Improving Traditional Stove Efficiency in Eritrea:
Efficient Stove Testing And Promotion Benefits

Eritrean Energy Research and Training Center

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Executive Summary

This document analyzes the potential benefits of a $16.1 million five year project to dramatically improve rural energy efficiency in Eritrea. The project, if implemented, is expected to double the efficiency of stoves in over 50% of Erit rean households over the project period. The entire project budget is less than the value to the international community of the reduced carbon emissions resulting from the rural efficiency program at the expected market value of $28 per tonne of avoided c arbon emissions (IEA, 1999). International assistance that may be given to the project is therefore not 'aid' in the traditional sense, but partial compensation for the global environmental benefits that the developed countries will enjoy from project imp lementation. The Eritrean Government together with rural Eritreans can provide some matching investments and cost sharing together if international assistance is provided. The rural efficiency improvement strategy has been supported by years of local form al and informal studies. In terms of the average market value of wood savings alone, the payback time for the energy efficiency investment is about three years. In addition to wood fuel savings, the benefits of the project include increased rural standa rd of living, improved health for rural women, environmental restoration, decreased carbon emissions, and increased soil fertility.

Introduction/Motivation

Eritrea is experiencing a rural energy crisis where demand for household energy has outstripped supply. Biomass, including wood, dung and crop residues, is the source for 80% of Eritrea's total energy use and is used primarily in the household. Yet the average efficiency of biomass use is only 10% (perhaps less). This combination of high demand aggravated by low use efficiency has contributed to deforestation, rural poverty and the rural energy shortage in Eritrea.

Since Eritrea's independence in 1993, a combination of measures and programs have been implemented to try to resolve the problems of uns ustainable biomass fuel use. First--since energy is lost when wood is converted to charcoal --Eritrea has instituted a ban on commercial charcoal sales. Second, restrictions and licensing requirements have been

placed on the harvesting and marketing of firewood. These restrictions include a ban on harvesting of live wood, and the establishment of wood transport checkpoints along major roadways in order to make sure that regulations and licensing requirements are enforced. Third, the Eritrean Department of Energy (E-DOE) has undertaken a national energy use survey in order to understand the scope and characteristics of the problem. And fourth, the Department of Energy and its Energy Research and Training Center (ERTC) has established research programs in stove efficiency evaluation and promotion.

The research by the E-DOE has both characterized the scope of the Eritrean biomass energy supply problem and has indicated some possible solutions. The national energy use survey indicated that about half of biomass is used for cooking the traditional bread, *injera*, in the traditional *injera* stove, called a *mogogo*. Meanwhile recent stove efficiency research has also found that the efficiency of wood stoves can be approximately doubled by using improved efficiency stove designs. Recent research by E-DOE extends earlier studies undertaken in the 1980's that efficiency can be doubled through improvements in the design of the stove firebox and combustion chamber. Eritrean households can cook the same amount of injera with half of the amount of biomass fuel in such improved stoves.

But there are several barriers to the use and adoption of high-efficiency stoves in Eritrea.

The first barrier comes from the fact that the construction of improved efficiency injera stoves requires special training in improved efficiency design.

The second barrier to the use of improved efficiency stoves comes from the expense and difficulty of producing them. In Eritrea, there are no commercial providers of improved efficiency mogogos. The stove design and construction techniques are not widely known, and only a very few local ceramic shops are able to provide the ceramic fuel grates that are an integral part of the improved designs. In addition, the cash costs of $10 to $30 for improved efficiency stoves is very high in rural households that have per-capital incomes of less than $20 per month. By demonstrating the use and efficiency of improved efficiency stoves, and by providing a subsidy for the poorest households, it should be possible to surmount this barrier.

If barriers to efficient mogogo use can be removed, tremendous benefits can accrue. Currently, Eritreans use approximately 1.8 million tons of biomass per year. Of this amount, about three fourths is wood. Of the wood used in Eritrea, at least half is used for cooking injera. The value of wood is relatively high, about $100/ton in the capitol, while it is virtually free in some parts of the country. If the average value of wood is estimated at $30/ton, and if the value of dung is about 1/3 that of wood or $10 per ton, then a 50% adoption rate for high-efficiency stoves that reduces consumption by 50% can result in the following annual value of wood and dung saved (for a 3:1 mix of wood and dung):

50% X 50% X 50% X $25/ton X 1.8 million tons/year = $6.7 million/year

Recognizing this potentially large benefit from improved efficiency stoves, efforts are underway to organize a project to remove barriers to the adoption of high -efficiency stoves. (*Please note, that while $6.7million per year is the value of the savings, most of the resources represented by this savings are distributed in unmonetized local markets, and therefore only a relatively small proportion of the savings is recoverable as cash* .) This document discribes one possible way to remove barriers to the adoption of high efficiency stoves by organizing an Efficient Stove Testing And Promotion (ESTAP) project. The ESTAP project would conduct field testing and evalution of improved stove performance, and would train and assist local Eritrean stove producers in the manufacture and promotion of improved efficiency stoves. It would also rapidly replicate efficient stove training and promotion programs within Eritrea's six regions in order to ach ieve rapid national adoption of the improved technologies. Furthermore, recognizing the national and international benefits of reduced carbon emissions, reduced biomass consumption, and reduced household health hazards, ESTAP should solicit investment funds to match the non-cash and local contributions for improved stoves in low -income households.

Background

High efficiency stoves for cooking *injera* is not a new discovery. Traditional experimentation has resulted in several effective, traditional energy s aving strategies while more recent modern research on stove efficiency improvements over the last decade has verified the efficacy of new stove efficiency improvement strategies.

Traditional energy saving strategies for *injera* cooking include the cooking of thick, moist injera (which has a lower cooking energy intensity), and organizing multi -family cooking sessions that reduce the heat lost in the heating and cooling of the mogogo. These energy savings strategies are in continuing use in areas that have severe fuel shortages.

Modern research in *injera* stove efficiency began during the Eritrean war for independence when national freedom fighters sought to reduce the cooking fuel requirements of the independence forces through enhanced stove efficiency. The current high-efficiency designs are an outgrowth of this previous field experience.

It is also true that there are several ways of increasing the efficiency of mogogos. Two alternative (or complementary) improvement strategies exist: enhanced efficien cy of combustion through improved fire-box design, and enhanced thermal conductivity of the cooking plate. Recent field tests have shown that improvements in air control and firebox design is currently the most effective and socially acceptable stove desi gn modification.

The Eritrean Energy Research and Training Center (ERTC) since 1995 has conducted fairly exensive research on the efficiency and energy intensity of *injera* cooking. The average energy intensity for cooking injera is approximately 1 Megajo ule per kilogram of *injera* produced at 100% efficiency. Meanwhile the efficiency of the traditional *mogogos*

(*injera* stoves) is about 10% and may even be less for particular traditional designs. The high efficiency designs double the efficiency of the tra ditional biomass stoves and have average efficiencies of about 20%. This means that to cook a kilogram of injera costs only 5 Megajoules of fuel for an improved stove compared with 10 Megajoules or more for a traditional stove.

Since the heat content of animal dung is approximately 12 Megajoules per kilogram of wood (Mj/kg) and that of wood is about 16 Mj/kg, a more efficient stove saves 0.4 kilograms of animal dung or 0.3 kilograms of wood for each kilogram of *injera* that is produced.

We can estimate the per-capita savings from improved stoves using an alternative method as follows: If we assume that personal *injera* consumption averages about 0.7 kilogram per person per day (*Note: per-capita grain consumption is 380 g/day according to the FAO while the water content of injera is about 70%. The figure of 1 kg/day injera consumption represents about 80% of cereals being consumed as injera*), and that an average Eritrean household contains five people, this means that for each household that uses a more efficient stove nearly 500 kilograms of dung or 400 kilograms of wood will be saved each year. This estimate is slightly less than the:

(1.8 million tonnes) X (50%) X (50%)/(3 million people/5 people/household) = 750 kilograms/household

savings derived from the results of the 1996 national Eritrean energy survey.

Because there is about 0.45 tonnes of carbon per tonne of wood, the annual wood savings represents approximately 200 kilograms of annual carbon emissions which (*assuming a ten year average residence time for burnable carbon returned to the ecosystem*) represents approximately 2 tonnes of total carbon emissions reduction. Hence the international benefit of reduced carbon emissions from improved efficiency stoves in Eritrea is approximately U.S. $56 p er household (at $28 per ton of avoided emissions: please consult the International Energy Agency, specifically http://www.iea.org/clim/cop5/pubs/lanza.pdf for estimates of the future international market value of avoided carbon emissions).

As we will present below, the international value of the avoided carbon emissions exceeds the costs of providing improved stoves for Eritrean households.

Objectives and Approach

The overall objective of a stove efficiency improvement project in Eritrea is to increase the rural standard of living in Eritrea and to increase the health of the global ecosystem by decreasing environmental degradation, decreasing carbon dioxide emissions, increasing the delivery of useful energy services to the rural household sector, and

decreasing household costs and energy use through increased efficiency. Specifically, it is hoped that improved efficiency in rural biomass cook stoves will improve the living conditions of the average Eritrean woman by decreasing the time and effor t needed to collect wood and burnable dung, by improving the environment in the household through decreased burning and smoke production, and by increasing agricultural production and soil fertility through increased animal dung supply.

We believe that in order to attain these larger objectives, it is helpful for Eritrea to receive some matching investments from outside sources to assist in the removal barriers to the production and adoption of improved cook stoves. These outside investments can augment and complement the fairly extensive foundation for stove efficiency that has been built by Eritreans with their own resources. Outside assistance can take the form of covering some of the cash-costs of improved mogogo production, underwriting some of the educational and training expenses for local artisans who will be making the improved mogogos, and covering some of the research, support and market transformation costs of promoting the high efficiency mogogos.

Therefore the specific objectives of this stov e efficiency improvement project are as follows:

Objective #1: To expand field tests of improved efficiency mogogo..
Objective #2: To measure actual household savings from improved efficiency mogogos.
Objective #3: To make further improvements in effici ent mogogo design.
Objective #4: To promote use of improved efficiency mogogos by:
(a) assisting and training private and local artisans in the production of improved efficiency stoves.
(b) advertising and publicizing improved stove performance.
(c) providing public investment funds for low-income households.

Methods/Implementation

ESTAP project is proceeding in four phases:

Phase #1: Project preparation and inital research.
Phase #2: Social acceptability and field efficiency tests.
Phase #3: Promotion and market transformation and project scale-up.
Phase #4: Reporting and project evaluation.

Phase #1: Project preparation and background research

Much of Phase #1 of the project has been completed. In 1996 testing facilities and testing equipment for stove efficiency were built and the ERTC stove efficiency and testing program was organized. In cooperation with the University of Asmara both theoretical and experimental research on mogogo effiiciency was conducted on electric, gas, and wood mogogos. In 1997, a more comprehensive set of tests on wood mogogos

were begun. The ERTC also consulted with national experts who conducted stoved efficiency and design research during the 1980's and 1990's. Furthermore, the ERTC investigated in detail the impact of cooking plate conductivity on stove efficiency. In 1998 and 1999, the ERTC performed the research on efficiency design improvements for the stove firebox and air flow geometry and air flow control and finalized the design and construction methods for the improved efficiency mogogo. At the end of 1999, the ERTC conducted pilot tests of the social acceptability of the improved efficiency mogogo and found enthusiastic acceptance of the new mogogos in the village that was tested.

Project preparation and research are a continuing feature of the mogogo efficiency work in Eritrea as the ERTC continues to test the acceptability of the mogogos, and different design features and changes. Collaborations for promoting and supporting efficient mogogo use continue built with private producers, with local NGO's, with the Ministry of Local Government and outside donors. Reports and project descriptions are periodically prepared, as are solicitations for partnerships and support for the promotion o f Eritrean stove efficiency.

Phase #2: Social acceptability and field efficiency tests

The social acceptability and field efficiency tests consist of evaluating in the field with a variety of potential users the performance of improved efficiency mogogos . Performance is measured in terms of both the fuel used, and the quality of the injera produced. The tests can include at least three sub phases. The first is a demonstration sub phase. The second sub phase is measurement of the injera fuel use and co oking satisfaction baseline, where participants measure and record current energy use and injera quality for the traditional mogogos. Meanwhile the third sub phase consistes of improved mogogo tests where the participants systematically measure satisfactio n quality and fuel use for an extended period for the improved mogogos.

The tasks for phase two project activities include:

1. Village selection and agreement
2. Selection of project participants and training of researchers and research assistants
3. Demonstration of improved mogogo use
4. Conduct of calibration phase of mogogo tests
5. Improved mogogo testing in villages/neighborhoods
6. Periodic interviews of test participants
7. Redesign of improved mogogos and re-testing of mogogos

Phase #3: Promotion and mark et transformation

For the supply, marketing and promotion phase, ERTC would work with interested local villages and local government administration to develop systematic methods for supporting the dissemination of improved mogogos, for improving and chang ing mogogo designs, for publicizing the benefits of improved mogogo use, and for setting reasonable prices and financing of mogogo sales and distribution.

The tasks for phase three of the project include the following:

1. Training for improved mogogo construction
2. Testing of field performance of improved and revised designs
3. Partnerships with local administrations, NGO's, regional governments and private producers.
4. Revised cost evaluation of mogogo construction and project promotion.
5. Definition of promotional subsidy or low-income support program.
6. Village cooperation agreements.
7. Follow-up questionnaires for transformed villages
8. Promotion scale-up
9. Advertising and TV documentary promotion

Phase #4: Reporting and project evaluation

In the final phase of the project ERTC would document and publicize the results of the improved efficiency mogogo field tests and marketing and promotion efforts. Documentation would include a detailed report on results made available to the Department of Energy and other interested agencies, documents and reports published on the Internet, and one to several technical papers submitted to academic journals (e.g. the Eritrean Studies Review). Project success may be evaluated both in terms of reactions and responses of project partners in evaluation forms and meetings, and in terms of quantifiable measures such as fuel saved in field tests, the number of efficient mogogos produced and utilized, the number of commercial producers recruited, and the rate of increase of efficient mogogo production and distributions.

The tasks for phase four of the project include the following:

1. Production of research papers and reports including a paper for the Eritrean Studies Journal, Web Articles, and a detailed internal report with data sets.
2. Village meetings to review efficient mogogo acceptability and analysis of the village questionnaires
3. Market evaluation and determination of acceptable price and cost sharing levels.
4. Project evaluation with project constituents including partner agencies, businesses, villages, and customers.

Project Schedule:

Project scheduling would depend on coordination with the partner agencies and the availability of fund to invest in efficient mogogo testing, promotion and distribution. Initially, we expect the remaining portion of the preparation phase to take approximately four months, while the field testing and promotion stages will be on-going, but would require one to three months for each field test. The report writing and evaluations would use at least four person-months for the annual reports. The main measure of the project schedule would be the time required to scale up production, promotion and distribution of the new mogogos. We expect that it would be possible to expand promotion, production,

and distribution by a factor of three for each year of the projects growth phase. By year four, the expansion rate will slow as many Eritrean households are expected to have adopted the improved mogogos by that time.

Project Deliverables:

Project deliverables would include the following:

1. Research report on field efficiency and wood use impact of improved mogogos.
2. Research report on social acceptance of improved mogogos.
3. Internal report on efficient mogogo research.
4. Report on production, cost, and market analysis of high efficiency mogogo designs.
5. Transformation to high efficiency mogogos in 50% of Eritrean households.
6. Support for local high efficiency mogogo artisans
7. Establishment of loan fund for small scale women run high efficiency mogogo businesses.
8. Promotional brochure in both Tigrigna and Arabic on improved mogogos.
9. Newspaper (Eritrea Profile) articles on improved mogogos.
10. Final project evaluation report.

The quality, quantity, and content of these project deliverables would be the product by which project success can be evaluated by funders, Eritrean partner institutions and the interested public.

Project Budget

Funding for the ESTAP project will be described in two sections. The first section described the unit costs of project components, while the second section describes annual budgets for an aggressive implementation strategy that would result in 50% of Eritrean households adopting the high efficiency mogogos.

Improved Mogogo Construction Costs (per household):

Clay, sand, stone and clay cooking plate cost	$ 3.00
Ceramic fire grate	$ 1.50
Galvanized Iron Chimney*	$ 11.00
Skilled artisan labor	$ 12.00
Material transportation costs	$ 0.25
Subtotal per household mogogo construction costs	$ 27.75

** includes materials, labor, and facilities overhead costs for fabrication.*

Per Village Support Costs

Construction Aids Toolkit (Box, forms, tools)	$ 250
Artisan Training in Asmara (ERTC)	
(12 artisans X 14 days X $7.50 per person day)	$ 1260
On Site Artisan Training	
(12 artisans X 14 days X $7.50 per person day)	$ 1260
Subtotal per village costs	$ 2720

Note with a typical village size of 300, this corresponds to about $9 per house training and support expenses.

Research, Reporting and Design Expenses (annual)

Research Staff ($2000/year x 5 staff)	$ 10,000
Administrative and Institutional Overhead (50%)	$ 5,000
Facilities Overhead ($100/month 5 offices + workshop)	$ 7,200
Subtotal Research, Reporting & Design /year	$ 22,200

Budget Year #1

Mogogo Improvements 12 villages & 3600 households	
Mogogo Construction Costs	$ 99,900
Village Support and Training Costs	$ 32,640
Research, Reporting & Design	$ 22,200
Year 1 Subtotal	$ 154,740
Project Administration (10%)	$ 15,474
Contingency (15%)	$ 23,211
Year 1 Total	$ 193,425

Budget Year #2

Mogogo Improvements 35 villages & 10,000 households	
Mogogo Construction Costs	$ 277,500
Village Support and Training Costs	$ 95,200
Research, Reporting & Design	$ 22,200
Subtotal Year 2	$ 394,900
Project Administration (10%)	$ 39,490
Contingency (15%)	$ 59,235

Year 2 Total	$ 493,625

Budget Year #3

Mogogo Improvements 100 villages & 30,000 households	
Mogogo Construction Costs	$ 832,500
Village Support and Training Costs	$ 272,000
Research, Reporting & Design	$ 22,200
Subtotal Year 3	$ 1,126,700
Project Administration (10%)	$ 112,670
Contingency (15%)	$ 169,005
Year 3 Total	$ 1,408,375

Budget Year #4

Mogogo Improvements 350 villages & 100,000 households	
Mogogo Construction Costs	$ 2,775,000
Village Support and Training Costs	$ 952,000
Research, Reporting & Design	$ 22,200
Subtotal Year 4	$ 3,749,200
Project Administration (10%)	$ 374,920
Contingency (15%)	$ 562,380
Year 4 Total	$ 4,686,500

Budget Year #5

Mogogo Improvements 700 villages & 200,000 households	
Mogogo Construction Costs	$ 5,550,000
Village Support and Training Costs	$ 1,904,000
Research, Reporting & Design	$ 22,200
Subtotal Year 5	$ 7,467,200
Project Administration (10%)	$ 746,720
Contingency (15%)	$ 1,120,080
Year 5 Total	$ 9,334,000

Total Project Budget:

Year 1	$ 193,425
Year 2	$ 493,625
Year 3	$ 1,408,375
Year 4	$ 4,686,500
Year 5	$ 9,334,000
Project Total	$ 16,115,925

Conclusion

The total resources required to convert 343,600 Eritrean households (approximately 50%) to high efficiency stoves in five years is about US$16.1 million. The annual biomass savings from of moving to high efficiency stoves for this number of households is estimated to be from 150,000 to 300,000 tonnes of avoided biomass consumption per year. If biomass has a residence time in the ecosystem of approximately ten years, then this corresponds to 0.675 to 1.35 million tonnes of avoided carbon emissions. These avoided carbon emissions have a value to the international community of $18.9 million to $39 million at projected future carbon emissions trading prices. And therefore there is strong justification for the donor community to contribute substantially to this effort.

Eritrea, like many other African countries is especially vulnerable to the global climate changes that will result from the fact that the developed countries have already used up the Earth's global environmental capital. Because of Eritrea's dependence on rainfed agriculture and its susceptability to recurrent droughts that may become more seve re and more frequent in a high CO2 climate (IPCC, 1997), Eritrea is likely to suffer tens of millions to hundreds of millions of dollars in economic damage due to the CO2 -induced global climate changes. But Eritrea will be doing its part in the resolution of these global environmental problems through responsible, efficient, and environmentally sensitive energy resources development. The development of Eritrea's national energy resources is necessary to meet the rapidly growing demands of Eritrea's small, but quickly growing economy. These demands are best met through efficiency enhancements in the utilization of existing resources rather than through the expansion of consumption. This strategy is best for both Eritrea and the international community of na tions. Because of this mutual interest, Eritrea seeks international partners who wish to join with the national government in making investments for this ecologically progressive national energy resources development strategy.

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