economized in total. In order to gauge the total charcoal savings, we calculate in a **first step** the absolute savings that would accrue to a Malagasy stove using household in case she would replace this stove by an ICS. The weekly savings can be calculated based on the mean charcoal consumption per week of an individual Malagasy stove[6] and the charcoal savings rate per stove per meal determined in Section 5.1. We differentiate by whether the household is located in Dakar or Kaolack in order to account for the quite distinct charcoal usage patterns in the two cities. The weekly savings are then extrapolated to the annual values, which amount to 136.5 kg in Dakar and 216 kg in Kaolack (see Table 5).

In a **second step** we determine the amount of ICS that actually have replaced Malagasy stoves due to the FASEN intervention – as well differentiated by region. The project's monitoring system shows that in total 71,610 ICS have been disseminated by FASEN in Dakar and 6,460 in Kaolack. As delineated in Section 2, the system is quite meticulously implemented and the figures were found to be credible in an independent evaluation mission of the project. Some of the FASEN beneficiaries might have used ICS already before the FASEN intervention: We therefore subtract the share of those households that already had possessed an ICS before. According to our data this share is at around 7-8% among the ICS users. Hence, 65,880 and 6,460 ICS can be attributed to the FASEN intervention.

In a **third step**, we have to subtract those households that do not regularly use charcoal,

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[6] This average is calculated by means of values on the charcoal consumption of individual Malagasy stoves throughout a typical day extrapolated by the number of times the respective stove is used per week.

this is, the *LPG always* group who make up half the ICS owners in Dakar and 11 % in Kaolack. The remaining 32,940 and 6,179 regularly charcoal using ICS owners in Dakar and Kaolack, respectively, safe 136 kg and 215 kg of charcoal per year as calculated above. This yields a total annual amount of saved charcoal in both cities of 5,700 tons. Senegal as a whole consumes around 470,000 tons and Dakar around 94,000 tons of charcoal per year. For Kaolack, no reliable data on total charcoal consumption in the city is available. We therefore express the total savings attributable to FASEN as a share of the country's total charcoal demand and of the total Dakar consumption, which are 1.2% and 6.1%, respectively.

Table 5: *Calculation of total charcoal savings*

| | [step 1] | [step 2] | [step 3] | [steps 1– 3] |
|---|---|---|---|---|
| | Average annual charcoal savings due to ICS per household (in kg) | FASEN ICS that replaced Malagasy stoves | Discount factor accounting for irregular ICS users | Total charcoal savings (in tons) |
| | ▪ mean weekly household charcoal consumption of Malagasy stoves<br>▪ savings rate per stove per meal<br>▪ weeks per year | ▪ number of ICS disseminated by FASEN (2006-2009)<br>▪ share of current ICS owners who already owned an ICS before | ▪ share of ICS owners belonging to the group of *simultaneous LPG and charcoal users* | |
| **Dakar** | 10.3 kg * 25.2 % * 52.2<br>= 135.6 kg | 71,610 * 0.92<br>= 65,880 | 0.50 | 4,465 |
| **Kaolack** | 16.3 kg * 25.2 % * 52.2<br>= 214.6 kg | 6,943 * 0.93<br>= 6,460 | 0.89 | 1,235 |

Due to the discounting in step 3, these saving figures so far do not include the savings of *LPG always* households possessing an ICS. Although these households use the ICS only irregularly, their savings will not be zero and may sum up to a considerable amount, simply because 33,420 ICS owners belong to this group. Without having detailed individual information about their usage patterns in our data, we try to gauge their contribution based on our contextual knowledge from the field work: Taking into account the frequency of LPG shortages and family celebrations – the most important, but also erratic reasons for ICS usage among *LPG always* people – an average ICS usage over the whole year of 1.5-2 times per week (out of 21 potential meals) seems to be a reasonable approximation. If we assume that the savings per dish correspond to the *simultaneous charcoal and LPG* users, this yields an additional total charcoal saving of 770 tons when the *LPG always* households are included. We can take these values including the *LPG always* households as an upper bound for the impact assessment. According to this upper bound FASEN can claim a reduction in total charcoal consumption amounting to 6.9 % of Dakar's and 1.4 % of Senegal's total consumption.[7]

## 6. Conclusion

This paper has evaluated the impacts of the GIZ implemented project *Foyers Améliorés au Sénégal* (FASEN) that disseminates improved cooking stoves (ICS) in Senegal. The extent to which fuelwood consumption is reduced by the introduction of ICS was in the focus of the analysis. By the time of the evaluation FASEN had concentrated mainly on urban areas, namely Dakar and Kaolack, where nearly 80,000 ICS had been disseminated by supporting whitesmiths, potters, traders, and women groups. Assigned by the *Independent Evaluation Unit* of GIZ, we conducted a representative household survey among 624 households in those parts of the two cities were FASEN was active. One first important finding is that Liquefied Petroleum Gas (LPG) is the dominating fuel in urban Senegal. More than half of the interviewed households only use LPG and only occasionally resort to charcoal, for example for family celebrations or in case of LPG shortages. Firewood is practically not used in Dakar and Kaolack. Also around one third of the randomly picked ICS using households do virtually only use LPG. As a consequence, we cannot expect many impacts to unfold among these households, simply because they hardly use charcoal, and thus, the ICS.

We used the remaining households that use LPG and charcoal simultaneously to evaluate

[7] Looking at FASEN's impact on charcoal consumption of stoves disseminated in Dakar only, the savings rate amounts to 4.8 to 6.0% of Dakar's total consumption for the two ways of calculating the savings.

the effect on charcoal consumption if the household switches from a traditional stove to an ICS. We strongly benefit from the detailed data that we have at hand on each stove that is used in the household. This allows us to cross-sectionally evaluate the charcoal consumption on the level of each individual stove, for which we also dispose of information on cooking behaviour. We find that significant reductions in charcoal consumption per dish are realized. The average savings rate is at 25 % - with stark differences between different applications, though. If the ICS is used to prepare a typical lunch meal, for example, the observed savings come close to the 40 % that had been determined by FASEN in the so-called Controlled Cooking Tests. This savings rate, however, decreases substantially if the ICS is used to prepare a dinner meal. This leads us to the first recommendation to extend the horizon of these Controlled Cooking Tests to other meals than the lunch meal.

Furthermore, we used these calculations and the numbers of disseminated FASEN stoves to estimate the total amount of charcoal saved per week due to the intervention. Although we took into account that almost one third of the FASEN beneficiaries do not use the ICS in their day-to-day life we obtain an amount of saved charcoal of 110 to 125 tons per week. This corresponds to around 1.2 to 1.4 % of the total amount of charcoal consumed in the whole country, while the savings in Dakar only amount to around 6.1 to 6.9 % of the cities' total consumption. This can clearly be considered a success given the rather short intervention period of FASEN and its comparatively limited scope. The challenge for the project, of course, is to institutionalize the used approaches in order to assure the sustainability of the built up structures on the ICS market.

Nevertheless, it has also to be emphasized that ICS dissemination projects have to verify the targeting of their activities. If the real *energy poor* people are supposed to benefit from the project, urban areas with a widespread usage of LPG might better be avoided. It is therefore recommendable to extend the project activities to rural areas where most of the households – also in Senegal – still use firewood for their cooking purposes. This target group in addition bears much higher potentials for socio-economic impacts, in particular in terms of gender and health.

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