PHD DISSERTATION

Improved Biomass Cookstoves - A Strategy towards Mitigating Indoor Air Pollution and Deforestation
A case study of the North West Province of Cameroon

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By

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DOKTORARBEIT

Verbesserte Biomasse Kochherde – Strategie zur Schadensminderung hinsichtlich Luftverschmutzung von Wohnräumen und der Abholzung für Brennstoffe. Eine Fallstudie aus der Nordwest - Provinz, Kameruns

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Declaration

I hereby declare that this dissertation is the result of my exertion and hard work. This research was carried out at the Brandenburg University of Technology Cottbus (BTU) under the framework of the doctoral program in Environmental and Resource Management.

Professor Jürgen Ertel of the Chair of Industrial Sustainability of BTU Cottbus was the main supervisor of this thesis. Professor Wolfgang Schluchter of the Chair of Environmental Issues in the Social Sciences, BTU Cottbus and Dr. Agnes Klingshirn a Senior Adviser and Household Energy Consultant for "Deutsche Gesellschaft für Technische Zusammenarbeit" (GTZ) Eschborn, Germany, were co-supervisors.

This thesis has never been submitted in part or in whole for a degree at any institution. References to other sources or people's works have been duly cited and acknowledged.

____

Tangang Ernestine A. Yuntenwi

Dedication

I dedicate this work to my late dad, Tangang Bernard Nsunue, who was my prime source of motivation and my quintessence of success.

Who are we to question your ways, Oh God?

Acknowledgement

The time for modern biomass has drawn near. Despite its long existence, biomass has languished behind other renewable energy technologies like wind, solar and hydro. It still retains a poor image relating to the emerging smoke from poor combustion, soot, poverty and indoor air pollution illnesses associated with it. The recent abundance of well designed technologies and the success of stove bioenergy projects and dissemination programs around the world have created a renewed interest in this renewable, sustainable and low emission-producing source of energy.

When I think of my transcend from the Bachelors degree where I majored in Zoology (Natural Sciences), through the Master of Science degree when I first switched to renewable energy (Briquetting from Agricultural Waste), and now ending up in the Household Energy Sector for the PhD degree, I submit, "that change is the only constant in life". Today, I feel a fulfilment of a well chosen focus, however, I am left daunting as the challenges ahead are weighty and need immediate intervention. This dissertation serves as the first step towards achieving this goal and is written for those who are interested in learning more about biomass cookstoves, the possibilities of improvement of such stoves and fighting deforestation and climate change.

Behind great people are great minds! Such persons need to be duly cited and acknowledged after any achievement. My intriguing journey into the academia started when I enrolled in the International Study Course of Environmental and Resource Management for the Masters program at the Brandenburg University of Technology Cottbus. While there, I got to meet Professor Jürgen Ertel, head of the department of Industrial Sustainability, who welcomed me into his department with such warmth and groomed me into a full scholar and a robust researcher from my MSc through my PhD dissertation. I laud his inevitable contributions (academic, financial, social and moral) to the success of this work. He really is a genuine scholar and an epitome to be emulated. I equally owe gratitude to his wife, Kay Ertel, whose parties and gifts gave me such joy and distracted me from my academic work giving me an opportunity to relax. This goes to confer the saying that "all work and no play makes Jack a dull boy". Furthermore, the cordial relationship with my colleagues of the department, created a good working atmosphere for me.

I remember the day I walked into Professor Schluchter's office in November 2004 to discuss my research topic and seek his consent and supervision. How excited and ready he was. His expert knowledge in socio-economic issues and previous engagement in cook stove projects enhance his invaluable contribution to this piece of work.

When I started writing the literature review, I was clouded with doubt, pondering on how to proceed until I met Dr. Dieter Seifert who introduced me to Dr. Agnes Klingshirn. One can't talk about Household Energy in Germany or about GTZ without mentioning her. Dear Agnes, you have not only been a great supervisor, you have equally been a mother and a friend. Dedication to service, patience and humility are virtues I Iearnt from you. Your inputs have very much contributed to the success of this work.

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There was the shoulder on which I laid when I was tired, the one who consoled me when I was stressed up, who encouraged me when I was down trodden and who motivated me when I was hopeless; that is you my husband, Isidore Yuntenwi. Words of mouth cannot express my gratitude for your readiness, patience and sleepless nights proof reading this dissertation.

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List of Acronyms/Abbreviation

AER	Rural Electrification Agency
AES-SONEL	National Electricity Company, Cameroon
AS	Active Sum
APROVECHO	Advance Studies in Appropriate Technology
BOSTID	Board on Science and Technology for International Development
CAT	Centre for Appropriate Technology
CBC	Community Based Campaign
CCAST	Cameroon College of Arts, Science and Technology
CCT	Control Cooking Test
EAP	Energy Advisory Project
EERET	Energy Efficient/Renewable Energy Technology
ENS	Ecole Normale Superieure
EPA	Environmental Protection Agency
FAO	Food and Agricultural Organization
FP	Firepower
GATE	German Appropriate Technology Exchange
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
GVEP	Global Village Energy Partnership
H	Thermal efficiency
HERA	Household Energy in Rural Areas
IAP	Indoor Air Pollution
ICS	Improved Cook Stoves
IEA	International Energy Agency
IFSP	Integrated Food Security Programme
KPT	Kitchen Performance Test
LPG	Liquefied Petroleum Gas
MINPLAPDAT	Ministry of Planning, Development Programming and Regional Development
MDG	Millennium Development Goals
PANERP	National Energy Action Plan for Poverty Reduction

PCIA	Partnership for Clean Indoor Air
PEMS	Portable Emission Monitoring System
PM	Particulate Matter
ProBEC	Programme for Biomass Energy Conservation
PROTEGE QV	Promotion of Technologies that Guarantee Environment and a better Quality of Life
PS	Passive sum
PV	Photovoltaic
RECIPES	Renewable Energy in emerging and developing countries: Current situation, market Potential and recommendations for a win-win-win for EU industry, the Environment and local Socio-economic development
SADC	Southern African Development Community
SC	Specific Fuel Consumption
SHUMAS	Strategic Humanitarian Services
SM	Sensitivity Model
UN	United Nations
UNDP	United Nations for Development Programme
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
WBT	Water Boiling Test
WOCAN	Women organizing for change in Agriculture and Natural Resources Management
WB	World Bank
WHO	World Health Organisation
WRI	World's Resources Institute

Units

AS	Active Sum
^{o}C	Degree centigrade
cm	Centimeter
CO	Carbon monoxide
CO_2	Carbon dioxide
f_{cd}	Equivalent dry wood consumed
f_{cf}	Final wood consumed
f_{ci}	Initial wood consumed
f_{cm}	Wood Consumption
f_{cw}	Dry wood consumption
frs CFA	Central African francs
g	Grams
L	Liter
LHV	Net calorific value (dry wood)
m	Miles
mc	Moisture Content
min	Minutes
Mj	Mega joule
kg	Kilogram
km	kilometer
P	Dry weight of empty pot
PM	Particulate Matter
P_{ci}	Weight of pot with water before test
P_{cf}	Weight of pot with water after test
PS	Passive sum
SC_c	Specific fuel consumption
SC^t_h	Temperature corrected fuel consumption
t_{ci}	Time at start of test
t_{ct}	Time at end of test
Tci	Water temperature before test
Tcf	Water temperature after test

W		Watts
W_{cv}		Water vaporized
Δc	=	Net change in char during test

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Abstract

This dissertation seeks to assist beginners and stovers especially, to better understand the concept of cook stoves and their associated repercussions. It gives an insight on the general situation in developing countries and picks on Cameroon as case study, for a robust discussion on the status quo heat capturing techniques, technology improvement routes, the socio-economic influences and policy mitigation measures.

For easy assimilation, this thesis is divided into three main sections. Section one discusses the research methodology and socio – economic approach in the case study area. Section two deals with the technology aspect which - the stove performance test and lastly, section three handles the simulation model. It further elaborates on the existing challenges and opportunities associated to improved stoves and ends up with conclusions and recommendations.

A three tier methodological approach was used in this study. Firstly, questionnaires were distributed in the study areas and results analysed. Secondly, a laboratory based water boiling test was conducted using three stoves (open fire, rocket stove and “skirt” stove) to assess the effect of wood moisture content on combustion and heat transfer efficiencies. Lastly, a simulation model was used to understand the behaviour of key players within the system of cook stoves and indoor air pollution such that setbacks are better understood, controlled or mitigated.

Results of the questionnaires showed that the majority of the people did not know what indoor air pollution is but were aware of the fact that inhaling smoke is harmful to the health. Interestingly, a good number were ready to accept any innovations that will help abate the pending related social and health crises associated to poor cooking techniques.

From the water boiling test, results showed that fuel moisture content greatly affects combustion and heat transfer efficiencies. The degree of affection hugely depends on the stove type and the fire tender. Very little particulate matter (PM)

and carbon monoxide (CO) were produced at moisture content 15%. Fuel at moisture content 5% burnt very fast producing high amounts of PM, meanwhile fuel at moisture content 30% did not burn well and produced high amounts of CO and PM. Conclusively, one can say that some amount of moisture is needed in wood to obtain high combustion efficiency. The Chinese rocket stove produced the best results, seconded by the "skirt" stove and then the traditional open fire.

The simulation model laid down the basis for comparison and control mechanisms for the indoor air pollution problem. With the Sensitivity Model tool in combination with other research findings, one was able to understand the behaviour of variables vis à vis each other. Four different partial scenarios (PS) were used for the entire simulation model; PS 1 Stove Design, PS 2 Stove Performance, PS 3 Health Impact and PS 4 Economy.

From Partial Scenario 1, as one moved up the energy ladder from biomass stoves through kerosene stoves to gas cookers and electric cookers, stove efficiency and cleanliness improved with an increase in fuel prices thus making it less affordable.

Results of Partial Scenario 2 showed that an improvement in the stove design and a decrease in moisture content caused an improvement in combustion efficiency with a slight increase in affordability.

After simulating Partial Scenario 3, one realised that health is greatly affected by the inhalation of particulate matter and carbon monoxide. The degree of health damage caused does not only depend on ones exposure in the cooking area, but the inhaled concentration also matters. People's immunity varies depending on certain factors like age and ability to fall sick.

Partial Scenario 4 showed an increasing economic impact and a decreasing environmental impact of the simulation as one ascended the generic household ladder (Figure 3).

Chapter 1 BACKGROUND

Biomass fuel represents between 50% to 90% of primary energy consumption in developing countries and 12% to 15% primary energy consumed worldwide. Developing countries consume three quarters of global biomass where a greater majority of the world's population lives mainly in rural areas and poor urban zones (*Wereko-Brobby Ch Y and Hagen E.B. 1996*).

Traditional fires and cook stoves are some of the earliest technologies, so it is often assumed that much is known about them already such that little or no further research is necessary to improve on their efficiencies and dissemination. Although stoves have been studied on a continuing basis for over 35 years, unfortunately, there today exist no clear-cut internationally accepted design standards for biomass burning stove (*Dean S. et al*. *2007*). This is because of the lack of knowledge and understanding in the building and functioning of the stove. Worse still, the currently available local stoves do not usually represent the best designs that modern engineering can offer. However, the increasing interest on climate change and global warming issues has created awareness on the environmental and social costs of using traditional fuels and stoves nowadays.

The challenge of cook stove design is not only a technical issue but a social issue as well. How and what we cook greatly depends on our culture, lifestyle and resources. In many areas and for many people, the three stone open fires are used extensively and continually. A good stove should be able to boil water quickly, simmer foods and cook an almost infinite variety of foods in different ways depending on the culture while minimizing fuel use and emissions produced. They need to be easy to handle, require little attention, safe, aesthetic and respond quickly when needed. To achieve this goal, the engineer cannot work independently from the cook thus an integrated approach of the cook stove design and implementation is necessary. Research results so far show that one stove may be efficient, another may heat faster, another safer, and each of them pollutes more or less than the other. It therefore depends on the stove designer to pick out a design that will best suit the locality and food types for which it is intended.

Lack of access to appropriate energy sources is undoubtedly one of the roots of poverty which hinders economic and social development. The energy consumed per capita was in the past used as an indicator of development progress. However, it was recognised in the nineties that it is not necessarily the amount of energy provided that mattered but the quality of the energy services needed at a certain development stage and its distribution. While better stoves may save energy, they will not by themselves prevent deforestation, though they may help slow it. Population growth, the conversion of land to agriculture, the reduction or elimination of fallow periods and the increasing numbers of gracing animals are all playing their part in reducing the available resources. The cumulative effects of this pressure are such that in many areas, wood will continue to be scarce even if fuel wood demand were to be eliminated completely. This idea should not prevent further research in cook stoves and dissemination programs.

Even though traditional small scale combustion of biomass degrades air quality and is thermally inefficient, the high price and unavailability of cleaner substitutes in many locations hinders the rapid shift away from the use of traditional fuels thus making it unlikely. Biomass fuels therefore, are likely to continue to meet the cooking energy needs of a majority of people in the developing countries (*Ahuja D. R. et al. 1987*).

This thesis through its nine chapters briefly discusses the state-of-the-art cook stove technology worldwide and elaborates on the case of the North West Province in Cameroon. It seeks to address the issue of indoor air pollution and deforestation associated to poor cooking techniques. It also elaborates on the effect of fuel moisture on thermal efficiency, energy consumption, time to boil a fixed quantity of water and emission factors at both high and low power using the water Boiling Test. A conceptual model is used at the end of the study to better understand the interaction of the major key players involved in improved cook stove technology such that reasonable recommendations are made to mitigate any envisaged problems.

1.1 Energy Use Worldwide

In a world of about 6.8 billion people, more than 2 billion rely on wood, dung and other biomass as a primary source of fuel. Exposure to indoor air pollution causes the premature deaths of more than 1.6 million persons, that is, 1 person every 20 seconds (*Shell Foundation, 2006*). With the exception of biomass, renewable energy is presently a minor contributor to energy supply of Eastern and Southern Africa, accounting for less than 2 percent of the total supply (*Karekezi, S. and Ranja, T., 1997).* Will there one day exist an affordable, efficient and durable decentralized mode of energy supply for all to have access to? There can be no real social or economic development without secure energy services. People's lifestyles to a certain degree are determined by the type of affordable energy sources available.

Biomass fuel or biofuel is defined as any plant or animal based material deliberately burned by humans. Wood is the most common used biomass fuel, however, animal dung use and crop residues use are widespread *(De Koning et al 1985)*.

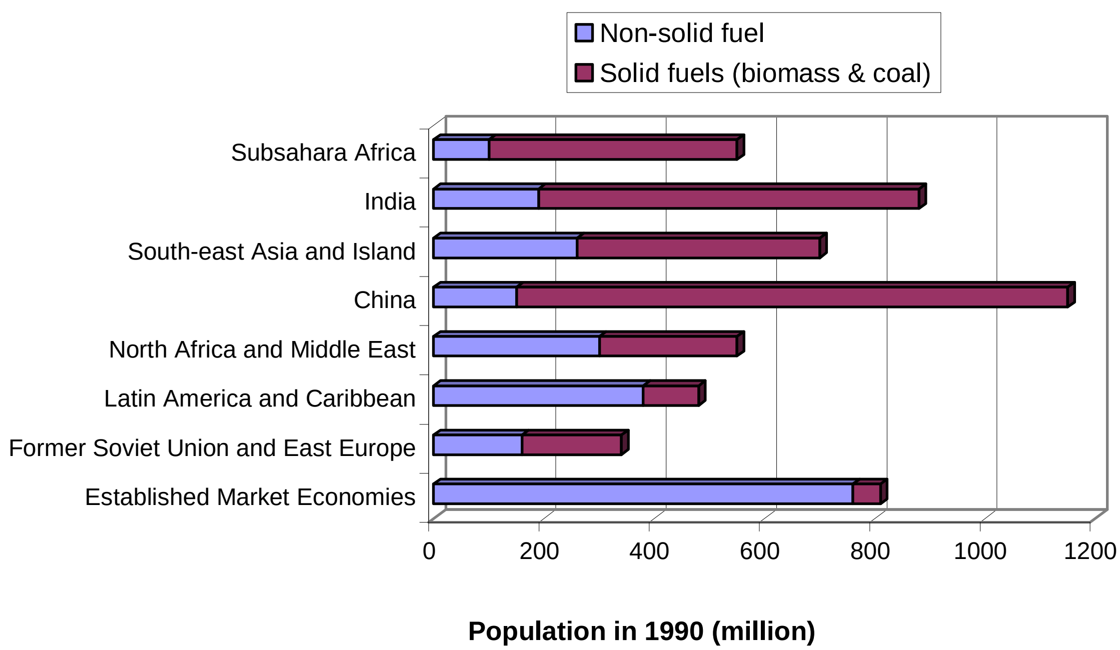

Figure 1: World Distribution of Household Fuel Use

Source: Smith, K. R et al. (2003)

Fuel wood is a very important energy resource for a considerable part of the world population, especially in developing countries (Figure 1). Some 2.4 billion people rely on traditional fuel – wood, charcoal, agricultural residues and dung for cooking and heating. That number will *increase* to 2.6 billion by 2030 (*World Energy Outlook, 2002).* The situation is particularly grave in sub-Sahara Africa where over 80% of the population lives in rural areas and the average electrification rate is less than 5% (*A Report of the World Energy Council, 2005).* How can the lives of these people be affected such that they can benefit from the use of sustainable and appropriate technologies? This research to a greater extent will provide some answers in the subsequent chapters.

According to the World Resources Institute, about 41% of the world's population rely on fossil fuel as a source of energy; meanwhile only 19% rely on primary solid biomass (Figure 2). China is the world's highest consumer of solid fuels that is biomass and coal (*World Resource Institute, 2003*).

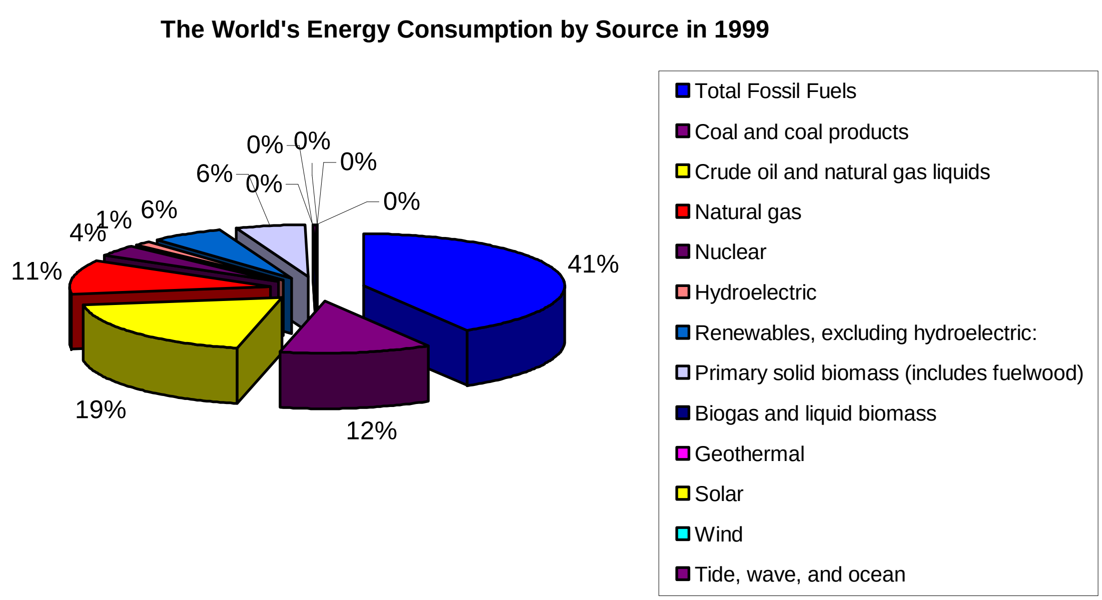

Figure 2: The World's Energy Consumption by Source in 1999
Source: World's Resources Institute (WRI), 2003

Biofuels are among the most important fuels globally, in terms of the number of people affected. In energy content and considering developing countries, they are the most important fuels, although second to fossil fuels on a global basis. Besides, they are likely to remain important in many developing countries for many decades (*Saksena, S. and Smith, K. R., 2003).*

Smith et al (1994) used the household energy ladder (Figure 3 below) to illustrate the evolutionary pathway for cooking fuels and stoves in most developing countries. Animal dung is on the lowest rank of the ladder progressing to crop residues, wood, charcoal, kerosene, gas and finally electricity. In general, people prefer to move upwards if possible but in some cases, changes in income or availability of other resources may force some groups back down the ladder. Although it is useful in describing large scale historical movements in fuel use, individual households often rely on two or more fuel types. This may shift fuel use up and down depending on the time of the year, fuel cost and other parameters.

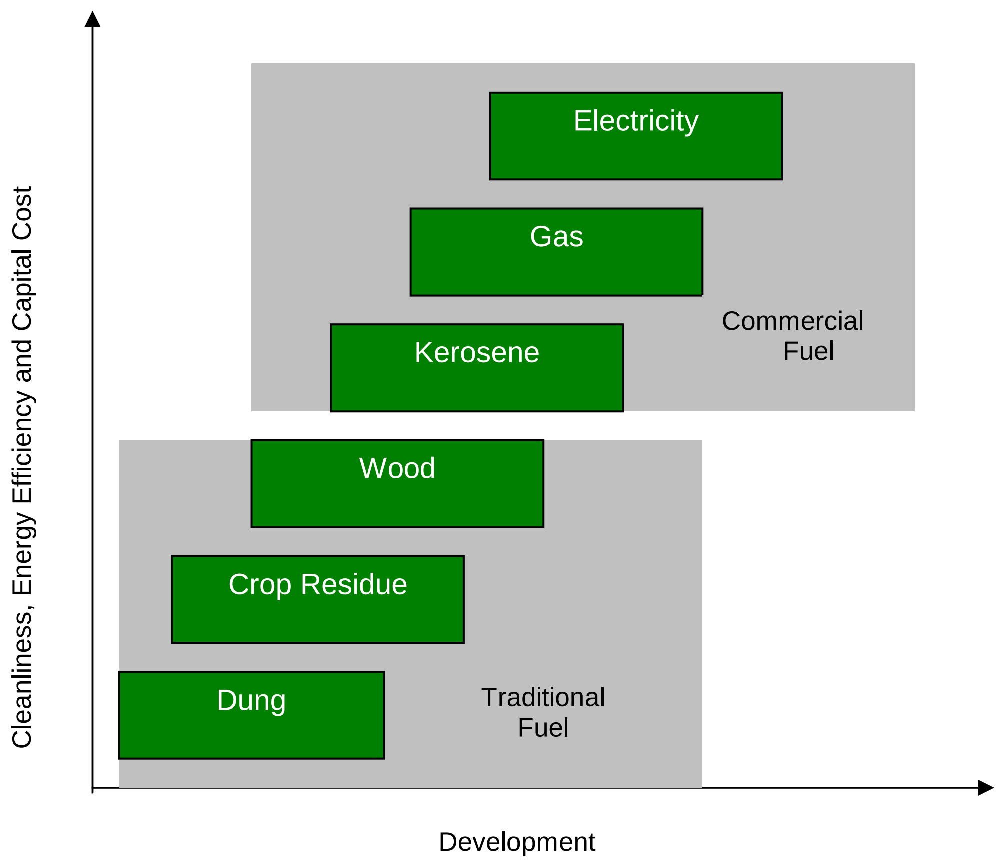

Figure 3: Generic Household Energy Ladder

Source: Kirk et al., 1994

According to table 1 below, the transition to modern fuel will take some time. This can be explained by the fact that in the lower-income developing countries, high percentages of especially rural people (but also of the urban poor people) continue to rely heavily on biomass.

Table 1: Rural Energy Use Patterns in Developing Countries by End Uses (*Rural Energy and Development)*

End use Household	Low	Household income Medium	High
Cooking	Wood, residues & dung	Wood, residues, dung, kerosene & biogas	Wood, kerosene, biogas, LPG & coal
Lighting	Candles & kerosene (sometimes none)	Candles, kerosene & gasoline	Kerosene, electricity & gasoline
Space heating	Wood, residues, & dung (often none)	Wood, residues & dung	Wood, residues, dung & coal
Other appliances	None	Electricity & storage cells	Electricity & storage cells

Source: *WB, 1996, p.132*

The greatest proportion of national energy in many developing countries, is consumed in the form of firewood or charcoal for cooking (and to a lesser extent, heating and lighting) purposes. The efficiency of traditionally burned firewood and charcoal is very low. Perhaps 5-10 percent of the energy is actually transferred to the material being heated. Consequently, much effort needs to be directed to designing and diffusing stoves of higher efficiency, thereby reducing the amount of fuel required.

Three factors mostly affecting fuel use are moisture content, completeness of the combustion, and the efficiency of heat transfer (this will be further discussed in chapter 5). Air-dried wood yields nearly twice as much heat (on a weight basis) as freshly cut wood. Incomplete combustion, poor heat transfer, and heat wasted during heating and cooling are the principal causes of the energy inefficiency associated with open fires and the simple stoves used by mainly the poor in most developing countries. Among some of these peoples, the smoke from open fires causing indoor air pollution is recognized as an eye irritant and the cause of respiratory ailments. On the other hand, some of them appreciate it as a means of smoking foodstuffs and driving away insects. Improved woodstove design is required to improve indoor air pollution, provide more efficient heat transfer to the cooking pots by enclosing the fire and regulating the air flow. The higher efficiency may contribute to reducing deforestation.

1.1.1 Improved Cooking Technology

Most people in the countryside cook on open fires, usually enclosed between three or more stones or lumps of mud (the three stone fire) which act as pot supports. It is commonly alleged that such fires have efficiencies of only 5-10% (amount of energy transferred from fuel wood) compared with the 20% or more obtainable with a properly designed cooking stove (*Lloyd Timberlake, 1988*).

Despite the challenges and limitations stemming from stove dissemination and IAP, there is a greater awareness on household energy issues today than ever before. Climate change and global warming have been in the limelight for a while now. To address these issues, many organisations, institutions and researchers are either funding or embarking on projects in the third world countries especially, to combat problems surrounding the use of biomass fuel. So there have been and still are numerous programmes to promote improved cook stoves throughout Africa and other developing countries.

The United Nations in its effort to fight against climate change and improve the existing energy situation calls on countries to reduce the number of people without effective access to modern cooking fuel by 50% and make improved stoves widely available by the year 2015 through its Millennium Development Goals (MDG). For this target to be met, 1.6 billion people will have to gain access to LPG (Liquefied Petroleum Gas), natural gas and biogas and other modern fuel. In other words these services will need to be extended to about 500,000 people every day between now and 2015. Reaching these people will still leave 1.5 billion people cooking with biomass fuel. It is estimated that by 2030, more than 2.7 billion people will cook on biomass (*HERA, 2007*). The challenge therefore is to come up with solutions that will better the lives of those still tangled with biomass fuel which leaves us with the option of mitigating the heat capturing technologies.

Alongside the United Nation's MDGs which seeks to fight deforestation, green house gases emission and climate change is the Kyoto Protocol of 1997. Article 3 of the Protocol states that each participating country is bound to a carbon dioxide emission level that may not be exceeded.This same article stipulates that participatory countries should each reduce green house gases (GHGs) emission by 5% (based on the 1990 emission level) between the period of 2008 – 2012. The Clean Development Mechanism (CDM) which is an instrument under the Protocol allows industrialized countries with a greenhouse gas reduction commitment (called Annex 1 countries) to invest in projects in developing countries. Besides, the Bali conference of 3rd-14th, Dec. 2007 incorporated improved cook stoves in her action plan and encouraged stove dissemination projects as one means of fighting deforestation. Such joint projects are a milestone in cook stove research and could be a means of overcoming poverty by providing a powerful and durable means of subsistence through subsidies and jobs creation for poor families in developing countries. Of the 2,424 projects in the CDM pipeline at the end of August 2007, less than 3% were hosted in Africa (*Cooper D., 2007*). This low percentage is attributed to high additional investment cost required for infrastructure which already exists in industrialized countries (China, India, Brazil etc) and an unfavorable political and business climate in some countries.

Besides CDM projects, hundreds of cook stove projects exist nowadays. Up to date, China and India have hosted the world's largest improved cook stove programs with over 18 million stoves disseminated in China and approximately 30 million disseminated and used in India (*Sinto et al. 2004; Kishore and Ramana, 2002*). Each of these projects developed its own stove standards based on the standardized laboratory based test (*FAO, 1993b; a*).

The Southern African Development Community (SADC) Programme for Biomass Energy Conservation (ProBEC) is currently active in eight SADC countries and is spreading improved cooking technologies for the efficient and sustainable use of biomass energy since 1998. Several types of improved stoves are being disseminated in Southern African countries. In Malawi, for example, the clay and ceramic stoves were introduced through the Integrated Food Security Programme (IFSP), targeting small-scale industry and private households, women in particular. In its vision to enable all populations, especially lower income groups to satisfy their energy requirements in a socially and environmentally sustainable manner, technology and knowledge about biomass energy conservation is imperative.

For over 3 years, the Information Centre for Food and Fuel Security and the Programme for Biomass Energy Conservation (IFSP/ProBEC) have been helping the people in Mulanje district of Malawi to improve their level of awareness, skills and techniques on the use of improved and sustainable energy saving cook stoves. So far, the fixed mud stoves as well as the portable clay stoves have been typically promoted. However, the “Chitetezo” clay stove has won the hearts of the indigenous in all settings including rural, peri-urban, and urban households, by Malawian standards. The stoves have proved to be highly efficient at achieving wood fuel savings up to 60% - 70% (*IFSP/ProBEC, 2005).* 5,044 portable stoves were produced in 2007 and there has been a successful mainstreaming of ProBEC activities. ProBEC together with the Dutch donor, DGIS, have worked with 16 partner organizations in Malawi, covering 14 districts. In 2007, as a result of ProBEC interventions, 487 fixed mud stoves, 18767 portable clay stoves; 1795 institutional rocket stoves, and 13 restaurant double pot rocket stoves were produced (*GTZ, 2007*).

The German Development Corporation (GTZ) following its Household Energy Strategy also has implemented Integrated Household Projects in Uganda, Senegal and Ethiopia, where improvement of the quality of life for the poor by enabling them to fulfil their energy needs in a socially and environmentally sustainable manner was their priority. Through the Energy Advisory Project (EAP) in Uganda, over 200,000 households were able to improve their cooking energy needs within the last two years. So far 20,000 stoves were built in Rakai district and 110,000 in Bushenyi district during the last year (HERA, 2007). Artisans were trained and have won tenders to supply institutional stoves in army barracks and in schools. These same artisans are fully marketing charcoal stoves in the city. Stoves like the rocket stove originally developed by Larry Winiarski from APROVECHO, are also disseminated in a larger version as the rocket institutional stoves and rocket bread ovens *(Kuteesakwe John, 2005).*

Practical Action formerly known as Intermediate Technology Development Group (ITDG) is a leading organisation in fighting the “killer in the Kitchen”. With the aim of reducing poverty and conserving the environment, Practical Action has IAP projects in Kadjiado Kenya, Kassala Sudan and Rasuwa District Nepal. Their projects center around promoting the use of smoke hoods, pollutants monitoring and educating the communities on the dangers of indoor air pollution.

Because there today exist no internationally accepted test standards, none of the executed projects so far used an official field based measurement of fuel consumption by end user to assess the actual performance of the stove. However, a number of studies where independently conducted to assess field performance (*Rob Bailis et al. 2007; Sinto et al. 2004; Kishore and Ramana, 2002; TERI, 1989*). Leading organisations like WHO, USAID and Aprovecho have set their own emission standards. This will be discussed in the chapters ahead.

De Lepeleire et al. (1981) issued a compendium of stove designs. They described over 100 models, many of which were traditional and some experimental - from simple, shielded variations of three-stoned fires to complex multi-cavity, multi-control and monolithic units. These stoves represent a broad spectrum of gadgets for improving fuel efficiency. However, the main problem is to make new stoves acceptable by adapting them to meet the widely varying circumstances and cultural expectations of diverse populations. Ashworth and Neuendorffer observed that "Cooking is one of the most culture-bound human activity. Food preparation, serving time and place, food flavour, and cooking participants often are established by long tradition and, therefore, are resistant to change. Social and religious customs may dictate all of the characteristics of the energy demand and may eliminate certain technology options even if energy output is . . . good. . . "(*Ashworth and Neuendorffer, 1980*).

Nienhuys et al analysed the metal and mud cooking stoves in Dolpa, a remote high altitude district in Nepal. In their aim to cut down cost, improve energy efficiency, improve user utility, reduce subsidy levels and promote market by demonstration, they suggested over 20 improvement options. *(Nienhuys et al., 2005).*

Summarised on Table 2 are projects and achievements of some leading NGOs in this area of household energy dessimination. The description and technical features of most of the stoves used in these projects will be discussed in the next chapters.

Table 2: A Summary of some International Organisations and their Achievements in Stove Projects

International Organizations or Institutions	Program	Host areas or Countries	Goals and targets	Intervention routes	Achievements
United Nations	Millennium Development Goals	Third World countries	To reduce the number of people without effective access to modern cooking fuel by 50% and make improved stoves widely available by the year 2015	Clean cooking fuels	Set the basis on which the CDM and other leading stove projects operates
Kyoto Protocol	Clean Development Mechanism	Latin America, China, India and Africa	To reduce emission and support sustainable development in developing countries.	Biomass and Solar cookers	2424 CDM projects are in the pipeline with less than 3% being hosted in Africa
GTZ-Southern African Development Community (SADC)	Information Centre for Food and Fuel Security (IFSP) and	Mulanje district Malawi	Promotion of efficient and sustainable use of biomass	Clay and ceramic stoves	5,044 portable stoves produced in 2007

	ProBEC		energy		
	ProBEC and Dutch Ministry of Foreign Affairs (DGIS) with 16 partner organizations	14 Districts in Malawi	Promotion of efficient and sustainable use of biomass energy	Mud stoves, clay stoves and rocket stoves	Produced 487 fixed mud stoves, 18767 portable clay stoves; 1795 institutional rocket stoves, and 13 restaurant double pot rocket stoves
GTZ	Energy Advisory Service	Rakai and Bushenyi districts, Uganda	Promote access to modern and sustainable energy services for the Ugandan population	Charcoal stoves, rocket stoves and rocket institutional stoves	More than 250,000 improved stoves and been produced around the country and used in households
Practical Action		Kadjiado in Kenya	. Develop solutions in IAP	Smoke hoods, chimneys and improved ventilation	Better standards of living and good health for many
Practical Action		Kassala in Eastern Sudan	Develop solutions in IAP	LPG fuels	30 households were provided with LPD appliances by 2003
Practical Action		Rasuwa district, Nepal,	Community monitoring and developing appropriate methods to reduce the levels of smoke	Home insulation, improved stove design, indoor carbon monoxide and pollutant monitoring, and education.	improving people's health, livelihood and quality of life

Source: Author's invention

The evolution in cook stove technology and research findings show the extent to which cooking stove research has gone, however, more work needs to be done such that a major breakthrough on cook stove designs and efficiency is attained.

1.1.2 Indoor Air Pollution

Table 3: Numbers of deaths attributable to indoor air pollution particles, by setting

Author	Total death attributable to indoor particles air pollution	**Excess mortality by setting (deaths and % of total)**			
		Developed countries		**Developing countries**	
		Urban	**Rural**	**Urban**	**Rural**
Smith	2.8 million	640 000 23%	1 800 000 67%	250 000 9%	30 000 1%
Schwela	2.7 million	363 000 13%	1 849 000 68%	511 000 19%	Not calculated

Source: Nigel et al, 1997

"Air pollution may be defined as the presence of substances in the air at concentrations, durations and frequencies that adversely affect human health, human welfare or the environment", (*McGranahan, G and Murray F. ed 2003. p 2*). As already stated, according to WHO, 1.6 million deaths is caused by indoor air pollution and 2.7% of the global burden. In 2002, Sub-Saharan Africa and South-East Asia led with 396,000 and 480,000 deaths due to indoor smoke respectively (WHO, 2006). Although Smith and Schwela had varying figures for the number of deaths attributed to indoor air pollution, the difference was not much and the results followed the same trend. Most of the deaths registered occured in developing countries with a majority in rural areas Table 3 (*Nigel Bruce et al.*).

Indoor and outdoor air usually contain complex mixtures of air pollutants which make it practically impossible to examine all the combinations of pollutants, exposure patterns and exposure concentrations under controlled conditions *(Folinsbee, 1992).* Indoor air pollution is substantially larger than indicated by outdoor concentrations when there are large indoor sources, such as open fuel or tobacco burning. Globally, the most important indoor sources related to the use of traditional household solid fuels are wood and *agricultural residues (McGranahan, G and Murray F. ed 2003).* Coal also plays an important role in some countries like China for example where it is estimated that such fuel accounts for about 20-35% of the total energy consumption. However, biomass fuel still dominates. For example, it is also estimated that roughly 62% of households in India use firewood and agricultural waste, 15% use animal wastes and 3% use coal or coke *(Saksena S. and Smith K. R., 2003).*

The World Health Organisation (WHO) and the United Nations for Development Programme (UNDP) refer to indoor smoke as the "Killer in the Kitchen". On the occasion of the World Rural Women's Day on Friday the 15th of October 2005 in Geneva– the UNDP and the World Health Organisation took the unprecedented step of issuing a joint statement calling the world to wake up to this 'silent killer'. In the WHO's call on the use and desperate need of cleaner stoves, it pleaded with governments and aid organisations to do more to highlight the dangers of indoor air pollution (IAP) *(Marc Lapartin, 2004).* This awareness in death rates also caused the World Bank to declare indoor air pollution in developing countries one of the top four environmental health problems facing the world (*Trees, Water and People, 2006*).

After WHO and UNDP raised the importance of improved cook stove technologies and IAP, in October 2004, the Paris based International Energy Agency (IEA) in its authoritative World Energy Outlook (2004), again drew attention to solving IAP. In a chapter entitled Energy and Development, the report pointed out that 'the achievement of the Millennium Development Goals would most likely require a substantial reduction in the use of biomass fuel for cooking and heating'. The IEA estimated that if poverty alleviation targets were to be met, the use of modern cooking and heating fuels would have to be extended to 700 million more people by 2015 *(Marc Lapartin, 2004).*

In an effort to combat indoor air pollution and in support of World Rural Women's Day and the Partnership for Clean Indoor Air, the Environmental Protection Agency (EPA) announced $1.3 million in grants to reduce health risk from IAP resulting from burning crop waste, animal waste, wood and coal for home cooking and heating *(Marc Lapartin, 2004).* This might not be much but the effort in supporting such projects is commendable.

It is rather unfortunate that many people around the world are still very ignorant about the negative impacts of poor cooking techniques and the repercussions of IAP on health and environment. A medium to reach the rural communities and poor people who are directly exposed should be created. How and when this is attained remains yet unsolved, however research facilities and expert knowledge should be expanded to any persons in need. Nevertheless, a journey begins with a step and in years to come much may have been achieved against this vice.

1.2 Energy Situation in Cameroon

According to a study from the Ministry of Water and Energy in 2006, most inhabitants of rural areas of Cameroon (who account for about 60% of the approximately 18 million residents of this Central African country) still use biomass fuel and kerosene lamps for cooking and lighting. Of the 30,000 villages in the country, only 2,000 have access to the electricity grid of AES-SONEL, the sole national electricity provider in Cameroon (*Sylvestre Tetchiada, 2007*). Renewable energies despite its huge potential are under-exploited. Three quarters of the country has enormous potential for wood but the system of production, transportation and distribution is still informal. Other renewable energies such as solar, wind, geothermal and micro-hydro are less developed.

Cameroon currently relies heavily on hydro power for its energy. Hydro is the most popular and best developed renewable energy source in the country. Second only to the Democratic Republic of Congo in Africa, Cameroon possesses hydro-electric potential of 55,200MW and generates 294,000,000 MWH per annum (294 TWM per annum) (*Belda Pascal, 2007*). Some 110 water sources have been identified in the country. Photovoltaic (PV) cells are currently being tested where some PV cells are in use around the Yaounde central post office for the provision of traffic lights. There is a project by AES sonel (Electricity Company) for the construction of windmill plants in the cities of Limbe and

Bamenda. All these contribute very little to the total amount of energy consumed in the country.

According to the World Resources Institute, the reliance of developing countries on biomass as a source of energy for cooking, heating and lighting is very high (Fig 1). About 65% of Cameroon's energy source comes from primary solid biomass, 19% from crude oil and natural gas liquids, 12% from fossil fuel and 4% from hydroelectricity (Figure 4) (*World Resource Institute, 2003*).

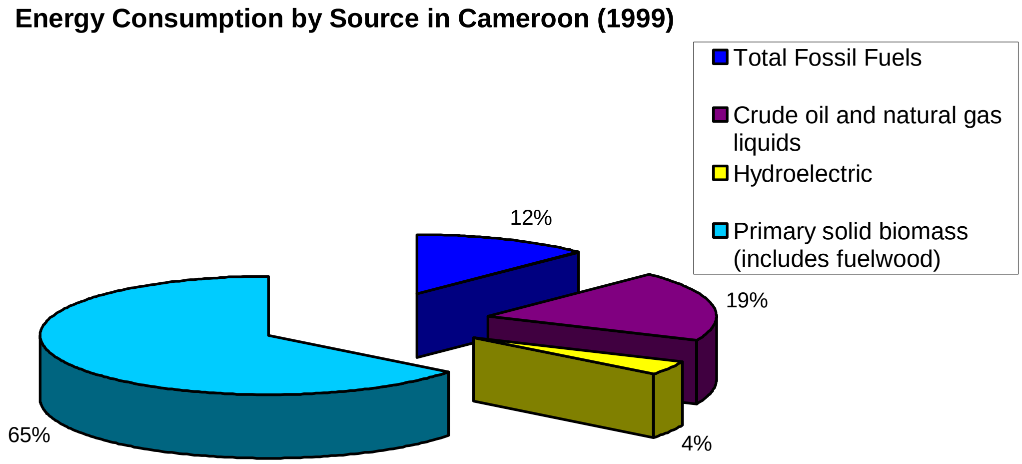

Figure 4: Energy Consumption by Source in Cameroon (1999)
Source: World's Resources Institute (WRI), 2003

1.2.1 Energy Consumption Distribution

The energy consumption distribution of Cameroon in 2001/2002 showed that 60% of total fuel consumed was wood fuel, 21% was petroleum and 16% was electricity meanwhile biomass waste, agricultural waste and charcoal each contributed 1% (Figure 5). For that same year, the largest energy consumer by sector was the residential with 70% consumed. The industrial sector consumed 17%, the transportation sector consumed 11%, the commercial and public services and the non energy sector and other consumption each consumed 1% (Figure 6).

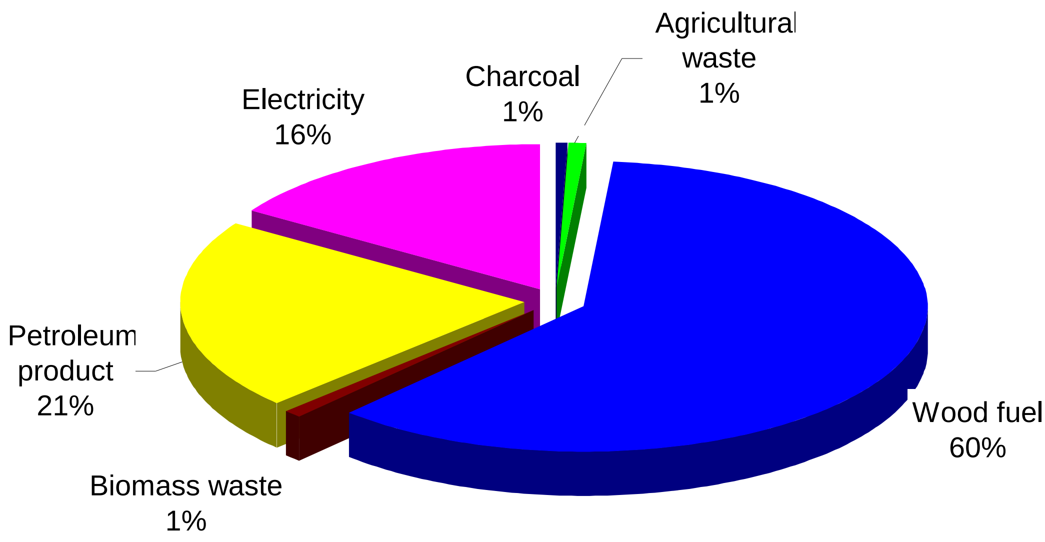

Figure 5: Energy Consumption Distribution in 2001/2002
Source: UNDP 2004

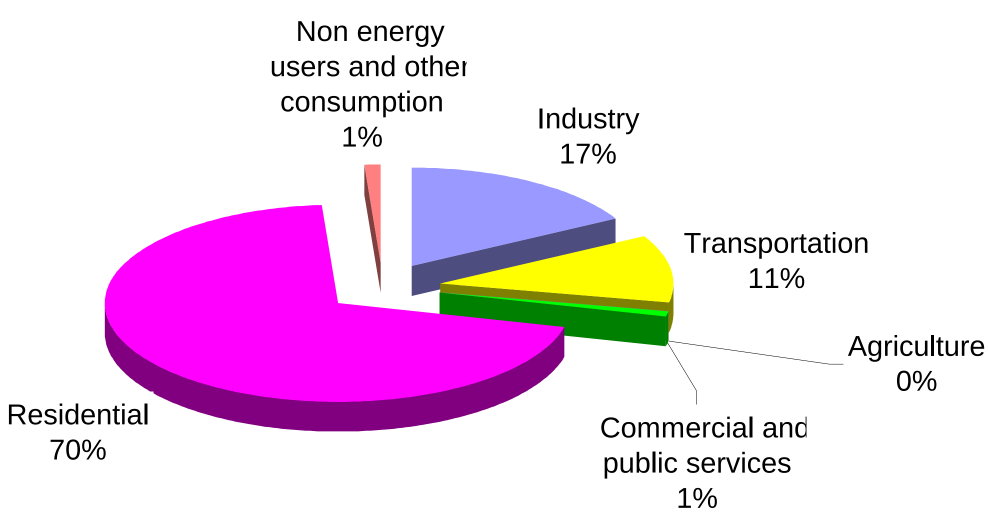

Figure 6: Cameroon's Energy Consumption by Sector, 1999
Source: UNDP 2004

With the pending cook stove technology limitations and IAP health problems, deforestation, global warming and climate change challenges, the need for research facilities and expertise can not be overemphasized. High consumption rates of wood fuel by the residential sector especially in Cameroon could by implication tell the degree of health hazards caused by the use of this energy source on the population. Yet the country is lacking in renewable energy policy and reforms and much is still to be done to meet up with other third world countries like China, India and some Eastern and southern African countries.

In Uganda for example, 93% of primary energy consumption is based on biomass with wood being the highest contributor. Only 1% of the rural area is electrified. Because wood is burned for cooking in the absence of gas and electricity, the threat of shortage is looming large. Consequently, the Ugandan national Energy Department within the Ministry of Energy and Mineral Development in cooperation with GTZ energy experts drew up a political and legal framework that helped to establish the use of renewable energy sources in Uganda. Through the designed Energy Advisory Project, the volume of investment in the energy sector rose by 20%. They marketed technically improved stoves and produced efficient charcoal-fuelled cookers, institutional cooking stoves and baking ovens. This way, the pressure on forest stock use up was greatly reduced and overexploitation was therefore minimized (*GTZ, Energy Policy Advisory Service, 2004*).

Another country which is very involved in ICS programmes is Ethiopia where up to 96% of its energy comes from biomass such as charcoal, wood, dung, and plant residues. Private households consume 88% of energy generated, half of which goes into the baking of the “injera”, a type of round flat loaf made with sour dough. Because of the ever growing population, biomass demand keeps increasing and today exceeds the regrowable supply by a factor of five. Consequently, the GTZ in cooperation with the Ethiopian Ministry of Agriculture began work in the four most heavily populated provinces. A project which aimed at improving energy efficiency by replacing the conventional stoves with the much more efficient “Mirt” stove in private households was implemented. Since its introduction in 1998, about 100 small businesses have been setup which have manufactured 27,000 “Mirt” stoves and sold them at a price of between 40 and 50 birrs (4-5 Euros) in 35 small and medium sized towns. A single stove reduces the demand for wood by 570 kilos per year. The amount of fuel wood saved since the start of this project now totals 16,000 tonnes which is equivalent to an area of 2,000 hectares of forest (*GTZ-Household Energy Service, 2004*).

1.2.2 Types of Technologies Employed

Cameroon being one of the partners of the Partnership for Clean Indoor Air (PCIA) which was launched by a number of countries and non-governmental organizations at the World Summit on Sustainable Development in Johannesburg in August-September 2002 is still struggling to meet up with the rational of this Summit. The Partnership is led by the U.S. Environmental Protection Agency and operates with the active participation of numerous other partners. In its effort to meet up with the stipulations of this summit, it came up with the National Energy Action Plan for poverty reduction in the country (PANERP). This encouraged the government to approve projects of certain energy oriented NGOs like the CAT (Centre for Appropriate Technology) and SHUMAS (Strategic Humanitarian Services).

The aim of the Centre for Appropriate Technology (CAT) which is a renowned NGO in Cameroon is to eradicate poverty and improve environmental quality through the development and use of appropriate technology, by demonstrating results, building skills and influencing people. It collaborates with the Global Village Energy Partnership (GVEP), the Rural Electrification Agency (AER) of Cameroon, and the Ministry of Planning, Development Programming and Regional Development (MINPLAPDAT) in facilitating the development of a National Energy Action Plan for poverty reduction in Cameroon (PANERP). So far in 2004, CAT with the support of GTZ Germany through the GATE programme organized a project known as the Energy Efficient/Renewable Energy Technology (EERET). This is a sensitization and Capacity Building Project which was published in the International Action Programme of the Renewables 2004 Bonn Conference. Sensitization workshops for key local stakeholders in all the divisions of the North West Province of Cameroon were organised. These stakeholders were sensitized and trained on the types, uses and benefits of EERETs (electric and non-electric); some basic EERET devices such as improved cook stoves, solar cookers, solar water heaters, solar home systems, thermo boxes, and dynamo power units were constructed during training workshops for teachers and students and donated to seven schools in the Province (*Center for Appropriate Technology - CAT Cameroon, 2000).* So how has the project evolved from then?

Cameroon is currently promoting the use of a wide range of energy efficient/renewable energy systems (micro/mini/small hydropower, solar, wind and biomass systems). The Ministry of Energy and Water accords projects to NGOs which are willing to install systems as well as offer consultancy services on household energy programs. The predominantly used technologies for household consumption are the three stone fireside (Fig. 7), sawdust stoves (Fig. 8), kerosene and gas cookers. However, more than 75% of households use the three stone fire for cooking and heating (*Njomgang C., 2002*). In some cases, more than one technology are used.

Improved metal stoves are not new in Cameroon although not widespread. However, women do not have to be convinced to use them since it is easy to see how efficient they may be. Affordability poses the main problem because they just do not have the money. Many women tend to use the traditional open fire, since they can get stones for free and can equally get wood for free. Meanwhile, improved metal stoves may cost up to 20,000 frs CFA (approximately 30 Euros) for smaller stoves or even four times more for the bigger ones. Examples of such stoves are shown by figures 10 and 12 whose description and technical features are elaborated in technology design section 1.2.3 ahead.

Figure 7: Traditional Open Fire
Source: Author's Collection

Figure 8: Sawdust Stoves
Source: Author's Collection

Figure 9: Sawdust stove
Source: Author's Collection

Figure 10: "Tangem" stove
Source: Author's Collection

On the other hand, metal stoves are predominantly used at institutions and for commercial purposes. Small businesses like restaurants and make-shift tents along the streets either use sawdust stoves (Figure 8) or metal stoves (Figures 11 and 12). The sawdust stove is just a metal container on which a small rectangular hole has been cut through which wood is burnt. No combustion chamber is present in this stove. Meanwhile Bakeries and Boarding School Institutions use "Ngwenjack" stoves (Figure 14 and 15). Normally, it is expected that in the urban areas, those who can afford modern stoves would use them. But the reverse nowadays is true as economic hardship is causing many to go back to the use of traditional fuels because they are cheap.

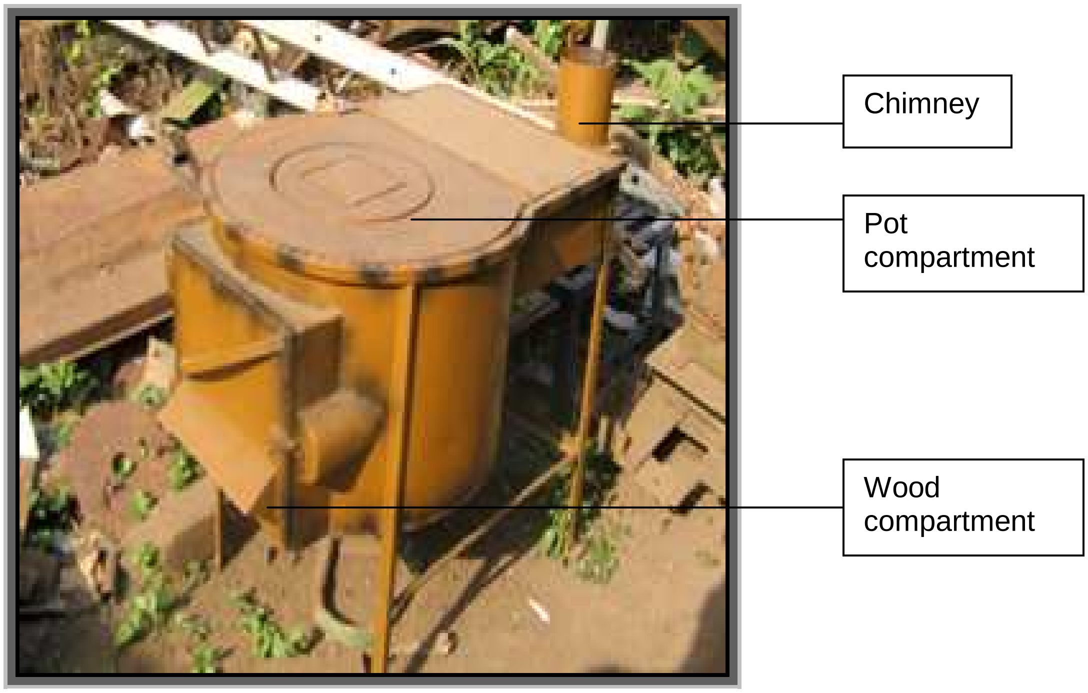

Figure 11: Ngwang Stove
Source: Author's Collection

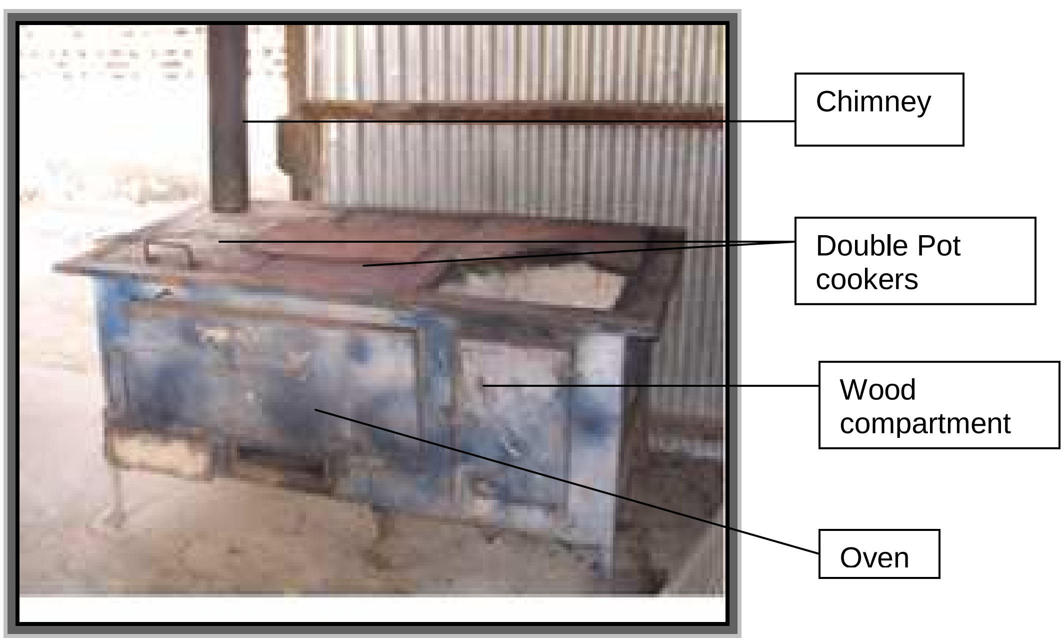

Figure 12: Aftang stove

Source: Author's Collection

The Ngwang stove is a one pot cylindrically shaped stove which has a chimney. It is made out of metal and is insulated with cement. The Aftang stove which is of a similar design as the Ngwang stove has been well described below (Figure 16).

Fuel inlet. The door of the oven is at the front.

Figure 13: Clay Stove at the Bambili Bakery (Rear view)
Source: Author's Collection

Dating back many decades ago, the first known improved stove of the North West Province was installed by the Germans at the Mbengwi Monastery. The monastery now runs several cooking stove seminars and constructs many improved stoves for household and industrial use.

The Trade Centre for Self Reliance (an NGO in the Buea, South West Province, Cameroon) has been very instrumental in disseminating improved stoves. It is noticed that even those with improved stoves (institutions and households) are constantly working on getting better stoves. Sacred Heart College Mankon Bamenda (Secondary and High School institution) for example, just recently in January 2007 constructed an inbuilt Rocket stove which now cooks faster and uses less fuel than what was there before ("Ngwenjack" stove). This stove is an inbuilt one pot stove that is made out of metal and is insulated to prevent heat losses. The pot is totally submerged in the stove and has a lid. There is a tap at the side to let out water, during and after cleaning the pot. Nowadays, many boarding school institutions especially, enjoy the facilities of having their own stoves. The question still remains, do these so called improved stoves really cut down emission? Nevertheless, the issue of concern here is how efficient these stoves are and how the entire community can be sensitized and encouraged to use them.

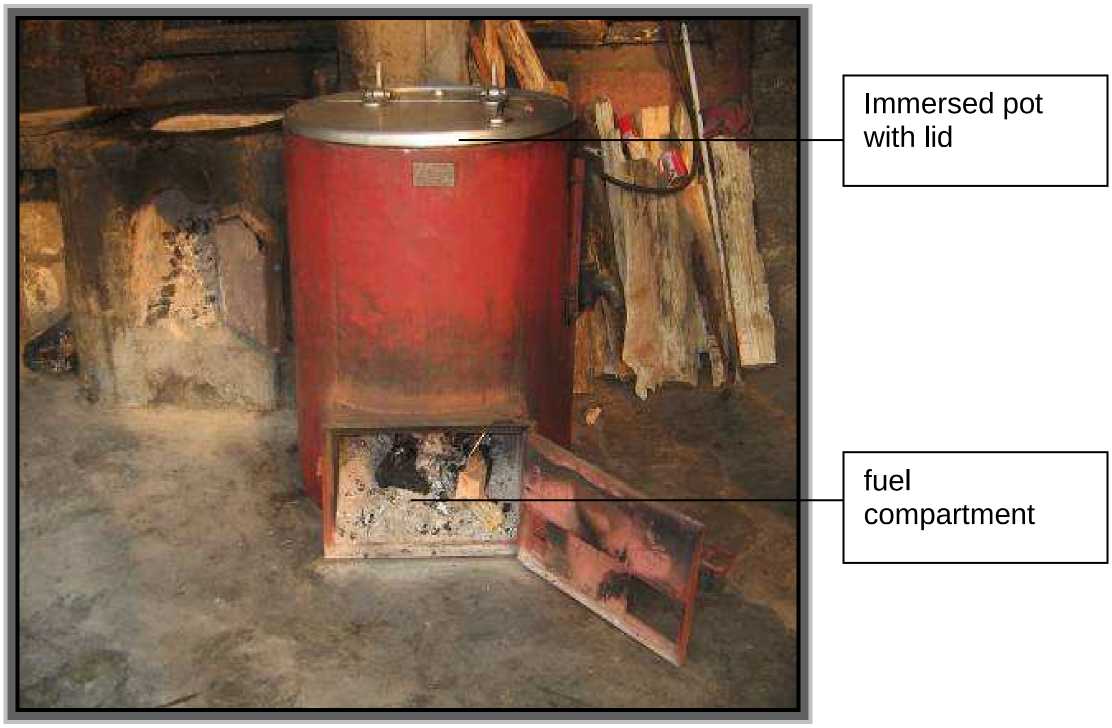

Figure 14: "Ngwenjack" Stove (Front view)

Source: Author's Collection

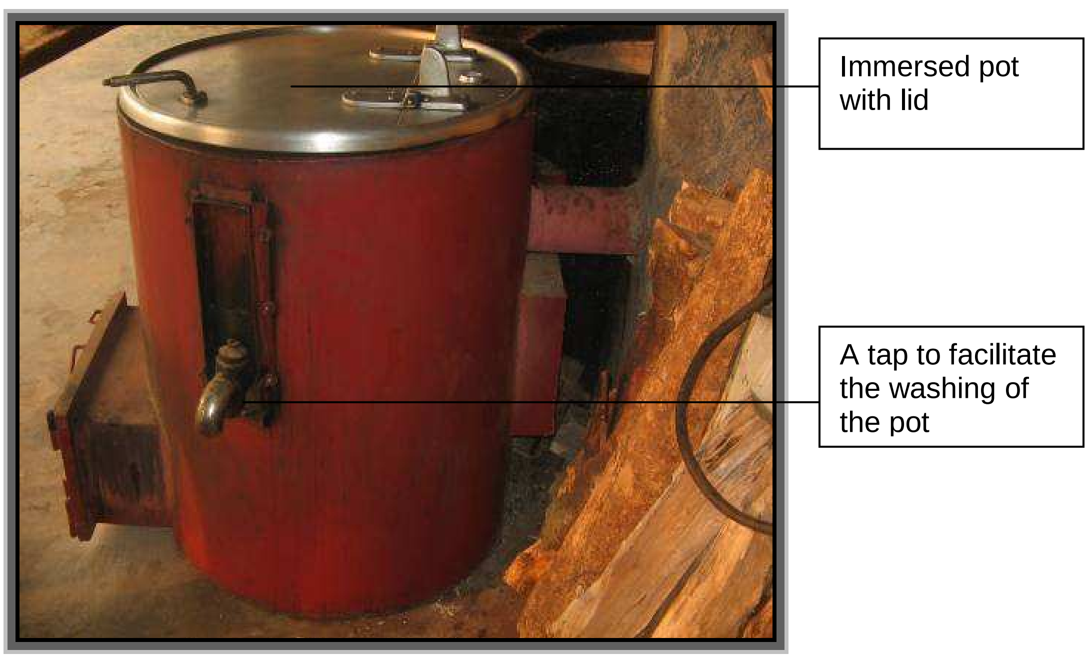

Figure 15: "Ngwenjack" Stove (Side view)

Source: Authors Collection

PROTEGE QV (Promotion of Technologies that Guarantee Environment and a better Quality of Life) is a local NGO in Cameroon. Since its creation in 1995, it conceived and put in place strategies of improving the living standards without jeopardizing natural resources, sensitizing communities and groups of women on some of the direct and indirect hazards felt in their society and to promote individual and collective initiatives to induce rural development. The goals of this organization could be summarized as to protect the environment and improve the well being of the community. Together with "Women organizing for change in Agriculture and Natural Resources Management" (WOCAN), the "Project of Assistance to Diversify Modern Cook Stoves" in some villages (Bangoua and Batoufam) in the Western Province was launched. They had as objective to sensitize and orientate the population of the villages concerned towards the formulation of a major widespread dissemination programme of modern cook stoves capable of alleviating the problems diagnosed in this province and the difficulties encountered in household firewood supplies *(Momeni A. 2005).* They have also been instrumental in changing the lives of many women through their internet training workshops and radio sensitization programs in the centre province (Yaounde 6 District).

Funds for running their projects come from membership contributions and subsidies from leading organizations like Global Knowledge Partnership, the World Bank, French Cooperation in Cameroon, United States Embassy in Cameroon and the Japanese Embassy in Cameroon. Taking into consideration the academic levels of those running this organization, their exposure to other relating groups and their achievements so far, their planning and technical know-hows could be assessed as being of standard. Like the Protégé QV project, WWF (Worldwide Fund for Nature) started a program on improved stoves in the Northern part of Cameroon in 2004. These among others are the accomplishments in promoting cook stoves in the country.

The stove type employed in Cameroon largely depends on its purpose e.g. for commercial or household use. Each stove has a certain advantage and depending on fuel availability, its use would be affected. Additionally, the cost of fuel and stove purchase equally affect the choice of stoves used by these people. Therefore, it is common to find households with more than one stove type.

After carefully reviewing, the historic and current research activities of governmental and non-governmental bodies in the developing world, this research work needs to concentrate on solving the recognised problems caused by using inappropriate cooking stove technologies in Cameroon. To ease this work and come up with credible results, case study areas of two localities in the North West Province are mapped out. The methodology employed as explained in chapters 4 shall be used to attain this goal. By using questionnaires, focal group discussions, interviews, the water boiling test and a simulation model, the system of heat capturing and indoor air pollution is better understood and its possible negative effects on humans and the forest can be minimised or eradicated. Indoor air pollution has only recently been recognised as a serious problem in the country, especially in the case study areas and this is the first of such research to have taken place.

1.2.3 Technology Design (Aftang Stove)

A typical Aftang stove (Figure 12) is rectangular in shape and has an oven. It also has at least pot stands, a fuel compartment, a vent, a heat passage and a chimney which is usually extended through to the ceiling to let out smoke. An average size Aftang stove has a length of about 160cm, width of about 60cm and a height of about 75cm. It is recommended that the height of the stove should not surpass 80cm considering human height. The fuel compartment has a length of about 50cm and a height of about 45cm. This compartment has a door and a vent which allows the passage of air necessary for combustion. There is a heat passage of about 110cm long and 20cm high that connects the fuel chamber and the oven. Through this passage, the oven is heated. Depending on the design chosen, the oven could be located on top of the stove like in figure 16 below. The oven usually has a size of about 60 × 60cm.

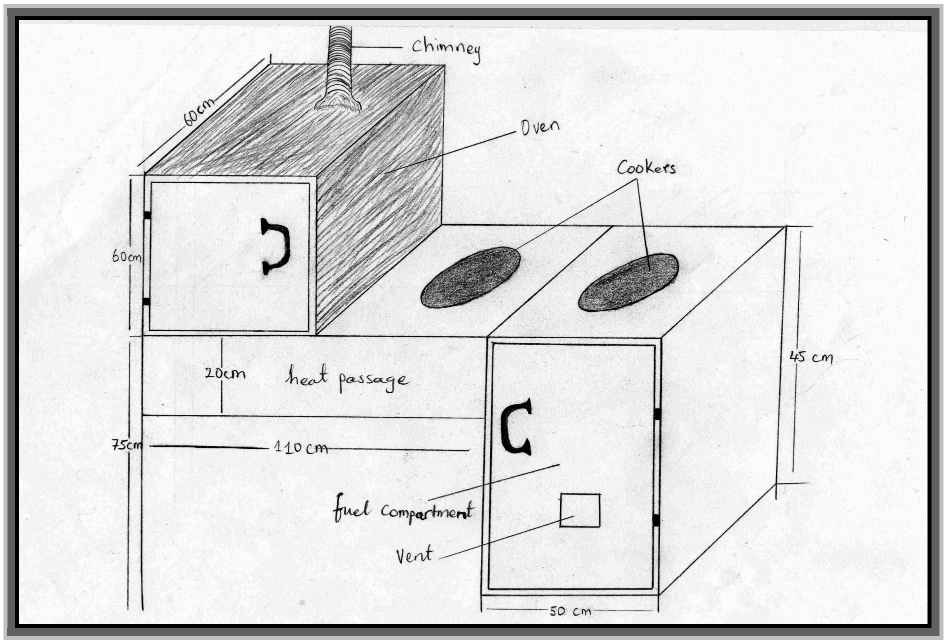

Figure 16: Improved Aftang Stove

Source: Author's Collection

The improved Aftang stove (Figure 16) is entirely insulated. This is important because it helps retain heat and prevents burns. The fuel compartment is, particularly profoundly insulated. Initially white cement or clay was used as insulating material. Nowadays, clay is no longer used since it takes a longer time to dry and it cracks faster. Since 2005, a mixture of white and brown cement is used. This is thought to serve as a better insulator as it is more resistant to the heat capacity. 50kg of white cement is mixed with about 12.5kg of brown cement and 10kg of sand and 3 buckets (7.5L) of water. Literature today holds it that an even better insulator is vermiculite. The lighter the insulating material the better it is. An average size Aftang stove has a weight of about 100kg and costs about 100,000 Frs. CFA (approximately 150€). It is worth noting that these stoves could be adapted for household purpose or commercial use depending on their functions. This therefore implies that the shapes can vary according to interest and need.

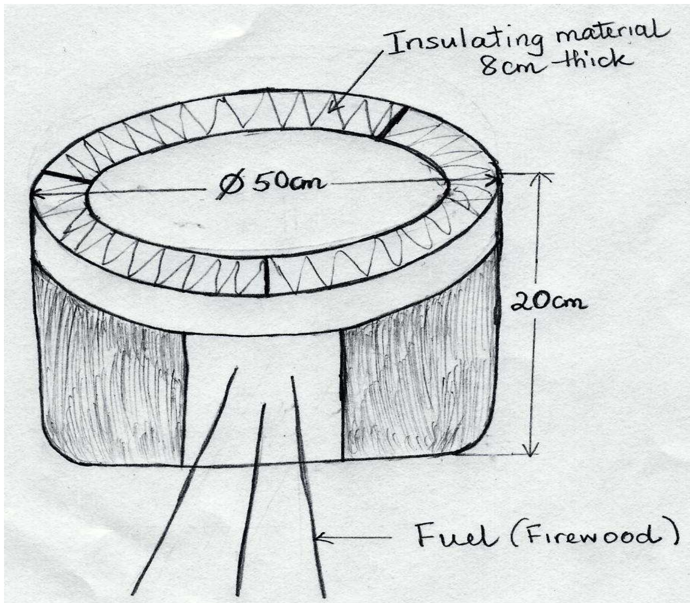

Figure 17: **Tangem Stove**
Source: **Author's picture**

Apart from the Aftang stove, the Tangem stove (Fig 10 and17), is much smaller and more affordable. This is a metal stove which is cylindrical in shape and easily handled, however it has its limitations as pots of varying sizes cannot be used on the same stove since each stove is adapted for use of a particular pot size. The stove has a height of about 20cm and a diameter of about 50cm. It is equally insulated with a thickness of about 8cm. The Tangem stove cost about 20,000 Frs. CFA (approximately 30€). Because many of these stoves are produced without field or laboratory tests, their performance and acceptance are still questioned.

Chapter 2 INTRODUCTION TO THE RESEARCH STUDY

2.1 Statement of the Problem

As stated before, in 1991, about 69% of the population in Cameroon was still without access to electricity or any form of modern commercial energy (*United Nations Industrial Development Organization (UNIDO) 2003, Developing Energy to Meet Development Needs, p 253*). Today, over 85% of the rural population in Cameroon does not have access to any form of modern commercial energy. They mostly rely on fuel wood and kerosene for cooking and lighting. The inefficient, extensive and intensive use of fuel wood for cooking in particular puts a lot of stress on the environment and the family budget for those who buy. It also brings about indoor air pollution, deforestation and increased burden on women and children who spend considerable time in search for wood. According to John Beale, "it is a tragic irony that the very act of preparing food, which is designed to aid and nurture a family, is putting that very same family at risk" *(Kounteya Sinha, 2007)*.

Figure 18 below, in form of a sketch, represents the identified problems this research work aims at understanding and, to a greater extent solving. These problems fall within four major categories which include; health issues (indoor air pollution), environmental issues (deforestation and unsustainable use of fuel), social crisis (lack of electricity, poor living conditions, sex discrimination), Political issues (lack of well structured governmental policies) and economic issues (affordability).

AES SONEL is the lone National Grid Company in Cameroon. It is not capable of meeting up with the present energy demand of the country let alone cater for the future needs and supplies to yet unconnected communities. On the contrary, this company has resorted to huge charging rates and power sharing that is neither announced nor its duration notified. Besides the lack of electricity in some areas, there are constant fluctuations in energy prices like electricity, petrol, kerosene and cooking gas. A liter of kerosene for example now equates the cost of a liter of palm oil in the market. This constant increase in fossil fuel prices has caused a shift back to fuel wood use. In areas of wood scarcity, people have to trek long distances in search for fire wood. The issue of division of labour now sets in, as the woman and her children are responsible for wood fetching and taking care of the house chores.

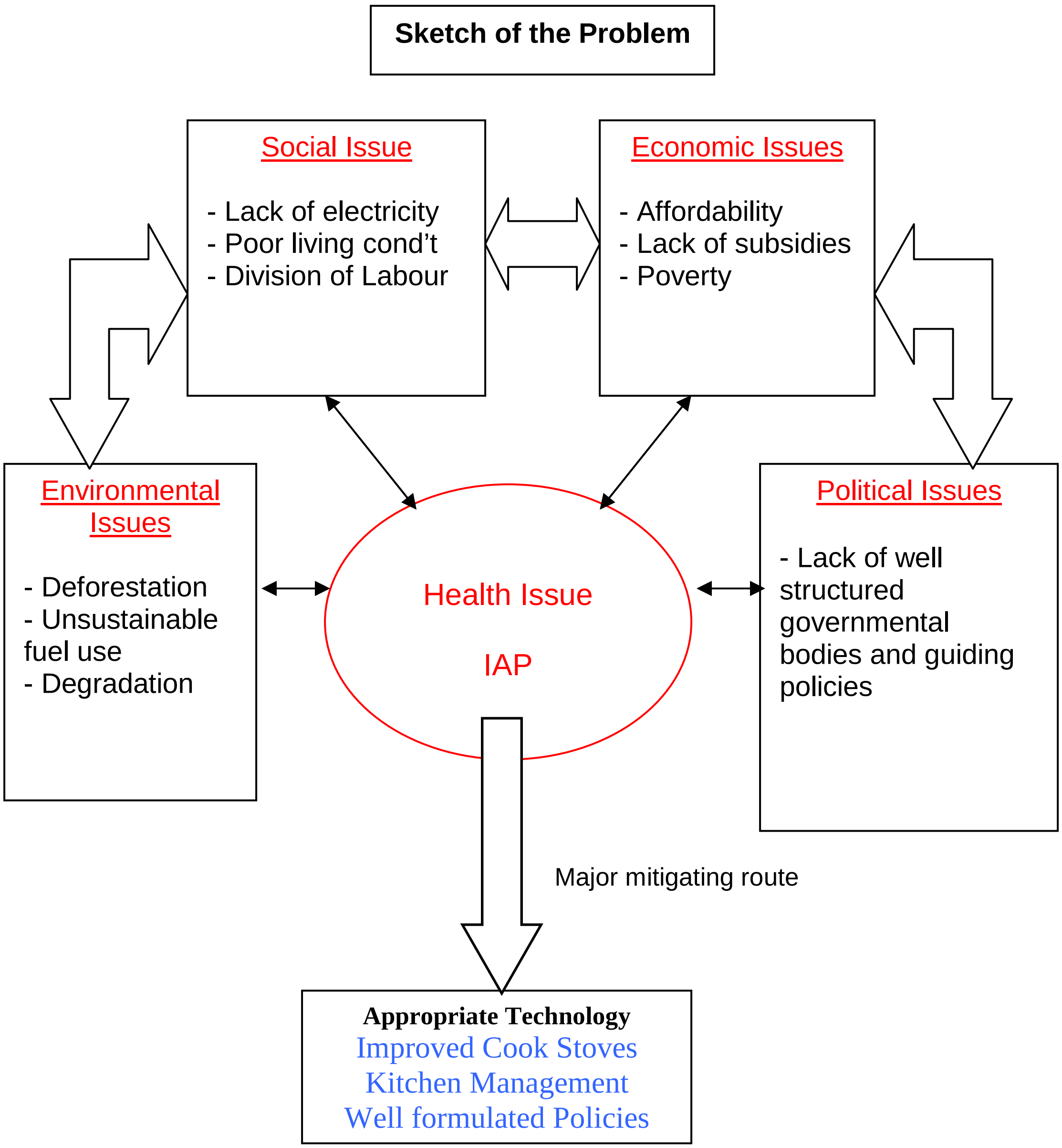

Figure 18: A Schematic Representation of the Problem Structure

Fuel wood in itself, is a renewable source of energy. However, when unsustainably exploited and used inefficiently, it causes terrible repercussions to human health and the environment. Dating many years, it was believed that only the poor who relied on fuel wood. Nowadays, formally rich are going back to fuel wood use while population increase plus urbanization all contribute to the increasing pressure on the forest. The collection of large scale and uncontrolled quantities of fuel wood often has a negative impact on fuel wood resources, particularly in poorly managed natural forests. Undervaluation of these fuel wood sources might lead to their unsustainable use and management and deforestation. When wood fuels are scarce, the time people spend collecting fuels reduces the time they devote to productive agricultural activities.

Apart from the economic hardship associated with gathering and cooking with biomass, indoor air pollution (resulting from poor cooking technologies and techniques and lack of knowledge on how to handle wood fuel) causes health problems. Poor cook stoves have been identified in the study area. The currently most used open fire, metal and saw-dust cook stoves have air-intake above the firewood, lowering fire temperatures and causing incomplete combustion. This results to the forming of soot and production of ash. The kitchen location and aeration are contributive factors which will equally influence the amount of soot produced. Apart from smoke emissions, the women who are cooking over these open fires and children who are playing around the cooking area run the risk of being seriously burnt. Although a greater majority of the population are not familiar with improved cook stove technologies, the few organisations and individuals promoting and disseminating them still can sell them at very high prices. This scares the few who might be interested and willing to purchase them.

Despite the numerous benefits of renewable energy technologies to the sustainable development of our communities and households, Cameroon's government lacks a defined guiding policy and a well structured governmental body to tackle the discussed socio-economic and environmental issues. The gross lack of project incentives and access to small-scale credit remains a major barrier, especially for low-income and medium-income groups: given the intensity of poverty prevalent in the North West Province. With a population of about 1.8 million inhabitants, (*2001 est. Statistical Provincial Services of the North West Province)* the people have resorted to the use of cheap and affordable fuel types and cooking stoves without paying attention to the hazards they may be causing to their health and the environment. This could be attributed to ignorance, carelessness or simply poverty.

In the North West Province of Cameroon, some of the most commonly used cook stoves include the three stone fire (figure 13), saw dust cookers (figure 14) and charcoal stoves. They have serious health repercussions for users except where existing technologies are improved or better ones substituted. The real advantage of improved stoves is that they are safer and cleaner than open fires, reducing the risk of children burning themselves and cutting out the smoke inside the homes which damage health and dirties every thing. They equally use less fuel thus reducing the level of deforestation. Even with these improvements, we cannot avoid all health problems, but at least one can mitigate the situation.

2.2 Hypothesis

Indoor Air Pollution (IAP) is a health problem in Cameroon, but the government and people have up till now not fully realized the resulting consequences. Very little is done to improve the situation. Energy experts and policy makers have a lukewarm attitude towards household energy issues. Although traditional stoves have been in existence for a long time now, its health repercussions almost go unnoticed. Cameroon is rich in forest resources, but its distribution in the country is uneven: some parts have plenty while there is scarcity in others. For areas where scarcity is a problem, there is urgent need for mitigating solutions. For areas with plenty, there is need of sustainable management. Whatever the case, part of the solution could be the use of improved cook stoves and kitchen management. Other measures like forest management, rule of law and policy and improved economic situation would have an impact as well.

In the case study area, wood fuel is not a scarce commodity but the system of exploitation is unsustainable. Most of the people in the cities buy fuel while those in the villages collect fuel. The intensity of damage caused by indoor pollution varies with communities and individuals. The effect of IAP is more serious in rural than in urban communities since the rich settle in urban areas while the poor remain in the villages - reason being more economic boom (through industrial activities, businesses and trading) in urban areas which is the main source of income. Therefore, the rich can easily afford better stoves or can afford having more than one stove type depending on their needs and budget. This in itself is an advantage over a household which solely depends on one stove type that might not even be the best stove.

Nowadays, based on my observations in the country, metal stoves are believed to be improved stoves but this is not always true. Most of the stove producers do not really test their stoves before getting them into the market. Therefore, what is thought to be an improved stove may be less efficient than the traditional open fire. There is no serious on going research in the country - especially as far as laboratory and field tests are concerned. This can be attributed to lack of facilities, equipment and expert knowledge.

The degree of damage caused by IAP depends on the stove type as some wood stoves burn more efficiently than others. Other factors like fuel moisture content and improper handling by the stove operator would affect the level of pollution as well. Wet wood is a big problem for many who cook with wood because when wet wood is burnt, more pollution is emitted. To understand the effect of wood moisture on stove performance, a WBT (Water Boiling Test) was carried out on wood moistures of 5%, 15%, and 30%. In the case study area, the rainy season is longer than the dry season. During the rainy season especially, many people tend to use wet wood without knowing its repercussions on health.

Based on the above, my research hypotheses are:

1. IAP is a health problem in Cameroon, but the government and people have up till now not realized the resulting consequences. Although traditional stoves have been in existence for a long time now, its health repercussions almost go unnoticed. Energy experts and policy makers have a lukewarm attitude towards household energy issues, thus, very little is done to improve the situation.

2. It is generally believed that the effects of IAP are more felt in the villages than in the cities. This is not always true because the so called rich are turning back to the use of traditional stoves due to ever increasing fuel prices. Furthermore, rural exodus which causes an increase in the number of people living in the cities would influence the number of those who actually use wood fuel for cooking. This is because the villagers who are used to using fuel wood would continue to do so while in the city, at least in the beginning. Nevertheless, the intensity of damage caused by IAP varies with communities and individuals.

3. There is no on-going research (be it laboratory or field based) in the country. Many of the metal stoves being produced and marketed now have not been tested, so they cannot be referred to as improved stoves. Besides, some of these stoves perform worse than the three stone fires.

2.3 Research Objectives

Bearing in mind that biomass fuel will continue to play an important part in the energy mix of low-income households for some time to come, this research work has as objectives:

1. To study the-state-of-the-art cook stove technologies by carrying out a comparative study of the existing technologies in the case study area and to assess the socio-economic impacts of poor cooking techniques on health and the environment.

2. To carry out a stove performance test by assessing the effect of wood moisture on combustion efficiency and heat transfer efficiency of three stoves (three–stone–fire, Chinese rocket stove and the “skirt” stove) using the laboratory based Water Boiling Test.

3. To use a conceptual model (Sensitivity Model) to simulate the system of heat capturing technologies. This simulation will give an insight into the dynamic development, a better understanding of the relationship

between existing components involved in cook stove technology and the possibilities of controlling the system.

2.4 Research Questions

In the light of the above mentioned hypotheses, this study would be carried out with the following working research questions in mind:

I. Which are the main household energy sources in the study area?

II. What is the level of involvement of the government and non governmental organizations (NGOs) in fostering sustainable household energy use?

III. What is the level of awareness of the community on household energy issues and the impacts of IAP on health?

IV. What can be done to ensure that maximum stove efficiency is attained; and kitchen management techniques are employed so that the kitchen becomes a more conducive place for cooking and relaxing?

SECTION I

A CASE STUDY OF CAMEROON

RESEARCH METHODOLOGY AND THE SOCIO – ECONOMIC APPROACH

Chapter 3 CASE STUDY AREA OF CAMEROON

3.1 Situation of Cameroon

Situated 6 00N and 12 00E of the Equator and usually referred to as “AFRICA IN MINIATURE”, gained independence on January 1st 1960 from her colonial master France.

Cameroon (Fig. 19) covers 475,440km^2 on the west coast of Africa, and shares boundaries 1.094km to the North East with the Republic of Chad, 797km to the East with the Central African Republic, 532km with Congo, 189km with Equatorial Guinea and 285km with Gabon in the South, and 1.690km to the West with the Federal Republic of Nigeria.

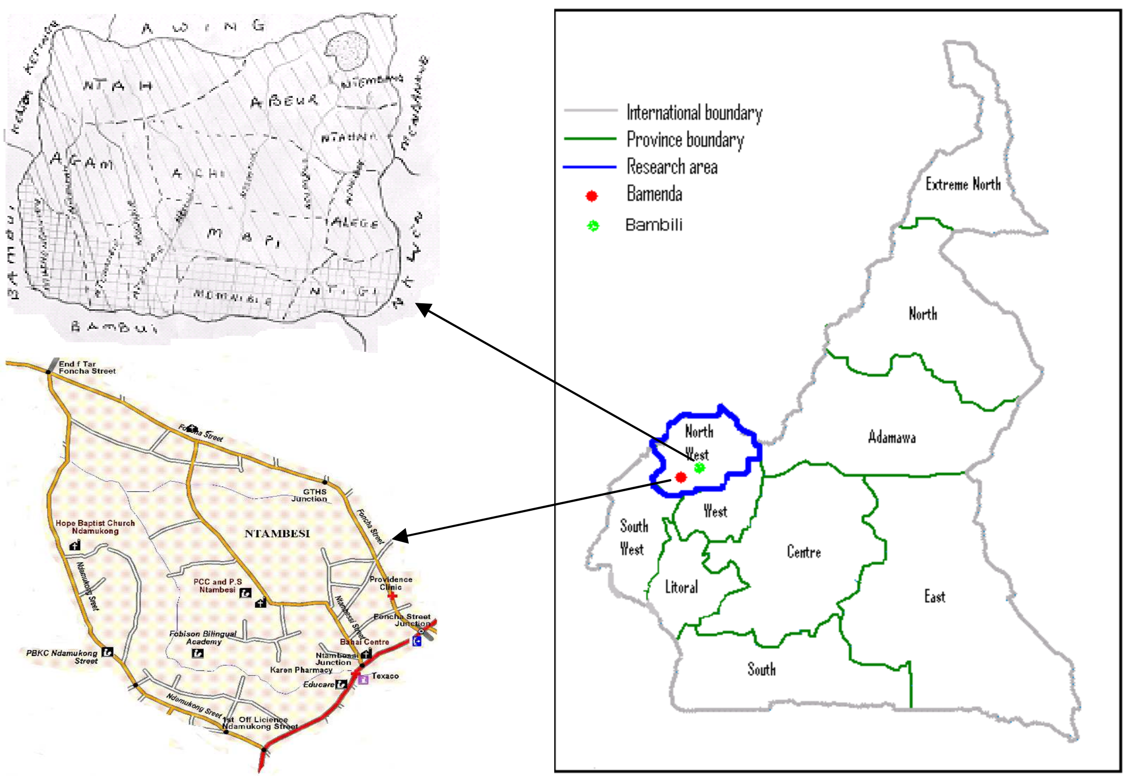

Figure 19: The Map of Cameroon

Source: http://www.mapsofworld.com/cameroon/cameroon-political-map.html

Diverse with coastal plains in the South West, dissected plateaus in the Centre, mountains to the West and plains in the North, her terrain ranges from tropical forests to coastal plains and central plateaus to western mountains, with the lowest point recorded 0m at the Atlantic Ocean and the highest in Mt Fako with

4.095m, the highest in West Africa. Cameroon has a coastline that stretches over 402km (*http://geography.about.com/library/cia/blccameroon.htm*).

3.1.1 Demography

According to the CIA – World Factbook Dec. 2007 estimate, the population of Cameroon stands at about 18,060,382 inhabitants. Of this number, 57% live in the rural areas while 43% live in towns and sub-urban centers. 70% of this population occupies only 30% of the habitable surface area, with an average density of 25 inhabitants per km^2 in 1992. This shows a sharp disparity in the population distribution.

The degree of urbanization is steadily on an increase from 28% in 1976 through 38% in 1987 to 42% in 1992. Estimates show that by the year 2010, the population of Cameroon shall stand at about 20 million inhabitants with 68% living in urban centers. About sixty towns now have more than 10,000 inhabitants with eight towns having more than 100, 000 inhabitants (*Mbenkum T.; 1995*).

3.1.2 Resources and the Environment

Cameroon presents an exceptional environmental diversity that gives the country opportunities for long-term development. However, the current exploitation of natural resources is detrimental to their regeneration and the country risks jeopardizing its opportunities for a sustainable development.

The differences in latitudes are largely responsible for the diversity of the landscape, soils, climate and relief and this has earned Cameroon the name “Africa in Miniature”. Cameroon has become an ideal area for the mastery of inter-tropical environment and also a natural laboratory visited by curious researchers from the four corners of the globe. Current environmental issues prevalent in the country include water-borne diseases, deforestation, overgrazing, desertification, poaching and over fishing. The inventory on forest resources has not yet covered the whole of Cameroon’s territory. According to UNDP and FAO research figures, 22.5 million hectares of the surface area of Cameroon is covered by forest, including degraded forest. This ranks Cameroon second among forested African countries. Of this forest area, 17 million hectares are covered by productive forest. However, the forests (woods) are not uniformly distributed around the country, there are areas of plenty and there are areas of scarcity.

Concerning the southern part of Cameroon, the inventory of resources was used to estimate the total volume of tree species with a diameter of above 20cm, at more than 4 billion m^3. The volume of tree species with a higher exploitable diameter currently under industrial exploitation (by the government and other foreign companies), about 30 of 300 species, stand at about 300 million m^3. Cameroon therefore has one of the richest forest resources which can readily be exploited with tree species like the ayous, iroko, sappelli, movingui, sipo, burbinga, etc. (*Mbenkum T. 1995*).

3.2 Case Study Areas: Bambili Village and Bamenda-Foncha Street

3.2.1 Bambili Village

Bambili (Figure 20) is a village situated eight kilometres north of Bamenda, along the Ring Road, in the Tubah Subdivision, Mezam Division, of the North West Province, Cameroon. Bambili with an estimated population of about 20,000 inhabitants is a semi urban area composed of thirty-eight quarters, each of which has a quarter head. Bambili has basically two settings, a typical village setting and a semi-urban setting.

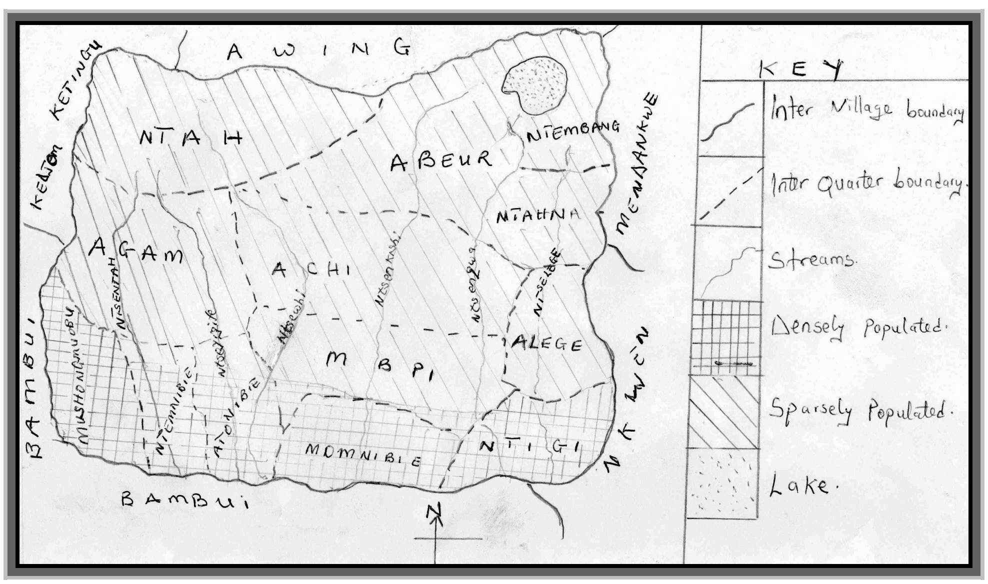

Figure 20: A Sketch Map of Bambili

Source: Author's Collection

The name Bambili is a Bali-Germanic pollution of the name Mbeligi (People of Aligi). This name Bambili was adopted by the German explorer Zingraff, during his grassland exploration in 1889, for easy orthography writing. The guide told Zintgraff “ba-mbeligi” and Zintgraff wrote “Bambili”, hence the name Bambili. The people call themselves “Mbeligi” (Mbili) and their language is refered to as “agimbeligi” (‘language of Mbili’). “Mbeligi” simply means “I will take a rest”. The first German explorers added the prefix ba, meaning ‘people of’, to the name of each language group they encountered. Thus, their original name was transformed eventually into the name Bambili (ba-Mbili) (*Anuafor P. T., 2006*)

3.2.2 Bamenda Town - Foncha Street

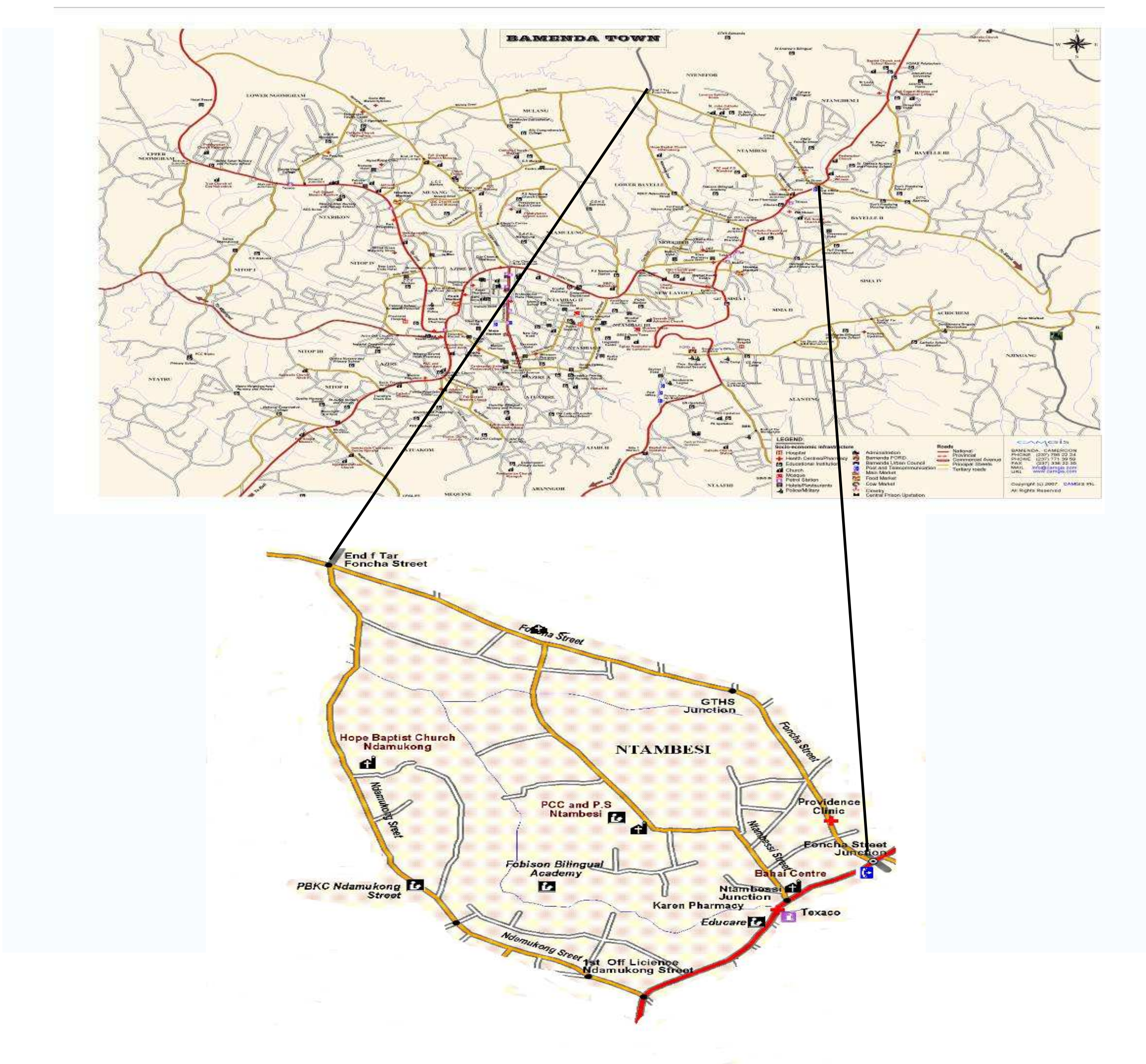

Figure 21: The Map of Bamenda Town

Source: CAMGIS (2006)

Bamenda generally referred to as Abakwa (Figure 21), is the capital city of the North West Province of Cameroon. This city is an amalgamation of three villages - Mankon, Mendakwe and Nkwen. Bamenda is located at 366 km (227 mile) northwest of the Cameroonian capital, Yaoundé and has an estimated population of 427,137 inhabitants. Bamenda is known for its cool climate and scenic hilly location (Wikipedia, Bamenda 2006 http://en.wikipedia.org/wiki/Bamenda).

Chapter 4 METHODOLOGICAL APPROACH

4.1 Research Design

This section explains the structure and sampling methods of this research work. It elaborates on the criteria and procedure used in selecting the research area. It equally discusses the sample size of the study.

4.1.1 Sample of Study Area

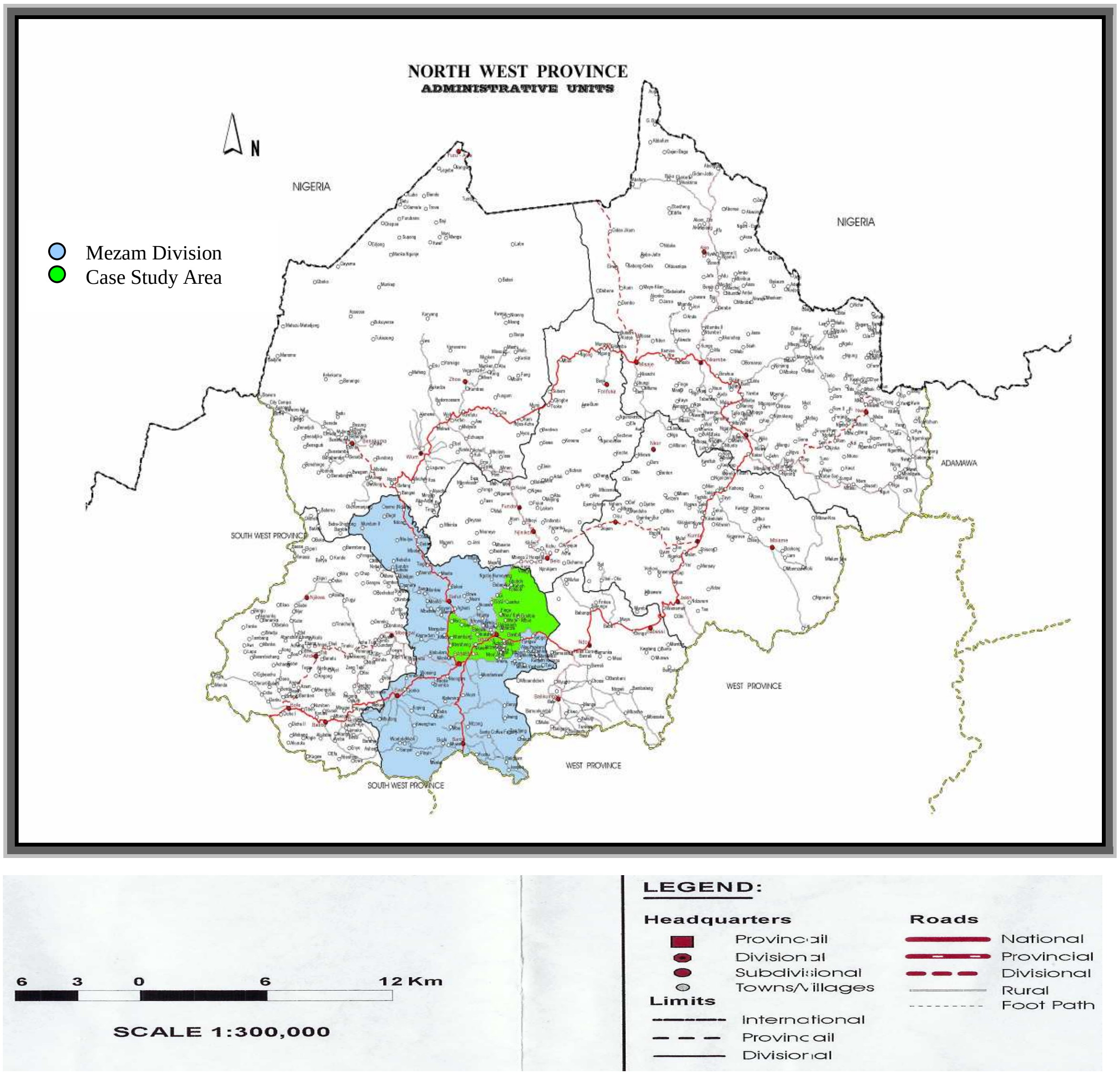

Figure 22: The Map of the North West Province
Source: CAMGIS (2006)

This study was carried out in two different localities of the North West Province of Cameroon (Figure 22) namely the capital city of the Province, Bamenda town and the Bambili rural community of the Tubah sub-division, Mezam Division.

4.1.2 Criteria of Choice and Sampling Procedure

The methodologies of selection of study employed in this research were the purposive sampling method and the simple random sampling. The political, socio-cultural and ecological division of the country were reviewed in making a choice of the case study areas.

Considering the political aspect of Cameroon, it is divided into provinces, divisions, sub-divisions, districts and villages. Each village is ruled by a traditional chief, the divisions and sub-divisions are governed by the divisional officer or sub-divisional officer, provinces are governed by governors while the entire country is headed by a President.

According to the socio - cultural aspect of the country, 8 large regional groups (Cameroon Highlanders 31%, Equatorial Bantu 19%, Kirdi 11%, Fulani 10%, Northwestern Bantu 8%, Eastern Nigritic 7%, other African 13%, non-African less than 1%) have been identified with over 230 indigenous languages *(Echu G. 1999, Wikipedia, 2007)*. These indigenous languages depending on the region of origin can be differentiated by their cultural activities.

Following the ecological and vegetation distribution, Cameroon can be divided into 3 regions namely the semi arid, the savannah and the highlands. The semi arid region is found in the northern part of the country and is mostly inhabited by the Fulani. Although this region is dotted by some savannah areas, it suffers most from scarcity of wood, caused by poor soil type and climate which inhibits the growth of plants. However, the inhabitants of this area are herders who rear cattle, sheep and goats thus the availability of dung which could be used as fuel in substitute of little or no fuel wood.

The savannah region which is principally the eastern and southern parts of the country is blessed with good soil and rain forest that boost the agricultural situation of the area, thus the availability of wood. This area of the country harbours the pygmies whose main route of subsistence is farming and hunting. It is very rich in natural resources and a bio-diversified equatorial forest.

The highland region (western and north west parts of the country) has the most fertile soil and a relatively healthy environment however, the cultural, social and customary believes that exist set the difference. The inhabitants of this locality are predominantly farmers who depend on farming for their up keep with a few civil servants and businessmen. However, there is still the need for improved technology such that wood is jealously, judiciously and sustainably used. My case study areas fall within this region.

After having an insight on how Cameroon is structured, there is now a shift from the political, social and ecological aspects to the reason behind the choice of the case study areas. Because of the well structured distribution and the existing cultural similarities in the country, one can pick out a locality of study that could represent the other. The choice of site and scope was based on the fact that households that actually depend on non traditional methods alone for cooking are not many, reason for the expansion in study area. To test one of my hypotheses, that most of those using only one traditional stove type are found in the rural areas, I resorted to working with two different settings for comparative reasons. This therefore led to the decision of carrying out a comparative study between the rural community and an urban area. To facilitate this research with maximum efficiency, I settled for the above mentioned case study areas. I am quite familiar with these regions and their traditions. Furthermore, the problems existing in these areas were easily identified and information was easily accessible thus the use of purposive sampling.

Foncha Street stretching through Ndamukong Street Mile 3 in Bamenda town was chosen to represent the urban area. This area is mostly made up of the middle class and high class citizens who are the top ranking civil servants and business men and women in the community. From here it was easy to have vital information and pictures of modern and transitory cooking devices.

Bambili village is principally made up of two settings; the typical rural setting around the Fon’s palace, and the semi-urban setting around the academic institutions. However, the former was of prime interest with homes solely depending on traditional cooking stoves (three stone fire). Of importance too were those homes where the same room was used for cooking and sleeping. The reason behind this was to get vital information and an on-the-spot statistics of the physically effects of smoke and otherwise.

4.1.3 Sample Size

The Bamenda town according to the 2005 statistics (Provincial Chief of Statistics) has a population of approximately 427,137 inhabitants. Meanwhile, Bambili has a population of about 20.000 inhabitants. On the hills of the village are the majority of the indigenous population who are principally peasant farmers and gardeners. Immediately below the foot of the hills overlooking the Bambui plain and Bamenda, the traders and some peasant farming population are found. Much of the section of the plain shared by Bambui and Bambili is largely inhabited by educational and administrative establishments. This area is noted for its small scale trading and social activities such as football competitions, cinema houses and drinking spots.

4.2 Survey Methods

Following the methodological sketch in figure 23 below, three different approaches were envisaged.

Firstly, the water boiling test and other testing tools were used to assess stove efficiencies such that a particular stove type or types could be recommended for use in this locality.

Secondly, the quantitative and qualitative survey methods were used to ease the success of this research amongst which includes standard questionnaires, interviews, focal group discussions, personal observations and modelling.

Thirdly, results from the stove performance test and survey was applied in a conceptual model (Sensitivity Model). The sensitivity model was used to simulate the dynamism of the system to understand its behaviour. Simulations made will help in suggesting possible remedies to the system sustainability (Chapter 7).

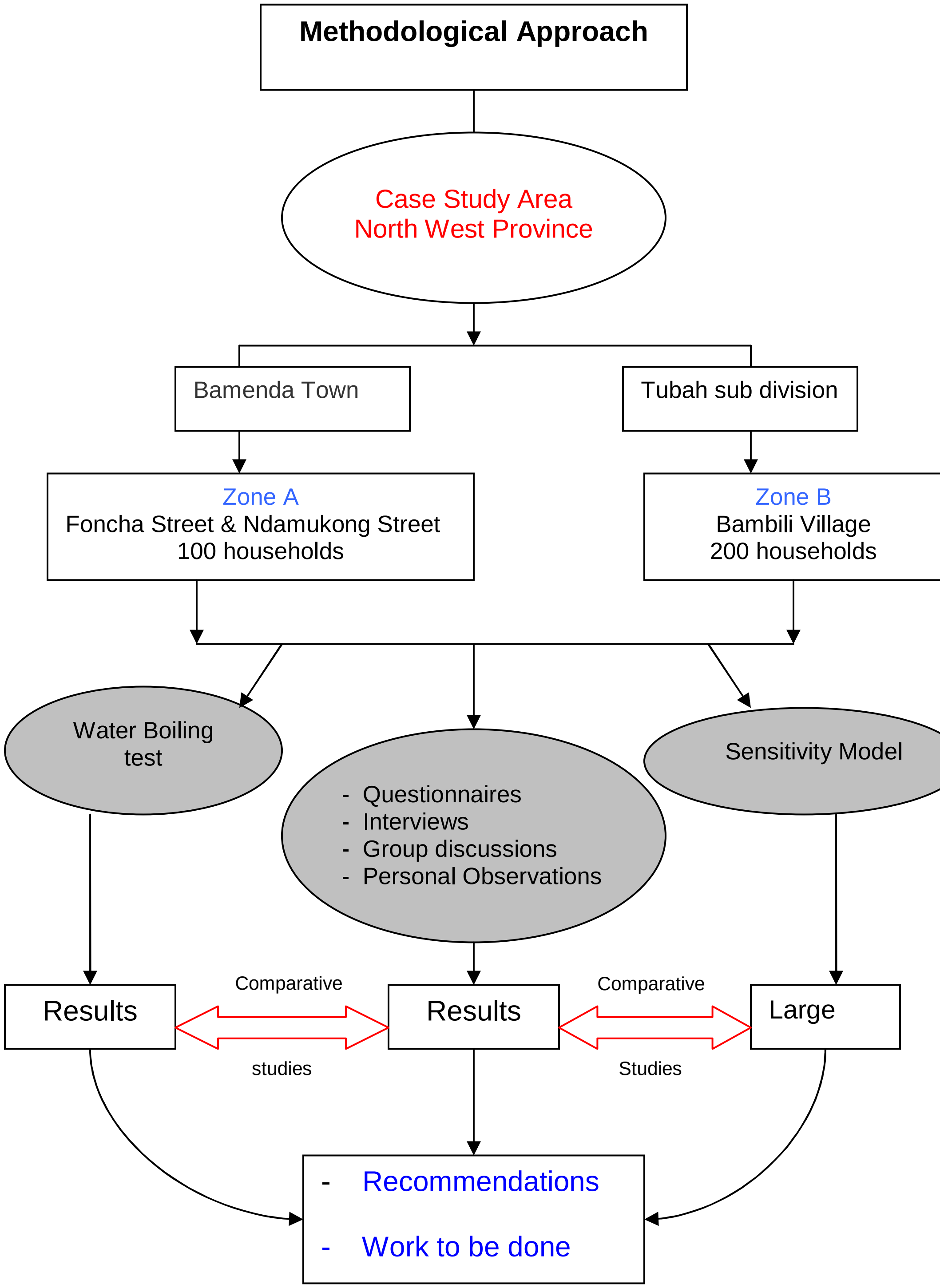

Figure 23: The Schematic Representation of the Research Methodology

A comparative study was done using the results of all three approaches such that plausible recommendations are suggested. This will equally help to assess the level of work done and suggest what is still to be done regarding this research work.

4.2.1 Instruments Used- Questionnaires, Interviews, Focus Group Discussions

Questionnaires were developed and randomly distributed to households and health personnel within the case study areas. Foncha Street stretch through Ndamukong Street had a sample of 100 respondents meanwhile Bambili had a sample of 200 respondents. The difference in number of questionnaires distributed was as a result of the variation in sampling sizes; Bambili had a larger sample size than the Bamenda selected area. The time frame and logistics involved with the distribution of questionnaires were established and are shown on table 4.

Table 4: Time frame for Questionnaire Distribution

Activity	Requirement	Duration	Location
Distribution, completion, collection of questionnaires	- 4 persons	2 days	Bambili (200 respondents)
Distribution, completion, collection of questionnaires	- 3 persons	2 days	Bamenda (Foncha Street), (part of Ndamukong street) (100 respondents)

Chapter 5 QUESTIONNAIRE ANALYSIS AND RESULTS INTERPRETATION

5.1 Primary Data

The data in question is principally the results from the questionnaires, interviews, and focal group discussions. The sample of the questionnaire can be found in Appendix A IV.

5.1.1 Demographic Data

This study aims at mitigating the technology of heat capturing devices such that health and social aspects of women and children who are most affected are improved upon. To successfully carry out this survey with the acquisition of a representative contribution, the questionnaires were randomly distributed. From the questionnaires, there were more female than male respondents (Figure 24). This is probably because women are directly involved with household chores and cooking than men.

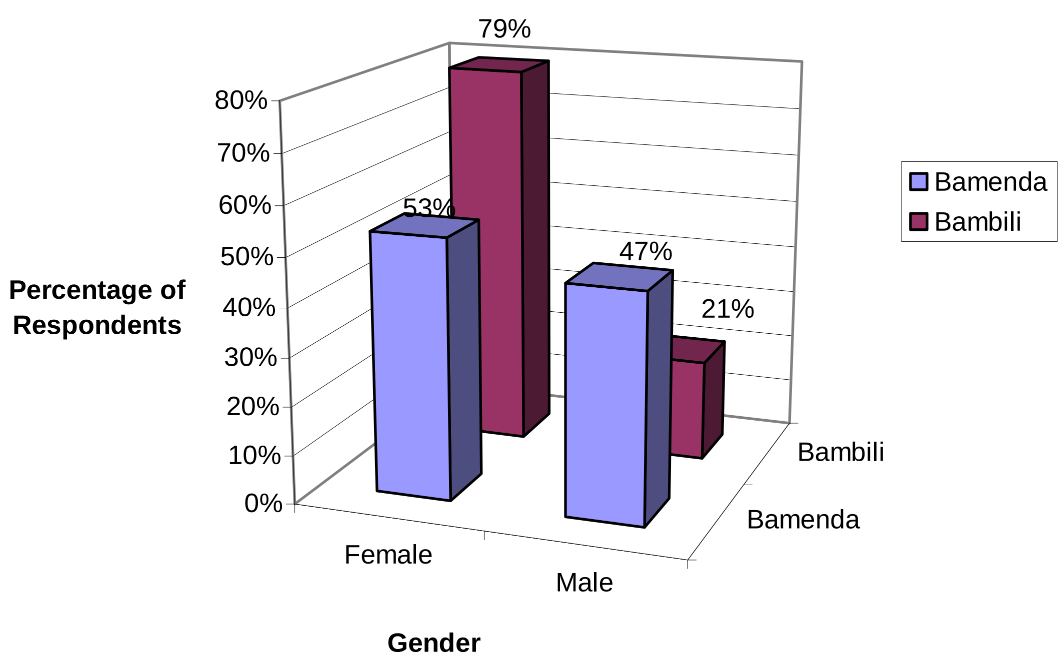

Figure 24 The Category of Respondents in Bamenda and Bambili

For the Foncha Street-Ndamukung Street area in Mile three Nkwen Bamenda town, 53% of the respondents were female while 21% of them where males. In Bambili Village, 79% of the respondents were female while 21% of them where male. This discrepancy in the female to male ratio for the urban and rural settings can be explained by the fact that the women in the urban setting are more career oriented. Thus possibility of getting a male or a female respondent in the town is 50:50 unlike in the rural setting where most of the women are either farmers, housewives or “petit” traders (Figure 24 above).

To be able to conveniently arrive at a plausible conclusion, it was worthwhile noting the occupations of the respondents. Considering the urban setting, the majority of the respondents were businessmen and women, closely followed by civil servants. There were considerably few farmers and student respondents in the area. Contrarily, most of the respondents in Bambili were farmers who were closely followed by students and “petit” traders as could be seen in figure 25 below. This result portrays the reason of choice of study areas which clearly brings out the difference in both communities with the richer settling in the town and the poorer being in the village.

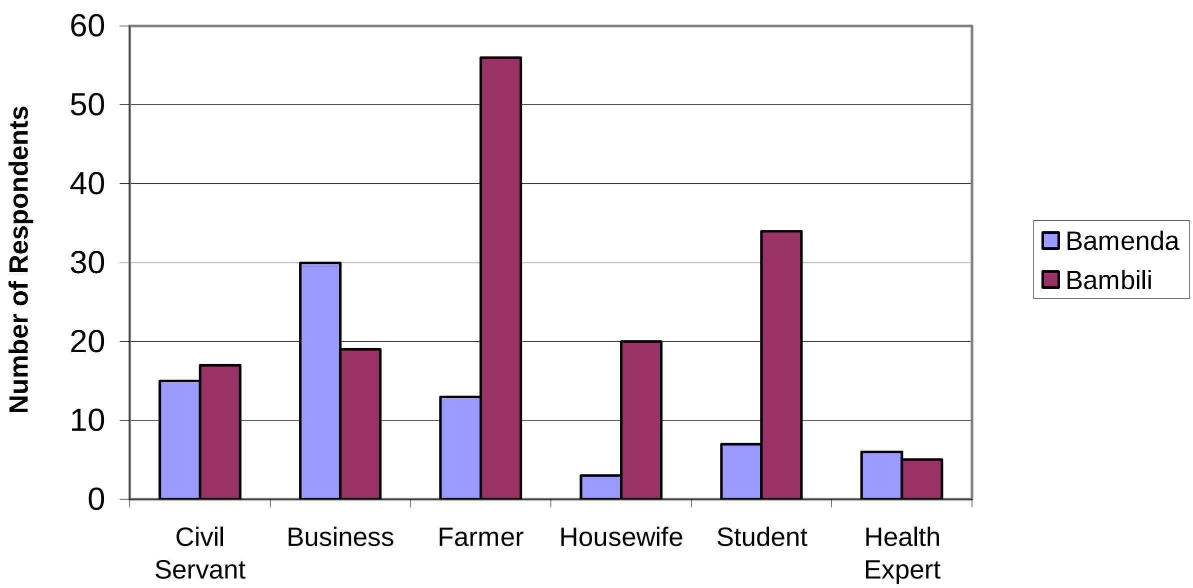

Figure 25: Occupation of Respondents in Bamenda town and Bambili Village

The tradition of the “Mbeligi” people (people of Bambili) has an eight-day-week calendar, of which one day of the week is named a “Country Sunday”. This is a day where no one is expected to go to the farm and most traditional group meetings or quarter meetings take place on this day. The “Country Sunday” could fall on any day of our usual 7 days calendar however, the day of choice follows a certain pattern. This made it easier for the questionnaires to be distributed in Bambili meanwhile the weekend was used to distribute questionnaires in Bamenda town.

5.1.2 Awareness/Knowledge Assessment

Out of 300 respondents, over 50% of them knew what indoor air pollution meant or at least had an idea about it. The literacy rate for both urban and rural settings was almost equal with percentage ratings of 65% and 64.4% respectively (Figure 26). This result is contrary to the expected, as it is generally believed that there are more illiterates in villages than in towns. However, the high level of literacy in Bambili can be explained by the presence of several government and private educational institutions. This, therefore, is a peculiar case unlike other rural settings.

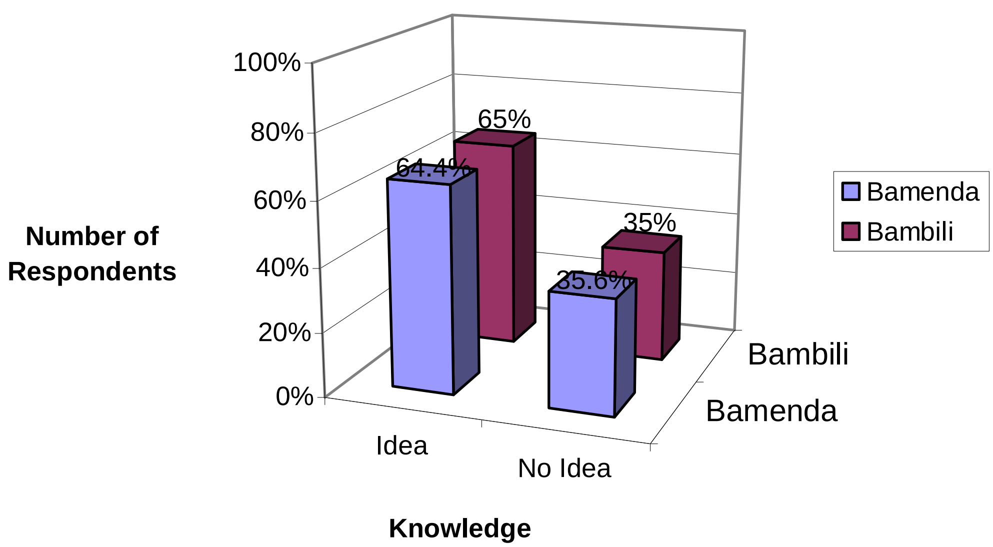

Figure 26: The Level of Awareness of IAP in Bamenda Town and Bambili Village

Knowledge is a good foundation for the implementation and acceptability of appropriate technology but the query is how to inform the other 35% who are ignorant. The majority of respondents agreed that IAP causes negative impacts on health, with 90.7% in Bamenda and 86.1% in Bambili confirming that. Some of these people may not know what IAP means but they at least know that smoke is harmful. Meanwhile, 2.7% in Bamenda and Bambili did not buy the idea. About 6.6% of the respondents in Bamenda and 13.3% in Bambili did not know about the impact of IAP on Health and the environment (Figure 27). Despite the small percentage of people's knowledge on the definition of IAP, much more important is that a good number of persons know that inhaling smoke has health repercussions. Thus medical expression is not very important. This result is quite encouraging and acts as a foot stool for innovative technology acceptability and applicability.

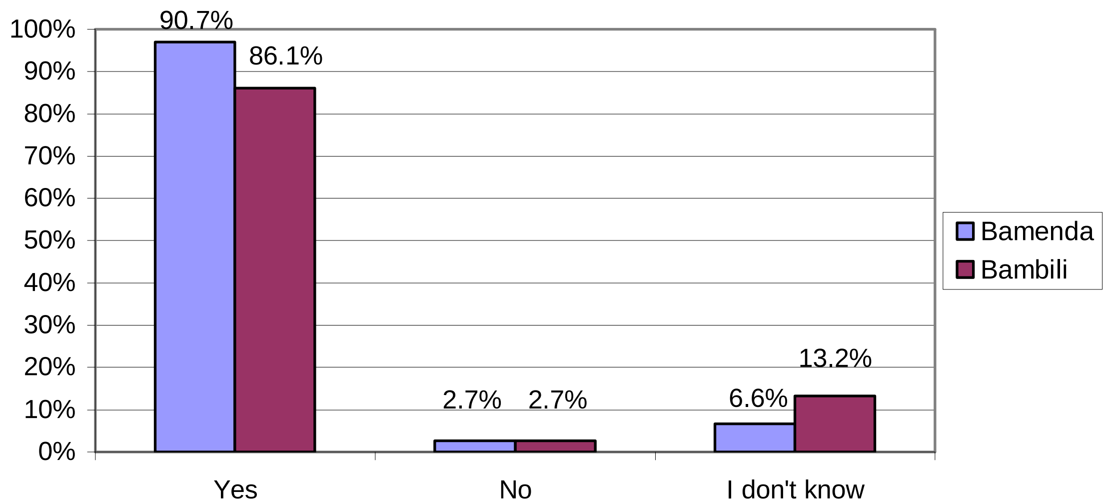

Figure 27: Awareness of Health Impacts caused by smoke inhalation

Another question sorts to know the respondents sources of information and knowledge about IAP so as to use them to reach out to the others who are ignorant. In the Bamenda area, most of the respondents learnt about IAP through the media and by reading books. A few of them used the internet and personal experiences. Very few attended seminars and Community based campaigns on IAP and health. Contrarily to the urban area, over 50% of the respondents gained knowledge from personal experiences based on their observations during cooking (smoke, eye irritation etc) (figure 28).

Consequently, the means of reaching out to the rural community has to be different from that of the urban community. However, there are certain ways through which one can reach out to both communities irrespective of whether they are rural or urban; for example, through the church, religious groups, meetings, schools and the media (radio and/or television).

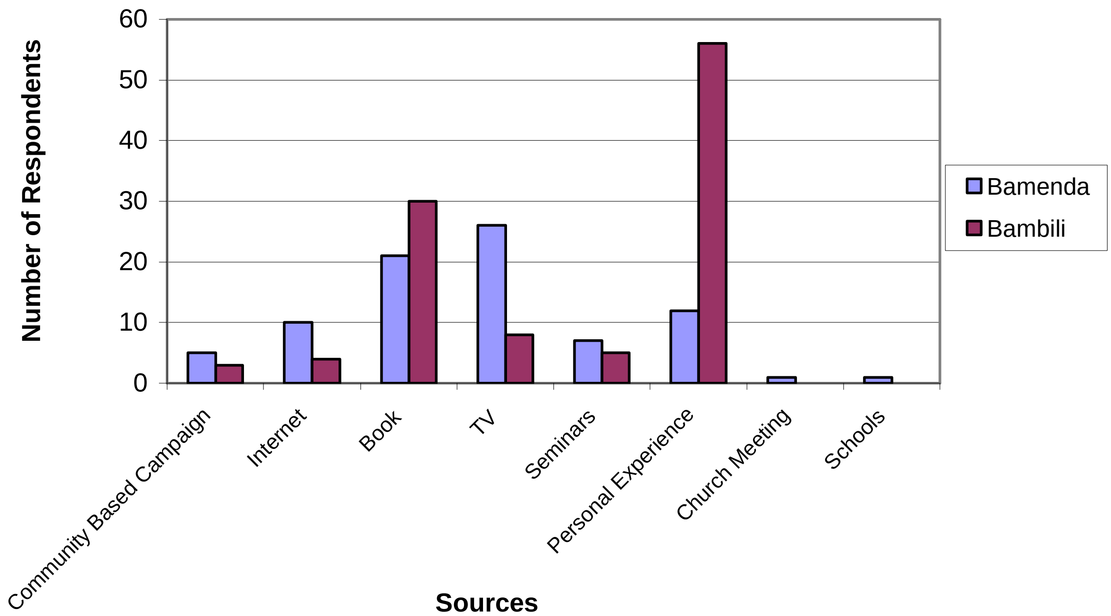

Figure 28: Sources of Knowledge of IAP in Bamenda and Bambili

5.1.3 Cooking Stove Technology

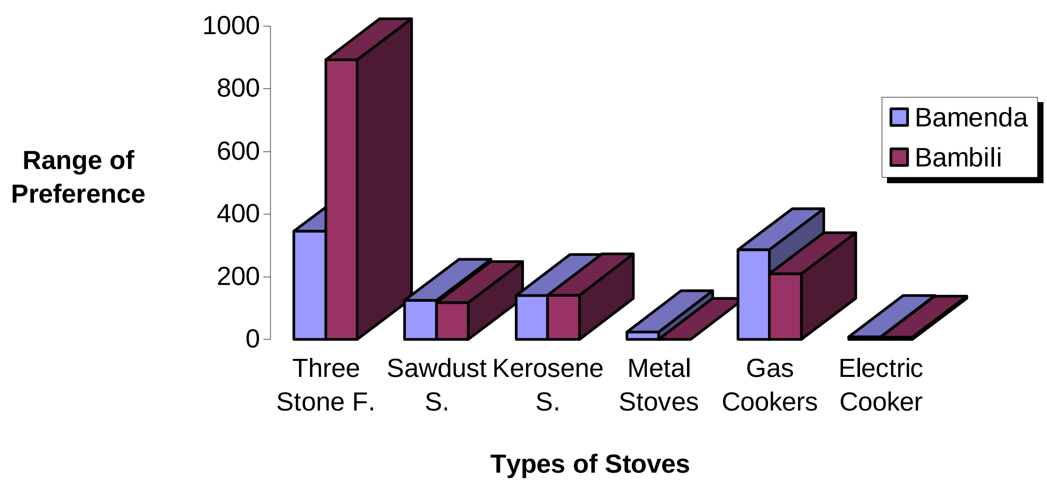

Figure 29: Preferred stove Types in Bamenda Town and Bambili Village

The most frequently used stove in Bamenda town is the three-stone fire, closely followed by the gas cooker. Infact, over 50% of the population in this area rely on these two stove types for cooking and heating. The kerosene stove and sawdust stoves are not frequently used. The metal stove and the electric stove are not common. Only about five homes in the Foncha Street Ndamukong Street stretch had a metal stove.

Contrary to the Bamenda locality, over 85% of respondents in Bambili rely on the open fire for cooking and heating. Of this percentage, over half rely solely on the open fire while the other half uses other stove types along side. Second to the open fire are the gas cooker, the kerosene stove and the saw dust stove. Unlike in Bamenda, there was no household with a metal stove in Bambili (Figure 29). However, the three major institutions in this locality (ENS, CCAST and Agricultural School) all use metal stoves. It should be noted that the discussed results and graphs represent individual household surveys and not institutions or commercial enterprises.

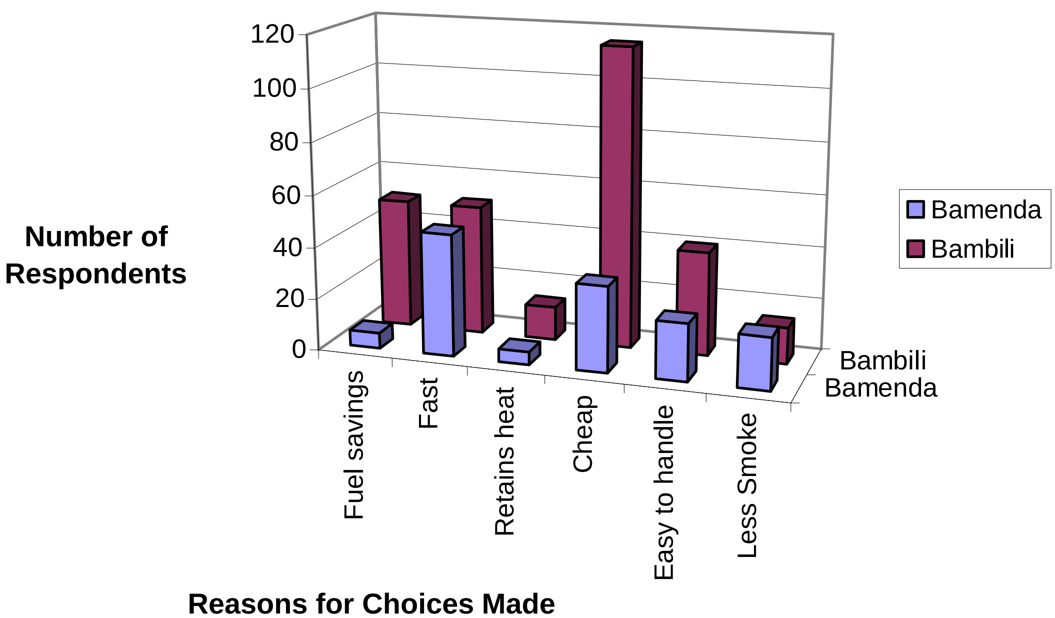

Figure 30: Reasons for Choice of Preferred Stove Type in Bamenda and Bambili

Comparing the results of the urban setting with the rural setting, one can say that many more people prefer to use the three stone fire to other stove types in the rural area. Varying reasons were given for this choice as over 50% of respondents in Bambili chose the three stone fire not because of its effectiveness but rather because it is cheap. The respondents in Bamenda preferred the three stone fireside and gas cookers because they are cheap and fast respectively (Figure 30). Of course, the issue of affordability in both cases is very important. Since more people in Bamenda Town use gas cookers it is proof, to a certain extent, of their ability to buy gas. But our emphasis here is on the poor who cannot afford buying wood fuel least buying gas. The general idea is not only to have a shift from fossil fuel to renewable energy but to provide affordable and sustainable cooking technologies for all. Cost is a very important factor to be considered during stove construction although it is not all encompassing. Other factors like stove efficiency, fuel saving, easy to handle and heat retention should be considered as well. Moreover, the price of gas in Cameroon keeps skyrocketing on a yearly basis which therefore implies that in days to come more people might not be able to buy gas thus returning to biomass fuel.

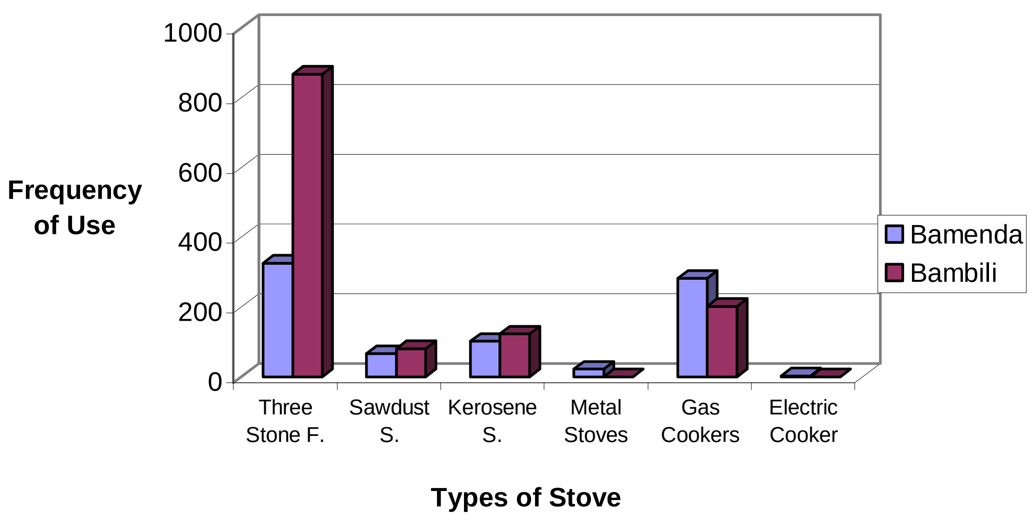

Figure 31: The Frequency of Use of Stoves in Bamenda Town and Bambili Village

To prefer a stove type does not necessarily guarantee one's interest in using it as many factors come into play. This is because one could prefer a stove type but, because of lack of finance, resorts to using a much cheaper one. However, the results of the survey showed that for Bamenda and Bambili, the most preferred stove types, the three stone fire and gas cookers were the most frequently used although the frequency of use of the three stone fire in Bambili far surpassed that of Bamenda town (Figure 31).

To facilitate the implementation or the applicability of appropriate technology of improved stoves or to better the existing technologies of stoves already in the study areas, it is important to know the degree of acceptability. Over 85% of the respondents in both communities thought that improving on the technology of heat capturing techniques would considerably reduce indoor air pollution and they would readily welcome any innovations in the technology, meanwhile less people for both Bamenda and Bambili communities shared a contrary view (Figures 32 and 33).

However, it is worth noting that the degree of discrepancy in both cases is not large (less than 10%). About 16.2% in Bamenda and less that 1% in Bambili did not believe that improving cooking stoves could enhance IAP, meanwhile about 4% in both localities did not welcome any innovations. Comparatively, the rural community was more ready to accept any innovations than the urban area. This is a very positive reaction from the rural community since they are more exposed to negative health threats (figure 47) from poorly constructed cooking stoves and IAP.

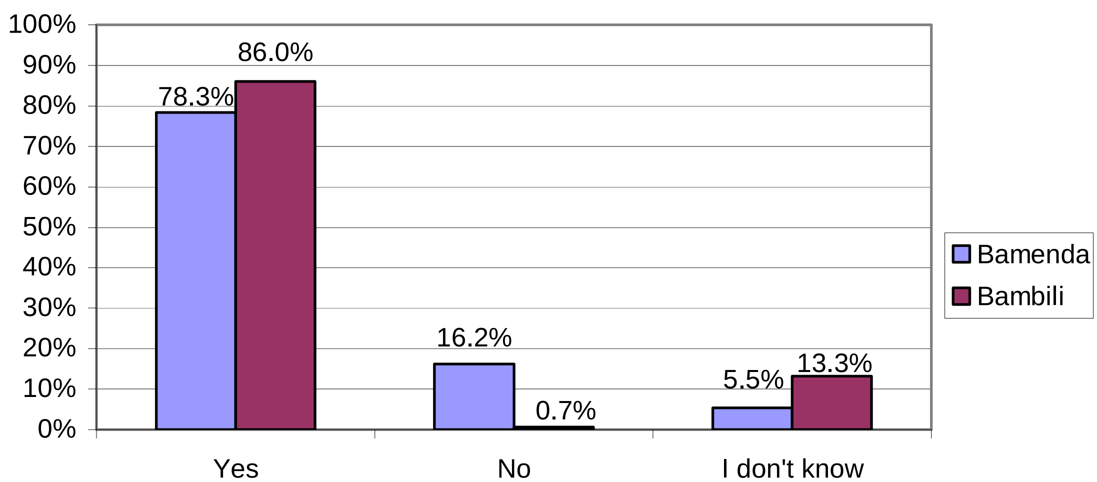

Figure 32: Respondents' Impression on Improving Cooking Stoves Technologies to Combat IAP

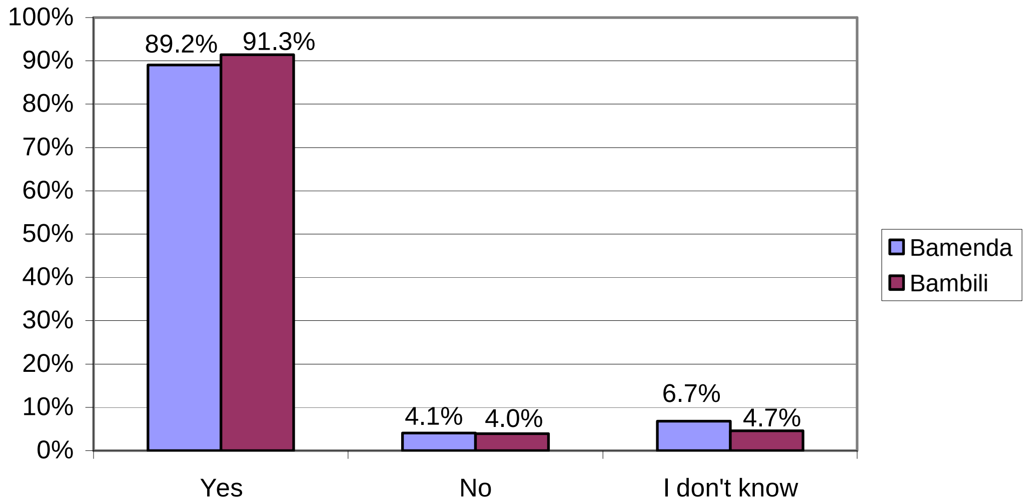

Figure 33: Respondents Readiness to Accept Innovations in Cooking Stove Technologies

5.1.4 Socio-economic and Environmental Impacts

5.1.4.1 Economic Impacts

Economic viability is a very important issue that needs to be emphasised in as far as purchase and produce of goods are concerned. The issue of affordability plays a major role in the lives of many especially the less privileged. The reasons behind the preference of stoves used differed from one community to the other. In the urban area, many preferred a stove type because of efficiency, affordability and maybe less smoke production meanwhile in the rural area, affordability was the main driving force behind stove use (Figure 34). Of course the open fire is most available and cheap because stones can easily be got. Furthermore, a greater majority of villagers collect their wood unlike those in the city who mostly buy fuel. About 55.9% of respondents in Bambili collect fuel while 84.4% in Bamenda buy fuel (Figure 35). This result does not quite reflect the real picture of a rural community as it is expected that more people from Bambili will collect than buy fuel. From literature, in cases of serious fuel shortages and skyrocketing fuel prices, many have resorted to various coping strategies, like changing to lower grade fuels, using wood more carefully, extinguishing the fire after use, reducing the number of meals cooked etc.

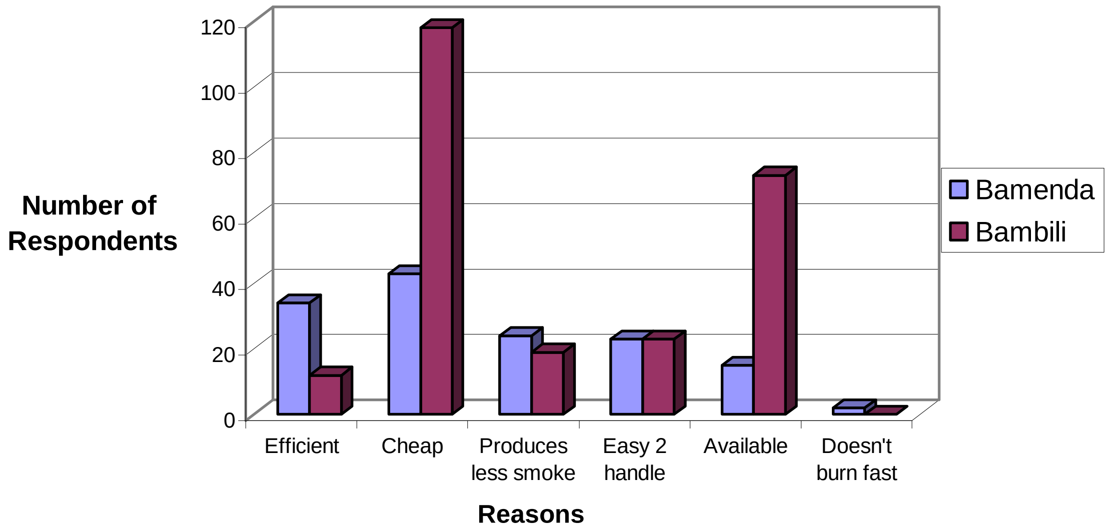

Figure 34: The Reasons for Choice of Fuel Types

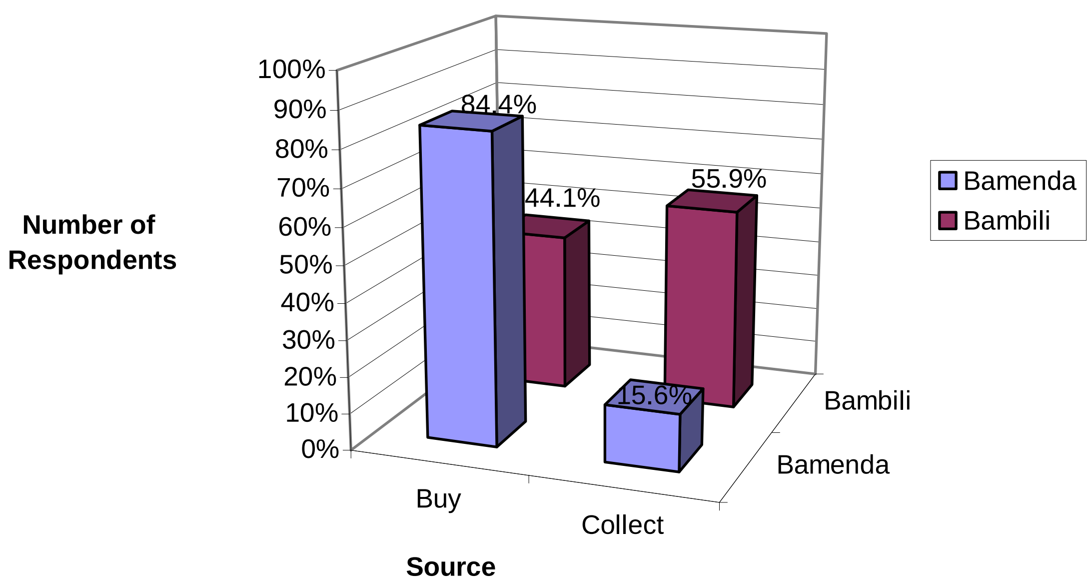

Figure 35: Source of Procuring Fuel for Bamenda Town and Bambili Village

If one were to consider stove efficiency in the strict sense of the word, the three stone fire would be out of the picture because most of the heat produced during combustion is lost. This means more fuel is being used with less heat transfer efficiency during the process of cooking or heating. The issue of sustainability now sets in as appropriate technologies have to be employed such that less fuel is used with maximum stove performance. This approach will greatly mitigate the pending issue of deforestation and IAP which are now major problems in some areas of Cameroon.

5.1.4.2 Socio-cultural Impacts

In a typical African home and according to most African cultures, a woman's place is in the kitchen. "Cooking is a woman's thing" so it is said, yet the best cooks are men *(Dhanyasree "World best chefs" living.oneindia.in/men/best chefs,html 21st May 2007)*.

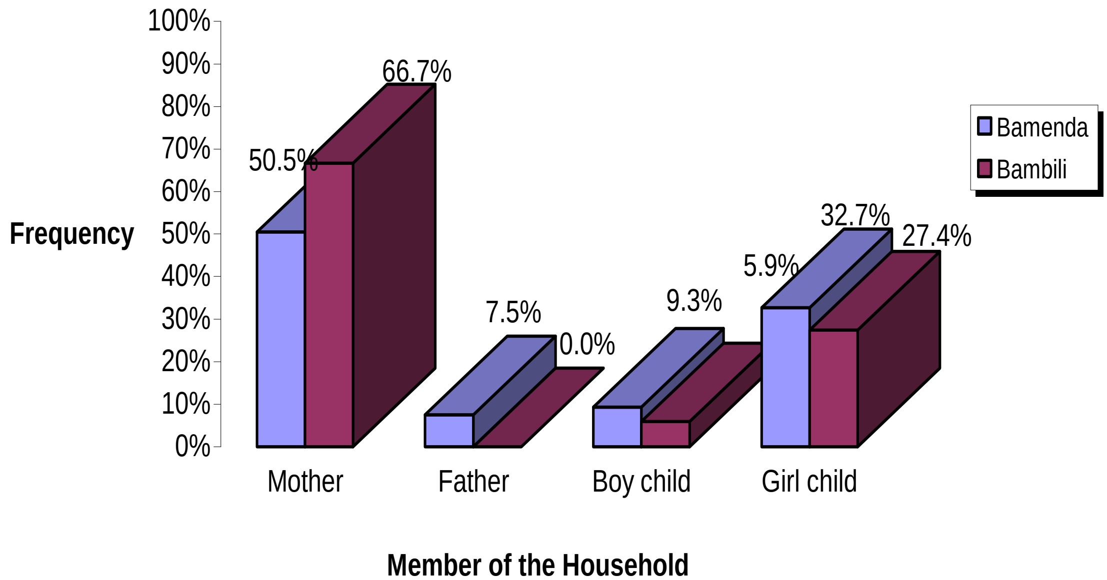

Figure 36: The One Who Spends the Most Time in the Kitchen

There exists a discriminative attitude towards women when it concerns the kitchen. Woman and her kids fetch fuel and do the cooking irrespective of the situation at hand, be it pregnancy, illness, tiredness etc. The results of the questionnaires clearly confirm that most of the cooking for both study areas is done by mothers and children (Figure 36). In the case of Bamenda, 50.5% of mothers do the cooking while 32.7% of female children, 9.3% of male children and only 7.5% of fathers (men) cook in their homes. It is interesting to know that those fathers who cook are either single parents, divorcees, bachelors or do not live with their wives maybe for academic or job reasons. This is same for the male child. In the African setup, especially in the cities, it is common to have a male or female house help. In the case where a boy child is brought in as house help, he automatically takes over cooking and house chores.

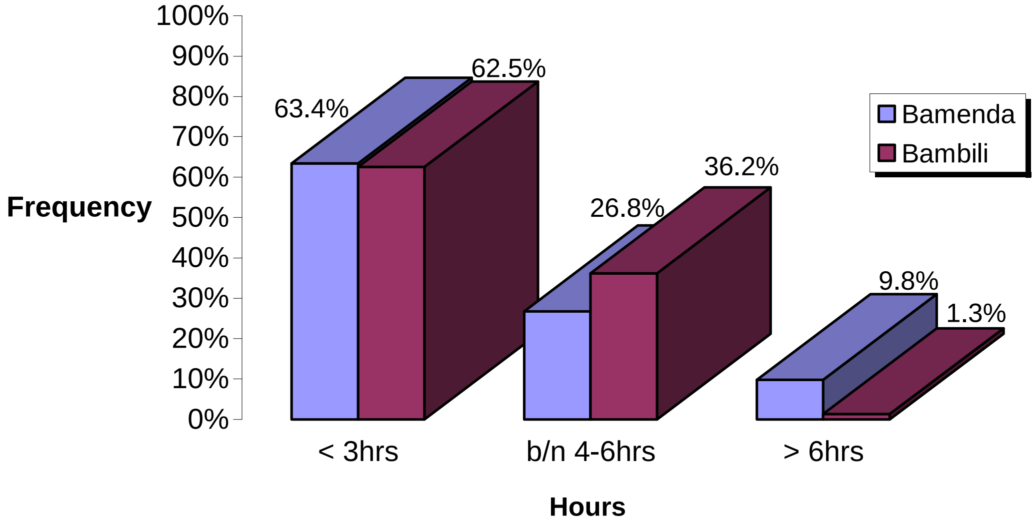

Figure 37: The Number of Hours Spent in the Kitchen per Day

Similarly, in Bambili, most of the cooking is done by the mother, girl and boy child who spend relatively long hours in the kitchen. A greater majority of those who do the cooking spend less than three hours in the cooking area. A good number of them spent between three to six hours in the kitchen. Also, less than 10% of the respondents spend more than 6hrs in the cooking area (Figure 37). This was the case of those who use the kitchen for sleeping or as their sitting room which compounds the problem. The shorter the time spent in the kitchen the better it is, as exposure time influences the inhalation process thus enhancing the degree of getting affected by the smoke.

Increasing modernization and globalization is having a great effect on African communities. The diffusion of western concepts of liberalization, and especially, gender equality is seriously changing the status-quo. Christianity too has helped to change the mentality of many because it spreads the doctrine of equality and respect between man and woman. Consequently, the idea of the “woman’s place is in the kitchen" is loosing grounds since it has made the African man to know that as equals, he should assist his wife even in the kitchen. An ever increasing number of men are beginning to see the African woman from a different perspective and many more women are getting involved in white collar jobs, thereby gaining liberalization from traditional male chauvinism.

5.1.4.3 Environmental Impacts

Climate change and environmental issues are of paramount interest and have become major areas of focus in the contemporary world. This is because of the increasing pressure and repercussions of the emission of CO_2 and other green house gases. It is difficult not to notice the environmental changes around us as the effects are felt right in our homes. Over 60% of the respondents in both Bamenda and Bambili are aware that their environment is changing while about 30% are not and below 10% are ignorant (Figure 38 and Figure 39).

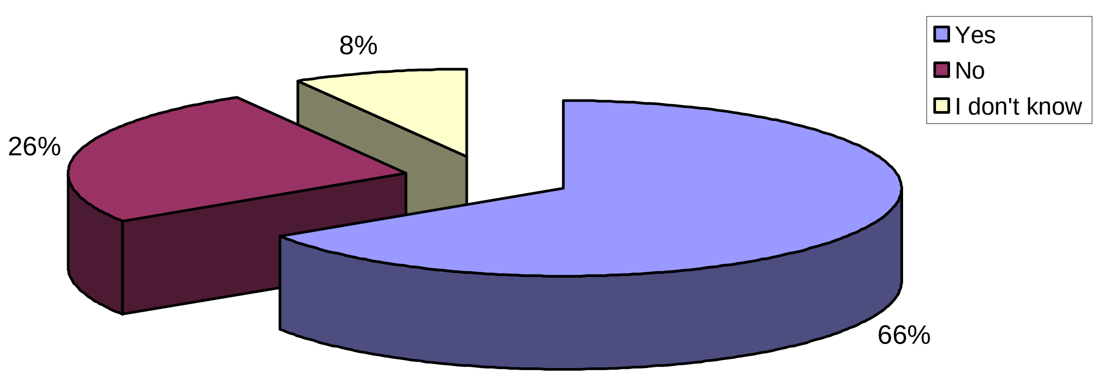

Figure 38: The level of awareness of Environmental Changes in Bamenda

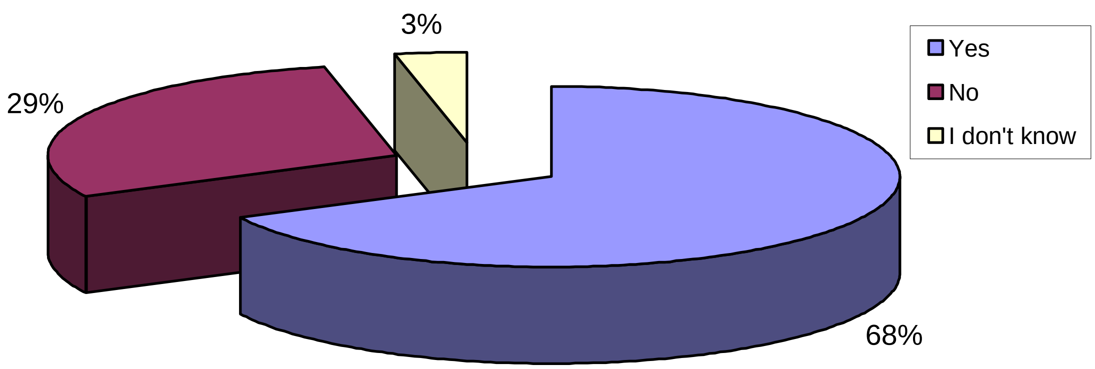

Figure 39: The level of awareness of Environmental Changes in Bambili

Ignorance is a pertinent problem as one has to first of all notice a problem before seeking a solution. Surprisingly enough, 75.3% of the respondents agreed to have noticed an increase in deforestation in Bambili as opposed to 63% in Bamenda (Figure 41). This means that some of the respondents who had not noticed any environmental changes in the community did not consider deforestation an environmental issue. This now remains a big puzzle to be solved.

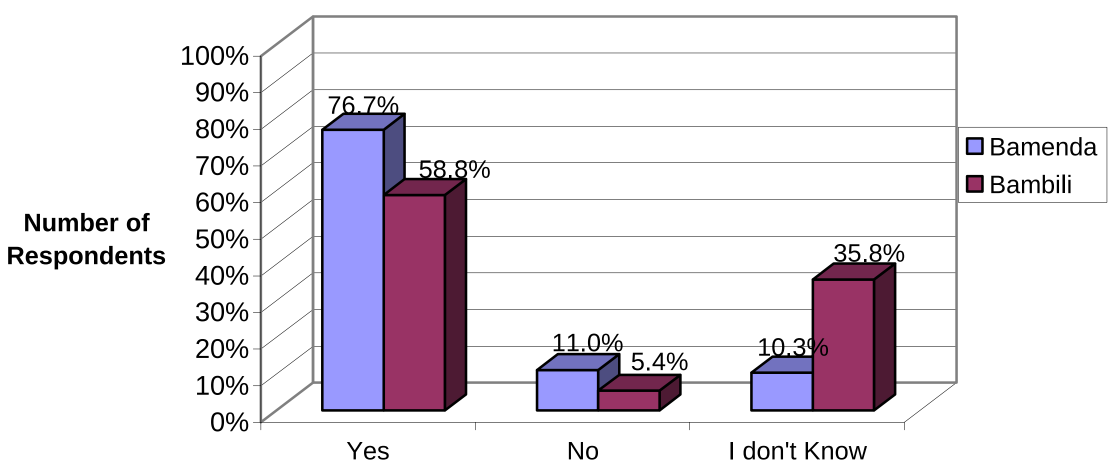

Figure 40: Level of Awareness on Environmental Changes in Bamenda and Bambili

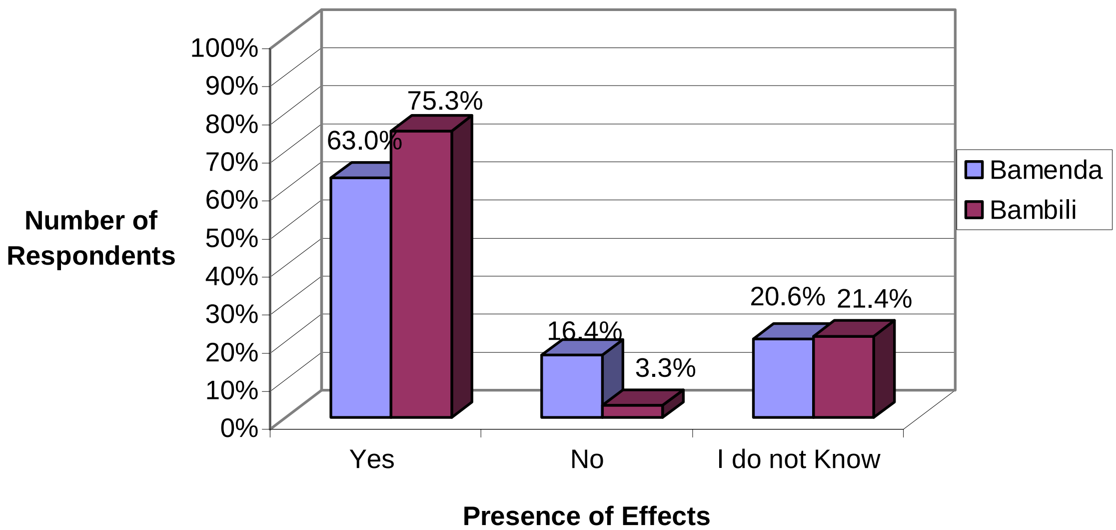

Figure 41: Level of Awareness of the Effects Deforestation in Bamenda and Bambili

It is clear that the effect of deforestation is obvious in both localities but little or nothing is being done to mitigate it. Over 75% of the respondents in Bambili deny the existence of any form of intervention by the government, stakeholders or communities (Figure 42). However, 22.7% of people in Bambili and 22.2% in Bamenda have resorted to planting of trees and still practicing subsistence farming as a means of combating deforestation (Figure 43). How effective this is, remains unanswered. The government resorted to implementing felling laws which are more or less not well monitored and executed. These laws even when executed apply mostly to the cities. The issue of bribery is another very big stumbling block for many who have engaged in fighting deforestation but this cannot be discussed in detail in this research work.

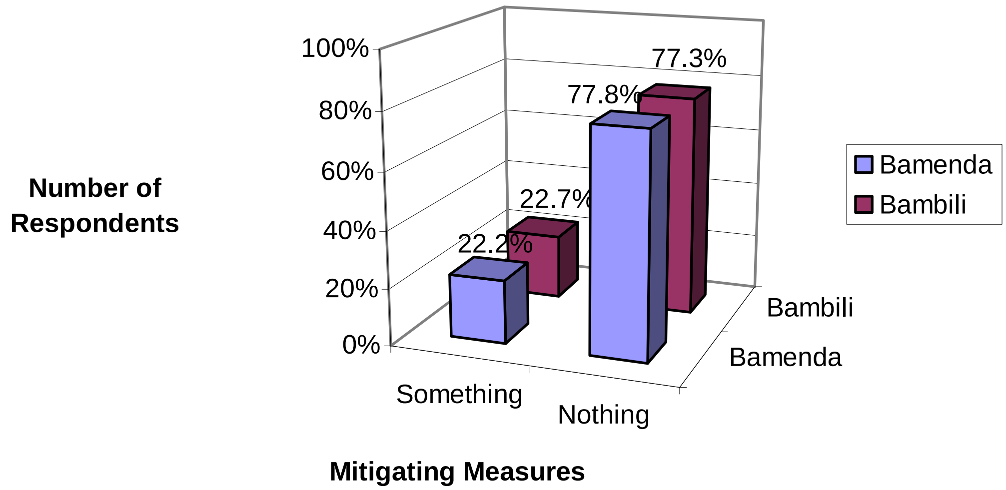

Figure 42: Mitigating Efforts against Deforestation

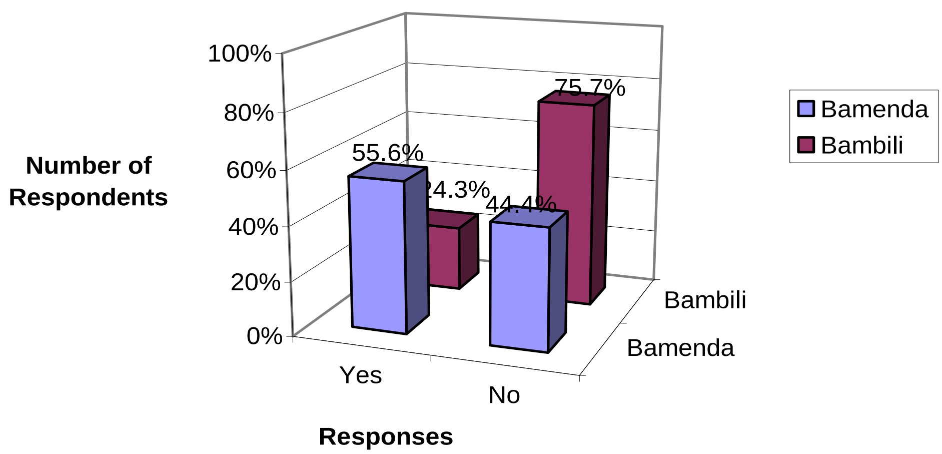

Figure 43: Measures taken by the community to fight against Environmental Hazards

5.1.5 Health Issues

There is only one Health Centre in Bambili and this Health Centre is headed by a Senior Nurse and not a medical doctor. The Health Centre suffers from lack of facilities and working staff. However, there is a much bigger Health Centre just about 3km away in Bambui with better health facilities and qualified health personnel. The results from both health Centres show that about 14 patients with IAP- related illnesses are consulted every month.

In the Foncha Street – Ndamukong Street stretch in Bamenda, two hospitals with relatively good health facilities and qualified personnel were visited. The results showed that an average of about 10 patients were consulted every month. The number of patients registered for Bambili surpassed that for Bamenda. However, both figures were seemingly low but could get worse if no attention is paid to cooking techniques. The main problem encountered in this area is how to identify patients with IAP related illnesses only. A lot of guess work is done since most of the commonly known IAP related illnesses like cough and catarrh could be caused by other factors like dust and cold as well. Because of lack of equipment, one cannot rightly and confidently identify such patients.

The commonly identified IAP illnesses in these areas included headaches, chest pain, asthma, pneumonia, catarrh, tuberculosis, conjunctivitis, cough, bronchitis, convulsion and pharyngitis. Of these illnesses, the most frequent in both localities was Catarrh with an average of about 4 patients consulted a month. Cough and bronchitis were equally common in Bambili. Conjunctivitis, which in my opinion should be rampant in Bambili, was surprisingly absent. This is rather surprising because eye irritation and discharge are very common and are experienced by many who cook especially on open fires. Asthma, pneumonia, conjunctivitis, cough and bronchitis were also common in Bamenda with an average of about 2 patients consulted each month. The lack of qualified personnel, equipment and interest of patients to visit hospitals because of lack of finance could be contributive factors to these low numbers. These results should therefore not create a picture that will make one minimise the hampering effects of poor cooking technologies and IAP in these areas. Most of the people in both rural and urban areas complain of lack of finance to go to the hospital. Because of these low figures, health experts, the government and NGOs are paying little or no attention on reducing IAP related problems. There exists no form of public campaign on IAP issues in Bambili or Bamenda. However, the government through its Ministry of Health is trying to do something minimal to alleviate IAP. By means of subsidies, drugs are provided at a cheaper cost to patients. Unfortunately, the local authorities whose impacts on the communities could be directly felt have not engaged in the fight against the use of inappropriate technologies and reduction of IAP.

Looking at the way indoor air pollution is tackled in Cameroon, one cannot help but appreciate the ongoing efforts of other developing countries towards alleviating indoor air pollution. Through a partnership with Practical Action (NGO), the Kenyan, Sudanese and Nepalese governments through their ministries of health resorted to projects in 2005 geared towards mitigating smoke in the kitchen.

In Kenya, Practical Action together with the Kenyan Ministry of Health and other NGOs provided a model to reduce smoke by as much as 77%. The project involved about 50 rural households in Kajiado and western Kenya. Appropriate technology to reduce pollution in people's kitchen was devised. Smoke hoods, eaves, windows and improved fuel efficient stoves were introduced in these households and the damaging particles could be reduced by two thirds. The project identified that the level of smoke particles in these rural households, in most cases, is more than 100 times greater than the acceptable level of 50 micrograms of smoke particles per cubic meter as suggested by US Environmental Protection Agency. Readings were taken in the cooking area of each home on two occasions before and after the smoke hoods were installed. The cooks' exposure to CO was independently measured.

Statistical results analyses showed that an introduction of hoods greatly reduced emissions. Health damaging particles in the house were reduced by 75% while carbonmonoxide was reduced by 77%. The results from the cook's personal monitors showed an improvement in carbonmonoxide exposure by 35% (*Practical Action, 2006*).

In a village community in Nepal, about 450 smoke hoods were installed during the project phase. The District Development Committee was responsible for project funds and provided continual support of initiative with manpower where necessary.

In eastern Sudan in Kasala, adoption levels of hoods and appropriate technology continued to be high with a steady installation rate of around 50 stoves per month during the project phase. LPG stoves were universally adopted, and the project has led to nearly 1000 households adopting this cleaner fuel. These stoves were sold at cheap prices and for those who could not pay on purchase, they were allowed to take the stoves on credit with long payment periods.

Satisfaction ratings in all three countries were close to 100% on all accounts. Major benefits in Kenya were reported as time saving, fuel reduction and smoke reduction. In Nepal, the key benefits included smoke alleviation, fuel savings and health improvement meanwhile in Sudan, where many households had reverted to charcoal; there was almost a universal support for the use of LPG stoves. Cooks cited time savings, increased comfort and smoke reduction as benefits from appropriate technology and hoods (*Bates E., 2005*).

With the implementation of such ICS projects in these countries, health problems associated to poor cooking techniques and practices were greatly reduced. This way, peoples health were improved, but also time, drudgery, saved money and increased comfort improved the standard of living of especially the poor communities. Cameroon could equally follow the example of these countries by inviting Practical Action or other leading organisations to implement such ICS projects and promote health campaigns which aim at reducing IAP and improving health. The government needs to diagnose its problems and seek expert knowledge and international partnership. Not until this is done can they boost of following the right path.

SECTION II

TECHNOLOGY ASPECT: THE STOVE PERFORMANCE TEST

(WATER BOILING TEST)

CHAPTER 6 STOVE PERFORMANCE TEST

Aprovecho Research Center is a non – profit organisation which aims at creating effective and widely usable appropriate technology solutions to problems such as cooking and heating with biomass. This research center has been investigating and developing cooking stoves for more than 25 years. Its founders helped to develop the “Lorena stove” and the “Rocket stove” which are of high performance and widely used. Also, Aprovecho was part of a large scale stove movement in the 70s and 80s (*Dean Still et al., 2007*). With such high profile and haven received financial assistance from them, I was honoured to pursue part of my research at their laboratory.

6.1 Stove Description

Three principal stoves namely the traditional stove, Chinese rocket stove and the “Skirt” stove were used to conduct the stove performance and the emission tests at the Aprovecho’s research laboratory. It is important to state why these three stoves were chosen. The reasons behind the choice of stoves are: the three stone fire is the most commonly used stove in developing countries. Understanding how the stove is operated and experimenting on its performance would provide a good basis of comparison with other stoves. The rocket stove is one of the highly recommendable improved cook stoves nowadays because of its high performance. The “Skirt” stove was newly developed by Aprovecho Research Center, so its performance needed to be tested and compared with other status quo technologies before putting it in the market.

6.1.1 Traditional Stove

Cement bricks of 19cm long, 6cm wide and 6cm high were used to construct the open fire. The distance between the pot and the floor is about 6cm This open fire (Figure 44) was well constructed with the bricks having equal distances between them and the sides well protected from the wind.

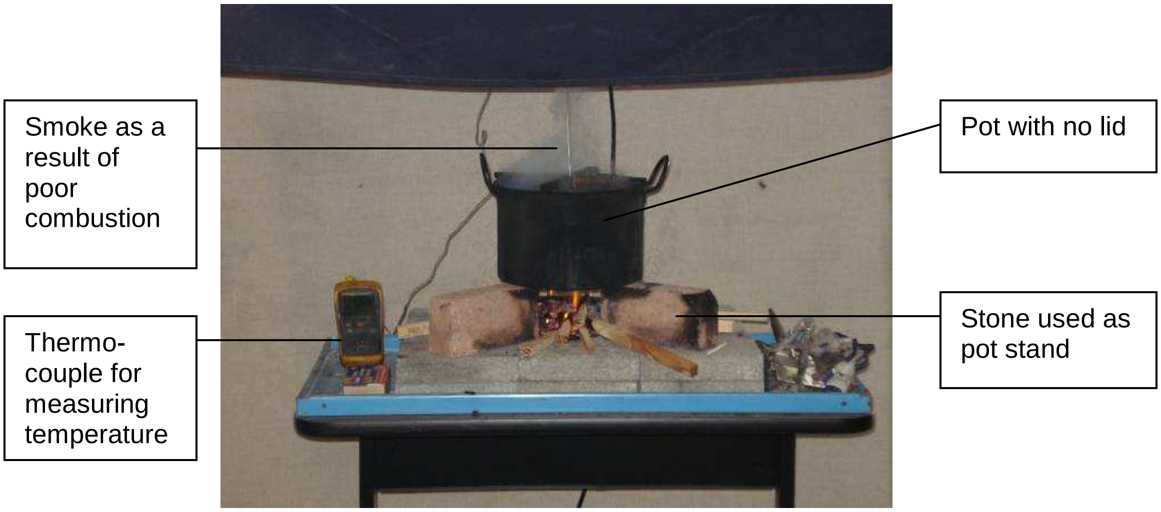

Figure 44: Open fire

6.1.2 Chinese Rocket Stove

The Chinese rocket is a portable, metallic, single pot stove without a chimney designed for wood burning operations. It is 29cm high and has a diameter of 26cm. The stove has an L-shaped combustion chamber which is 11cm wide. It is designed with two openings and a well fixed metallic grate that allows in-flow of air into the combustion chamber. The first opening serves as fuel passage and it is 11.5cm long and 7.5cm high. The second opening which is much smaller and serves as an inlet for air is 8cm long and 5cm high. The former is 7.5cm from the floor while the latter is 1cm from the floor (Figure 45). This stove was developed by Aprovecho Research Center and produced in China. It is hoped that the low cost and high efficiency of this stove will make it an excellent candidate for mass-production in China and exportation to regions with less manufacturing abilities.

Figure 45: Chinese rocket stove

6.1.3 „Skirt" Stove

Figure 46: "Skirt" Stove

The adjustable "skirt" is a portable, simple, metallic, single pot stove without a chimney (Figure 46). It is essentially an adjustable cylinder surrounding a pot that allows air to enter into the combustion zone through the one fuel entrance. The stove differs from the original VITA stove as described for construction in Sam Baldwin's Biomass Stoves: Engineering Design, Development, and Dissemination (Baldwin, 1987). Because air only enters the combustion zone through the fuel door there is minimal air flow up through the coals. Limiting the air results in a slower burn that seems to reduce pollution made while cooking from the original model. The pot is partially inserted in the stove and sits on a separate four legged stand inside the skirt. The pot stand is also cylindrical in shape with a diameter of 16cm and a height of 17cm. The space between the legs of the stand is 11.5cm. The four legged stand is placed inside the stove and the gap between the stand and the wall of the stove is approximately 10cm. The gap between the pot and the wall of the stove is 1cm. The stove is 26cm high and 27cm in diameter. This stove is a new idea, designed to be a low cost option for saving fuel while also reducing the health-harming PM emissions. Further development is underway at Aprovecho.

The basic principle underlying the burning of wood in the rocket stove is summarized in the sketch below. Wood burning efficiency is dependent on several factors like wood moisture and stove design alongside stove location and stove tender.

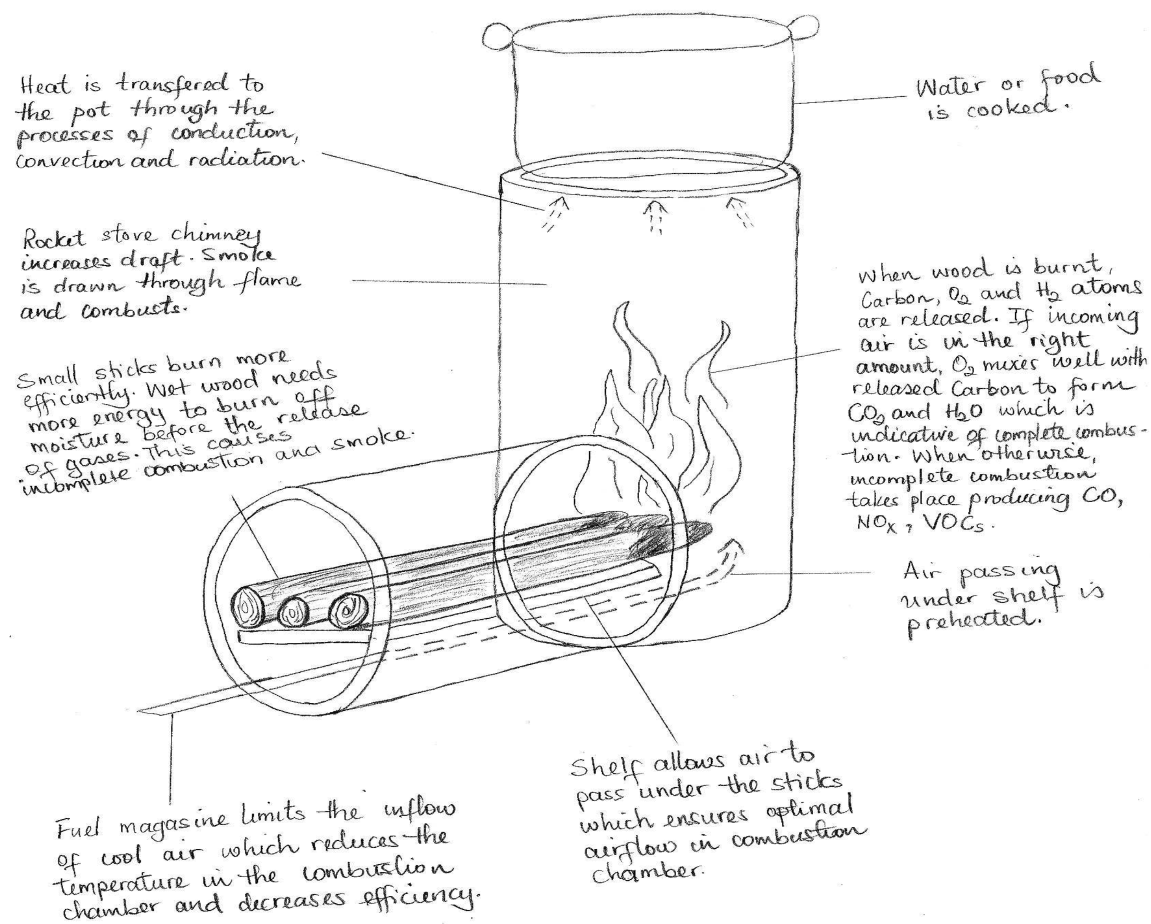

Figure 47: Wood burning Process in a rocket stove
Partly adapted from Still et al. 2000

6.2 Experimental Procedure

The experimental procedure followed a three tier approach which was adjusting the moisture of the fuel to the desired moisture content, carrying out the WBT (with the open fire, Chinese rocket and "Skirt" stove) and lastly, analyzing and interpreting the data collected by the computer-aided data acquisition system.

6.3 Stove Performance Test

The revised Shell/UCB Water Boiling Test (WBT) was used in evaluating all the stoves. This is a simple test method by which stoves made in different places and for different cooking applications maybe compared by a standardized and replicable protocol (Water Boiling Test, 2007). A copy of the test procedure could be downloaded at http://ceihd.berkeley.edu/heh.stove_perf_eval.htm.

The WBT consists of two phases; the high power phase which is conducted at both hot and cold starts and low power phase which is the simmering process. In the high power cold start phase, a stove at room temperature is used to bring a measured quantity of water (5L) to boil in the International Standard Testing Pot (7L) with no lid. The pot used in this study is the World Food Programme standard pot used in the evaluation of various cooking stove designs in laboratories throughout the world. It measures 24cm in diameter and 16cm in height and is made of stainless steel (Berick, 2007). In the high power hot start phase fresh water is boiled beginning with a hot stove in order to identify the differences in performance between when the stove is hot and when it is cold. There is no defined period for the hot and cold start phases due to differences in design. Some stoves would bring water to a boil faster than others. It is assumed that by the end of the first boil, the stove body has reached a steady-state hot operating temperature. In the simmer phase, the boiled water from the hot start is simmered at approximately $3^{o}C$ below boiling point for 45 minutes. Exploring stove performance at both high and low power helps to simulate what is likely to occur in a range of cooking conditions in the real world.

All three stoves where tested three times for the 5%, 15% and 30% moisture (wet basis). The international standard testing pot holding 5L of water was used in the experiment. No lids were used on the pot. The kiln-dried Douglas fir was used in the case of 5% and 15% moisture content while the green Douglas fir was used for 30%. For both cases the wood was either further dried or wetted to attain the required moisture content. The wood was machine cut into 1 by 1.5cm by 20-40cm long pieces. The result of each trial was recorded separately on the Water Boiling Test Data Sheets. A sample of the result sheet used during the water boiling test experiment could be consulted in Appendix B.

To adjust the moisture content to the required level, a small sample of wood was weighed on a calibrated scale with 1 gram resolution and dried in an oven at 105 ^{o}C for about 24hours. The sample is taken out and weighed again after a day. To check that the wood has attained dry mass, the exercise is repeated after every hour. No further decrease in weight ascertains that the wood has attained dry mass. It should be noted wood should not be dried in an oven of above 110 ^{o}C hot, as wood will thermally break down and lose matter that is not water, causing an inaccurate measurement of moisture content. Moisture content was calculated on wet basis using the following equation;

$$MC_{wet}(\%) = \frac{(\text{Mass of fuel})_{\text{wet}} - (\text{Mass of fuel})_{\text{dry}}}{(\text{Mass of fuel})_{\text{wet}}} \times 100$$

The key stove performance indicators emanating from the WBT are specific consumption and emissions, or the fuel used and pollution made to complete the task of producing a boiled and simmered liter of water. These values are corrected for the starting temperature of the water and moisture content of the fuel, allowing for a comparison on an even level. Thermal efficiency and firepower are also considered. The relevant terms used in this study are defined below immediately followed by the equations.

Thermal efficiency (H) is the ratio of work done by heating and evaporating water to the energy consumed by burning wood. It is mathematically represented as:

$$H = \frac{4.186 \times (\text{P}_{\text{ci}} - \text{P}) \times (\text{T}_{\text{cf}} - \text{T}_{\text{ci}}) + 2260 \times (\text{W}_{\text{cv}})}{\text{f}_{\text{cd}} \times LHV}$$

In this formula, the work done by heating water is determined by adding two quantities: (1) the product of the mass of water in the pot, (P_{ci} - P), the specific heat of water (4.186 J/g°C) and the change in water temperature (T_{cf} – T_{ci}) and (2) the product of the amount of water evaporated from the pot and the latent heat of evaporation of water (2260J/g). The denominator is determined by taking the product of the dry-wood equivalent consumed during this phase of the test and the LHV.

Firepower (FP) is the ratio of the wood energy consumed by the stove (Watts) per unit time.

$$FP = \frac{f_{cd} \times LHV}{60 \times (t_{ci} - t_{cf})}$$

Equivalent Dry Wood Consumed (f_{cd}) is the calculation that adjusts the amount of wood that was burned in order to account for two factors: firstly, the energy that was needed to remove the moisture in the wood and secondly, the amount of char that remains unburned.

$$f_{cd} = f_{cm} \times [1 - (1.12 \times mc)] - 1.5 \times \Delta c$$

Wood consumed (moist) (f_{cm}) is the mass of wood that was used to bring the water to a boil found by taking the difference of the pre-weighed bundle of wood and the wood remaining at the end of the test phase.

$$f_{cm} = f_{cf} - f_{ci}$$

Dry wood consumed (fc) is a calculation that further adjusts the amount of wood burned in order to account for the amount of energy in the char remaining unburned and the mass of water in the fuel. This calculation does not account for the energy that was needed to remove the moisture in the wood.

$$f_c = f_{cm} \times (1 - mc) - 1.5 \times \Delta c$$

Where

LHV = Net calorific value (dry wood) (kJ/kg)

P = Dry weight of empty pot (grams)

P_{ci} = Weight of pot with water before test (grams)

P_{cf} = Weight of pot with water after test (grams)

Tci = Water temperature before test (^{0}C)

Tcf = Water temperature after test (^{0}C)

W_{cv} = Water evaporated (grams)

f_{cd} = Equivalent dry wood consumed (grams)

f_{cm} = Wood consumption (grams)

f_{cw} = Dry wood consumption (grams)

f_{cd} = Equivalent dry wood consumption (grams)

f_{cf} = Final wood consumed (grams)

f_{ci} = Initial wood consumed (grams)

t_{ci} = Time at start of test (min)

t_{ct} = Time at end of test (min)

mc = Moisture content

SC_c = Specific fuel consumption

SC^t_h = Temperature corrected fuel consumption

Δc = Net change in char during test

6.4 Emission Test – Portable Emission Monitoring System (PEMS)

The Portable Emission Monitoring System (PEMS) (Figure 48) is a simple system designed by Aprovecho for inexpensive emissions monitoring in the field or lab. It consists of an emission collection structure and exhaust system, sampling system, and a computer-aided data acquisition system. The mass flow of emissions is calculated using pressure drop as read by a flow grid and temperature sensor. Gas concentrations are measured using off-the-shelf sensors for carbon monoxide (CO) and carbon dioxide (CO2), while particulate matter (PM) concentrations are measured using Aprovecho's PM meter utilizing light scattering. Flow, temperature, and concentrations are recorded each second to the computer by a data acquisition board.

Figure 48: The emission collection hood, sampling system and computer

Some important indicators used during emission testing and calculations include:

Specific emission (SE) is defined as the ratio of the amount of CO or PM emitted to the amount of water remaining at the end of a trial. The SE in this case refers to the measure of the amount of CO or PM emitted when one liter (or kilo) of water is brought to a boil. Thus specific emissions of CO and PM are calculated in the same way. It is mathematically represented as:

$$SE_{co}\,(g/L) = Mass\ of\ CO\ emission(g) \times \frac{f_{cd}}{f_{cm}} \times \frac{1000g}{1L} \times \frac{SC_h^t}{SC_c}$$

Temperature corrected specific fuel consumption (SC^t_c): This corrects specific consumption to account for differences in initial water temperatures. This facilitates comparison of stoves tested on different days or in different environmental conditions. The correction is a simple factor that “normalizes” the temperature change observed in the test conditions to a “standard” temperature change of 75^{o}C (from 25 to 100). It is calculated in the following way.

$$SC_c^T = \frac{f_{cd}}{P_{cf} - P} * \frac{75}{T_{cf} - T_{ci}}$$

Specific fuel consumption (abbreviated as SC or SC_c) is the ratio of the amount of fuel wood consumed to the amount of water remaining at the end of a trial. This can be defined for any number of tasks and should be considered “the fuel wood required to produce a unit output" irrespective of the output; be it boiling water, cooking beans, rice or loaves of bread. The SC in this case refers to the measure of the amount of wood required to produce one liter (or kilo) of boiling water. It is mathematically represented as:

$$SC = \frac{f_{cd}}{P_{cf} - P}$$

Emission factor (EF) is defined as the emissions per kilogram of dry wood burned. This factor is independent of the amount of heat transferred in to the pot, and is therefore an indicator of combustion efficiency only.

$$CO = \frac{Mass\ of\ CO\ emissions\ (g)}{Dry\ wood\ consumed\ (kg)}$$

6.5 Test Results and Discussions

The effect of moisture on CO emission, PM emission, fuel consumption and time to boil was investigated to establish the effects of moisture content on the performance and emission of the stoves. The error bars on the graphs discussed in this section, were derived from one standard deviation of the average of three trials per experiment. However, only two trials were done for the "Skirt" stove at 30%. The real data for the experimental measurements of all three trials of the 5%, 15% and 30% wood moisture content can be consulted in appendix iV.

6.5.1 Effects of Moisture Content on CO Emission

6.5.1.1 CO Emissions per Task Completed

The emission per task completed showed that the open fire at 5% moisture produced very high CO as compared to the rocket stove and the "skirt" stove at 5%, 15% or 30% moisture (Figure 49). However, the open fire and rocket stoves produced lower CO at 15% than the 5% and 30%. This can be explained by the absence of a grate and the little spacing between the pot and the stove wall which reduce air needed for efficient combustion. Furthermore, the partial insertion of the pot in the stove reduces the heat being transferred to the pot thus minimizing efficiency.

Wood needs some amount of moisture for it to burn effectively. The available moisture may help localize the fire and reduce the escape of volatiles out of the combustion zone before they can completely burn. The water may provide additional OH radicals which assist combustion (Baldwin, 1987). On one hand, in the open fire, extremely dry fuel produced elevated emissions because of lack of some moisture. According to Smith (1987) and Shelton et al. (1978), extremely dry fuel produces elevated emissions because the presence of some moisture is needed to suppress the onset and extent of pyrolysis. This is because heat can penetrate further and faster into dry fuel resulting in the release of volatiles and pyrolysis products far from the zone of combustion and char burning where they might be consumed. The amount of volatile gases could also be too much for the fire to burn. The level of pollution depends on the stove type: here, the open fire emitted more CO than the other two stoves. CO is formed when the fuel and air are not completely mixed and complete mixing does not usually occur in stoves with no controlled drafts of air.

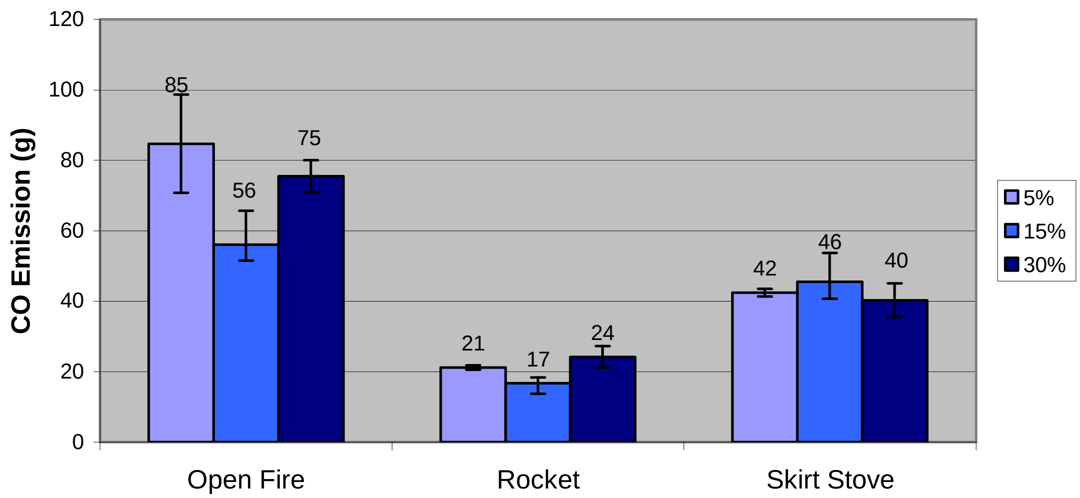

Figure 49: Amount of CO emitted when WBT was completed

On the other hand, extremely wet wood would likely produce higher CO emissions as well. It could be because the fire is cooler due to the water and because the fire burns more slowly. The rocket stove produced the lowest amount of CO at all moisture levels due to the air being forced up through the coals, resulting in lower production of charcoal. The “skirt” stove with less draft and no grate produced about twice as much CO than the rocket, but about half the CO of the open fire.

6.5.1.2 CO Emission Factor

In addition to the total mass of CO emitted during the entire test, which includes the reduction in emissions due to less fuel being burned (improved heat transfer efficiency), it is also interesting to investigate the Emission Factors alone. These indicate how cleanly the fuel is being burned at both high and low power, independently of how much fuel was required to complete the task of boiling and simmering the water.

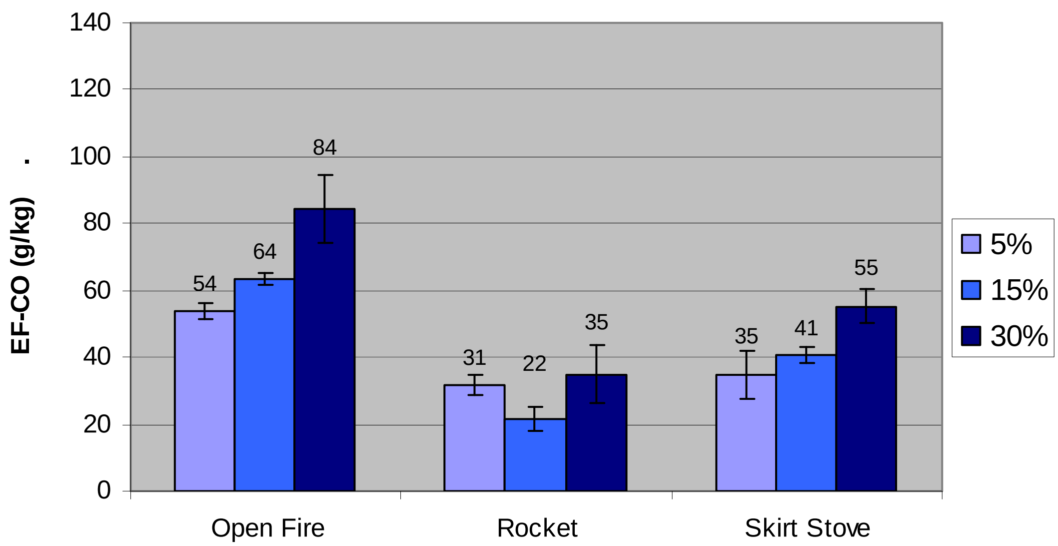

Figure 50: CO Emission Factor at High Power

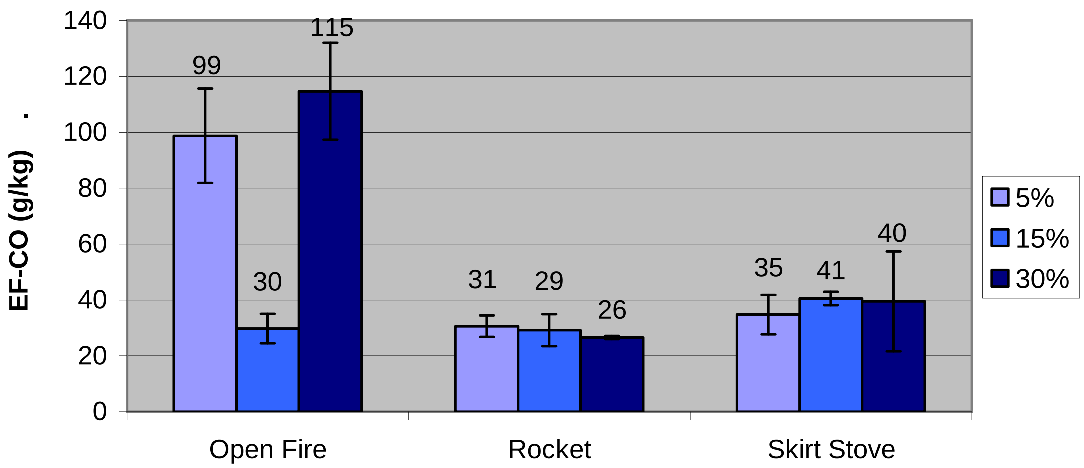

Figure 51: CO Emission Factor at Low Power

High CO emission was noted for the open fire at low power however the difference in CO emission for the rocket stove and the skirt stove was minimal. This is because at low power, less air is needed, and the skirt stove without grate is not much worse than the rocket stove. The highest CO occurred at 30% moisture for all three stoves at high power (Figure 50). This was likely because more charcoal was being produced due to the inefficiency of combustion. The production of charcoal during burning is directly related to the amount of CO emitted (Still et al. 2007).

6.5.2 Effects of Moisture Content on PM Emission

As discussed above, PM and CO emissions are directly linked to combustion efficiency which is partly influenced by wood moisture be it positively or negatively.

6.5.2.1 PM Emissions per Task Completed

There was a significant decrease in PM at 5% to 30% moisture contents with the rocket stove. The “skirt” stove made a relatively small amount of PM but was higher than the rocket stove at the higher moisture content. The open fire produced high amounts of PM about three times higher than both of the improved stoves (Figure 52). This can be explained by the presence of an insulated combustion chamber and a vent in the rocket stove which allowed a strong draft thus increasing turbulence and mixing of gases and the fire thus improved combustion.

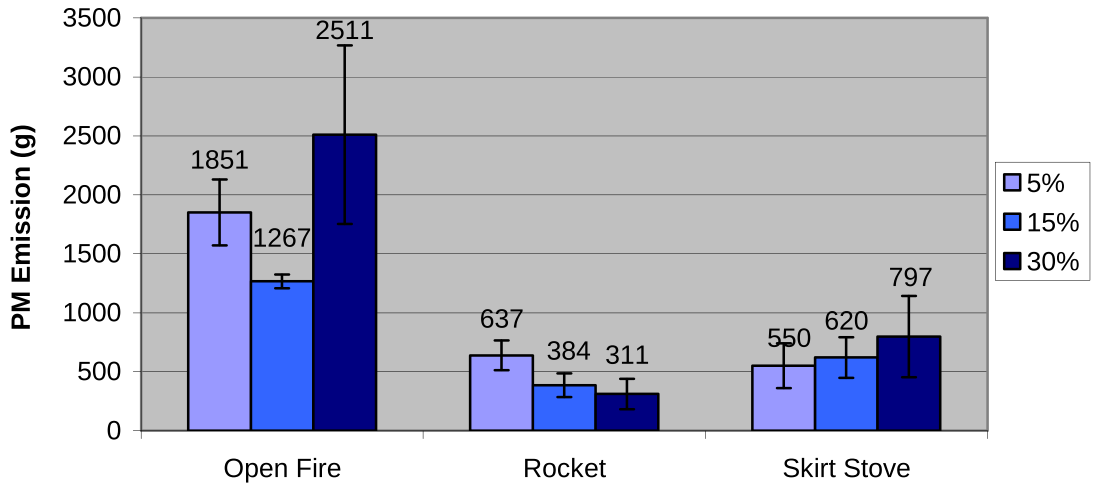

Figure 52: Amount of PM release when WBT was completed

6.5.2.2 PM Emission Factor

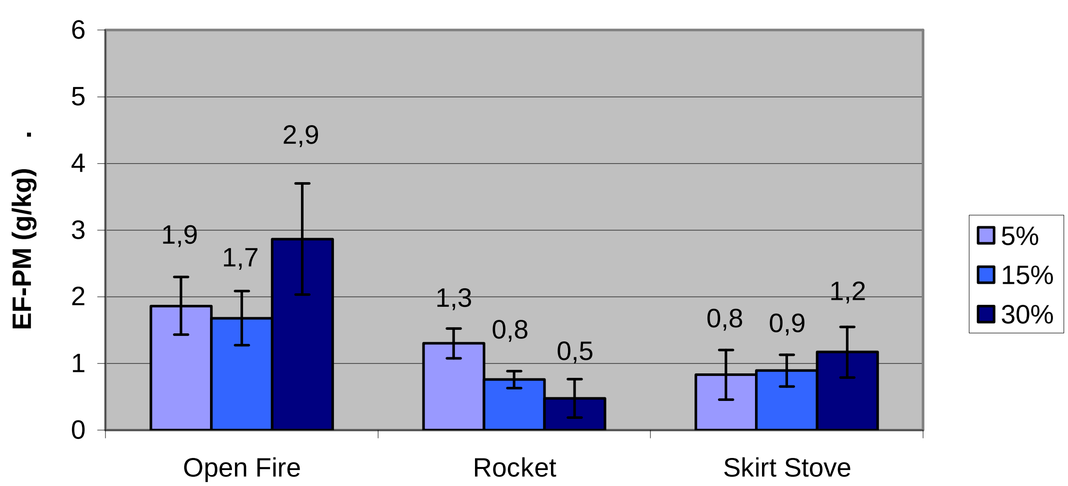

Figure 53: PM Emission Factor at High Power

Generally, more PM was released at high power than at low power for all three stoves (Figure 53 and 54). This is due to the lower amount of flaming combustion during the low-powered simmering which leads to reduced production of PM. The Rocket stove presented a significant and systemic result as the amount of PM released decreased from 5% to 30% at both high and low power. Therefore the emission factor of PM is highest at 5% moisture content for the rocket stove. Very dry wood can produce high levels of emissions since some moisture is needed to suppress the onset and extent of pyrolysis.

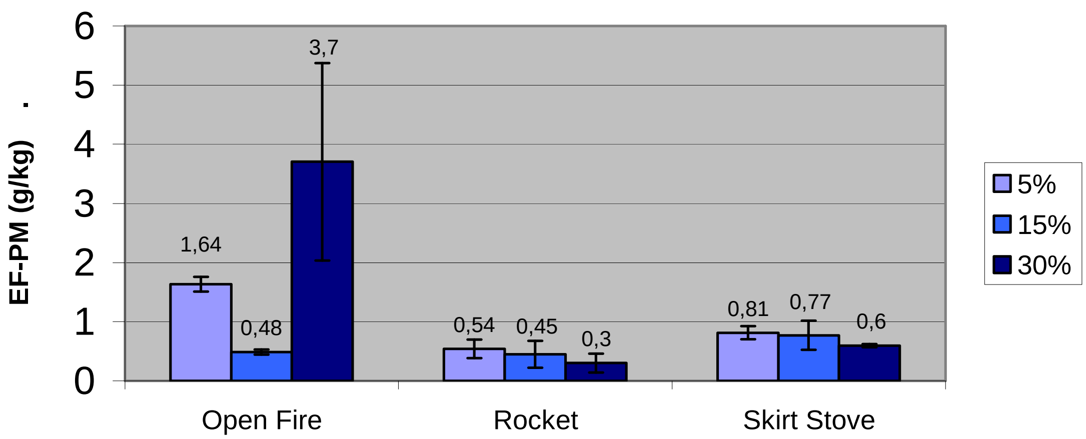

Figure 54: PM Emission Factor at Low Power

Contrarily to the rocket stove, the open fire produced the least PM at 15% moisture content. The PM produced at 30% was higher than that produced at 5%. This trend was observed at both High and Low Power. However, more PM was released with the open fire than the rocket and the "skirt" stove. The level of emission produced by the open fire will greatly depend on the operator; however, the open nature of the fire leads to great loss of heat and escape of gases which greatly affects combustion (Figures 53 and 54).

6.5.3 Effects of Moisture Content on Fuel used per Task Completed

According to Baldwin (1987), wood does not burn, it gets hot and releases volatile gases that combust. Sufficient time, temperature and turbulence are needed for this to happen. When wood is heated to 650^{o}C and sufficient oxygen is mixed with volatile gases, the result is complete combustion. Smoke is wasted energy.

As moisture content in the fuel increased, more fuel was consumed (Figure 55). This difference was significant at 95% confidence for both the rocket and the "skirt" stove. This is because more energy was needed to evaporate the moisture of the fuel. Besides, higher moisture content also reduces the flame temperature thus impairing on the rate of heat transfer to the pot. Because of the difficulty in keeping the fire burning for the "skirt" stove at 30% moisture content, the fuel size was reduced. By so doing, the surface area of absorption was increased thus increasing burning rates and the temperature inside the combustion zone.

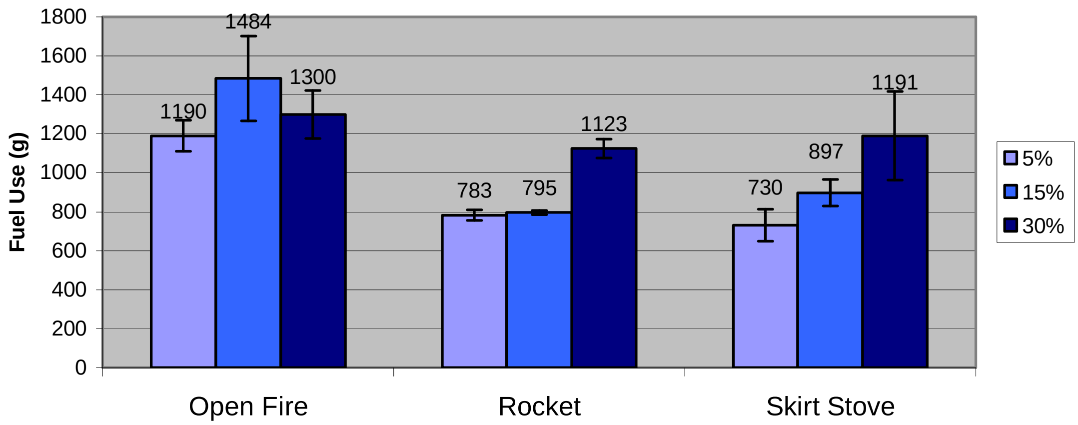

Figure 55: **Fuel used to complete WBT**

6.5.4 Effects of Moisture Content on Dry Consumption

The following section shows dry wood consumed in the fuel used when subtracting the mass of water in the fuel.

6.5.4.1 High Power

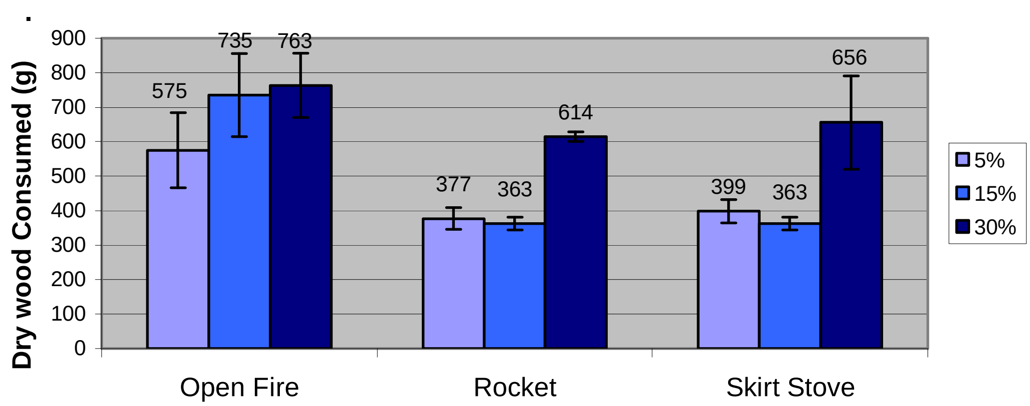

Figure 56: Dry Wood Consumed at High Power

Similar to the fuel consumed during the entire WBT, the fuel consumed at high power alone followed the same general trend. There was an increase in fuel consumption with increasing moisture content seen in the open fire, even without the correction for the energy required to evaporate the moisture in the wood (Figure 56). Refer to the moisture content correction equation of wood consumed (moist) and dry wood consumed above Wood use stayed even in the rocket and skirt stove from 5% to 15% but increased at 30%.

6.5.4.2 Low Power

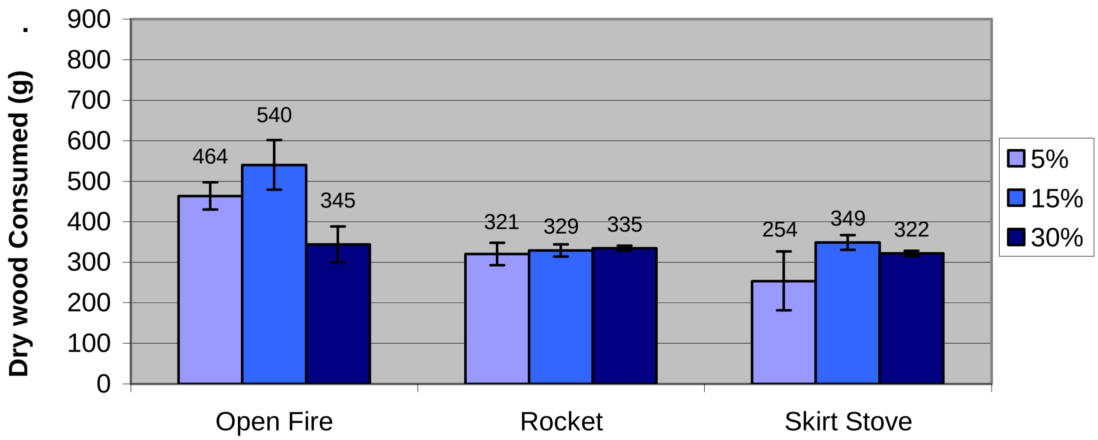

Figure 57: Dry Wood Consumed at Low Power

More fuel was used at high power than at low power (Figure 56 and 57). This is because more energy is needed to bring the water to a boil than to simmer. Maintaining the heat at boiling point or not more than 3^{o}C below boiling point for 45 minutes does not need as much energy as to bring the water to boil.

6.5.4 Effects of Moisture Content on Time to Boil

The time needed to bring water to boil is greatly dependent on the moisture in the fuel. There was a systemic increase in time to boil from 5% to 30% moisture content (Figure 58). The observed results were significant for all three stoves at 95% confidence. However, the variation is dependent on the stove type which influences combustion efficiency and heat transfer efficiency. The time needed to bring water to boil, is greatly dependent on the moisture in the fuel. High moisture content means more time needed and energy required to complete the same task. The emission hood results of each test for all three stoves can be found in Appendix B IV.

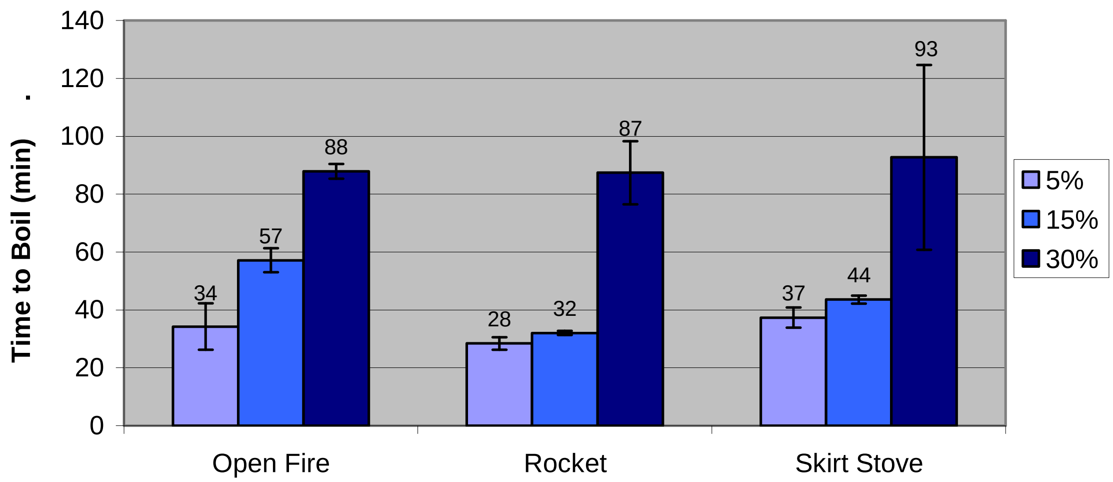

Figure 58: Time used to boil water during the WBT

The time needed to bring water to boil is greatly dependent on the moisture in the fuel. There was a systemic increase in time to boil from 5% to 30% moisture content (Figure 58). The observed results were significant for all three stoves at 95% confidence. However, the variation is dependent on the stove type which influences combustion efficiency and heat transfer efficiency. The time needed to bring water to boil, is greatly dependent on the moisture in the fuel. High moisture content means more time needed and energy required to complete the same task. A sample of the WBT data sheet and the emission hood results of each test for all three stoves can be found in Appendix B IV.

6.5.5 Conclusion

Fuel moisture is an important parameter to be considered when evaluating cook stove performance. How wet or dry fuel will greatly influence combustion. Some amount of moisture seems to be needed in fuel in order to minimize emissions, while too much moisture can result in longer cooking time, greater fuel use and higher emissions. 5% wood moisture is normally not available. A typically air dried wood is likely to have around 15 to 20% moisture in the best of circumstances. Green wood is less efficient because of high moisture contents and would generate more emissions as indicated by all the results at 30% moisture.

Stove design also plays a role in determining the behavior of the fuel when burnt whether it is dry or wet. Stoves with combustion chambers seem to burn wood more effectively at varying moisture contents. The rocket stove was more efficient in emission factors and fuel consumption than the “skirt” stove and open fire, and it was the least susceptible to increased moisture content. Overall, the type of stove exhibited a stronger effect on the overall emissions than did the moisture level in the fuel.

Because there are many differences between laboratory and field results, it is difficult to use only the results of the laboratory to predict how stoves will perform in real world situation. However, side by side comparison can be used to estimate performance.

The traditional fire like in many other developing countries is widely used in Cameroon. The rocket stove could be considered a representative cooking technology in Cameroon because of its high efficiency and cheap gross cost of production which stands at US$ 1 per stove in China. But like other one – sized -- pot stove, the rocket stove used in this study has a limitation. Therefore, the rocket stove technology could be adapted for the construction of bigger and affordable stoves which will meet the needs and expectations of the desired communities. Although the “skirt” stove performed slightly better than the traditional open fire, more work still needs to be done to improve its efficiency and safety.

SECTION III

SIMULATION MODEL
(THE NINE RECURSIVE STRUCTURED SENSITIVITY MODEL)

Chapter 7 THE SENSITIVITY MODEL

The integration of the sensitivity model in this study is to help understand the behaviour of the components and how they relate to or will affect each other within the system of the cook stoves.

The Sensitivity Model also referred to as the "Art of Network Thinking" was developed by Prof. Dr. Dr. rer. nat. Habil. Frederic Vesters (1925 – 2003). He was a biochemist and a renowned expert in Cybernetics. He dealt with environmental issues, energy and traffic planning issues, health issues, sustainable management, learning, and other areas that require adequate ways of dealing with complexity. His aim was to be able to pursue independently what he considered as the vital problems in the fields of traffic, health, education, agriculture and the underlying linear way of thinking.

The Sensitivity Model (SM) does not only describe the dynamics connected to system development, it is also a kind of seismograph that is capable of describing its inner cybernetics. Since the procedure involved in this model shows the flows of effects, it is possible to set a new course for them. Furthermore, it is possible to foresee the behaviour of cook stoves related components including all feedbacks, by means of simulation. Apart from the problem to be solved, its neutral design makes it applicable to any system that strives for sustainability, be it regional planning, management, social, medical care and technology assessment.

According to Vester, the key to achieving a mastery of one system lies in recognizing the essential patterns that shape the interaction of crucial aspects (critical variables) of networks, so that one can then focus on a reduced set of data that capture these patterns. Network thinking as Vester puts it, is as much a quest for reducing the need for data, and thus for practicability, as it is a quest for more holistic modes of thinking; or, perhaps more to the point, it is the art of combining the two concerns within one and the same framework (*Ulrich Werner, 2005*).

At the beginning of any reflection on a connected system, it is important to know if the system we are dealing with is a complex system, is part of a system or several mechanisms. A complex system consists of several different organs which are located in a certain dynamic order and that are sometimes linked to a network of interaction. One therefore cannot interfere without changing the relations of variables to each other thus changing the character of the whole system.

The dynamic of any situation refers to how the situation changes over the course of time. A dynamic system therefore can be defined as a physical setting together with rules for how the setting changes or evolves from one moment of time to the next. One basic goal of the mathematical theory of a dynamic system is to determine or characterize the long-term behavior of the system.

"The Sensitivity Model, offers practical tools for network thinking. They include surprisingly simple, yet powerful conceptual tools as well as software tools. Among the former are a basic sequence of conceptual steps for grasping a network's essential variables and the ways they interact, and then for judging the resulting behavior pattern against the background of the mentioned bio-cybernetic principles; the use of fuzzy logic (Zadeh et al., 1996), and most originally, the Paper Computer, an influence matrix for identifying and evaluating a system's critical variables. The matrix allows to calculate three approximate measures (called "influence indices") for the extent to which any variable: (a) influences other variables; (b) is itself influenced by them; and (c) is a critical leverage point for intervening into the system."

The Sensitivity Model is a major analytical tool available today for professional practice of network thinking. It is a framework for systems modeling and assessment that has been applied in countless applications to solve problems in diversified fields. It is now available as a computer-aided simulation and decision-support tool for the Windows XP platform and today, it is being used by individuals, Institutions and renowned organisations like DaimlerChrysler AG, Forschung, Gesellschaft und Technik, Berlin, Bosch GmbH, Stuttgart etc. It consists of three recursive levels of analysis:

- bio-cybernetic systems description (data collection and aggregation),
- bio-cybernetic systems interpretation (understanding the network, e.g., in terms of the mentioned influence matrix or Paper Computer), and
- bio-cybernetic systems evaluation (understanding the need, consequences, and risks of interventions).

Of course, like other softwares and modeling tools, the Sensitivity Model has its own limitations. What matters is not that one achieves complete knowledge, but rather, that one learns to understand and appreciate those essential patterns of interaction that shape the structure and dynamics of the network in question.

The SM through the nine steps of the system tool guides one through the process of information gathering and data reduction to the few system relevant key parameters that will model the system. Through specially developed tools, it is possible to build up, visualize and analyze the cybernetic dynamics in a feedback diagram of the whole system. By focusing on particular issues, "subsystems" of especially interesting "clusters" of the overall effect system are developed. To explain the dynamics and significance of the feedback cycles defined, in the previous steps, the partial scenarios are simulated. Through a relational database, the entire process could continuously be modified making the tool flexible. For sustainable and long-term viability of the system under consideration, the application of a set of biocybernetic rules is used to verify the final policy tests and the validation of the proposed measures (*Vester F., 2004*).

7.1 Why the Sensitivity Model?

The nine recursive permanently interactive working tool of the Sensitivity Model is a self-explanatory and visualization tool which even non-experts can easily understand. The feasibility of using this tool to better understand the problem of indoor air is very obvious, as it will clearly tell how the system will behave and react upon one or other changes in the environment and how the system as a whole will react upon certain strategy implementation. Using the results gotten from the questionnaires and the stove performance test above, the developed partial scenarios could be investigated via a simulation such that different outcomes of decisions by a series of policy-tests can be compared.

7.2 The Recursive Structure of the Sensitivity Model

The recursive structure of the nine tools of the Sensitivity Model software (Figure 59) is a replica of how evolutionary management works in nature making it a permanent working instrument where initial faults are successively corrected by the following steps.

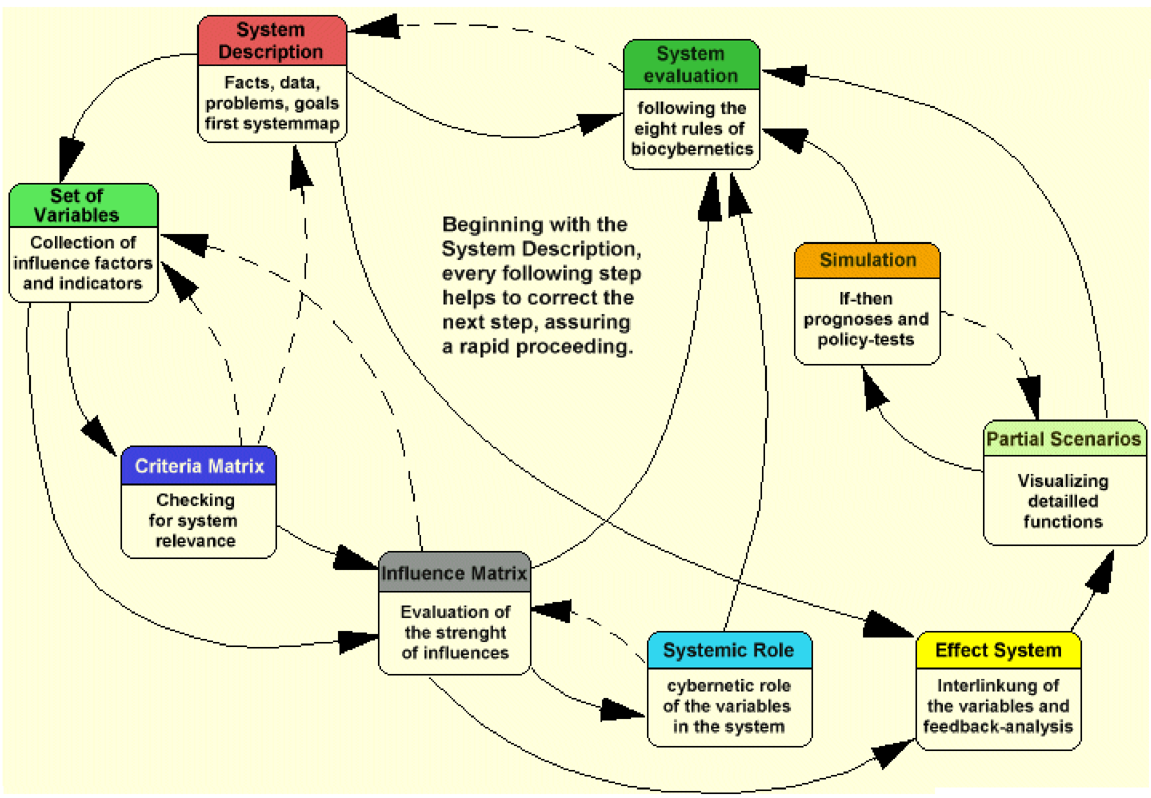

Figure 59: The Recursive Structure of the Sensitivity Model
Source: Vester, F. (2004)

7.2.1 System Description

To analyse the system within which indoor air pollution poses a threat, it is imperative to begin with a system description which can be constantly updated during the development of the model according to findings. Certain aspects are considered while describing the system like: the definition of a system boundary, the nature of the influencing factor, the meaning of their interdependencies, the sketching of a picture of the system and the construction of a preliminary effect system.

A typical part of the system description which is purely manual, is a sketch of collected facts, opinions and interlinkages arrived at through brainstorming, discussions, notes and records. It provides the basis for the establishment of a variable set and a preliminary effect system. The result of such brainstorming is represented in Figure 60 below.

The system to be investigated (Improved cook stoves) is an open system, limited to the area within which cooking, heating etc. takes place, that is the kitchen (the primary source of indoor air pollution). This system is linked to other larger systems and contains several smaller subsystems. Indoor air pollution poses a threat not only to human health but to our social lives and environment as well. The issue of deforestation sets in as wood fuel is the predominately used fuel type in the study area. Women and kids who are most exposed to illnesses caused by indoor air because they do the cooking and fetch firewood are of prime consideration. Other factors like wood type, moisture content of wood, length of time spent in cooking area and type of food being prepared, architecture of the house, susceptibility of falling sick etc. all influence the degree of hazard caused by indoor air. The economy and law and policy are also key players.

To ease the task of brainstorming, the main system consisting of direct observable parameters within the kitchen like fuel types, stove types, and smoke was first described. From this system emerged sub-systems like the stove design, stove uses, smoke components and the different impacts arising from IAP. With a well described system, it was easy to come up with a set of relevant variables.

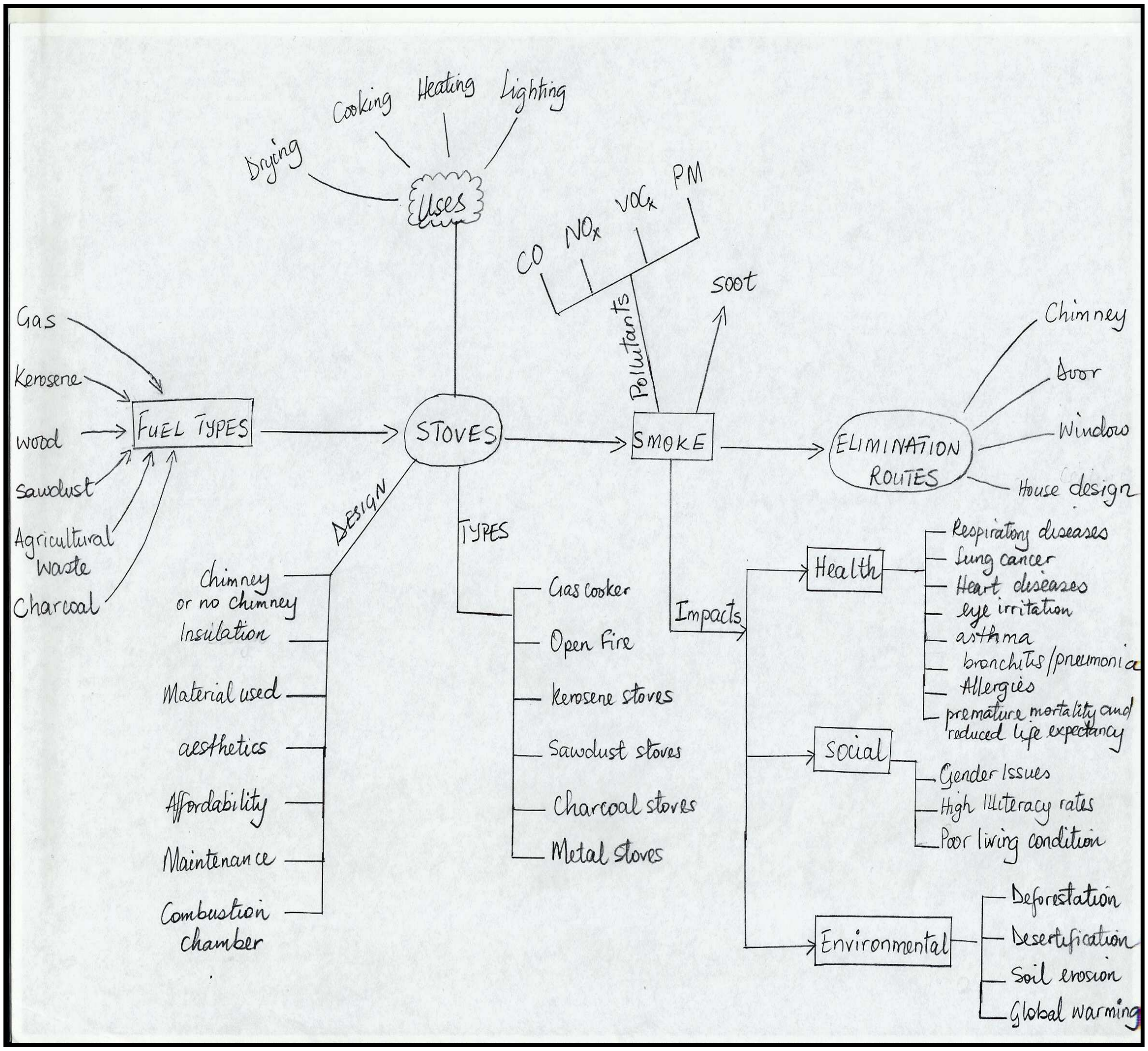

Figure 60: General System Design

7.2.2 Set of Variables

From a well described system, a collection of key variables is entered in the software. The resulting set of variables acts as a “genepool” and at the same time the fingerprint of the system model. Its content is automatically distributed to all steps of the model by the special relational database of the SM. There are 17 described variables (Figure 61) in total and these variables could be improved or updated at anytime if the need arises.

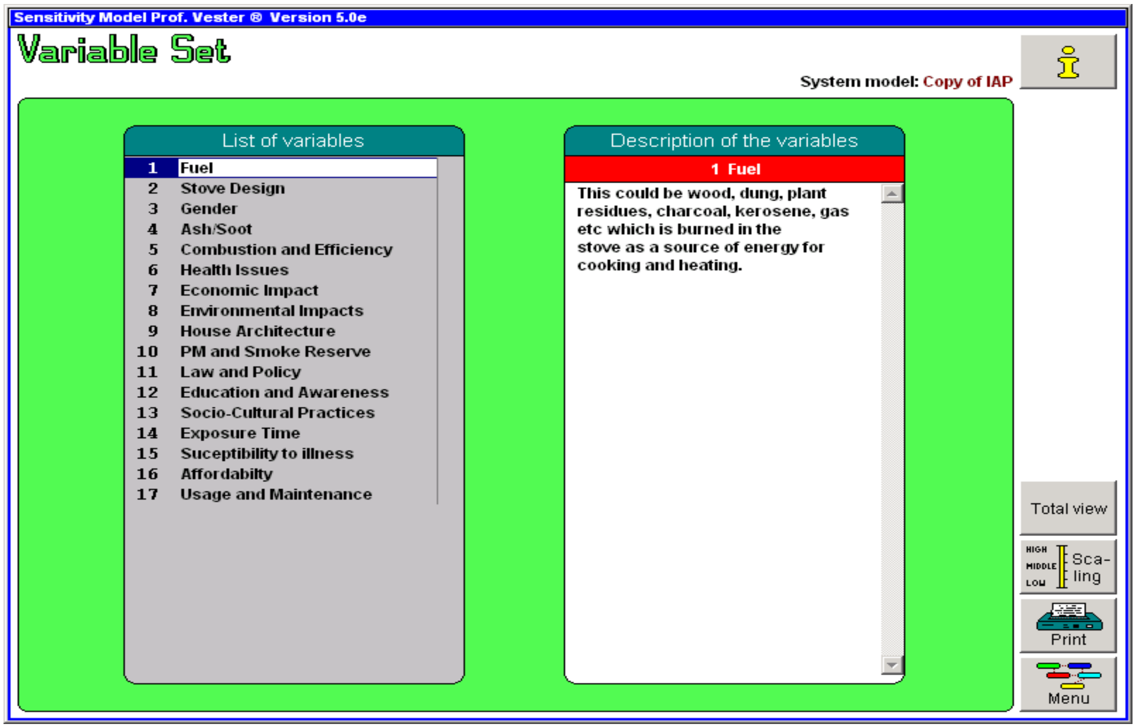

Figure 61: Set of Variables

7.2.3 Criteria Matrix

In the criteria matrix, the viability of the system is checked by screening through 18 essential criteria (Figure 62).

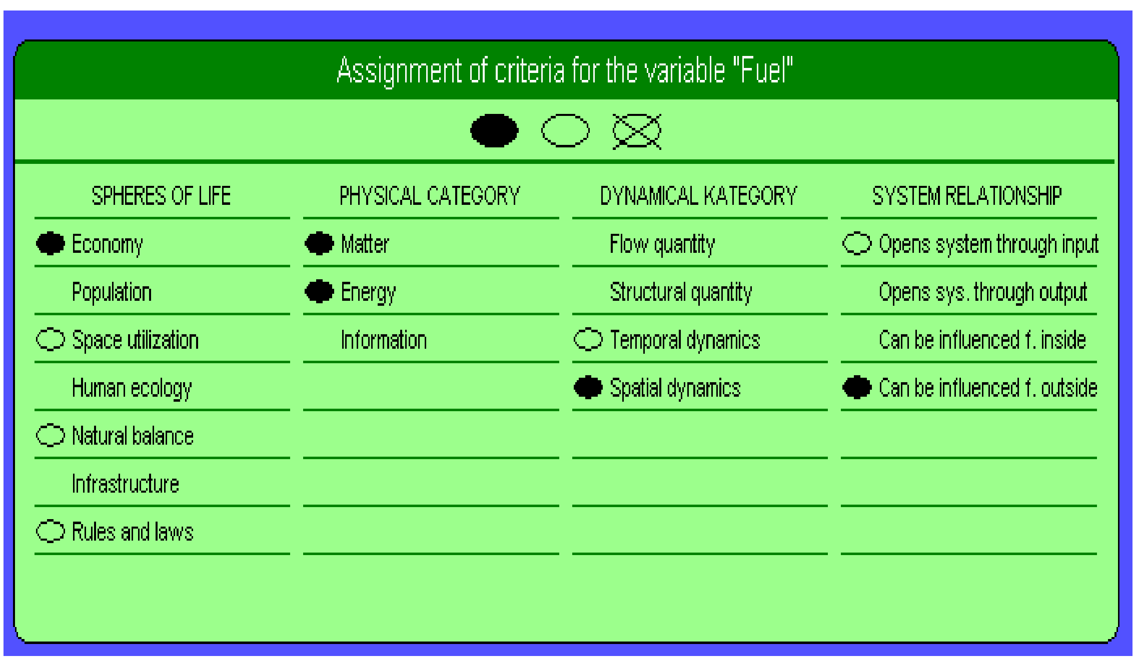

Figure 62: The I8 Essential Criteria for the Criteria Matrix

Beginning with the 7 seven spheres of life, through the physical category, the dynamic category and the system relationship, each variable is assigned a particular criterium. To show how the variable matches the criteria chosen, the dark and white circles are used. The black circle indicates exactly matching and is given the value 1 meanwhile the white circle indicates partly matching and given the value 0.5. The final results are displayed in a tabular form with the final summation of each criterion at the bottom (Figure 63).

Criteria →

● FULLY applicable
○ PARTIALLY applicable

		SPHERES OF LIFE							PHYS. CATEG.			DYN. CATEGORY				SYSTEM RELATIONS			
		Economy	Population	Space utilization	Human ecology	Natural balance	Infrastructure	Rules and laws	Matter	Energy	Information	Flow quantity	Structural quantity	Temporal dynamics	Spatial dynamics	Opens through input	Opens through outp.	Influenced f. inside	Influenced f. outside
1	Fuel	●		○		○		○	●	●				○	●	○			●
2	Stove Design	○	○	○			●	○			●		●		○		○		●
3	Gender		●		●			○	●		○			○					○
4	Ash/Soot			●					●	○	○			●	○		●	○	
5	Combustion and Efficiency					○					●	●						●	
6	Health Issues		●		●			○			●			○					●
7	Economic Impact	●	○					○			●			○		○			●
8	Environmental Impacts	○	●	○	○	○		●			○		○				○		●
9	House Architecture	○	○	○			●		○		○		●						●
10	PM and Smoke Reserve		○	●		○	○	●	●		○	○	●			●		●	○
11	Law and Policy		○					●			●	○							●
12	Education and Awareness		●		○			○			●	○					●		●
13	Socio-Cultural Practices		○		●		○	○			●			○					●
14	Exposure Time		○	○			●				●			●		○		●	
15	Suceptibility to illness		●				○							○					●
16	Affordabilty	●	○								●			○					●
	Sum:	4.5	10.0	4.5	4.0	2.0	5.5	7.5	5.0	1.5	12.5	2.5	4.0	5.5	2.0	2.5	3.0	3.5	13.0

Figure 63: Results of the Criteria Matrix

From the results of the criteria matrix and considering all 17 variables, "Influence from outside" had the greatest score, seconded by the physical category – "Information". This gives us a hint on the importance of the different categories.

7.2.4 Impact Matrix

At this stage, there is a shift from component behaviour to component interaction reason for which the set of variables appear in a cross-impact matrix where the effect of every variable upon another is verified. There are ten guidelines for professional working and successful completion of the impact matrix of this model. These include:

1 The necessary precondition is a system relevant set of variables.

2 The question has to be: if I change A, how strongly will B be changed?

3 The strength of influence is 0, 1, 2 or 3. The crucial point here is the strength of the direct relation and not the direction of the changes.

4 Only direct effects are entered in the matrix.

5 Attention is to be paid to the direction of effects (only “effects from A to B” are considered and not “effects between A and B”).

6 A chronology is observed that is working through a horizontal line to the next horizontal.

7 Work only with partners.

8 Three independent groups should fill the matrix.

9 A consensus matrix is formed with redefinition of the variables.

10 There should be a renewed orientation of the variables.

	Influence by ↓ to →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	AS	P
1	Fuel	X	0	0	3	3	2	0	2	0	3	0	0	0	0	0	0	0	13	273
2	Stove Design	3	X	2	3	3	3	0	2	0	3	0	0	0	0	0	0	3	22	396
3	Gender	3	3	X	0	1	1	1	1	1	0	3	3	2	1	0	1	2	23	414
4	Ash/Soot	0	0	1	X	0	2	0	2	0	0	0	0	1	0	0	0	0	6	72
5	Combustion and Efficiency	0	0	0	3	X	2	0	2	0	3	0	0	0	0	0	0	0	10	170
6	Health Issues	0	0	0	0	0	X	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Economic Impact	2	3	1	0	1	0	X	0	1	1	0	1	0	0	0	3	0	13	78
8	Environmental Impacts	0	0	0	0	0	0	0	X	0	0	0	0	0	0	0	1	0	1	23
9	House Architecture	0	0	0	0	2	1	0	1	X	1	0	0	0	1	0	0	0	6	36
10	PM and Smoke Reserve	0	0	3	0	0	3	0	2	0	X	0	0	0	0	0	0	0	8	176
11	Law and Policy	2	3	2	0	0	1	1	2	0	3	X	1	0	0	0	2	2	19	152
12	Education and Awareness	3	3	2	0	3	3	2	3	1	2	3	X	2	2	1	2	3	35	280
13	Socio-Cultural Practices	3	3	3	0	0	0	0	2	0	1	2	2	X	0	0	0	2	18	90
14	Exposure Time	0	0	3	0	0	3	0	0	0	0	0	0	0	X	1	0	0	7	35
15	Suceptibility to illness	0	0	0	0	0	3	0	0	0	0	0	0	0	0	X	0	0	3	12
16	Affordabilty	3	3	1	1	1	2	1	2	3	2	0	1	0	0	0	X	0	20	180
17	Usage and Maintenance	2	0	0	2	3	2	1	2	0	3	0	0	0	1	2	0	X	18	216
	Consensus / Compare with	21	18	18	12	17	28	6	23	6	22	8	8	5	5	4	9	12	PS	
	Group A / Group A	62	122	128	50	59	0	217	4	100	36	238	438	360	140	75	222	150	Qx100	
	Group B / Group B																			
	Group C / Group C																			

Figure 64: The Consensus matrix

The interaction of all variables were checked using the 10 above mentioned guidelines and the results presented in a matrix form (Figure 64). The set of variables appears in a cross-impact matrix where the effect of every variable upon any other is checked. The question for example is: If variable “A” changes, how strongly will it change variable “B” by direct interaction? To better understand the behavior of variables vis à vis each other and for better understanding of the system functionality, the matrix was done 3 separate times. Some variables were therefore redefined and described anew, until a consensus of the evaluations was reached.

The result of this evaluation is a 'consensus-matrix' which acts as the basis for the calculation of the “Index of Influence” of each variable, that is: between 'active' and 'reactive' on one hand and between 'critical' and 'buffering' on the other. These positions will enter the tool Systemic Role, where every variable is evaluated cybernetically due to its interdependencies.
On the Impact Matrix, the results are present as Active Sum (AS), Passive Sum (PS), P-value or Q-value.

Active Sum is the summation of the grading of the interaction of variables on the horizontal lines while Passive Sum is the summation of the grading of the interaction on the vertical lines.

P-value measures the consistency by calculating the probability of observing the results from one’s sample data or a sample with results more extreme, assuming that the null hypothesis is true. Therefore, the P- value is a measure of how much evidence one has against the null hypothesis. Null Hypothesis is that which presumes no change or no effect of a treatment.

In this matrix, P = AS x PS

The Q-Value measures the proportion of false positives incurred (called the false discovery rate) when that particular test is called significant. The smaller the q is, the more reliable the system is.

Q – Value = AS/PS x 100

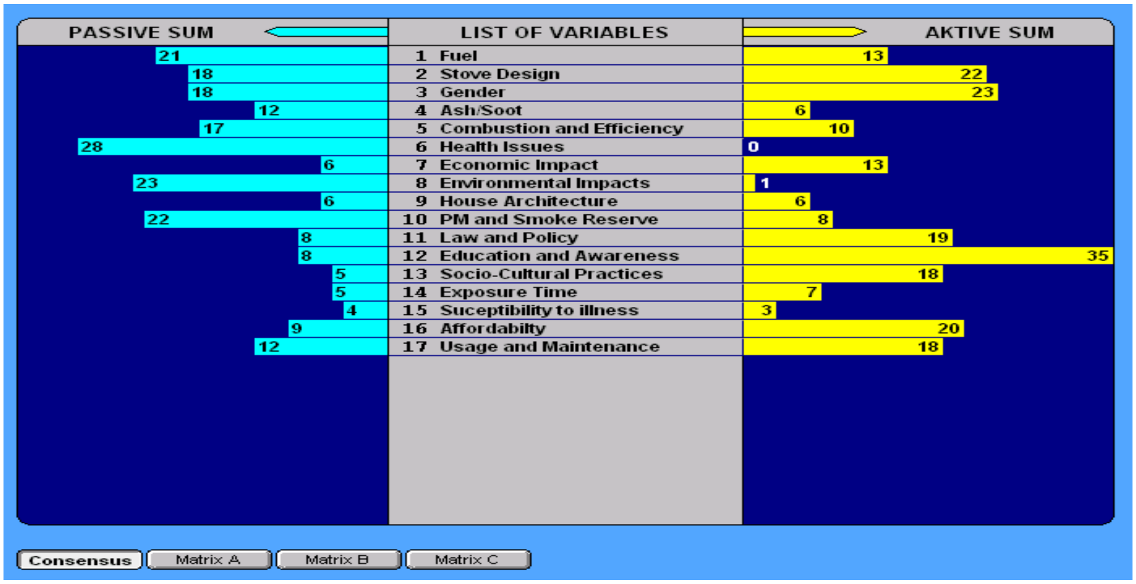

Figure 65: Distribution of variables as Active or Passive

According to figure 65 above, education and awareness is the most active variable while health issues is the most passive. Other active variables include gender, stove design, affordability, law and policy and usage and maintenance. Other passive variables include environmental impacts, PM and smoke reserve and fuel. Variables like gender and stove design could be classified as both active and passive, however, they were more active than passive.

Variables classified as being active, have huge effects on the system and could be changed meanwhile those classified as passive serve as source of information which subsequently changes a lot of things in the system since other variables rely on them.

7.2.5 The System Role

In the system role (Figure 66), each variable is evaluated cybernetically according to its interdependencies. At this stage, the system as a whole distributes the variables within a net of 50 fields of different meaning. Depending on its pattern of influence, each variable is sent towards the four corners of the "compass" which thus reveals its cybernetic role. This maybe a lever (active), a risk factor (critical), a measuring sensor (reactive), an inert element (buffering) or any position in between.

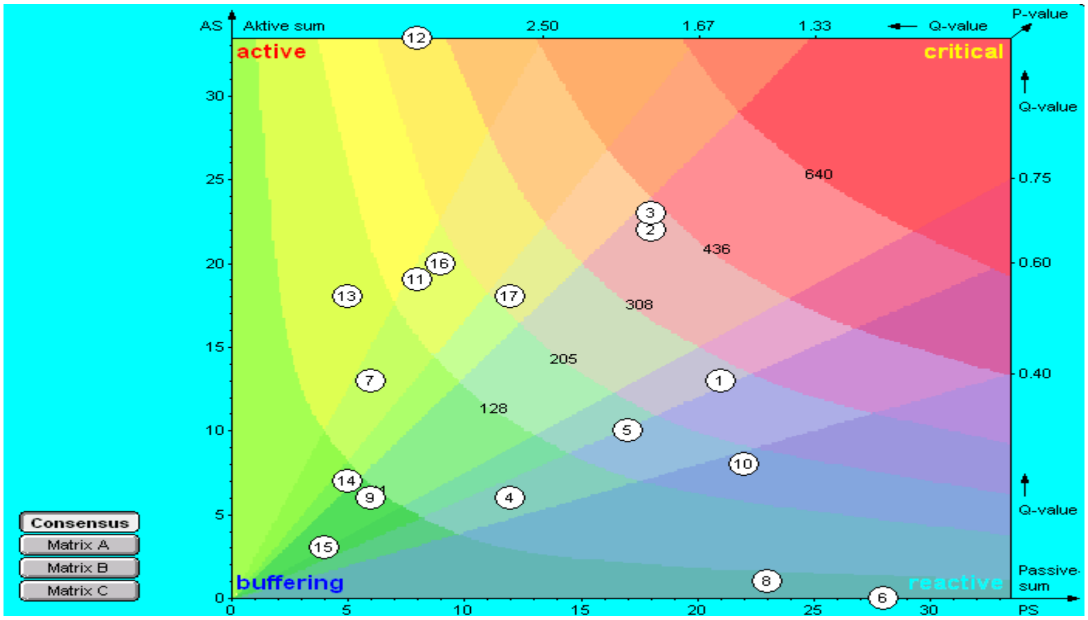

Figure 66: The system Role of the Sensitivity Model

In the Systemic Role, the matrix of consensus was automatically analysed and the results presented as follows;

Total number of points = 222

K-Value Deviation of $(n -1)^2$ = - 13.3%   where K is a constant

Highest value of sum = 35

n is equal to the number of variables

The total number of points is the summation of the Active Sum.

$K = \sum AS/ (n -1)^2$

K is directly proportional to ∑AS and inversely proportional to $(n – 1)^2$. Therefore increasing ∑AS, K becomes positive which makes the system more stable. This is because an increase in the summation of AS increases K, meaning that K becomes greater than $(n -1)^2$ thus gradually stabilizing the system.

A stable system keeps running while an unstable system explodes. A critical point grows from a stable to an unstable system. Therefore, the higher the points in the system, the more stable the system becomes.

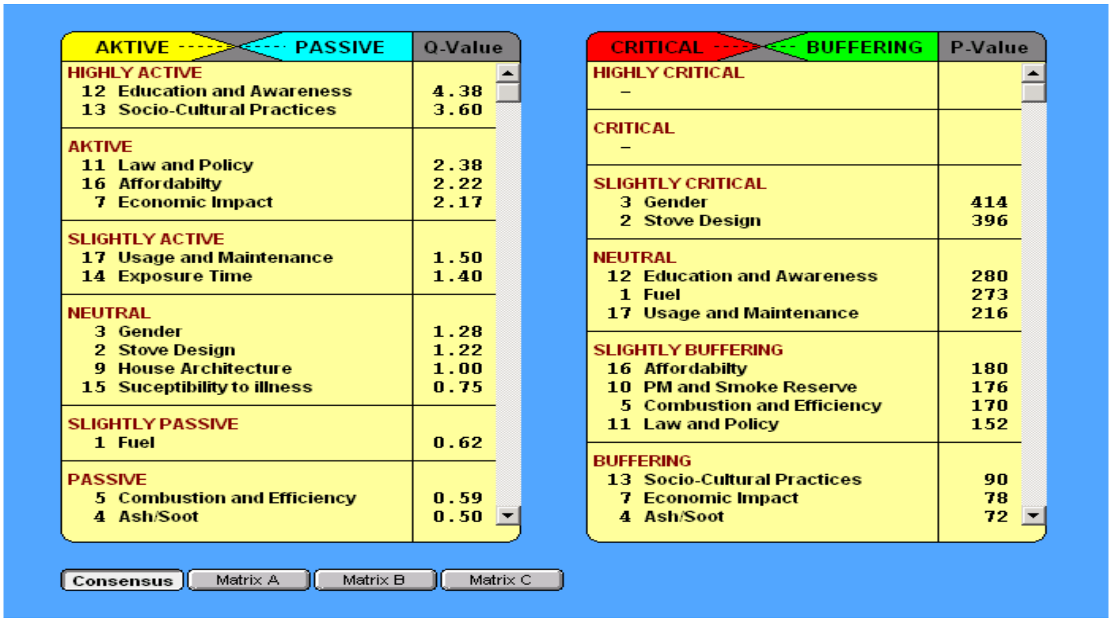

Figure 67: The Interpretation of the Systemic Role

The retrievable statements of the system role interpretation give the first strategic hint on the behaviour of the system. The results are displayed in the form of a table as the “Index of Influence”. The index of influence is made up of two columns; the Q Value column which determines the active and the passive variables and the P Value column which determines the critical and the buffering variables. Variables classified as being Active, have huge effects on the system and could be changed meanwhile those classified as passive, serve as a source of information. Since other variables rely on them, they subsequently change a lot of things in the system.

All 17 variables were distributed along each of these columns to determine its influence on the system. Education and awareness and socio-cultural practices were highly active, closely followed by law and policy, affordability and economic impact which were active. The highly passive variables included PM and smoke reserve, environmental impact and health impact. On the other hand, gender and stove design were slightly critical. No critical or highly critical variables were identified in this system. The highly buffering variables included house architecture, exposure time and environmental impacts. Usage and maintenance were neutral for both P and Q values.

7.2.6 The Effect Matrix

Unlike the impact matrix where the strengths and weaknesses of variables upon each other are assessed, the effect system shows their actual interactions. A kind of network is built between variables (Figure 68). This helps to visualize the system interaction from another perspective; the main focuses, structures and patterns within the system are then recognised.

In the effect system, variable interactions are linked by either broken or full lines. For those linked by full lines, there is a confirming effect that is an increase in variable A for instance, will cause an increase in variable B in the case where the arrow moves from A to B. For those linked by broken lines, there is an opposing effect that is an increase in A will cause a decrease in B in the case where the arrow runs from A to B.

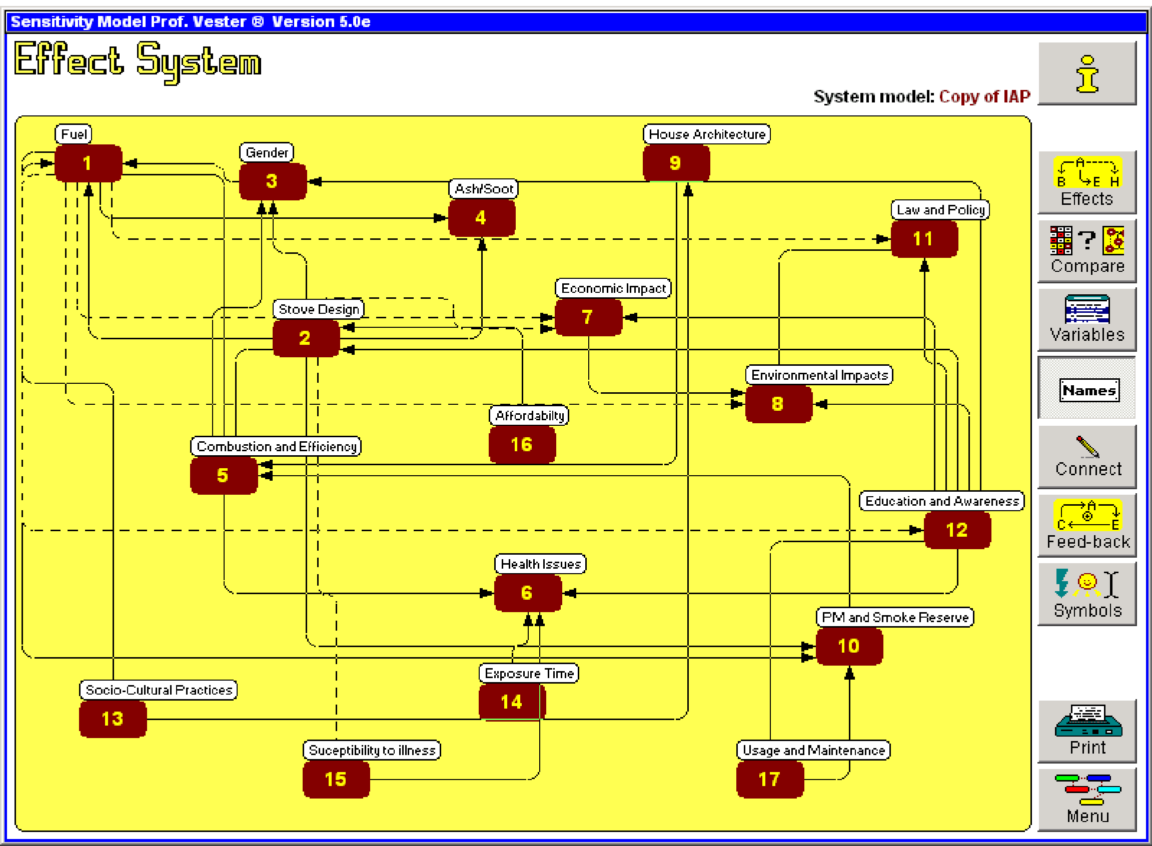

Figure 68: The Effect System of the Sensitivity Model

At this stage, the first cybernetic analysis is carried out where through the emerging feed back loops, the controlling function of single variables or a group of variables are recognised. The feed back analysis allows the recognition of the dominant cycles, the relation between self-control and mutual amplification. This way, one recognised how contradictory influences regulate or contradict each other, how they are connected to others and where one may run into a blind alley. Some variables were purposely deleted to see their importance for the behaviour of the system.

Negative Feedbacks (6)	Positive Feedbacks (2)
1→12→ 2→ 1	1→ 5→ 3→ 1
1→12→ 3→ 1	1→10→ 5→ 3→ 1
1→12→ 2→ 3→ 1	
1→12→ 2→ 5→ 3→ 1	
1→12→ 2→10→ 5→ 3→ 1	
1→12→17→10→ 5→ 3→ 1	

Figure 69: Feedback loops of the Effect System

This system has 6 negative feedbacks as against 2 positive feedbacks which make the system viable. It is always advisable to have more negative feedbacks than positive feedbacks so as to have the need to constantly improve on the system. This is because positive feedbacks have a cumulative effect on the system while negative feedbacks stabilize the system. In the former case, there is exponential growth or decline while in the latter; there is maintenance of the equilibrium (J de Rosnay, 1997).

A positive feedback loop if left to itself can only lead to the destruction of the system, either through explosion or through the blocking of all its functions. The feral behavior of positive loops must be controlled by negative loops. This control is crucial for a system to sustain itself in the course of time.

7.2.7 Partial Scenario

Out of the effect system, one can develop as many partial scenarios as required. It suffices to pick out variables from the existing list of variables or to even add new variables if need be. For this exercise, existing variables were combined into sub-groups depending on the special question of interest. Such group analysis facilitates the cybernetic examination of especially interesting areas in the systems in a clearer way.

Four partial scenarios were developed and these include; stove design, stove performance, health impacts and the economy. Feedback loops were derived from each developed partial scenario. The feedback-analysis at this stage is the same as in the effect system. The results are as follows:

Partial Scenario 1: Stove Design

This scenario principally considers the technology of cook stoves. Bearing in mind that stove efficiency is one of the major ways to combat indoor air pollution, stove design and the material used in constructing the stove are important factors to be considered. The variables comprising partial scenario 1 include; fuel (A), stove design (B), gender (C), combustion and efficiency (D), affordability (E), maintenance and usage (F), construction material (G) and aesthetics (H).

There are in all 8 negative feedbacks and 4 positive feedbacks for this scenario. The important negative feedback loops are A-D-C-A and A-E-F-B-D-C-A. This is because these variables are linked to each other. The behaviour of one will directly or indirectly affect the other, thus causing a big change in the system.

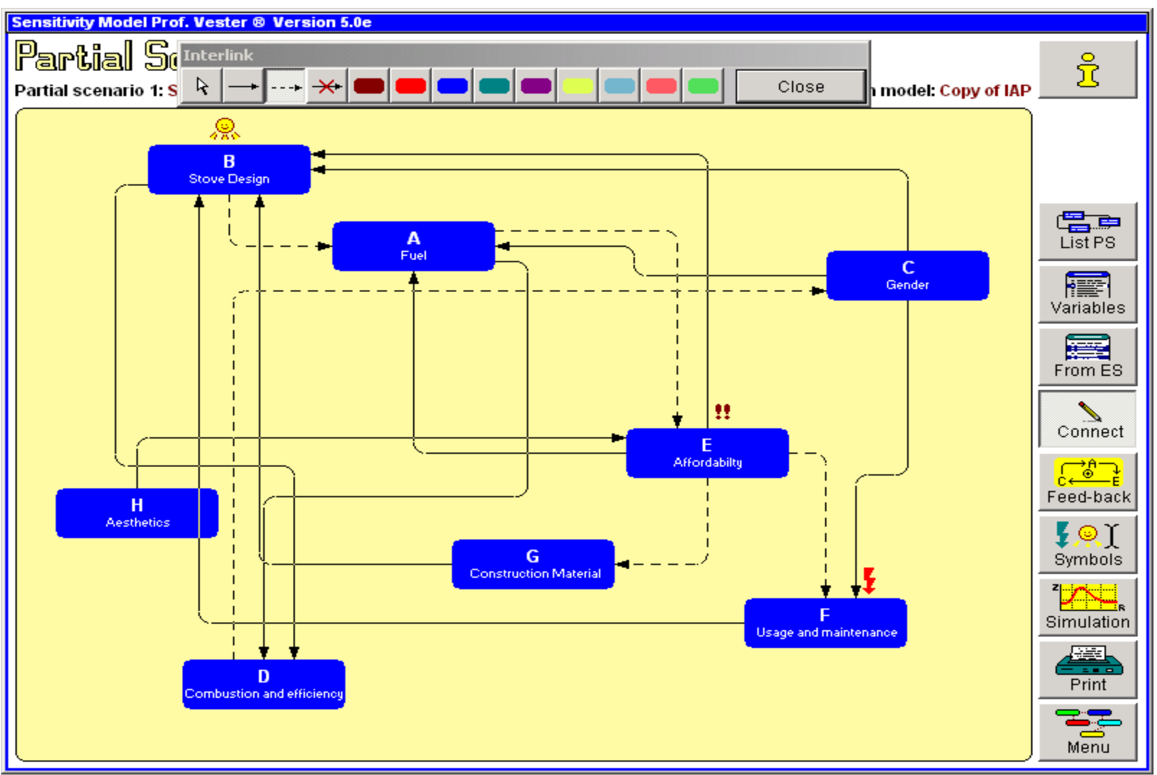

Figure 70: Partial Scenario 1: Stove design

Negative Feedbacks (8)	Positive Feedbacks (4)
A→E→A	A→E→B→A
A→D→C→A	A→D→C→B→A
B→D→C→B	A→D→C→F→B→A
A→E→F→B→A	A→E→B→D→C→A
A→E→G→B→A	
B→D→C→F→B	
A→E→F→B→D→C→A	
A→E→G→B→D→C→A	

Figure 71: Feedback loops of Partial Scenario 1

Partial Scenario 2: Stove Performance

This is the core of indoor air pollution. How well fuel burns, how apt the stove design is (for example the presence of a combustion chamber and the type of insulating material used) and how efficient the operator manipulates the stoves will affect combustion. The variables here include; fuel (A), stove design (B), ash/soot (C), combustion efficiency (D), health issues (E), PM and smoke reserve (F), exposure time (G) and stove operator (H). A total of twenty eight feedback loops emerged from this scenario; 15 negative feedback loops and 13 positive feedback loops.

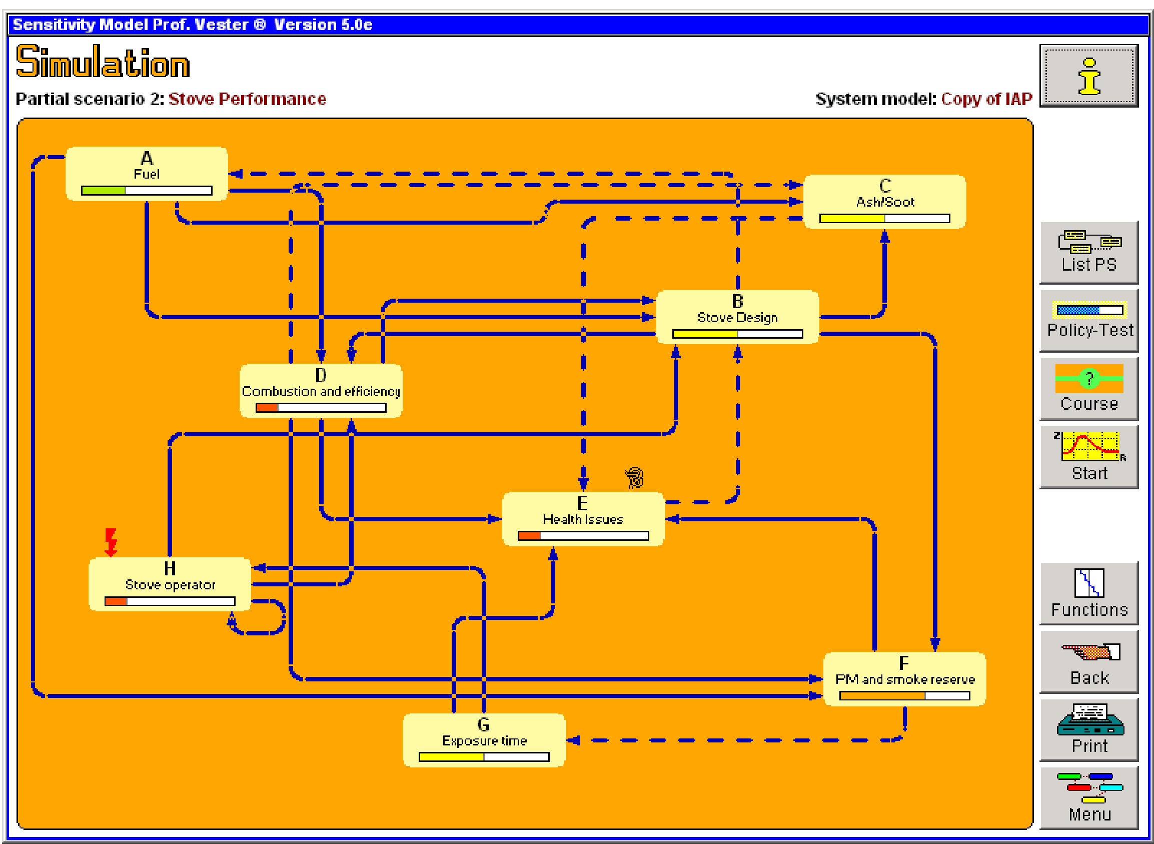

Figure 72: Partial Scenario 2: Stove Performance

Negative Feedbacks (15)	Positive Feedbacks (13)
A→B→A	B→D→B
A→D→B→A	B→C→E→B
B→D→E→B	A→D→E→B→A
B→F→E→B	A→F→E→B→A
A→C→E→B→A	B→F→G→E→B
B→D→C→E→B	A→D→C→E→B→A
B→D→F→E→B	A→D→F→E→B→A
B→F→G→H→B	A→F→G→H→B→A
D→F→G→H→D	B→D→F→G→E→B
A→F→G→E→B→A	A→D→F→G→H→B→A
B→D→F→G→H→B	A→F→G→H→D→B→A
B→F→G→H→D→B	B→F→G→H→D→E→B
A→D→F→G→E→B→A	B→F→G→H→D→C→E→B
A→F→G→H→D→E→B→A	
A→F→G→H→D→C→E→B→A	

Figure 73: Feedback loop of Partial Scenario 2

Partial Scenario 3: Health Impact

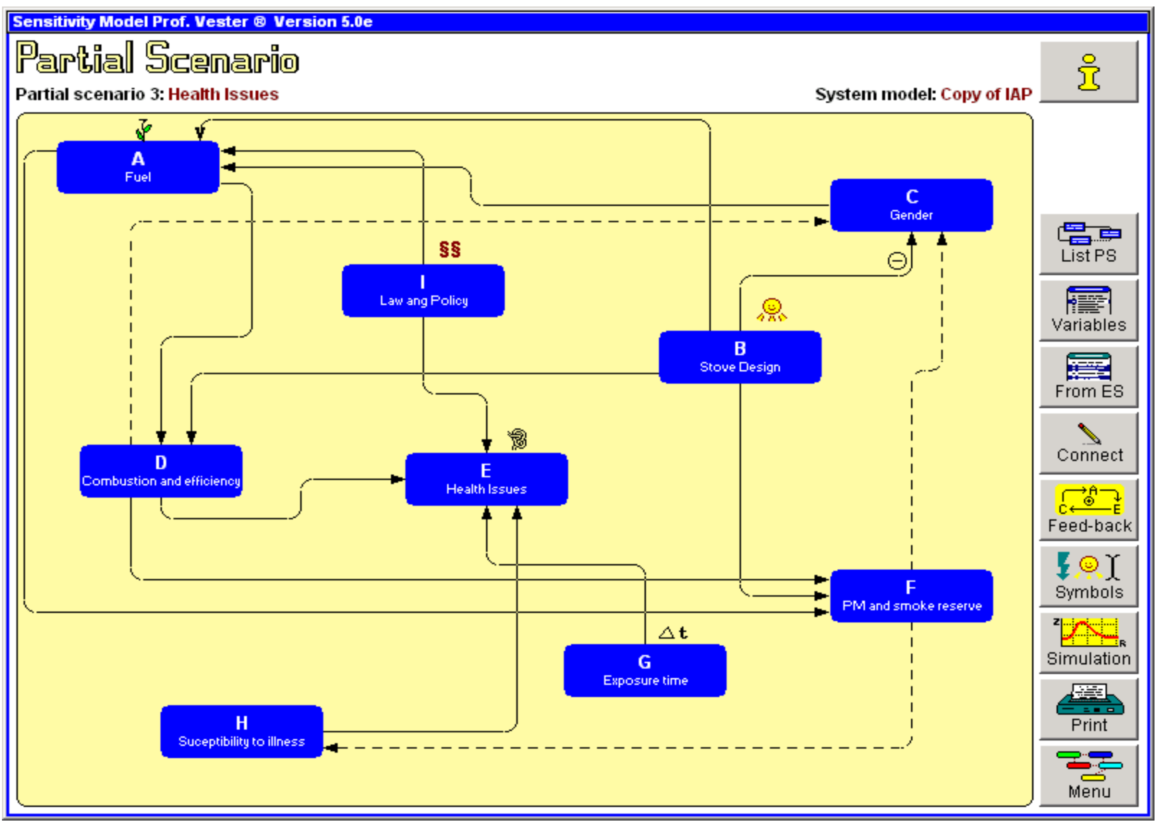

Figure 74: Partial Scenario 3: Health Issues

Negative Feedbacks (3)	Positive Feedbacks (0)
A→D→C→A	
A→F→C→A	
A→D→F→C→A	

Figure 75: Feedback Loop of Partial Scenario 3

The effects of indoor pollution on health are very devastating; mostly women and kids are affected. They range from respiratory illnesses to physical illnesses. The variables in this scenario are: fuel (A), stove design (B), gender (C), combustion and efficiency (D), health issues (E), PM and smoke reserve (F), exposure time (G), susceptibility to illness (H), and law and policy (I). There are in all 3 negative feedbacks and no positive feedback.

Partial Scenario 4: Economy

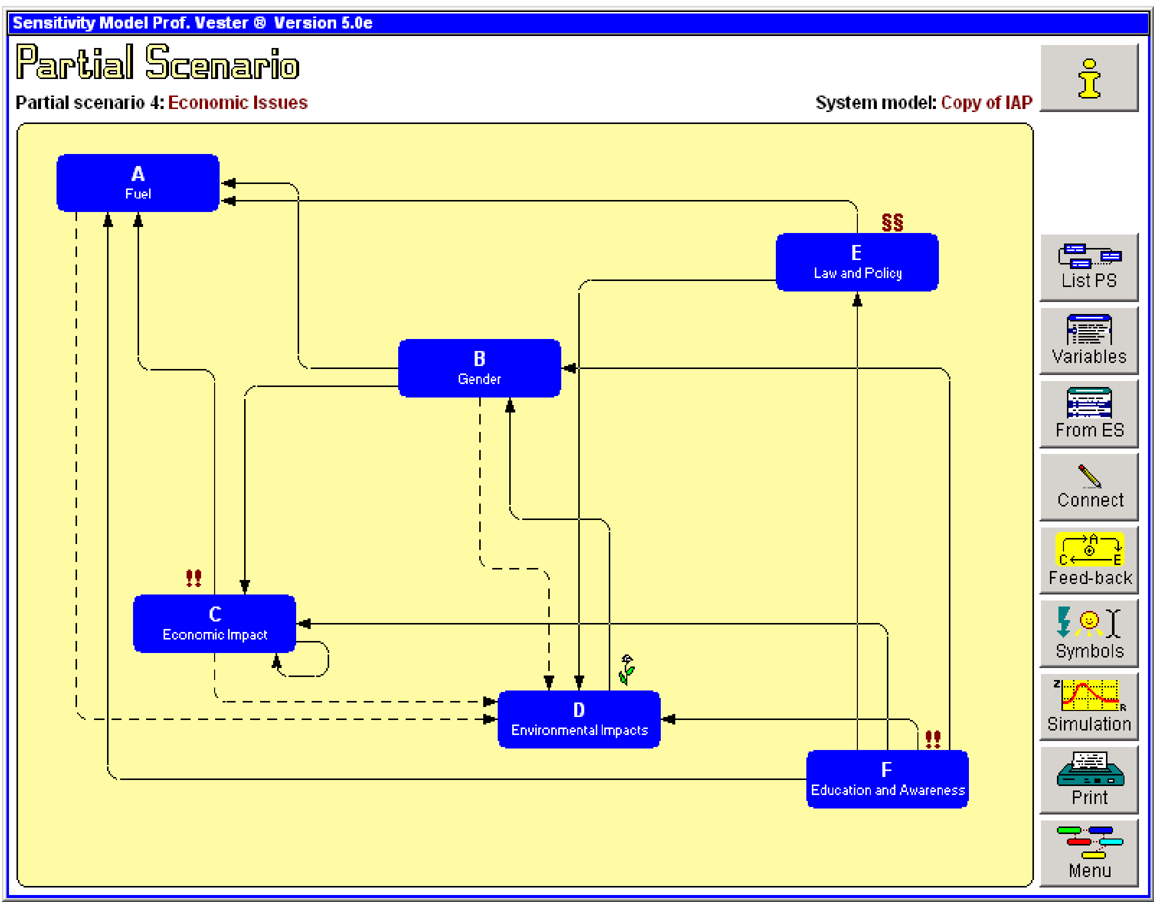

Figure 76: Partial Scenario 4: Economic Issues

Negative Feedbacks (4)	Positive Feedbacks (0)
B→D→B	
A→D→B→A	
B→C→D→B	
A→D→B→C→A	

Figure 77: The feedback loop of Partial Scenario 4

The role of the economy in sustainable development cannot be over emphasized. Economic boom in any country would largely depend on the implemented policy and integration strategies.

The variables making up this partial scenario include: fuel (A), gender (B), economic impact (C), environmental impacts (D), law and policy (E) and education and awareness (F). This is a peculiar case because there is no positive feedback, but there are 4 negative feedbacks.

7.2.8 Simulation

Whereas the feedback cycles give certain risks and chances of the system cybernetics, tool simulation gives an insight into the dynamic development and the possibilities of controlling the system. The algorithm used for simulation is based on table functions that allow non-linear relations. In this way, the mechanisms of stabilization or time delay as well as threshold values as they occur in reality will be recognised. However, the tool simulation does not serve as an instrument of prognosis. It is mainly used for policy test to test different strategies for selected groups of interlinked variables (Vester F., 2004).

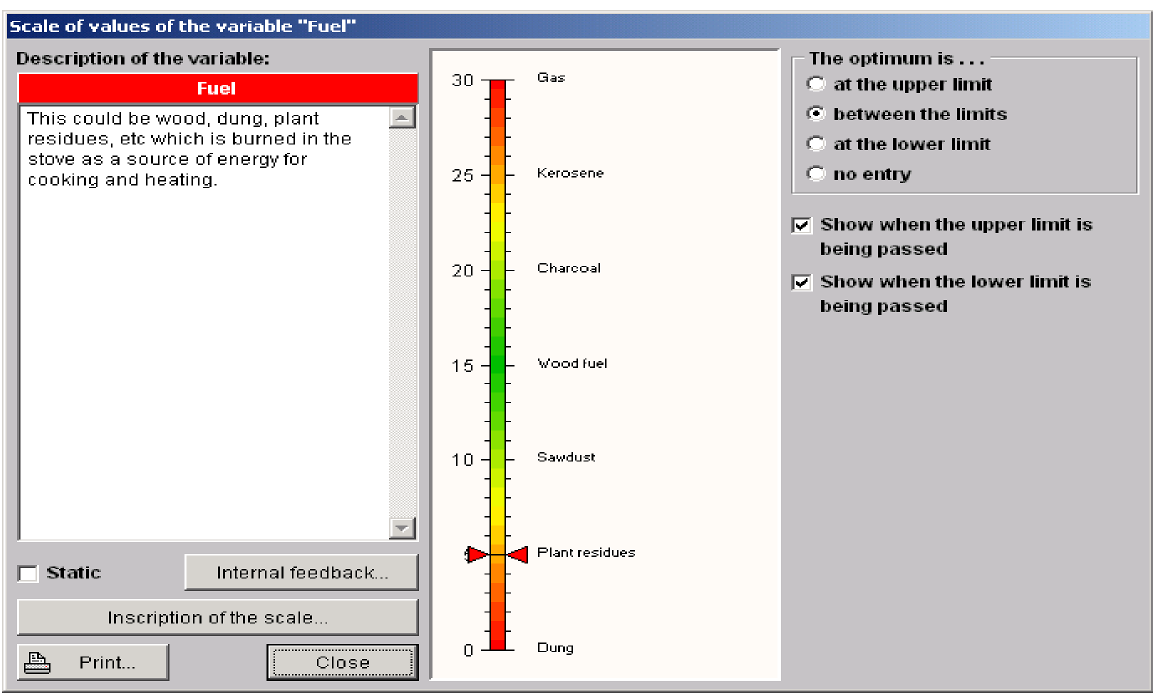

Figure 78: Scale of values of the variable Fuel

The graphical basis of the tool simulation is delivered by the partial scenario. This tool is rather not linked to the main effect system but to the partial scenario so as to avoid the misuse of definite prognosis which is deceptive for open complex systems. With this tool, it was possible to simulate the dynamics of the networks of variables that were present in the partial scenario and study them under different preconditions. This was done with complete scenarios as well as with parts of a scenario. For instance, the courses of certain feedback cycles were examined.

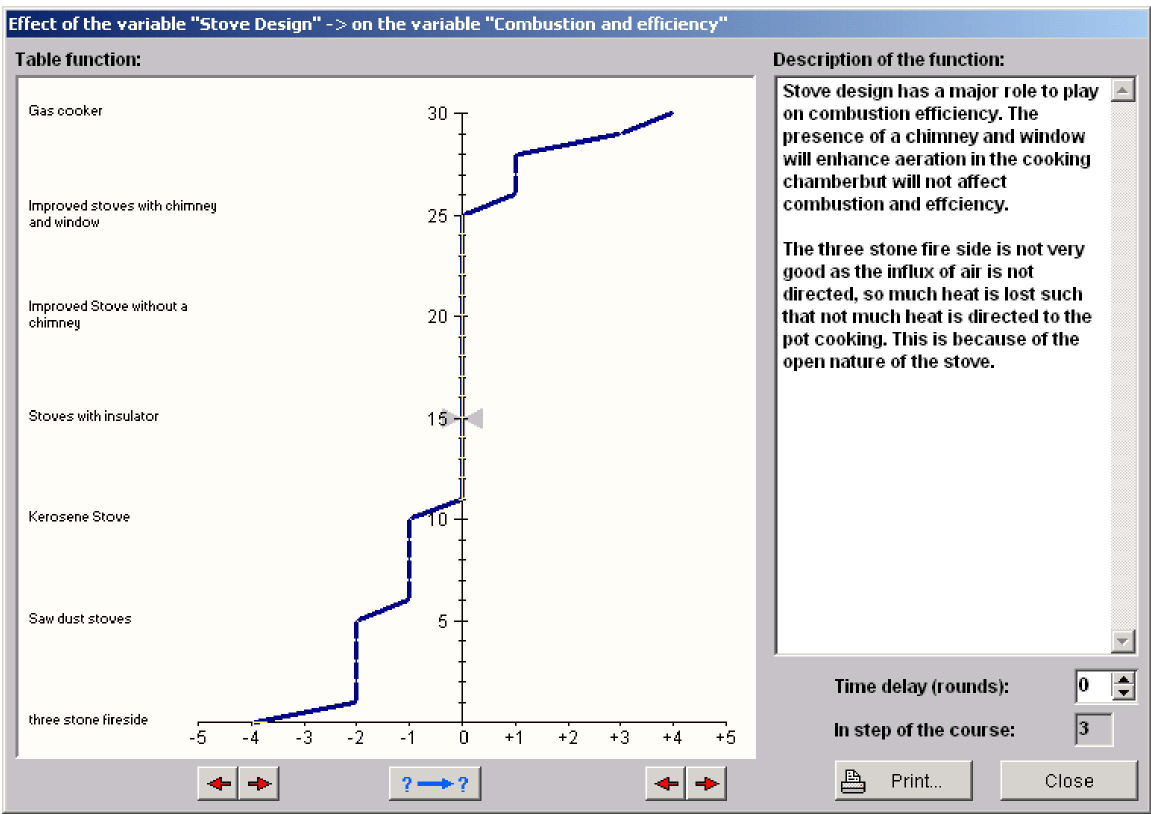

Figure 79: Effect of variable stove design on the variable combustion efficiency

For this exercise, all four partial scenarios where simulated one after the other. Before starting with the simulation, one partial scenario is selected and highlighted. All variables in the selected partial scenario are scaled and well described like shown in Figure 78 below. To describe each variable, the program offers an empty scale corresponding to positions ranging from 0 to 30 with a red cursor. Single descriptions of the variables are placed along the vertical scale starting with the least affecting/affected to the most affecting/affect. The intermediate states are named successively. The given inputs can be quantitative or qualitative. The read cursor is put on the scale at the desired initial starting position. Meanwhile on a separate sheet, the exerted effect from one variable is drawn step by step creating a kind of table function (Figure 79).

To fix the course for simulation, it is required that the unit length of one complete course is defined. The unit length for this exercise was 1year. By pressing on the start button, one can follow the happenings with or without interventions by as many runs as desired. There are a maximum of 15 runs which represents 15 years. The horizontal bars of the variable show the development of the variables. This was repeated for all partial scenarios and over twenty variables. The result of each of this is found on Appendix C. The result of each course depending on the number of runs is presented on a graph.

7.2.9 Discussion and Interpretation of Simulation Results

Using the partial scenarios on stove design, stove performance, health situation and economic influence, a simulation was carried out for a period of 15 years with each lapse of the process being equal to a year. The results are discussed below.

7.2.9.1 Simulation Results of Partial Scenario 1 on Stove Design

In this simulation, two aspects of fuel and stove were considered. Firstly, all fuel types on the household energy ladder (dung, wood, kerosene, gas and electricity; Figure 3) were considered and secondly, only wood fuel moisture was considered (<5%, 5%-10%, 10%-20%, 20%-30%, >30%). This resulted to two different simulations (A and B) for partial scenario 1.

For simulation "A" (Figure 80), the fuel types on the household energy ladder were matched against their corresponding cooking appliances. Other parameters of the scenario included gender, combustion efficiency, affordability, usage and maintenance, construction material and aesthetics. After the simulation, one could detect a varying trend in the behaviour of the variables. The results showed that as one switches use from wood fuel to gas (which is highest on the energy ladder), the design improves with increasing prices and efficiency.

For the first 5 to 7 years, an increase in combustion is caused by the improvement of the stove design and fuel use. This ascertains Kirk et al's idea that the higher one goes up the energy ladder, the cleaner and more efficient the stove becomes. Price now becomes a limiting factor because as one climbs up the energy ladder, making fuel more expensive.

After the 7th year, it is noticed that the gas cooker becomes very commonly used. During this period, fuel use and combustion become stable while prices increase. This could be attributed to increasing awareness and economic boom. Because gas fuel is expensive, many then returned to the use of kerosene and wood which are cheaper. However, the shift down the ladder from gas to kerosene is not drastic. Although kerosene is cheaper than gas, it is still quite expensive to the poor. The constant variables in this simulation are aesthetics, construction materials and usage and maintenance.

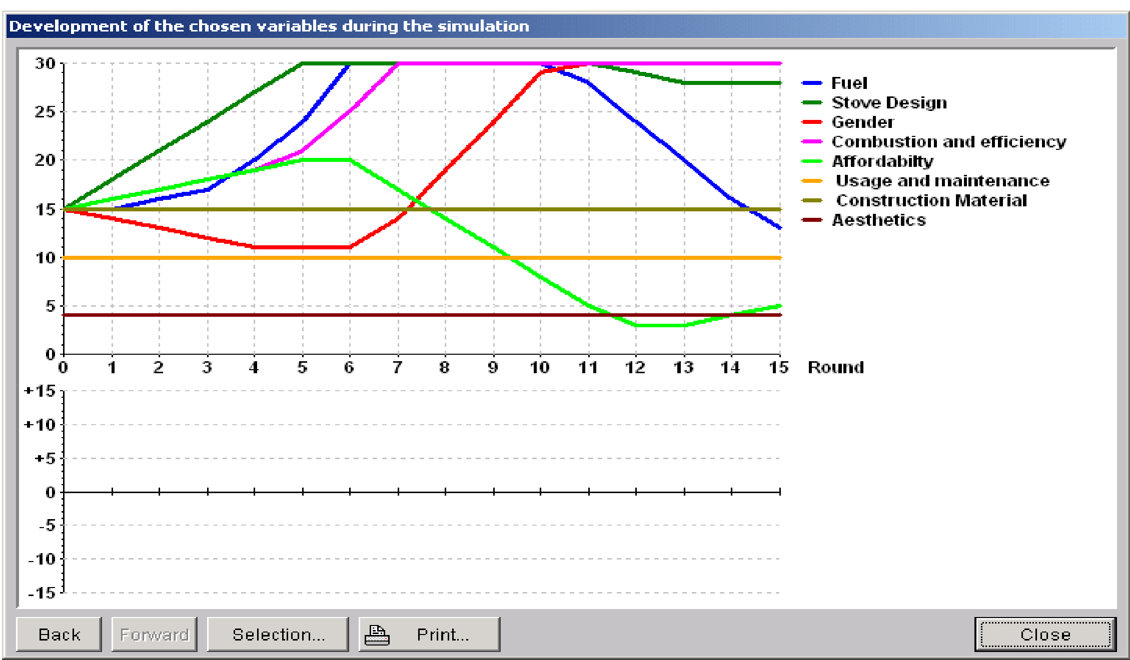

Figure 80: Graph of simulation "A" on Stove Design

For simulation “B” (Figure 81), moisture content was the determining factor of the fuel types while for stove design, construction patterns for wood burning stoves like the presence or absence of a combustion chamber, chimney, vent, “skirt” etc were the determining factors. Simulation A and B of Partial scenario 1 followed almost the same trend. Affordability and combustion efficiency play a major role in the way a stove is designed.

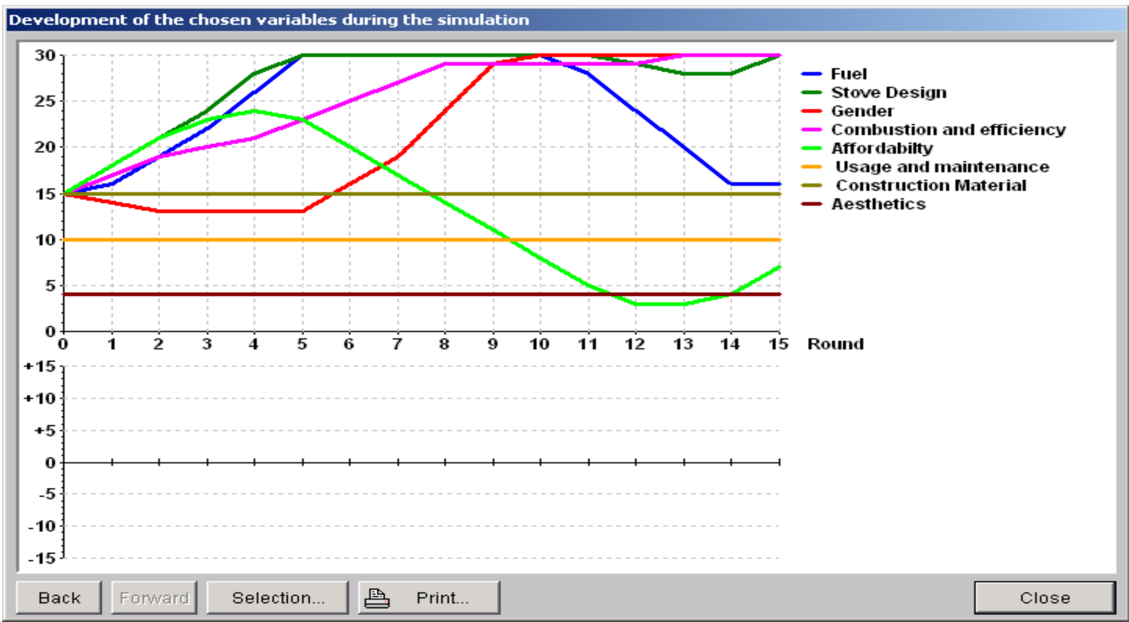

Figure 81: Graph of simulation “B” on Stove Design

After the simulation, the results showed an improvement in the stove design and a decrease in moisture content causing an improvement in the combustion efficiency with a slight increase in affordability. This happens for the first 6-8 years. To maintain an improved performance, price increases. Just like simulation “A”, construction material, aesthetics and usage and maintenance are constant variables.

7.2.9.2 Simulation Results of Partial Scenario 2 on Stove Performance

The simulated parameters include fuel, stoves, ash/soot, combustion and efficiency, health issues, PM and smoke reserve, exposure time and stove operator. After the simulation, an improvement in combustion and efficiency caused an improvement in health meanwhile PM concentration decreased from the fourth year and became constant for about 4 years (Figure 82). After this time combustion efficiency started dropping with increasing PM concentration thus impacting on health. Smoke and PM concentration is primarily caused by incomplete combustion which leads to the formation of soot. Stove design, fuel and stove operator were constant variables. However, fuel and stove design which are supposed to be influencing variables in the simulation, where constant. There was an impression that these variables were not influential during the simulation, however a conclusion cannot be drawn.

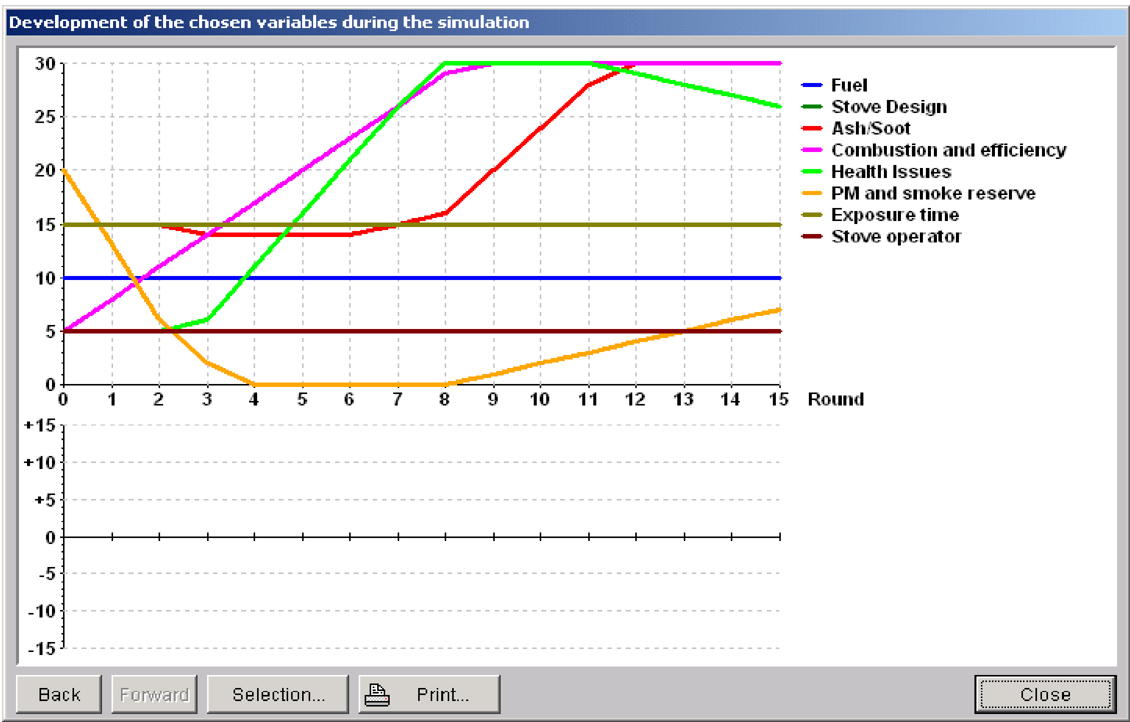

Figure 82: Graph of simulation on Combustion Efficiency

7.2.9.3 Simulation Results of Partial Scenario 3 on Health Situation

Like partial scenario 1 which was simulated twice using the varying types of fuel (according to the household energy ladder and moisture content) and moisture content (<5%, 5%-10%, 10%-20%, 20%-30%, >30%), the same parameters and approach were considered for this scenario.

For simulation "A" (Figure 83), using stove design, fuel, susceptibility to fall sick, and PM and smoke concentration, it was possible to simulate the health situation within the next 15 years. Health is greatly affected by PM concentration not only in the surrounding area but the amount inhaled by whoever is present in the cooking area matters also. People's immunity varies depending on certain factors like age, ability to fall sick , livelihood etc.

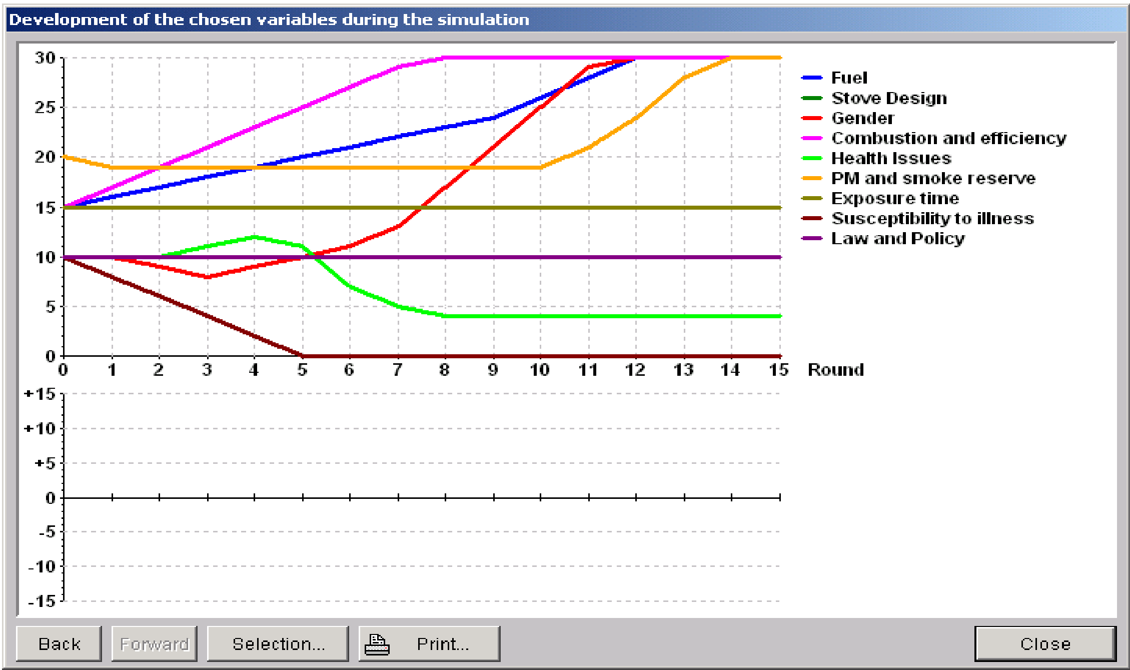

Figure 83: Graph of simulation "A" on Health Situation

Results showed that as we increase the household ladder (Figure 3), combustion efficiency is improved causing a decrease in PM and smoke reserve. However, health situation slightly increased at the beginning of the simulation probably because of the transient period from one stove type to the other. Health situation improved with a decrease in susceptibility to illness and later did not change after the 5th year (Figure 83). When combustion becomes constant PM becomes constant too. There was a progressive improvement of efficiency for the first seven years after which it became constant. Unlike expected, exposure time which is an important parameter and a determining factor of the level of impact of IAP on health played no role in the simulation. This could maybe be explained by the fact that the body can only take in so much and no more after a certain time frame. The other constant variable included law and policy.

For simulation "B", fuel type was determined by fuel moisture. Varying wood burning stove designs were used as well (Figure 84). An increase in combustion efficiency led to a decrease in PM levels however, in some peculiar cases, there was increased combustion with increasing PM. This was the case of very dry fuel which burns really fast but inefficiently. Questionable, is the fact that there was increased PM with little health damage. Maybe the stove operators did not spend long periods in the polluted areas or they have high resistance and immunity.

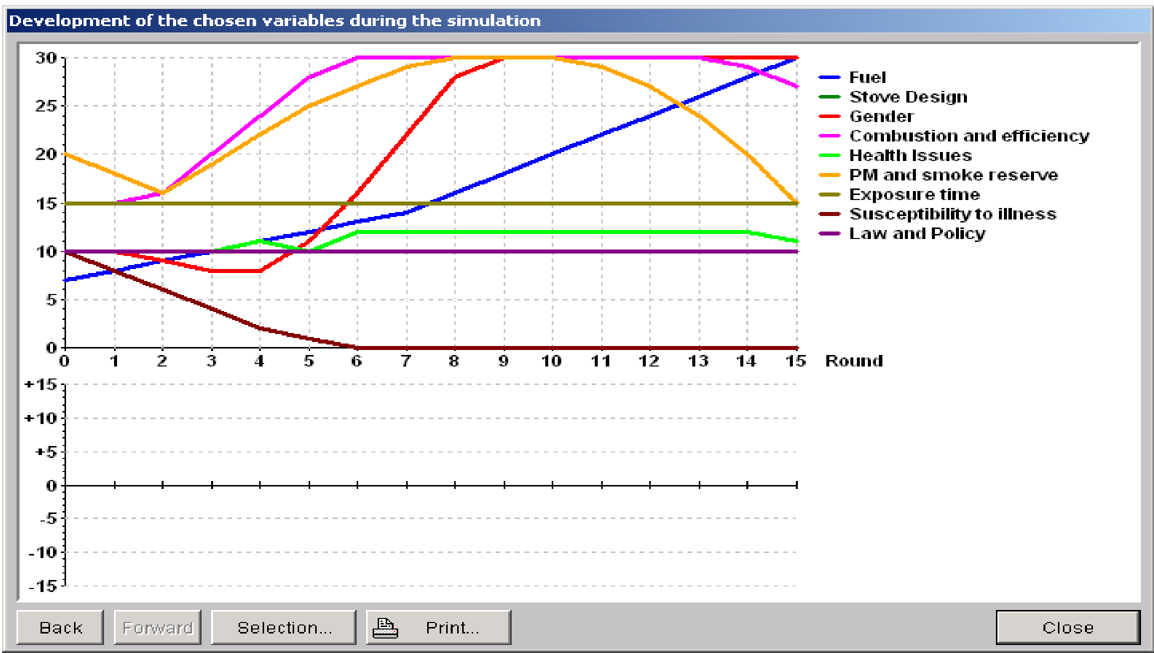

Figure 84: Graph of simulation "B" on Health Situation

7.2.9.4 Simulation Results of Partial Scenario 4 on the Economy

The principal factor in play here are fuel, the local community, economic impacts, environmental impacts and law and policy. Education and awareness was a constant variable during the simulation. An increase through the generic household ladder (Figure 3) will have an increasing impact on the economy and a decreasing impact on the environment for the initial years of the simulation (Figure 85). This is because as one gets up the ladder, fuel prices increase although the technology is more efficient and cleaner. People will suffer less from health repercussions, but the economic setbacks are enormous especially for the poor communities as they do not have the alternative of purchasing these expensive technologies. Therefore improving on the technology of wood burning stoves and putting them in the market at low prices will be favourable for the less privileged.

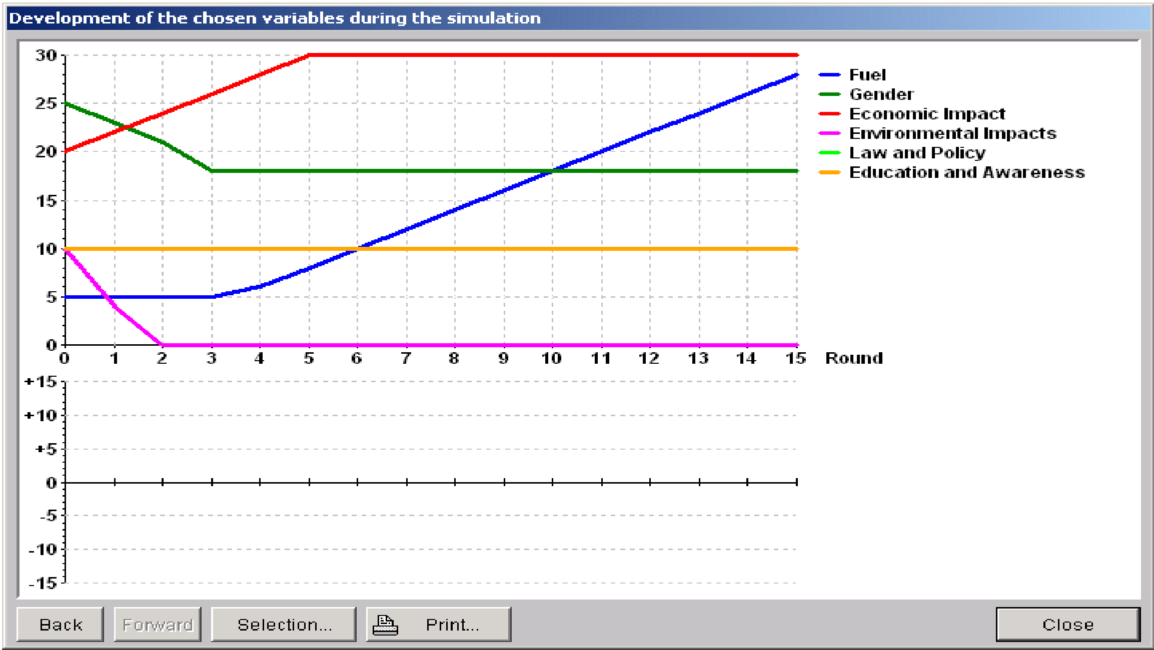

Figure 85: Graph of simulation on the Economic Issues

Chapter 8 CHALLENGES AND OPPORTUNITIES

8.1 Challenges

There can be no real social or economic development without secure energy services. In a publication by FAO in 2000, it is stated that "the energy challenge now faced by countries around the world is to provide energy services that allow all people to achieve a decent standard of living consistent with sustainable human development. This link between energy and development remains a key factor in development policy. It will be shaped by current trends of globalization, markets and popular participation in decision-making processes, the changing roles of government and energy utilities, and the mix of sources of national and external funding" (*Klingshirn, 2003*). Therefore, the real challenge is to reach economies of scale in order to make the technologies accessible to the majority of the poorer sectors of society. This leaves the government with the task of meeting up with the challenges at all levels be it environmental, economic or social.

The challenges emanating from cook stove use and indoor air pollution range from technical, resource management, human development to policy formulation. How we cook, what we cook and the stove we use in cooking is tightly coupled to our cultures, lifestyle and resources. People's lifestyles to a large degree, are determined by the type of affordable energy sources available. Lack of access to appropriate energy sources, undoubtedly, is one of the root causes of poverty.

8.1.1 Institutional Framework

Following decree n^{o} 2005/087 of 29th May 2005 the Ministry of Energy and Water was created in Cameroon. In the 80s, it used to be the Ministry of Mines and Power, and later became the Ministry of Mines and Power, Energy and Water and as from Dec. 2005 when the above mentioned decree was finally promulgated, it became The Ministry of Energy and Water. The Ministry of Energy and Water (MINEE) headed by a minister, is made up of 7 broad sections which are further sub-divided into sub sections and departments (Figure 86). The Renewable Energy department mostly concentrates on hydro, biomass and solar energy sources. The other Renewable Energy sources like wind and geothermal are, therefore, not well represented. This creates a big lapse as to the substantial management of energy issues in the country.

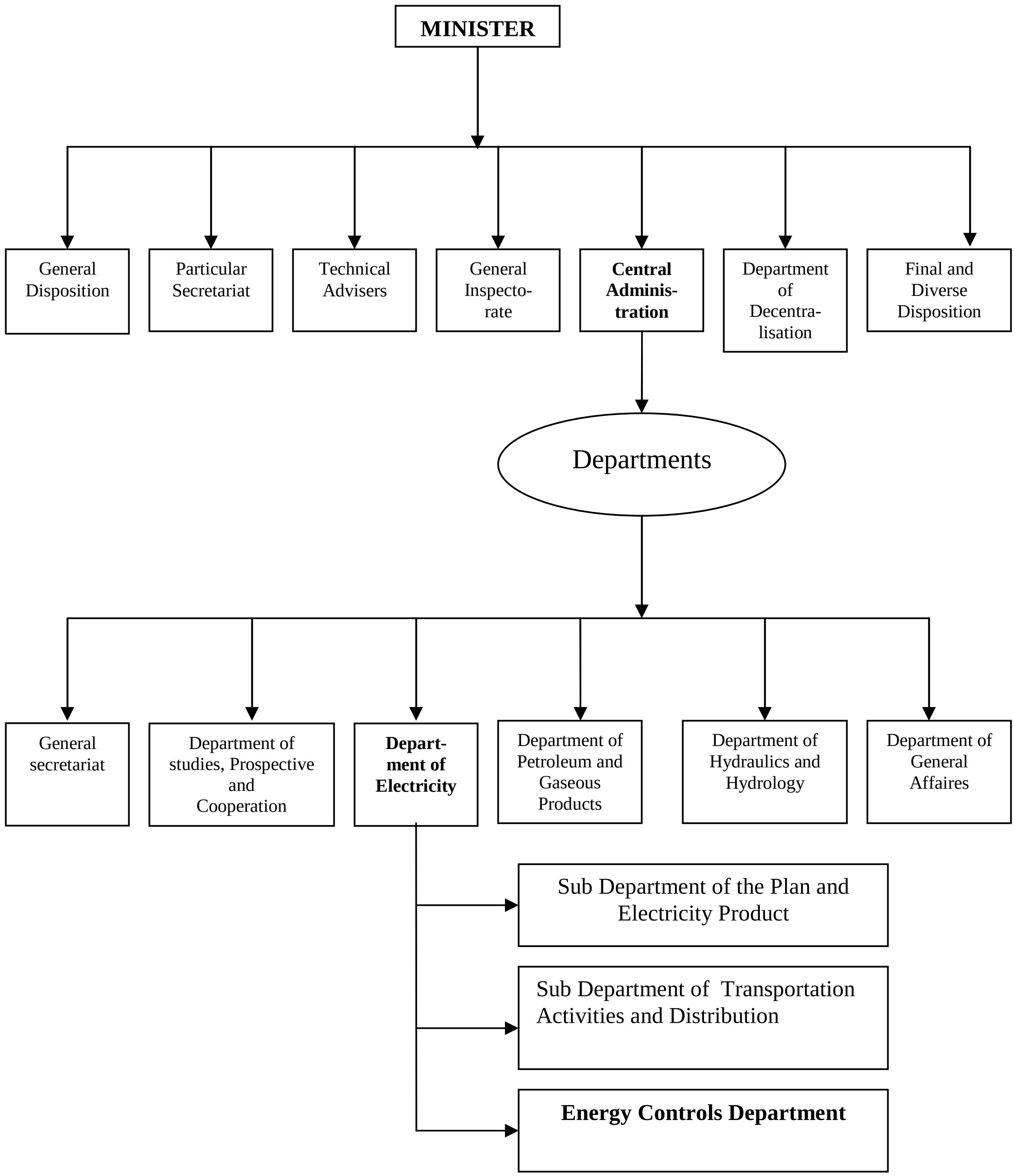

Figure 86: The Organisational Framework of the Ministry of Energy and Water in Cameroon

Cameroon had a well defined energy policy and National Energy Plan in 1990, which integrated all the energy sources. The present energy laws active since

1998 focus only on the development of hydro electricity. In 2005, the government launched a new Cameroon National Energy Action Plan (NEAP) which is in the trial process. The implementation of this plan began in 2006 and the programme will run for 10 years. The plan has many components including providing electricity to social and community establishments, mini hydropower, biomass development for off grid electricity access and new rural electrification programs based on achieved results. Though the production of electricity is an open market in the country, its distribution is not open. Because of exorbitant tax prices on equipment and inaccessibility to bank loans, private companies and organizations active in the field of smaller RE systems criticize the energy policies and system. Furthermore, foreign investors especially, encounter difficulties with the management and maintenance of their projects in some regions. This leads to a negative attitude towards RE (*GVEP, 2005*).

Cameroon mostly relies on fossil fuels and water for its energy (electricity). The country has a huge potential for hydro power (medium and large), the second in the whole of Africa. Biomass and especially the use of waste can also contribute to the energy need. Cameroon can reach a RE contribution level of 7.7% in 2020 (including all power capacities of hydro) and if traditional biomass is excluded from the total consumption the RE contribution will be 25% (*RECIPES, 2006*).

8.1.2 Economic Issues

Cameroon is richly endowed with natural resources and has a diversified commodity-based economy. The presence of petroleum and favourable agricultural conditions has earned Cameroon one of the best-endowed primary commodity economies in sub-Saharan Africa. Like other underdeveloped countries, it is plagued with serious problems like a bloated civil service and generally unfavourable conditions for business enterprises like high taxes, bribery and corruption. The government, in an effort to remedy these problems, in 1990 embarked on IMF and World Bank programs designed to spur business investment, increase efficiency in agriculture, improve trade and recapitalize the nation's banks. Meanwhile the government, in June 2000, completed an IMF-sponsored three year structural adjustment program. However, the IMF is still pressing for more reforms, including privatisation, increased budget transparency and poverty reduction programs.

According to the 2004 CIA World Factbook, the 2001 estimate of Cameroon's GDP (purchasing power parity) stood at $30.17 billion meanwhile the GDP-per capita was $1.900. The services sector accounted for 33% of the country's GDP. Industries accounted for 21% of GDP and agriculture contributed 46% to the country's GDP. In recent years, comparative studies with the 2007 CIA estimates show a decrease in GDP composition by sector. Agriculture contributes 44.3%, industries account for 15.9% and services 39.8% of the countries GDP. This is to explain the diminishing financial situation of the country contributing to low salary pay-offs and poor standards of living for many (*CIA, 2007*).

By 1972, Bamenda was one of the five major towns in the Anglophone part of Cameroon, including Victoria, Buea, Tiko and Kumba, which were electrified. The then POWERCAM which took over from the Electricity cooperation of Nigeria (E.C.N.) after independence (1960) was in charge of electricity distribution in Cameroon. Thereafter, came SONEL (Société National d'Electricité) which was privatised following the conclusion of the concession agreements in July 2001 to AES – SONEL. The AES – SONEL embarked on a five year program through which they concentrated on the rehabilitation of hydro-generation facilities, the erection and upgrading of transmission lines and high voltage stations and the upgrading and extension of distribution facilities. This led to a downward trend in energy distribution as it took AES-SONEL a while to get used to the system before fully meeting its set objectives. Although a few more villages today enjoy the pleasure of having electricity in the Northwest Province, the changing pace is still very slow. In fact, the privatization scheme has not yet yielded the desired effects of increasing power production and expanding energy grid.

8.1.2.1 Salary Scale

The government of Cameroon categorises its state functionaries in two groups namely civil servants and contract officers/state agents. While civil servants must have undergone some sort of formation in one or more of the many institutes of professional training on the one hand, contract officers or state agents, on the other hand, are those who are not trained professionals but who are qualified based on their academic achievements. Payment of functionaries is based on an individual's qualification or functions accorded to his/her post of duty. Salary payoffs are low and even government employees cannot afford the energy sources they might prefer (Appendix A III).

Judging from the above, functionaries of the lower categories, poor traders, farmers and the jobless would rather consider affordability rather than efficiency and sustainability of the technology and energy types used. This can be explained by the fact that their meagre salaries cannot cater for their basic needs. Worse still, the jobless and poor farmers who have no consistent source of income are most desperate. It is therefore a challenge for the government to improve the standard of living of her fellow citizens by creating more job opportunities, increasing salaries or by reducing the cost of fuel. She could equally encourage private investment in RE technologies by cutting down taxes and giving out loans.

8.1.2.2 Fluctuations in Fuel Prices

Energy prices that, of course, influence consumer choices and behaviour can affect economic development and growth. High energy prices can lead to skyrocketing import and transportation bills which eventually could have adverse effects on businesses, employment, and social welfare. The low income earners tend to spend more on fuel purchase and therefore are not able to cater for other important daily needs like school fees for their children, good medical care and better quality food. Furthermore, where fuel wood has to be bought, biomass-using families often spend a substantial amount of their total income on fuel not only in relative but in absolute terms. This is because poorer families can only buy in small amounts while richer families can afford to buy in bulk where a kilogram of wood, for example, may cost only a fraction of the retailed price. In the case of the North West Province (case study area), 1 cube of wood (1m long x 1m high x 1m wide) sold at 2000frs CFA (3 Euro) in 2003. Today, 1 cube of wood is sold at 3000 frs CFA (4,50 Euro). Who knows how it would be sold in the future? Kerosene which used to sell at 75frs CFA (app. 10cents) per litre in the 70s, rose to 120frs CFA (15cents) in the mid nineties, then to 250frs CFA (app. 40cents) in 2003 and today sells at 450frs (70 cents) (Figure 87). A bottle of gas (25Kg) which was sold at 4,500frs CFA (6,90 Euro) in the early 20s is today sold at 6,500 frs CFA (10 Euro). According to the 2001 estimate, the distribution of family income – Gini index of Cameroon stands at 44.6 (*CIA – World Fact Book, 2007*).

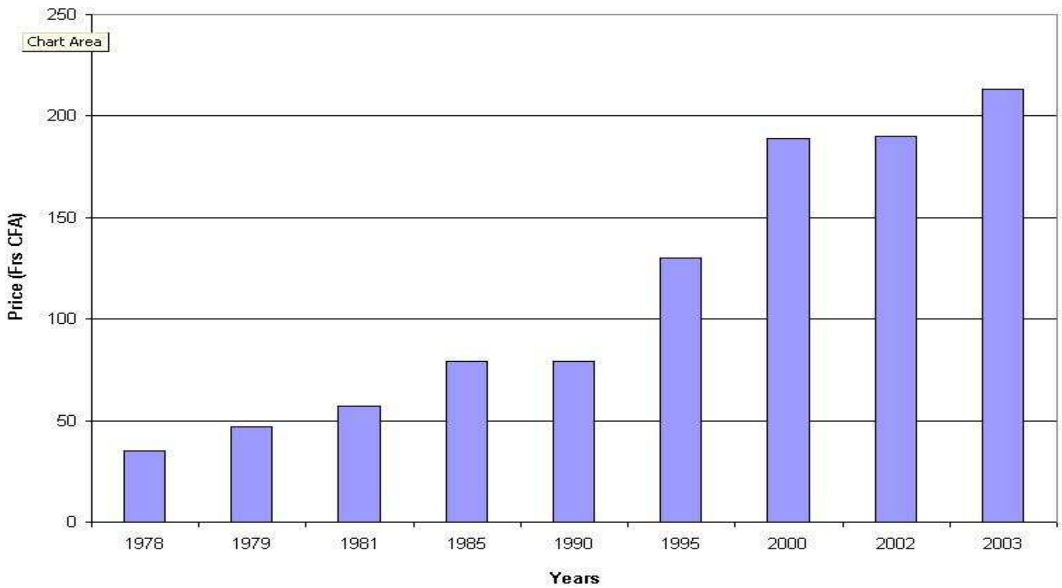

Figure 87: Evolution of Kerosene Prices from 1978 – 2003
Source: UNDP 2004

Although the prices of wood fuel, kerosene and gas are on a more or less regular increase, the pressure on wood fuel remains the same as it still is the most affordable and most used. The regular increase in prices could therefore stimulate the exploration and development of other resources, foster innovation, and encourage efficiency improvements. Interest could now turn to sustainable use of fuelwood and the promotion of solar cookers and biogas fuel for example so as to mitigate the situation.

8.1.3 Environmental Issues

Cameroon has a very rich forest potential. Contrarily, wood – energy is unevenly distributed such that the Sahel region experiencing advanced desertification and the extreme tropical humid zone of the south are suffering from a deficit of combustible fuel. Although in 1985, about 28,233 hectares were reforested, nearly 7 times as much is degraded on a yearly basis (*MINMEE, 2004*). The FAO estimate of gross deforestation, net deforestation (= gross deforestation – reforestation) and net degradation for the years 1990 – 2000 stood at -0.28%, -0.19% and -0.02% respectively (*Mayaux P. et al, 2006*). This shows the gap that exists between means of regeneration and maintenance of the forest potential in the future. By implication, the regeneration level has not kept up the degradation rate.

When biomass is burnt, carbon dioxide is released which contributes to global warming, meanwhile cut down trees are no longer available as carbon dioxide sink. Forests and woodlands do not only act as habitats for certain species but provide natural protection systems for the earth. They also take over important functions with regards to the water reservoir, soil protection from erosion, climate regulation, temperature balance, air filtration and regional distribution of humidity at the macro and microclimate levels. Therefore high deforestation levels enormously contribute to the loss of biodiversity and climate change.

8.1.4 Socio-cultural, Gender Issues and Health Risks

Deduced from the questionnaire analysis and personal discussions, there are certain customary barriers which hinder the use of cook stoves. These include;

- The use of smoke for preservation (drying). It is thought that smoked food tastes better.
- The use of smoke as a mosquito repellent since the kitchen, in many rural communities, doubles as a sleeping room.
- The use of the three stone fire for heating and lighting.

In a typical Cameroonian home in rural communities, it is strongly believed “that a woman’s place is in the kitchen”. This has so much affected the reasoning of some “African men” such that concerns of the kitchen and every thing that goes with it is considered a woman’s thing. In the Bamenda town for example, where about 84% of the people living there buy fuel, the burden is less. But in the case of a village like Bambili where over 50% collect fuel, these women who provide fuel and sometimes spend more time trekking long distances and carrying heavy loads maybe affected healthwise. When the burden becomes too heavy, they are helped by their children who sometimes stay away from school. It is therefore a challenge to the government to strengthen women's role of innovative and organisational capacities by involving them in planning and management of household energy programs.

Another serious impact associated with biomass use is its health repercussions. Incomplete combustion of biomass fuel is responsible for the release of a number of health-damaging pollutants. Indoor air pollution, though not an issue of concern to the government of Cameroon, causes a series of illnesses such as asthma, bronchitis, pneumonia, lung cancer, catarrh, tuberculosis, cataract, cardiovascular disease, adverse pregnancy outcomes which mostly affect women and children. The government therefore needs to enhance studies on IAP related issues and promote more efficient and ergonomic technologies like improved stoves.

8.1.5 Intervention of International NGOs and World Leaders

Our world today can be referred to as a "Global Village". In order for certain wrongs to be corrected in the Cameroonian energy system, the influence of the industrial world is necessary. Many lives could be saved. The standard of living of the poor and destitute could be upgraded by just providing a household with an improved cook stove for example. This is where leading organisations and countries could intervene to fight against IAP (Indoor air pollution) and deforestation which are plaguing the developing world. Although the government of Cameroon and other developing countries have a major role to play in the mitigation process, the challenge still remains in the hands of NGOs and research personnel. Very little has been done so far in Cameroon concerning household stoves and indoor air pollution. A greater majority of the population are indifferent to the effects this has on their health and the society.

8.1.6 Stove Design and Performance

Table 5: Getting rid of smoke and soot

Changing the source of pollution	**Improving the living environment**	**Modifying user behaviour**
Improved cooking devices - Improved stoves with biomass fuel	**Improved ventilation** - Smoke hoods - Eaves space - Windows	**Reduce exposure by changing cooking practices** - Fuel drying - Pot lids to conserve heat - Food preparation to reduce cooking time (e.g. soaking beans) - Good maintenance of stoves, chimneys and other appliances
Alternative fuel-cooker combinations - Briquettes and pellets - Kerosene - Liquefied petroleum gas - Biogas - Natural gas, producer gas - Solar cookers - Modern biofuels (e.g. ethanol, plant oils **Reduced need for fire** - Retained heat cooker (hay box) - Efficient housing design and construction - Solar water heating - Pressure cooker	**Kitchen design and placement of the stove** - Kitchen separate from house reduces exposure of family (especially for men, as children stay with their mothers) - Stove at waist height reduces direct exposure of cook leaning over fire	**Reduced exposure by avoiding smoke** **-** Keeping children away from smoke (e.g. in another room if available and safe to do so)

WHO (2006) Fuel for Life: House Energy and Health

The principal challenge of improved cook stoves is to achieve high stove performance. A 100% performance is almost impossible; however improved wood burning stoves probably save between 30% - 50% of the fuel used to cook compared to the three stone fire (*Still et al., 2007*). Better combustion and ventilation reduce levels particulate matter and carbonmonoxide in the kitchen by at least 30% (*GTZ, 2004*). Besides, fuel moisture (discussed in chapter 6) which greatly affects combustion efficiency, other variables like stove design, air inflow and fire tender will affect stove efficiency. Stove efficiency is ascertained by the combustion and heat transfer efficiency which could be measured either in the laboratory or in the field using the WBT, the Kitchen Cooking Test (KCT) or the Controlled Cooking Test (CCT). As already stated in chapter 6, the laboratory based water boiling test cannot be solely used to predict what happens in the real world, however, it lays the basis for comparison with other stove performances. The six commonly used factors to measure stove performance include efficiency, fuel consumption, turn-down-ratio, speed of cooking, user satisfaction and emissions. The principal goal is to produce efficient stoves which get rid of smoke and soot and are appealing to the consumer. More often than not in Cameroon, stove aesthetic is preferred to stove efficiency by the cooks, so the manufacturers tend to produce what is bought. Therefore expert knowledge needs to be employed and much done to raise the level of awareness of the people. Table 5 above suggests how getting rid of smoke and soot in a kitchen can be achieved.

8.2 Opportunities

8.2.1 Improved Cook Stoves

Stoves occupy a vital place in health, environment, economy and social lives of families in developing countries. Therefore, improved cookstoves can provide a number of remunerations, for example: they can reduce indoor and out door air pollution by providing more complete combustion, can boost household economies and empower women by reducing the time, dangers, labour and expense involved in obtaining and preparing fuel, leaving more time for childcare or economic activities. Reducing fuel consumption also improves soil fertility and reduces deforestation, soil erosion and desertification. The community and the economy benefit from jobs associated with stove construction and repairs.

Improved stoves have been a major concern of appropriate technology for decades and hundreds of designs have been produced, adapted and field tested across both the developed and developing world. Several compendia have been made available to facilitate introduction into new areas although much still needs to be done to maximize efficiency and use (*De Lepeleire et al., 1981*). Such documents could be consulted by the Cameroonian government and interested persons to facilitate technology transfer or dissemination programs. Consulting leading organisations and research personnel will help in making the right stoves to suit consumer interest. But even more important is knowing the needs and preferences of the people before such stoves are produced and disseminated.

8.2.2 Suggested Fuel Alternatives

Other renewable energy sources like water, wind, geothermal and ocean energy, while of considerable importance for some areas in some countries, will not be available for substitution for fossil fuel on a large scale because of investment cost. An exception to this is biofuel and solar energy in the form of photovoltaic for lighting purposes and in the form of solar thermal for cooking, baking and crop drying (*Klingshirn, 2004*).

8.2.2.1 Biofuels

Biofuels like alcohols and biogas have been an essential source of energy for decades. In future global energy needs, (including for use in domestic cook stoves), biofuels are expected to play a greater role partly because they have two advantages over other renewable sources. Firstly, unlike solar, wind and small hydro sources, energy is stored and can be drawn at any time. Secondly, biofuels are more versatile and can meet all forms of energy needs like gas and liquid which the others cannot. Furthermore, they can be prepared to produce less domestic IAP than many traditional fuels.

A review of the preliminary calculations of biofuels prospects and potential suggest that in Africa and Latin America alone, the availability of bio energy resources is equal to more than 890million tons of oil equivalent (*Leach G and Johnson F X, 1999*). Two primary biofuel resources were considered in these calculations; energy crops such as trees, grasses or tubers of plants specifically for fuel production and biomass wastes and residues including animal wastes, urban organic wastes and agricultural and forest residues.

Biogas is another unexploited potential household energy source that could substitute fuel wood, but because of the high cost involved (approximately $500 for a family biogas plant), it becomes unaffordable for many small scale farmers (*Klingshirn, 2004*). Biogas has already shown great utility as a clean, renewable cooking gas. It is now used in some institutions (St. Rita's college Nkambe and Government Teacher's Training College Tatum) in the country and the results are promising. It can also serve for lighting, heating, welding, crop drying and electricity production needs.

There is no doubt that biomass stove programs together with sustainable agro-forestry practices and integrated farming have the potential to improve both the energy and food sectors in the country. It can create new opportunities for decentralised commercial activities in the energy/agricultural sector and can help develop rural areas. Biofuels hold meticulous promises for developing countries by providing rural jobs, increasing the profitability of agriculture and restoring degraded land.

8.2.2.2 Solar Cookers and Ovens

Apart from biomass and biogas energy sources, solar energy probably has the highest potential for making a significant impact as far as energy for cooking, baking and food processing is concerned. The potential of solar energy in Cameroon is very high. The trend towards alternative energy use in Cameroon is gaining momentum amidst difficulties with giving all homes access to the national electricity grid.

Solar cookers are convenient for basically all domains; household use, home based food processing businesses, restaurants and institutions, however, the sophisticated ones like the parabolic cookers, have proved to be too expensive. Furthermore, setting up independent local production centres is proving difficult because in most cases, parts still have to be imported from Europe. Besides, such solar cookers are largely limited to days when sun is shining therefore the raining season poses a major problem in their use. Nevertheless, simple and inexpensive but less efficient solar cooker and box cooker could be encouraged.

The box cookers are simple to build often using locally available material which reduces procurement costs and makes it easier to produce in developing countries. They do not have to be realigned with the position of the sun very often making them easier to use in everyday life. The limitation in box cookers is that they do not achieve the peak performance values of other solar cookers like the parabolic cookers, however, they better compensate for fluctuations in solar irradiance. The highest temperature attained by box cookers is 180^{o}C as opposed to 250^{o}C by the parabolic cooker (*GTZ, 2007*).

As previously mentioned, solar energy is not without its own cost; however, it can fill a useful cooking niche. Although it is generally agreed that solar cookers are not a stand-alone product, there is no doubt that a blend with other fuel efficient technologies, can make a significant contribution to a threatened energy security of households and small businesses alike.

CHAPTER 9 ACCOMPLISHMENTS AND RECOMMENDATIONS

9.1 Accomplishments and Results

The main driving force behind cooking programs to date has been health issues and forest conservation. To this effect therefore, the following research findings focus on issues that have direct bearings on health improvement and conservation efforts especially in under privileged communities in ACP countries. This research has accomplished the following findings:

- The slow pace of development in many ACP (African Caribbean and Pacific) countries indicates that dangerous, smoky cook stoves will remain in widespread use for decades to come, unless governments, the private sector and civil societies take the millennium goals seriously. The UN Millennium Development Goals seeks to eradicate poverty, promote primary education and gender equality, improve health care, ensure environment sustainability and develop a global partnership for sustainable development (*Seifert D., 2006*). Together with the Clean Development Mechanism of the Kyoto Protocol, there exist immense chances for the MDGs to be achieved. According to Sanchez T. 2007, there are some serious doubts about the equity of benefits of the CDM. While large economies like China, India and Brazil have been taking great advantage of CDM, small countries with poor economies have got little or no access to the benefits of this mechanism. The main difficulties for small and poor economies are caused by lack of technical and institutional capacity and high transaction costs. Conclusively, the CDM has not reached poor communities, or the poorest countries. This research therefore, provides a robust and baseline status quo information on the involvement of international organisations in enhancing clean cooking fuel in poor communities. It also provides success stories and encountered challenges by projects in developing countries.

- Technical advances in energy efficiency are crucial for a developing nation like Cameroon, since a majority of the country's population depends primarily on biomass fuels such as wood, charcoal, and agricultural residues. Although some metal stoves have existed in the country for some decades now, the whole issue of improved cook stoves is at its novice state. There is an increasing interest by research personnel and some NGOs on cook stoves and projects are coming up. Unfortunately, many improved stoves projects have not reached their maximum potential because they focus on either fuel efficiency or on reducing smoke, but often not both. Although there are stove projects and stove performance testing in ACP countries, very little is known and done in this domain in Cameroon. This research provides feasibility knowledge and first hand research findings on cooking techniques in the study area.

- Even though, presently, there are no internationally agreed emission benchmarks and standards based on the various performance test (WBT, KPT, CCT), those of some leading organisations like FAO, Shell Foundation and Aprovecho are commonly used. There is urgent need for an agreed standard so as to avoid conflicting results based on several benchmarks.

- Fuel moisture is an important parameter to be considered when evaluating cook stove performance; reason for the laboratory based work at Aprovecho. How wet or dry fuel is will greatly influence combustion. Some amount of moisture seems to be needed in fuel in order to minimize emissions, while too much moisture can result in longer cooking time, greater fuel use and higher emissions. For example fuel moisture of 5% and below produced high concentrations of PM and CO with high fuel consumption rates. However, this study does not define the limits of these effects. On the other hand, high fuel moisture of 30% and above produced high levels of PM and CO with low fuel consumption rates and more charcoal production. Fuel moisture of 10-15% produced high efficiency with little or no PM and CO emission. However, stove design also plays a role in determining the behavior of the fuel when burnt whether it is dry or wet. Stoves with certain types of combustion chambers seem to burn wood more effectively at varying moisture contents. The rocket stove was more efficient in emission factors and fuel consumption than the "skirt" stove and open fire, and it was the least susceptible to increased moisture content. Overall, the type of stove exhibited a stronger effect on the overall emissions than did the moisture level in the fuel.

- The sensitivity model is a good tool for understanding the behaviour and controlling of systems. The simulation analysis helps in mitigating unforeseen problems that one may incur during stove dissemination programs. Stove promoters and interested persons should be encouraged to use such tools for comprehending the interaction of important variables within the cooking environment. This simulation tool could even be used for laying down modes or IAP governing policies as long as the interactive patterns of variables and their corresponding impacts on each other are well understood. This tool could also be used to develop appropriate marketing strategies and educate stove promoters, stove manufacturers and consumers through workshops and seminars. This way, both the government and the local communities shall benefit from the emerging results. Chapter 7 clearly describes how this tool works.

- Although much more remains to be learned about IAP (Indoor Air Pollution) and ICS (Improved Cook Stoves), we know enough about their impacts on the environment, economy and health to concentrate our efforts in this area. Summarily, this research has identified three main areas of intervention which include technology improvement, healthy environment and behavioural changes of those concerned (Appendix A II).

9.2 Recommendations

After a careful review on cook stoves and based on the findings of this research work, the following recommendations are suggested to the Cameroonian government, stove experts and interested persons:

- **Establishment of a good organizational framework and robust energy policy and strategy**

The Cameroon Ministry of Energy and Water (MINEE) needs to undergo a well planned energy policy and structural reformation and a decentralisation process. The National Energy Plan of 2005 should be well monitored and implemented. This will ensure the apt functioning of the agreed policies. As for the structural reformation and decentralisation process, the department of renewable energy should include all renewable energy sources with well defined functions. The authorization for the execution of any cook stove projects for example, must not only come from the Ministry of Energy and Water in Yaounde (capital city of Cameroon). The Ministry at the provincial level should be allowed to take such decisions. This will not only reduce travelling costs and time, it will also lessen long periods of wait for approval, thereby encouraging many to get involved in cook stove programs. Besides, a well structured energy policy with low tax rates on equipment will encourage private and even national investors to execute improved stove projects.

Cameroon is a rich country endowed with diverse natural resources which if well utilized could earn her a lot of income. Egoism, bribery and corruption have taken the better part of many. That not withstanding, the Cameroonian government can still better the lives of her citizens by expanding the industrial sector to create more jobs for the poor and jobless (who are the main targets) and improving the salary scale of civil servants. With a more or less comfortable allowance and source of subsistence, many will be able to provide their desired cooking appliances. The now increasing pressure on biomass fuel will greatly reduce thus minimising the level of deforestation.

The system of production, transportation and distribution of wood and charcoal in Cameroon is informal. This sector is therefore not well controlled. Unfortunately, deforestation in some cases, has led to advanced stages of desertification. This could be attributed to negligence or the lack of knowledge to form a well organised system and the insufficiencies in parameters necessary to put such a study in place. Firstly, the people need to be educated on the dangers and shortcomings of indiscriminate felling of trees. This could be through organised seminars, workshops, media amongst others. Secondly, the government through its ministry of Environment and Forestry needs to hire well trained and devoted staff that would strongly and successfully execute felling laws and agreed policies.

- **Training and capacity building**

Training in technical and business skills, stoves promotion and quality control is very important, while at the same time, the demand of ICS is boosted by awareness creation through information campaigns and mainstreaming into the public sector. These could take the form of trade fairs, use of different media, theatre tours, market demonstrations and advertising but these all have to be developed with regard to the socio-cultural background of the targeted communities. Pilot tests or focus groups are good methods to choose the most effective promotional tools. Stove experts could be hired to organise workshops and seminars so as to educate the people especially women on how to improve their cooking and managerial habits. TV adverts or series could also be used but require a careful analysis of the mass media in use by the target population.

To develop an appropriate marketing strategy, stove producers should be trained in marketing and business skills as they need to understand the requirement for simple promotion activities to attract new customers. Moreover, it helps to be aware of the customers' opportunities, abilities and motivations to buy an improved stove.

- **Raising awareness**

Raising awareness among people especially women by information and marketing campaigns is imperative. Education and knowledge within communities and awareness about general resource availability, sustainable fuel use and improved stoves is important. There should be involvement and support of traditional leadership and Village Development Committees so as to enhance the acceptance of these new technologies.

- **Promotion of the use of efficient techniques and marketing strategies**

Large scale and small scale projects disseminating improved stoves and kitchen practices should be encouraged by the government. Such projects could be subsidized or credit facilities made available with low interest rates and long periods of payment.

For technology improvement, certain key aspects are to be considered aimed at improving cooking/heating devices and fuels. These include: better stove design, better ventilation to reduce IAP particulate levels in houses, switch to cleaner (but typically more costly) fuels, reduce size of fuel pieces and better stove insulation. For the optimisation of cook stove technology, this thesis recommends the ten design principles for wood burning stoves by Larry Winiarski of Aprovecho Research Center (See Appendix A I). This is because these principles have been field tested and proven to work out well. They are today used by stovers and renowned organisations like USAID (United States Agency for International Development), Shell foundation, Aprovecho and others for their stove dissemination programs.

The government could, through financial support for workshops and subsidies encourage NGO's, institutions, communities and interested individuals to carry out stove performance tests before dissemination and marketing any new stove. This will assure the quality of the stove people are using and ensure good health for many. Stove promoters and designers should also be encouraged to have their stoves tested before putting them in the markets or promoting them so as to improve stove quality. To differentiate these stoves from other stoves on the market, a control system should be put in place. This control system in cooperation with a scientific institution shall ensure a defined quality standard and could make the difference visible by way of labelling. Only after quality control audits should certified producers get labels for their stoves, creating a unique brand identity for stove promotion. The Cameroonian government, in her structural reform program, could create a department or a scientific Institution incharge of standardization, control and improved stove audits.

Also, with the presence of several tests like the laboratory based Water Boiling Test, Kitchen Performance Test (KPT) and the Controlled Cooking Test (CCT), stove developers and dissemination programs could design and test their stoves such that high quality stoves with high levels of acceptance are promoted.

In order to create a sustainable market for improved stoves in Cameroon, the 4Ps marketing strategy is suggested (*Feldmann L., 2007*). This is a solid marketing strategy which is used by GTZ in its projects and has proved to work out successfully. These include identification and development of new **P**roducts, suitable **P**rice development, distribution channels and **P**laces and **P**romotion. The underlying marketing principle means getting the right stoves to the target users, in the right quantity, quality and price. This also means that each business person in the market chain makes a fair profit.

- **Improved kitchen management**

For a healthy living environment, the room should be partitioned such that the cooking area is separated from the sleeping/living areas. Better ventilation or ducts, chimneys or hoods should be installed to carry smoke and particulates outside the house.

Lastly, for behavioural changes aimed at reducing exposure and/or reduce smoke generation by changing cooking practices, time spent in kitchen/cooking area should be reduced, lids should be kept on pots while cooking, there should be proper stove maintenance and cleaning, fuel should be pushed deeper into stove so that less smoke “escapes” into the room and children should be kept away from smoke so as to reduce the risks of any accidents occurring. The use of mosquito nets is equally recommended since some people use smoke to keep away mosquitoes. This way, smoke will no longer be a necessity.

- **Knowledge management and networking with other partners and projects**

Cameroon, like many other developing countries should involve more in international activities for a better implementation of Renewable Energy Technologies. Being a member of leading organisations and a signatory to several treaties can help the country to meet up with set standards. Besides, this will increase the country's exposure to foreign aid through subsidies or project execution.

The GTZ and Practical Action have many stove dissemination projects in the East and Southern parts of Africa. These projects have, no doubt, reduced the levels of deforestation and Indoor air pollution in these areas. Meanwhile Shell Foundation and Aprovecho Research Centre are also engaged in IAP and improved cook stove dissemination programs in Asia (India, Nepal…) and South America. If the responsible government department could approach such organisations – for instance during governmental consultations and negotiate for assistance in this area, it will be awesome. This would show that the government of Cameroon has understood the importance of such activities and is willing to make an effort to improve the situation of its people.

- **Further development of alternative renewable energy sources**

Other improved stoves like gasifier stoves and solar stoves could be encouraged as well. Though a little more expensive to produce, they could, in the long run, save more money and equally be very efficient if appropriately designed. The Hay box which is a cheap heat retainer box that can be used in addition to a stove could also be encouraged.

Conclusively, this thesis through the aforementioned submissions hopes to reach out to the many who are yearning to learn about improved cook stoves. It lays the foundation for a good start on stove design and performance testing but much remains undone. For the fact that technology keeps advancing, hundreds of stoves are being produced on a daily basis and testing needs to be done regularly. There is need for further research in this area with proper implementation efforts. Furthermore, a generally agreed international stove emission standard should be put in place so as to minimize the already existing conflicts in stove monitoring results. This way, research is made easier and technology integration becomes less of a problem.

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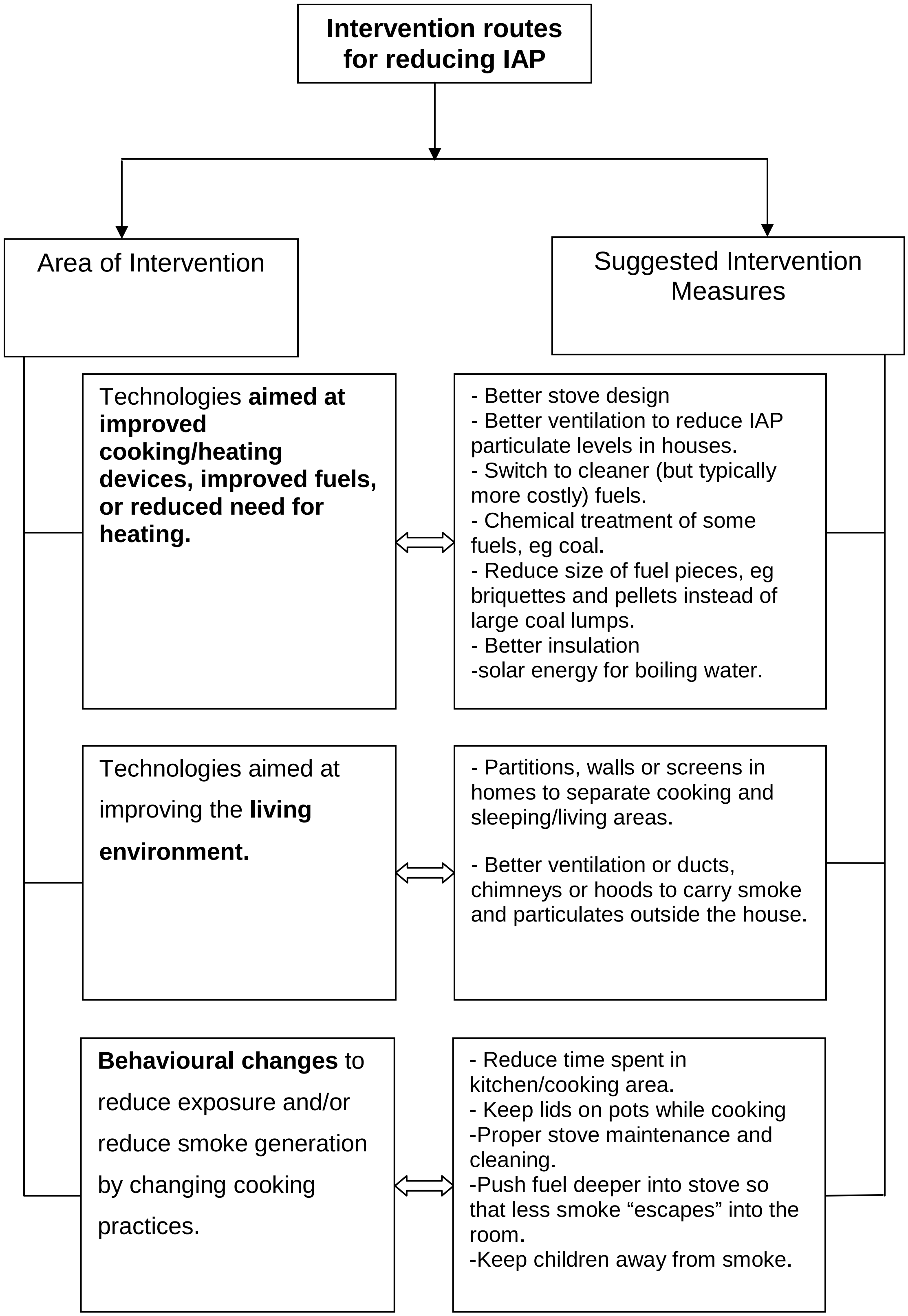
APPENDIX A

I Ten Design Principles for Wood Burning Stoves

1. The fire area should be Insulated using light weighted, heat resistant materials.
2. An insulated short chimney should be placed right above the fire to burn up the smoke and speed up the draft.
3. The tips of the sticks should be heated and burned as they enter the fire to make flame, not smoke.
4. High and low heat is created by how many sticks are pushed into the fire.
5. A good fast draft should be maintained from under the fire up through the coals. Avoid allowing too much extra air in above the fire to cool it.
6. Too little draft being pulled into the fire will result in smoke and excess charcoal.
7. Keep unrestricted air flow by maintaining constant cross sectional area through the stove. The opening into the fire, the size of the spaces within the stove through which hot air flows and the chimney should all be about the same size.
8. A grate should be used under the fire.
9. The heat flow path should be insulated from the fire, to and around the pot(s) or griddle.
10. Properly sized gaps should be used to ensure maximum heat transfer to the pot.

II Intervention Routes for Reducing IAP



III Salary Scale of Civil Servants in Cameroon

BAREME

NOUVEAU BAREME DU TRAITEMENT
INDICIAIRE DES FONCTIONAIRES
CIVILS EN ACTIVITE
(Pour compter du 1er Juillet 2000)
Décret 2000/209 et 2000/212 du 27/07/2000

DE 1 à 300 = 378 F
De 301 à 1140 = 155F

Indice 1	Solde de base 2	Complément forfaitaire 3	Logement 10% 4	Total 5	Indice 1	2	3	4	5
CATEGORIE D					CATEGORIE B2				
100	37800	2000	3780	43580	290	109620	2000	10962	122582
105	39690	2000	3969	45659	335	118825	900	11882.5	131607.5
110	41580	2000	4158	47738	375	125025	900	10502.5	138427.5
115	43470	2000	4347	49817	420	132000	900	13200	146100
120	45360	2000	4536	51896	445	135875	900	13587.5	150362.5
140	52920	2000	5292	60212	485	142075	900	14207.5	157182.5
150	56700	2000	5670	64370	540	150600	550	15060	166210
165	62370	2000	6237	70607	560	153700	550	15370	169620
185	69930	2000	6993	78925	575	156025	550	15602.5	172177.5
200	75600	2000	7560	85160	610	161450	550	16145	178145
205	77490	2000	7749	87239	650	167650	550	16765	184965
210	79380	2000	7938	89318	685	173075	550	173075	190932.5
CATHEGORIE C					CATHEGORIE A1				
180	68040	2000	6807	76844	375	125025	900	12502.5	132487.5
185	69930	2000	6993	78923	430	13355	900	13355	147805
200	75600	2000	7560	85160	480	141300	900	14130	156330
210	79380	2000	7938	89318	530	149050	550	14905	164505
225	85050	2000	8505	95555	580	156890	550	15680	173030
235	88830	2000	8883	99713	630	164550	550	16455	181555
250	94500	2000	9450	105950	680	172300	550	17230	190080
270	102060	2000	10206	114266	740	181600	550	18160	200510
280	105840	2000	10584	118424	785	188575	550	18857.5	207982.5
295	111510	2000	11151	124661	835	196325	550	19632.5	216507.5
310	114950	2000	11495	128445	900	206400	550	20640	227590
330	118050	900	11805	130755	945	213375	550	21337.5	235262.5
CATEGORIES B1					CATEGORIES A2				
270	102060	2000	10206	114266	430	1333550	900	13355	147805
300	113400	2000	11350	126740	465	138975	900	13927.2	153802.5
335	118325	900	11882.5	131607.5	530	149050	550	14905	164505
370	124250	900	12425	137575	605	160675	550	16067.5	177292.5
405	129675	900	12967.5	143542.5	665	169975	550	16997.5	187522.5
445	135875	900	13587.5	150362.5	715	177725	550	17772.5	196047.5
480	141300	900	14130	156330	785	188575	550	18857.5	207982.5
495	143625	900	14362.5	158887.5	870	201750	550	20175	222475
505	145175	550	14517.5	160242.5	940	212600	550	21260	234410
530	149050	550	14905	164505	1005	222675	550	22267.5	245492.5
560	153700	550	15370	169620	1050	229650	550	22965	253165
575	156025	550	15602.5	172117.5	1115	239725	550	23972.5	264247.5
					1140	243600	550	24360	268510

IV Field Questionnaire

Socio-eco-environmental Impacts of Cooking Stoves adapted for Biomass Use in Cameroon: Improving Indoor Air Pollution in Rural Communities.

Case Study areas: - Bamenda Town and Bambili Village, Cameroon

Dear Respondents,

I am Tangang Ernestine A Yuntenwi, a PhD research student on the above mentioned topic at the Brandenburg University of Technology Cottbus, Germany. This research study seeks to investigate the-state-of-the-art cooking stove techniques, the level of awareness and hazards caused to the population while meeting up with its targeted objectives such that plausible recommendations are made that will go a long way to benefit the entire community.

To be able to come up with a qualitative and quantitative research work, I decided to narrow my study area, choosing Bamenda town and Bambili village as case studies because of easy accessibility and availability of Data. I kindly solicit your cooperation while assuring you that all furnished information will be treated with utmost confidentiality and strictly for academic purpose as the outcome of study will benefit everyone.

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Section A DEMOGRAPHIC DATA

Please fill in the blank spaces and tick one of the boxes whose information applies to you.

Community Area of residence ______________________________

Sex

Female ☐ Male ☐

Number of Household members ☐

Duration of Education (Years)

……………………………………………………………………………………

Occupation / profession
Civil Servant ☐ Business ☐ Farmer ☐ Housewife ☐
Others, specify ____________________

Section B AWARENESS/KNOWLEDGE ASSESSMENT

This section aims at investigating respondent's knowledge on Indoor Air Pollution and its associated impacts or consequences. It seeks to know the level of awareness on this subject matter.

1. What do you understand by Indoor Air Pollution?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………………………………………

2. **What are your knowledge sources of Indoor Air Pollution?**

Community based campaigns ☐ Internet ☐ Books ☐
Television ☐ Seminars ☐ Others, specify ________________

3. **Are you aware that the inhalation of smoke is detrimental to your health?**

Yes ☐ No ☐ I don't know ☐

4 **Do you think improving on the technology of cooking stoves will help reduce Indoor Air Pollution?**

Yes ☐ No ☐ I don't know ☐

5 **Would you readily welcome any innovations in the Technology of cooking stoves for use in your household if it reduces the amount of smoke emitted?**

Yes ☐ No ☐ I don't know ☐

Section C COOKING STOVE TECHNOLOGY

This section deals with respondents preferences with regards to stove technologies and fuel. There are some households which employ more than one of these technologies for certain reasons. This section seeks to identify the most used technologies and reasons behind their usage.

6 **STOVE USAGE**

6.1 **What kind(s) of technology do you use for cooking? Rate your answer according to preference. 1 is the highest and 7 the lowest.**

Stove Types	**Ratings**						
	1	2	3	4	5	6	7
Three-stone fireside							
Sawdust stoves							
Kerosene stove							
Metal stoves							
Gas cookers							
Electric cookers							
Others, specify							

What is/are the reason(s) for your most preferred stove type?

Fuel saving ☐ Fast/time saving ☐ Retains heat ☐
Cheap ☐ Easy to handle ☐ Less smoke ☐ Others, specify ____________________

6.2 **How many improved stoves do you know (types)?** ________________

Since when (months)? ___________________

How often do you use your stove (s)?

Stove types	Estimates (Weekly)
Three-stone fireside	
Sawdust Stoves	
Kerosene stove	
Metal stoves	
Gas cookers	
Electric cookers	
Other, specify	

6.4 How did you get your stove?

Buy it ☐ Build it yourself ☐ Pay someone to build it for you ☐

Who provided the money for stove purchase?

You ☐ Other family member ☐ Ohers, specify _______________

7 FUEL USAGE

7.1 Which fuel type(s) do you use? Rate them in order of preference. 1 is the highest and 7 the lowest.

Fuel Types	Ratings						
	1	2	3	4	5	6	7
Wood							
Kerosene							
Saw dust							
Charcoal							
Gas							
Electricity							
Biogas							
Other, specify							

Give reasons for your scale of preference in 7.1 above.

Efficient ☐ Cheap ☐ Produces less smoke ☐

Easy to handle ☐ Availability ☐ Does not burn fast ☐

Others, specify ________________________

7.2 How do you get your fuel (Wood)?

Buy ☐ Collect ☐ Donated ☐

In case of purchase, how do you pay for it?

In cash ☐ In kind ☐

SECTION D SOCIO-ECO-ENVIRONMENTAL IMPACTS

This section seeks to know the respondents expenditure on purchase of fuel and stoves. It equally seeks to know his or her awareness on environmental issues while bringing out the socio-cultural effects of this type of technology on our day to day life.

8 ECONOMIC IMPACT

8.1 If you buy your fuel, how much did you spend before/ without a stove (monthly estimate)? ____________________

How much do you spend now with stoves? ____________________

If any savings are made, what do you use the saved money for?

____

8.2 If you collect your fuel, how much time was spent on collection before? (Estimate in hours/days/weeks)

____

How much time do you spend now with stove? ________________

If any time is saved, what you do during this time? ____________

8.3 Do you make any money selling stoves? Yes ☐ ☐

If yes, how much per month? ____________

8.4 Do you build stoves for others? Yes☐ No ☐

If yes, how much is it per month? ____________________

9 SOCIAL CULTURAL IMPACTS

9.1 Who takes decisions in the household e.g as to whether to buy an improved stove or not?

Father ☐ Mother ☐ Both ☐

9.2 Who spends the most time in the kitchen (for diverse activities e.g cooking, heating) in your household?

Mother ☐ Father ☐ Boy child ☐ Girl child ☐

Other, specify ____________________

How much time does he/she spend on average in the kitchen per day?

Less than 3 hours ☐ 4 hours – 6 hours ☐ More than 6 hours ☐

9.3 How do you compare the amount of smoke now to before using the new stove?

The same ☐ Less ☐ More ☐

9.4 **Have you noticed any differences in your health now to when you did not have any improved stove?** Yes ☐ No ☐

If yes, what has changed? ______________________________

____

9.5 **How do you estimate the danger of the stove(s), did you hear about burns or other accidents?**

Yes ☐ No ☐

10 **ENVIRONMENTAL IMPACTS**

10.1 **Did you notice any environmental changes in your area in the past years?**

Yes ☐ No ☐

If yes, what are the changes? ______________________________

____

10.2 **Has the use of wood and deforestation increased in the past years?**

Yes ☐ No ☐ I don't know ☐

If yes, what are you doing about it? ______________________________

____

10.3 **Has the loss of soil (soil erosion) and soil degradation increased?**

Yes ☐ No ☐ I don't know ☐

If yes, what are you doing about it? ______________________________

____

10.4 **Do you think there is a greater awareness these days about how the environment around you is changing?** Yes ☐ No ☐ I don't know ☐

If yes, do you talk with other people around you? ______________

Do you discuss what you can do to improve it? ______________

Section E HEALTH ISSUES/ MEDICALS

This section is dedicated to respondent's knowledge on health related issues associated with Indoor Air Pollution.

12 **Which illness (es) in your opinion is/are associated to smoke inhalation?**

Asthma Bronchitis ☐ Pneumonia ☐ Lung Cancer ☐

Catarrh Convulsion ☐ Tuberculosis ☐ Cataract (blindness) ☐

Cardiovascular disease ☐ Adverse pregnancy outcomes ☐

All of the above ☐ Others, specify __________ I don't know ☐

13 **Which indoor air pollution illness (es) is frequent in your household?**

Asthma Bronchitis ☐ Pneumonia ☐ Lung Cancer ☐

Catarrh Convulsion ☐ Tuberculosis ☐ Cataract (blindness) ☐

Cardiovascular disease ☐ Adverse pregnancy outcomes ☐

All of the above ☐ Others, specify ____________ I don't know

14 **What is your yearly estimated expenditure on drugs for this illness(es)?**

<10,000 frsCFA ☐ 10,000 frsCFA – 20,000frsCFA ☐ > 20,000frsCFA ☐

RESERVED FOR MEDICAL DOCTORS AND HEALTH EXPERTS

15a **Do you normally consult patients with illnesses resulting from Indoor Air Pollution?**

Yes ☐ No ☐

15b **How many of such patients do you on the average consult per month?**

____

16 **What are the most common indoor air pollution related illnesses of you patients?**

17 **What drugs do you administer and what are the costs of the drugs?**

Illnesses	Drugs	Costs (per drug)

18 **Are the drugs or their substitutes readily available?**

Yes ☐ No ☐ I don't know ☐

19a **Is there any public awareness campaign towards reducing Indoor Air Pollution in your area?**

Yes ☐ No ☐ I don't know ☐

19b **If yes, who is organizing these campaigns?**

Government ☐ Local Authorities ☐ NGO's ☐

Others, specify ____________________

19 **What is the delegation or Ministry of Health doing to reduce the impacts of Indoor Air Pollution?**

…………………………………………………………………………………………………..

END - THANK YOU

APPENDIX B

I Glossary of Terms

Baldosa The **i**nexpensive ceramic floor tile about one inch thick that can be cut or molded into appropriate shapes to make a combustion chamber.

Boundary Layer The very thin layer of slow moving air immediately adjacent to a pot surface; insulates the pot from hot flue gases and diminishes the amount of heat that enters the pot.

Charcoal The black, porous material that contains mostly carbon that is produced by burning of wood or other biomass.

Convection The heat transfer in a gas or liquid by movement of air or water.

Combustion Chamber The region of the stove where the fuel is burned.

Combustion Efficiency The percentage of the fuel's heat energy that is released during combustion. It refers to the amount of energy from the biomass that is turned into heat energy.

Draft The movement of air through a stove and up a chimney

Emissions The byproducts from the combustion process that are discharged into the air.

Excess Air The amount of air used in excess of the amount for complete combustion.

Firepower The rate of fuel consumption, usually in Kg-fuel per hour

Flue Gas The hot gases that flow from the combustion chamber and out the chimney (if the chimney is present).

Fuel Efficiency The percentage of the fuel's heat energy that is utilized to heat food or water.

Grate A framework of bars or mesh used to hold fuel or food in a stove, furnace or fire place.

Hay box A relatively air tight insulated enclosure that maintains the temperature of a pot enabling food to be cooked to completion after the pot is removed from the stove.

Heat Transfer Efficiency The percentage of heat released from combustion that enters the pot.

High Mass Stove A stove made of uninsulated earth, clay, cast iron, or other heavy material that requires significant energy to be warmed during stove operation.

High Power A mode of stove operation where the objective is to boil water as quickly as possible; the highest power at which a stove can operate.

Low Power A mode of stove operation where the objective is to simmer the water or food product; the lowest power at which a stove can operate and still maintain a flame and simmer food.

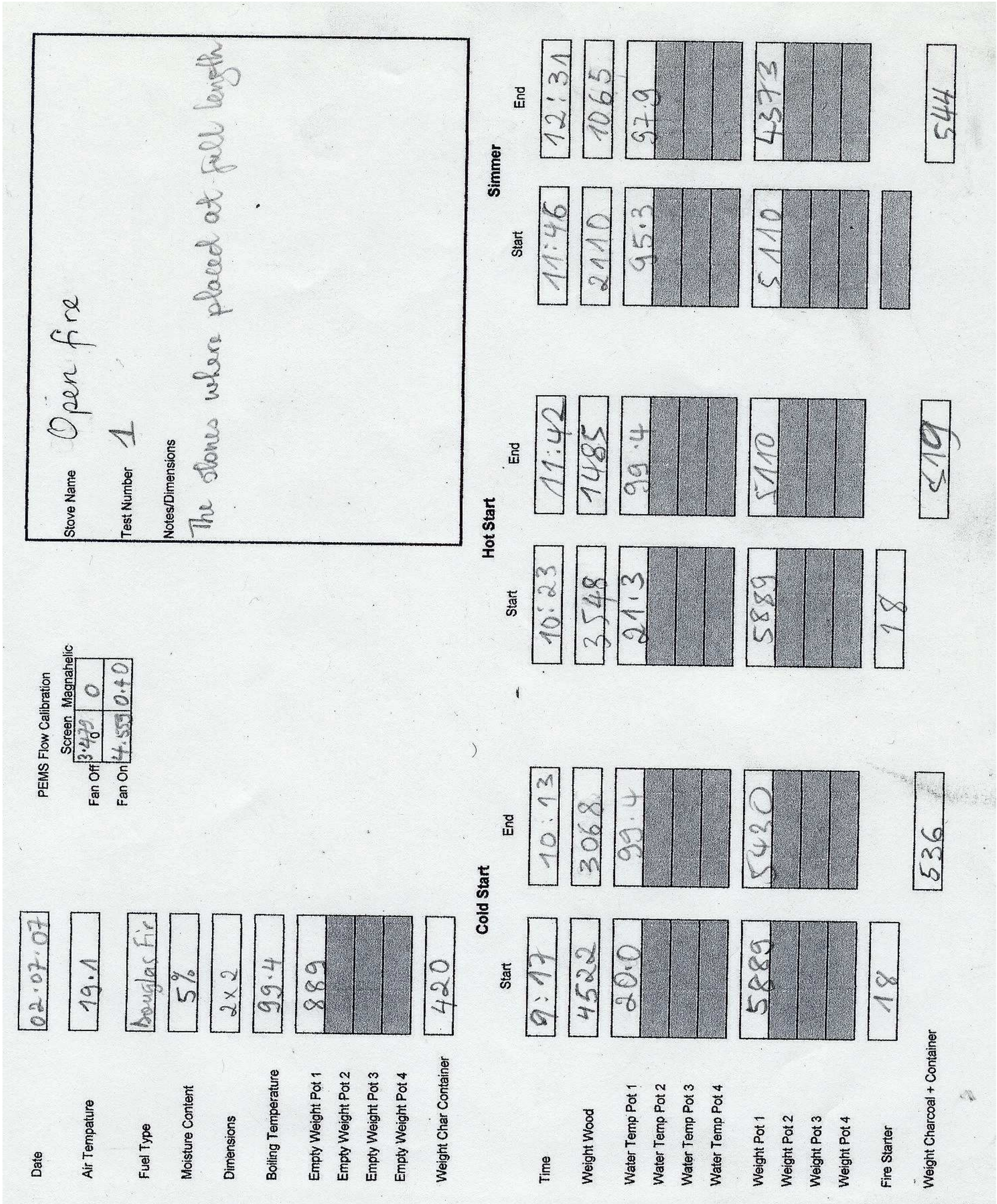
Pot Skirt A tube, usually made of sheet steel, that surrounds a pot creating a narrow space so that more of the heat in flue gases enter the pot.

Retained Heat Heat energy that warms the enclosures around the fire that does not escape to the surroundings; can be used for space heating.

Vermiculite A lightweight, cheap, fireproof material produced from natural mineral deposits in many parts of the world. Vermiculite can be made into strong, lightweight, insulative ceramics with very little effort. It is very strong and resistant to heat, and appears to be one of the best possible choices for making isolative ceramics.

Water Boiling Test (WBT) A test used to measure the overall performance of a cook stove. There are several**.**

II Sample of the Water Boiling Test Data Sheet



Date	02.07.07
Air Tempature	19.1
Fuel Type	Douglas Fir
Moisture Content	5%
Dimensions	2x2
Boiling Temperature	99.4
Empty Weight Pot 1	889
Empty Weight Pot 2	
Empty Weight Pot 3	
Empty Weight Pot 4	
Weight Char Container	420

PEMS Flow Calibration

	Screen	Magnahelic
Fan Off	3.420	0
Fan On	4.553	0.40

Stove Name: Open fire

Test Number: 1

Notes/Dimensions: The stones where placed at full length

	Cold Start Start	Cold Start End	Hot Start Start	Hot Start End	Simmer Start	Simmer End
Time	9:17	10:13	10:23	11:42	11:46	12:31
Weight Wood	4522	3068	3548	1485	2110	1065
Water Temp Pot 1	20.0	99.4	21.3	99.4	95.3	97.9
Water Temp Pot 2						
Water Temp Pot 3						
Water Temp Pot 4						
Weight Pot 1	5889	5420	5889	5110	5110	4373
Weight Pot 2						
Weight Pot 3						
Weight Pot 4						
Fire Starter	18		18			
Weight Charcoal + Container		536		519		544

III Detailed WBT and Emissions Results

1 Averages at 5% Moisture Content (MC)

Stove type/model		**Open fire**	**Chinese Rocket**	**Skirt Stove**
Location		Aprovecho	Aprovecho	Aprovecho
Wood species		Douglas Fir	Douglas Fir	Douglas Fir
Basic Operation		5% mc	5% mc	5% mc
1. HIGH POWER TEST (COLD START)	units			
Time to boil Pot # 1	min	37	31	43
Burning rate	g/min	16	13	10
Thermal efficiency	--	21	27	30.30
Specific fuel consumption	g/liter	124	86	86
Temp-corrected specific consumption	g/liter	118	82	83
Firepower	watts	5198	4301	3075
Equivalent Dry Wood Consumed	g	582	411	404
2. HIGH POWER TEST (HOT START)	units			
Time to boil Pot # 1	min	34	28	34
Burning rate	g/min	16	12	12
Thermal efficiency	--	22,3	32,30	29,3
Specific fuel consumption	g/liter	120	71	82
Temp-corrected specific consumption	g/liter	117	69	81
Firepower	watts	5193	3848	3713
Equivalent Dry Wood Consumed	g	558	339	388
3. LOW POWER (SIMMER)	units			
Burning rate	g/min	10	7	6
Thermal efficiency	--	22.0	31.0	32.5
Specific fuel consumption 45 min	g/liter	120	81	64
Firepower	watts	3287	2275	1801
Turn down ratio	--	2	2	2
Equivalent Dry Wood Consumed	g	461	319	253
Energy Consumption				
COLD START				
Net Calorific Value (dry)	kJ/kg	19260	19260	19260
Effective Calorific Fuel Value	kJ/kg	18343	18343	18343
Temp-Corr Time to Boil	min	35	29	42
Energy Consumption Rate	kJ/min	297	246	176
Temp-Corr Specific Energy Consumption	kJ/liter	2166	1503	1530
Dry Wood Consumed	g	586	414	407
Total Energy Consumed	kJ	10672	7537	7408
HOT START				
Temp-Corr Time to Boil	min	33	27	33
Energy Consumption Rate	kJ/min	297	220	212
Temp-Corr Specific Energy Consumption	kJ/liter	2144	1259	1481

Dry Wood Consumed	g	563	341	391
Total Energy Consumed	kJ	10244	6209	7124
SIMMER				
Energy Consumption Rate	kJ/min	188	130	103
Temp-Corr Specific Energy Consumption	kJ/liter	2210	1491	1173
Dry Wood Consumed	g	464	321	254
Total Energy Consumed	kJ	8452	5849	4632

Total Emissions

Totals				
CO	grams	30	13	14
CO2	grams	604	493	472
appx PM	mg	900	513	339
CO/CO2ratio		0,0809	0,0428	0,0473
Totals				
CO	grams	32	9	13
CO2	grams	616	438	395
appx PM gr	mg	1245	457	307
CO/CO2ratio		0,0890	0,0321	0,0524
Totals				
CO	grams	45	10	24
CO2	grams	527	483	397
appx PM gr	grams	756	177	208
CO/CO2ratio		0,1452	0,0319	0,0937

Specific Emissions

Correction Factor	0,168699			
CO	gr/liter	5	2	2
CO2	gr/liter	96	87	81
appx PM mg	mg/liter	142	91	58
Correction Factor	0,170076			
CO	gr/liter	5	2	2
CO2	gr/liter	100	78	69
appx PM mg	mg/liter	201	81	54
Simmer for 45 Minutes				
Correction Factor	0,267061			
CO	gr/liter	12	2	6
CO2	gr/liter	139	113	103
appx PM mg	mg/liter	199	42	54

Emission Factors		Open fire	Chinese Rocket	Skirt stove
COLD START				
g CO/kg wood consumed	g/kg	51	32	35
g CO2/kg wood consumed	g/kg	1011	1209	1161
mg PM/kg wood consumed	g/kg	2	1	1
HOT START				

g CO/kg wood consumed	g/kg	57	26	34
g CO2/kg wood consumed	g/kg	1053	1282	1030
mg PM/kg wood consumed	g/kg	2	1	1
SIMMER				
g CO/kg wood consumed	g/kg	99	31	99
g CO2/kg wood consumed	g/kg	1157	1504	1634
mg PM/kg wood consumed	g/kg	2	1	1

Standard of Performance		Average	Average	Average
Fuel to Cook 5L (850/1500)	g	1189,88	782,83	729,96
CO to Cook 5L (20)	g	84,72	21,13	42,47
PM to Cook 5L (1500)	mg	1850,67	637,50	549,53
Energy to Cook 5L (15,000/25,000)	kJ	21825,72	14359,25	13389,50
Time to Boil	min	34,23	28,38	37,37
CO2 to Cook 5L	g	1184,78	976,17	890,98

2 Averages at 15% MC

Stove type/model		**Open fire**	**Chinese Rocket**	**Skirt Stove**
Location		Aprovecho	Aprovecho	Aprovecho
Wood species		Douglas Fir	Douglas Fir	Douglas Fir
Date				
Basic Operation		15% mc	15% mc	15% mc
1. HIGH POWER TEST (COLD START)	units			
Time to boil Pot # 1	min	67	39	51
Burning rate	g/min	11	10	9
Thermal efficiency	--	0	0	0
Specific fuel consumption	g/liter	170	89	94
Temp-corrected specific consumption	g/liter	164	88	90
Firepower	watts	3583	3197	2762
Equivalent Dry Wood Consumed	g	753	392	436
2. HIGH POWER TEST (HOT START)	units			
Time to boil Pot # 1	min	50	26	38
Burning rate	g/min	14	12	11
Thermal efficiency	--	0	0	0
Specific fuel consumption	g/liter	151	67	90
Temp-corrected specific consumption	g/liter	149	67	90
Firepower	watts	4356	3989	3539
Equivalent Dry Wood Consumed	g	682	319	422
3. LOW POWER (SIMMER)	units			
Burning rate	g/min	11	7	8
Thermal efficiency	--	0	0	0
Specific fuel consumption 45 min	g/liter	140	82	89
Firepower	watts	3687	2298	2439
Turn down ratio	--	1	2	1

Equivalent Dry Wood Consumed	g	529	322	342

Energy Consumption

COLD START				
Net Calorific Value (dry)	kJ/kg	19260	19260	19260
Effective Calorific Fuel Value	kJ/kg	16747	16747	16747
Temp-Corr Time to Boil	min	65	39	49
Energy Consumption Rate	kJ/min	187	167	144
Temp-Corr Specific Energy Consumption	kJ/liter	2752	1472	1515
Dry Wood Consumed	g	771	401	447
Total Energy Consumed	kJ	12605	6561	7310
HOT START				
Temp-Corr Time to Boil	min	49	26	38
Energy Consumption Rate	kJ/min	227	208	185
Temp-Corr Specific Energy Consumption	kJ/liter	2491	1115	1507
Dry Wood Consumed	g	699	326	432
Total Energy Consumed	kJ	11418	5336	7068
SIMMER				
Energy Consumption Rate	kJ/min	192	120	127
Temp-Corr Specific Energy Consumption	kJ/liter	2350	1370	1495
Dry Wood Consumed	g	540	329	349
Total Energy Consumed	kJ	8864	5395	5726

Total Emissions

Totals				
CO	grams	49	8	19
CO2	grams	939	495	532
appx PM	mg	1336	187	450
CO/CO2ratio		0,0801	0,0267	0,0534
Totals				
CO	grams	45	7	17
CO2	grams	873	424	504
appx PM gr	mg	1078	340	342
CO/CO2ratio		0,0802	0,0300	0,0527
Totals				
CO	grams	16	10	28
CO2	grams	245	493	485
appx PM gr	grams	263	150	268
CO/CO2ratio		0,0105	0,0281	0,0941

Specific Emissions

Correction Factor	0,168699			
CO	gr/liter	8	2	3
CO2	gr/liter	151	89	86
appx PM mg	mg/liter	214	34	72

(Corrected for water temp and Moisture)

Correction Factor	0,170076			
CO	gr/liter	7	1	3
CO2	gr/liter	139	72	83
appx PM mg	mg/liter	170	58	56

Simmer for 45 Minutes

Correction Factor	0,267061			
CO	gr/liter	4	2	6
CO2	gr/liter	57	101	109
appx PM mg	mg/liter	61	31	60

Emission Factors

COLD START				
g CO/kg wood consumed	g/kg	63	21	42
g CO2/kg wood consumed	g/kg	1216	1233	1189
mg PM/kg wood consumed	g/kg	2	0	1
HOT START				
g CO/kg wood consumed	g/kg	64	22	39
g CO2/kg wood consumed	g/kg	1249	1301	1157
mg PM/kg wood consumed	g/kg	2	1	1
SIMMER				
g CO/kg wood consumed	g/kg	30	29	79
g CO2/kg wood consumed	g/kg	458	1499	1389
mg PM/kg wood consumed	g/kg	0	0	1

Standard of Performance		Average	Average	Average
Fuel to Cook 5L (850/1500)	g	1484,33	795,36	897,35
CO to Cook 5L (20)	g	56,03	16,73	45,54
PM to Cook 5L (1500)	mg	1266,85	383,75	619,73
Energy to Cook 5L (15,000/25,000)	kJ	24858,79	13320,21	15028,33
Time to Boil	min	57,18	32,10	43,60
CO2 to Cook 5L	g	1010,36	909,82	966,04

3 Averages at 30% MC

Stove type/model		**Open fire**	**Chinese Rocket**	**Skirt Stove**
Location		Aprovecho	Aprovecho	Aprovecho
Wood species		Douglas Fir	Douglas Fir	Douglas Fir
Date				
Basic Operation		30% mc	30% mc	30% mc
HIGH POWER TEST (COLD START)	units			
Time to boil Pot # 1	min	93	107	93
Burning rate	g/min	7,70	6,32	7

Thermal efficiency	--	26%	28%	0
Specific fuel consumption	g/liter	172,07	159,95	152
Temp-corrected specific consumption	g/liter	161,92	150,20	144
Firepower	watts	2471	2030	2097
Equivalent Dry Wood Consumed	g	719,8	669,9	622
LOW POWER (SIMMER)	units			
Burning rate	g/min	7,18	7,67	7
Thermal efficiency	--	33%	29%	30%
Specific fuel consumption 45 min	g/liter	98,07	102,75	94
Firepower	watts	2306	2461	2178
Turn down ratio	--	1,08	0,83	1
Equivalent Dry Wood Consumed	g	323,3	345,0	305
Energy Consumption				
COLD START				
Net Calorific Value (dry)	kJ/kg	19.260	19.260	19.260
Moisture Content		30%	30%	30%
Effective Calorific Fuel Value	kJ/kg	14.815	14.815	14.815
Temp-Corr Time to Boil	min	87,9	100,8	93
Energy Consumption Rate	kJ/min	114	94	97
Temp-Corr Specific Energy Consumption	kJ/liter	2.399	2.225	2129
Dry Wood Consumed	g	763	707	656
Total Energy Consumed	kJ	10.664	9.924	9209
SIMMER				
Energy Consumption Rate	kJ/min	106	114	101
Temp-Corr Specific Energy Consumption	kJ/liter	1.453	1.522	1399
Dry Wood Consumed	g	345	365	322
Total Energy Consumed	kJ	4.789	5.112	4523
Total Emissions				
Totals High Power				
CO	grams	63,79	24,40	37
CO2	grams	742	842	801
appx PM	mg	2145	320	792
CO/CO2ratio		0,1376	0,0453	0.0694
Totals Low Power				
CO	grams	39,25	6,59	13
CO2	grams	432	311	340
appx PM gr	grams	1296	92	191
CO/CO2ratio		0,1430	0,0349	0.0553
Specific Emissions				
Correction Factor	0,168699			
CO	gr/liter	8,6292	3,5805	6
CO2	gr/liter	100,4176	123,9266	122
appx PM mg	mg/liter	288,5148	46,	121

(Corrected for water temp and Moisture)

Simmer for 45 Minutes

Correction Factor	0,267061			
CO	gr/liter	6,4682	1,2524	3
CO2	gr/liter	71,4620	59,1798	67
appx PM mg	mg/liter	213,5907	17,5439	38

Emission Factors

COLD START				
g CO/kg wood consumed	g/kg	84,36	34,29	55
g CO2/kg wood consumed	g/kg	975,24	1197,99	1215
mg PM/kg wood consumed	g/kg	2,87	0,47	1
SIMMER				
g CO/kg wood consumed	g/kg	114,64	19,21	40
g CO2/kg wood consumed	g/kg	1255,78	907,75	1061
mg PM/kg wood consumed	g/kg	3,70	0,27	1

Standard of Performance

Fuel to Cook 5L (850/1500)	g	1299,94	1264,74	1190.73
CO to Cook 5L (20)	g	75,49	24,16	40,32
PM to Cook 5L (1500)	mg	2510,53	322,11	797,50
Energy to Cook 5L (15,000/25,000)	kJ	19258	18737	17640,36
Time to Boil	min	87,86	100,78	92,71
CO2 to Cook 5L	g	859,40	915,53	943,32

IV Stove Benchmarks as Set by Aprovecho Research Centern

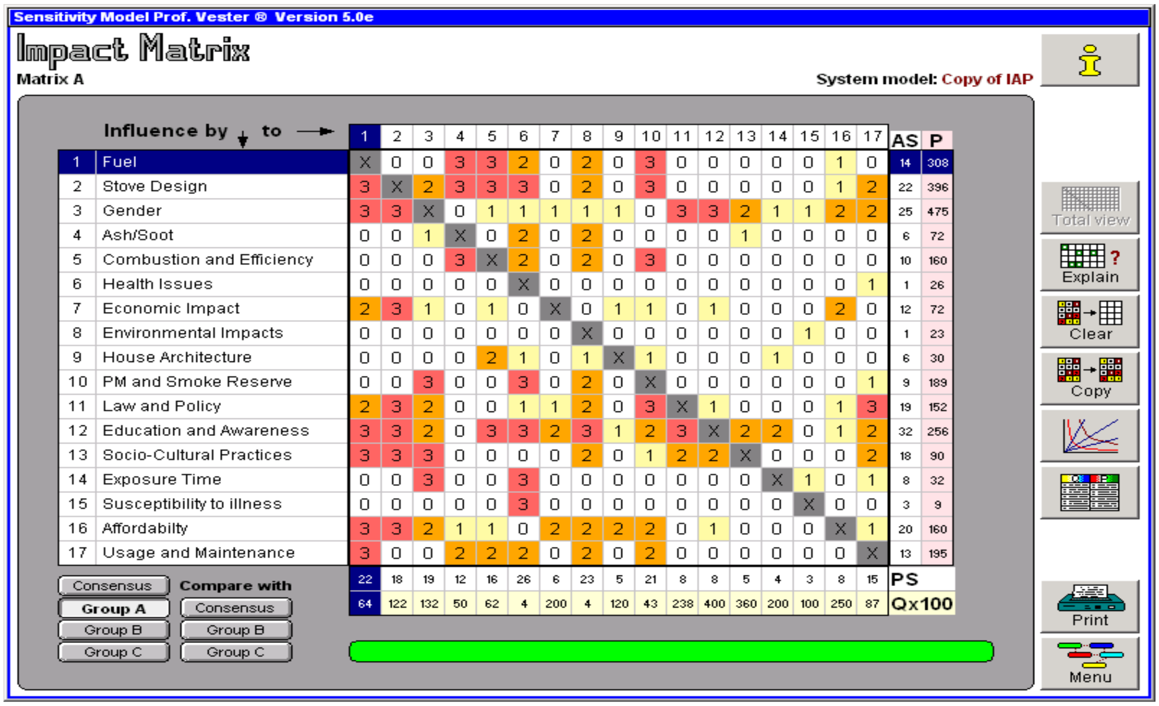
		Benchmark	Stove With Skirt	Stove W/Out Skirt
Fuel Use	g	850	589	835
CO Emission	g	20	16	17
PM Emission	mg	1500	591	972
Time to Boil	min		20	30
Safety Score			35/40	36/40

		Benchmark	Stove Performance
Fuel Use	g	1500	1080
Fugitive CO Emission	ppm	50	4
Time to Boil	min		28
Safety Score			38/40

APPENDIX C

I Sensitivity Model Graphs

Impact Matrix A

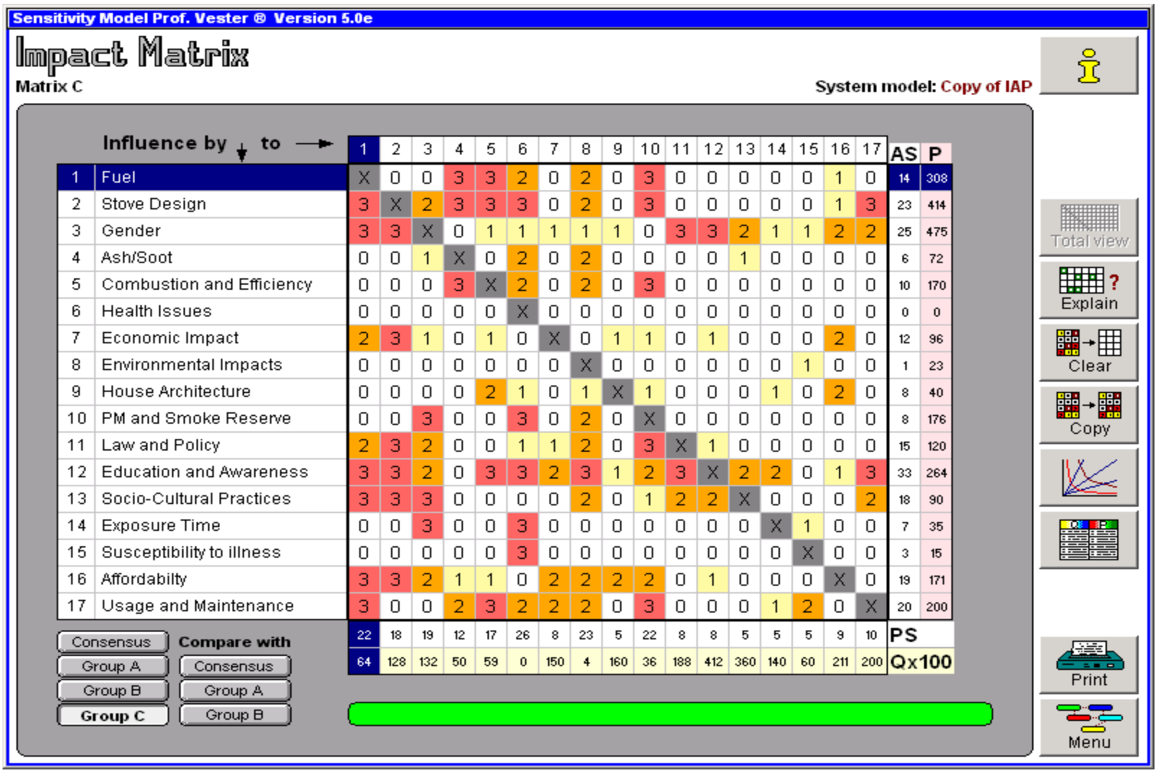


No.	Influence by ↓ to →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	AS	P
1	Fuel	X	0	0	3	3	2	0	2	0	3	0	0	0	0	0	1	0	14	308
2	Stove Design	3	X	2	3	3	3	0	2	0	3	0	0	0	0	0	1	2	22	396
3	Gender	3	3	X	0	1	1	1	1	1	0	3	3	2	1	1	2	2	25	475
4	Ash/Soot	0	0	1	X	0	2	0	2	0	0	0	0	1	0	0	0	0	6	72
5	Combustion and Efficiency	0	0	0	3	X	2	0	2	0	3	0	0	0	0	0	0	0	10	160
6	Health Issues	0	0	0	0	0	X	0	0	0	0	0	0	0	0	0	0	1	1	26
7	Economic Impact	2	3	1	0	1	0	X	0	1	1	0	1	0	0	0	2	0	12	72
8	Environmental Impacts	0	0	0	0	0	0	0	X	0	0	0	0	0	0	1	0	0	1	23
9	House Architecture	0	0	0	0	2	1	0	1	X	1	0	0	0	1	0	0	0	6	30
10	PM and Smoke Reserve	0	0	3	0	0	3	0	2	0	X	0	0	0	0	0	0	1	9	189
11	Law and Policy	2	3	2	0	0	1	1	2	0	3	X	1	0	0	0	1	3	19	152
12	Education and Awareness	3	3	2	0	3	3	2	3	1	2	3	X	2	2	0	1	2	32	256
13	Socio-Cultural Practices	3	3	3	0	0	0	0	2	0	1	2	2	X	0	0	0	2	18	90
14	Exposure Time	0	0	3	0	0	3	0	0	0	0	0	0	0	X	1	0	1	8	32
15	Susceptibility to illness	0	0	0	0	0	3	0	0	0	0	0	0	0	0	X	0	0	3	9
16	Affordabilty	3	3	2	1	1	0	2	2	2	2	0	1	0	0	0	X	1	20	160
17	Usage and Maintenance	3	0	0	2	2	2	0	2	0	2	0	0	0	0	0	0	X	13	195
	PS	22	18	19	12	16	26	6	23	5	21	8	8	5	4	3	8	15		
	Qx100	64	122	132	50	62	4	200	4	120	43	238	400	360	200	100	250	87		

Impact Matrix B

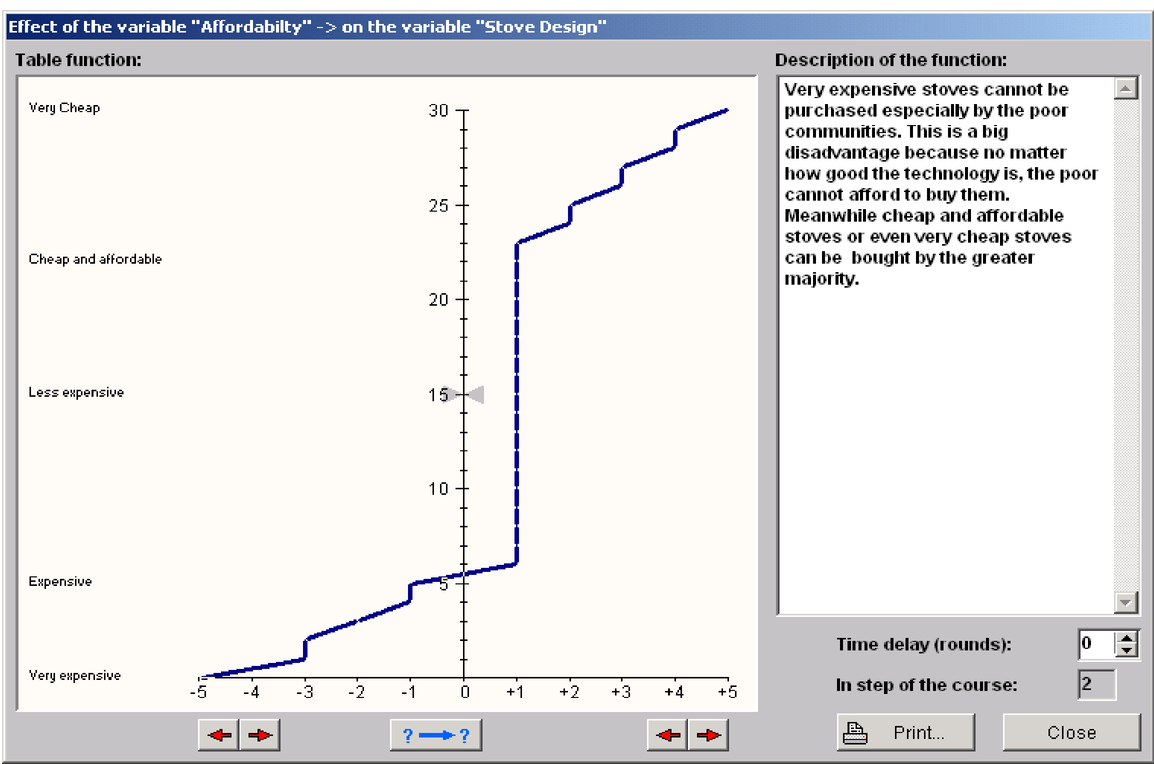
No.	Influence by ↓ to →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	AS	P
1	Fuel	X	0	0	3	3	2	0	2	0	3	0	0	0	0	0	1	0	14	294
2	Stove Design	3	X	2	3	3	3	0	2	0	3	0	0	0	0	0	1	0	20	360
3	Gender	3	3	X	0	1	1	1	1	1	0	3	3	2	1	1	2	3	26	494
4	Ash/Soot	0	0	1	X	0	2	0	2	0	0	0	0	1	0	0	0	0	6	72
5	Combustion and Efficiency	0	0	0	3	X	2	0	2	0	3	0	0	0	0	0	0	0	10	170
6	Health Issues	0	0	0	0	0	X	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Economic Impact	2	3	1	0	1	0	X	0	1	1	0	1	0	0	0	2	0	12	84
8	Environmental Impacts	0	0	0	0	0	0	0	X	0	0	0	0	0	0	1	0	0	1	23
9	House Architecture	0	0	0	0	2	1	0	1	X	1	0	0	0	1	0	2	0	8	40
10	PM and Smoke Reserve	0	0	3	0	0	3	0	2	0	X	0	0	0	0	0	0	0	8	176
11	Law and Policy	2	3	2	0	0	1	1	2	0	3	X	1	0	0	0	0	1	16	128
12	Education and Awareness	3	3	2	0	3	3	2	3	1	2	3	X	2	2	0	1	3	33	264
13	Socio-Cultural Practices	3	3	3	0	0	0	0	2	0	1	2	2	X	0	0	0	0	16	80
14	Exposure Time	0	0	3	0	0	3	0	0	0	0	0	0	0	X	1	0	0	7	28
15	Susceptibility to illness	0	0	0	0	0	3	0	0	0	0	0	0	0	0	X	0	0	3	9
16	Affordabilty	3	3	2	1	1	0	2	2	2	2	0	1	0	0	0	X	0	19	171
17	Usage and Maintenance	2	0	0	2	3	2	1	2	0	3	0	0	0	0	0	0	X	15	105
	PS	21	18	19	12	17	26	7	23	5	22	8	8	5	4	3	9	7		
	Qx100	67	111	137	50	59	0	171	4	160	36	200	412	320	175	100	211	214		

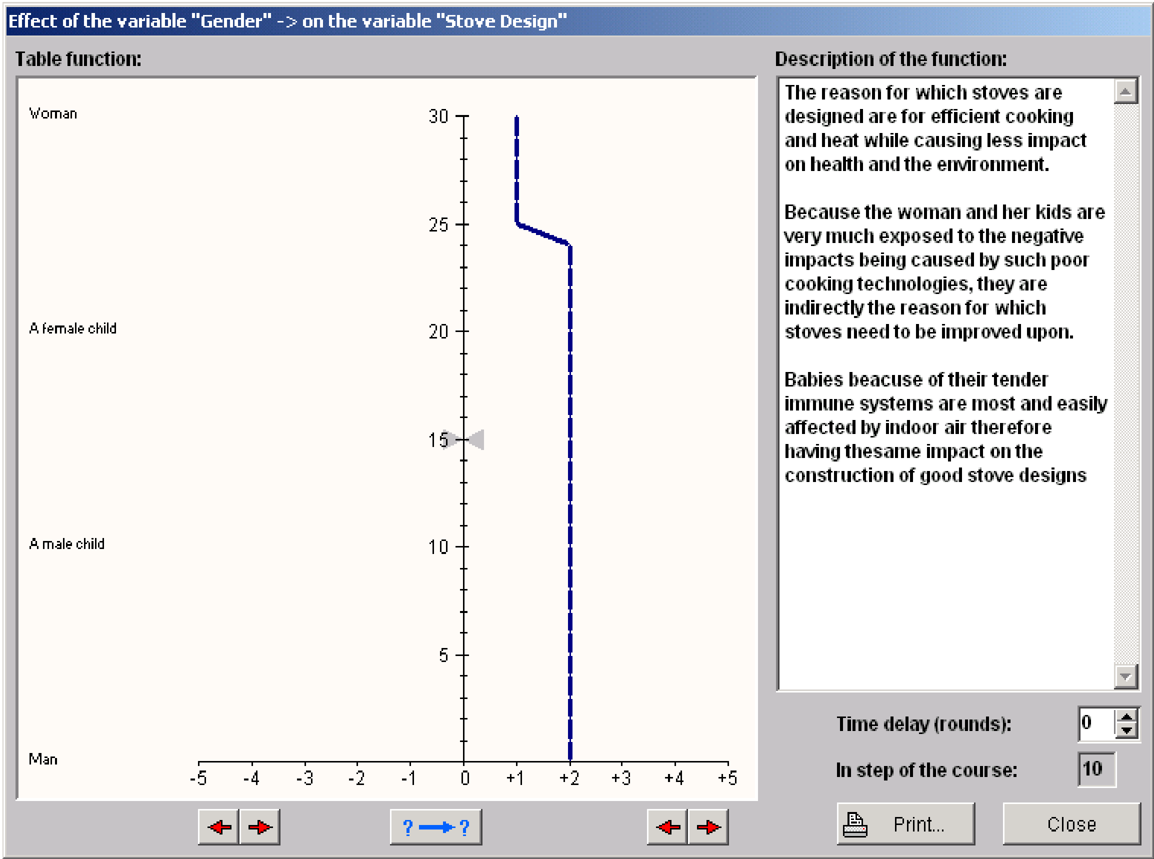
Impact Matrix C

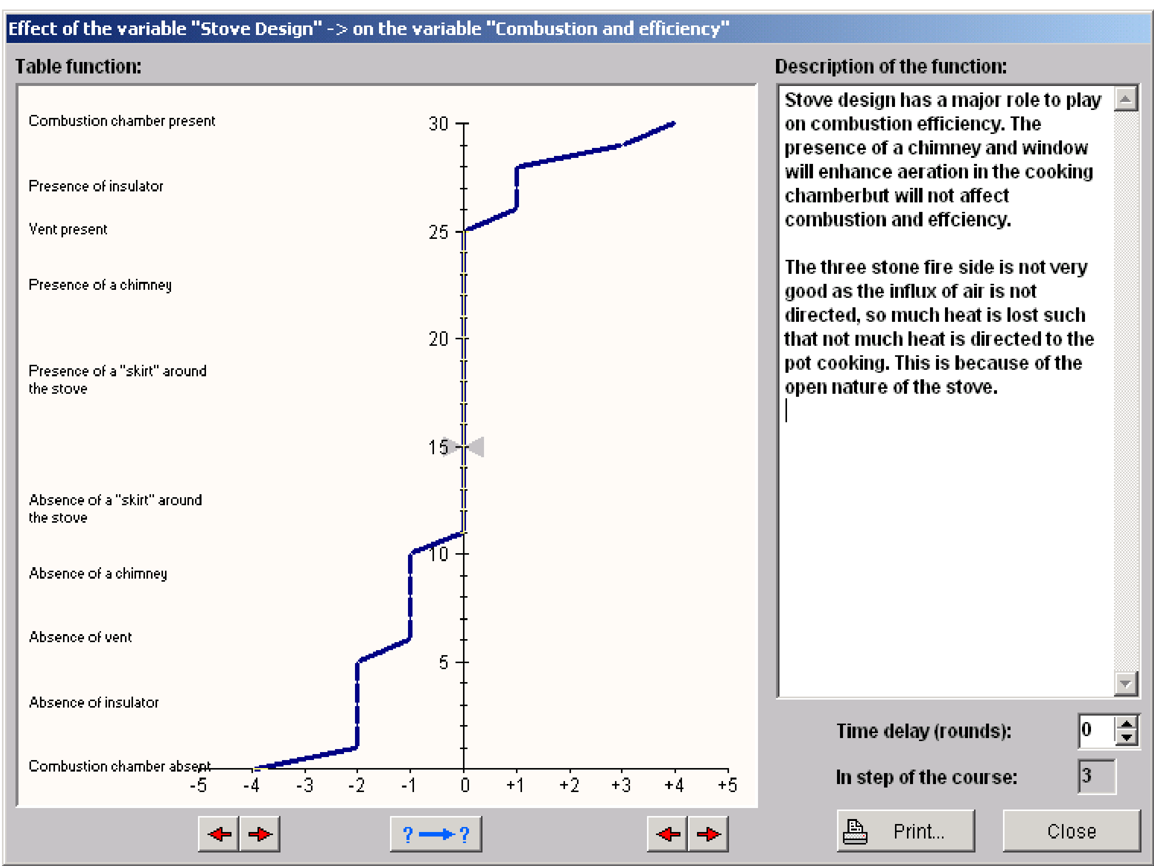


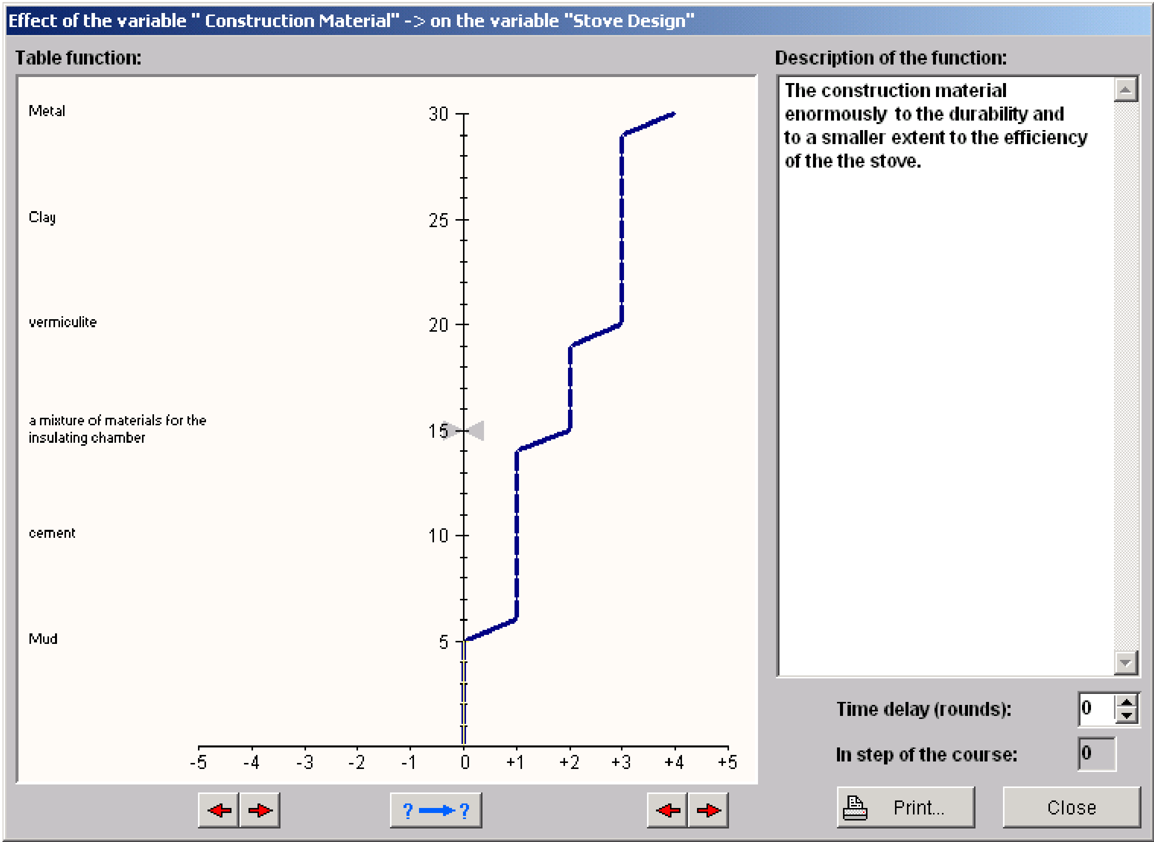
	Influence by ↓ to →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	AS	P
1	Fuel	X	0	0	3	3	2	0	2	0	3	0	0	0	0	0	1	0	14	308
2	Stove Design	3	X	2	3	3	3	0	2	0	3	0	0	0	0	0	1	3	23	414
3	Gender	3	3	X	0	1	1	1	1	1	0	3	3	2	1	1	2	2	25	475
4	Ash/Soot	0	0	1	X	0	2	0	2	0	0	0	0	1	0	0	0	0	6	72
5	Combustion and Efficiency	0	0	0	3	X	2	0	2	0	3	0	0	0	0	0	0	0	10	170
6	Health Issues	0	0	0	0	0	X	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Economic Impact	2	3	1	0	1	0	X	0	1	1	0	1	0	0	0	2	0	12	96
8	Environmental Impacts	0	0	0	0	0	0	0	X	0	0	0	0	0	0	1	0	0	1	23
9	House Architecture	0	0	0	0	2	1	0	1	X	1	0	0	0	1	0	2	0	8	40
10	PM and Smoke Reserve	0	0	3	0	0	3	0	2	0	X	0	0	0	0	0	0	0	8	176
11	Law and Policy	2	3	2	0	0	1	1	2	0	3	X	1	0	0	0	0	0	15	120
12	Education and Awareness	3	3	2	0	3	3	2	3	1	2	3	X	2	2	0	1	3	33	264
13	Socio-Cultural Practices	3	3	3	0	0	0	0	2	0	1	2	2	X	0	0	0	2	18	90
14	Exposure Time	0	0	3	0	0	3	0	0	0	0	0	0	0	X	1	0	0	7	35
15	Susceptibility to illness	0	0	0	0	0	3	0	0	0	0	0	0	0	0	X	0	0	3	15
16	Affordabilty	3	3	2	1	1	0	2	2	2	2	0	1	0	0	0	X	0	19	171
17	Usage and Maintenance	3	0	0	2	3	2	2	2	0	3	0	0	0	1	2	0	X	20	200
	PS	22	18	19	12	17	26	8	23	5	22	8	8	5	5	5	9	10		
	Qx100	64	128	132	50	59	0	150	4	160	36	188	412	360	140	60	211	200		

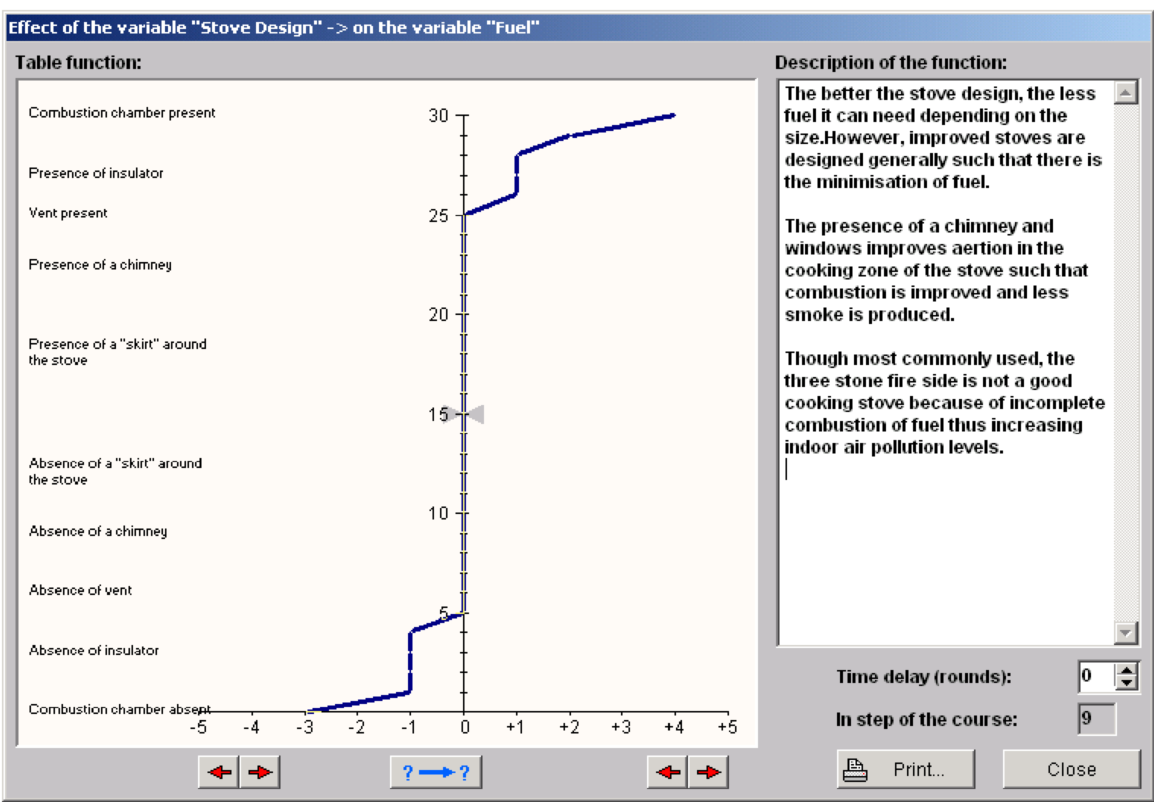
The Effect Matrix Graphs of Partial Scenario 1: Stove Design

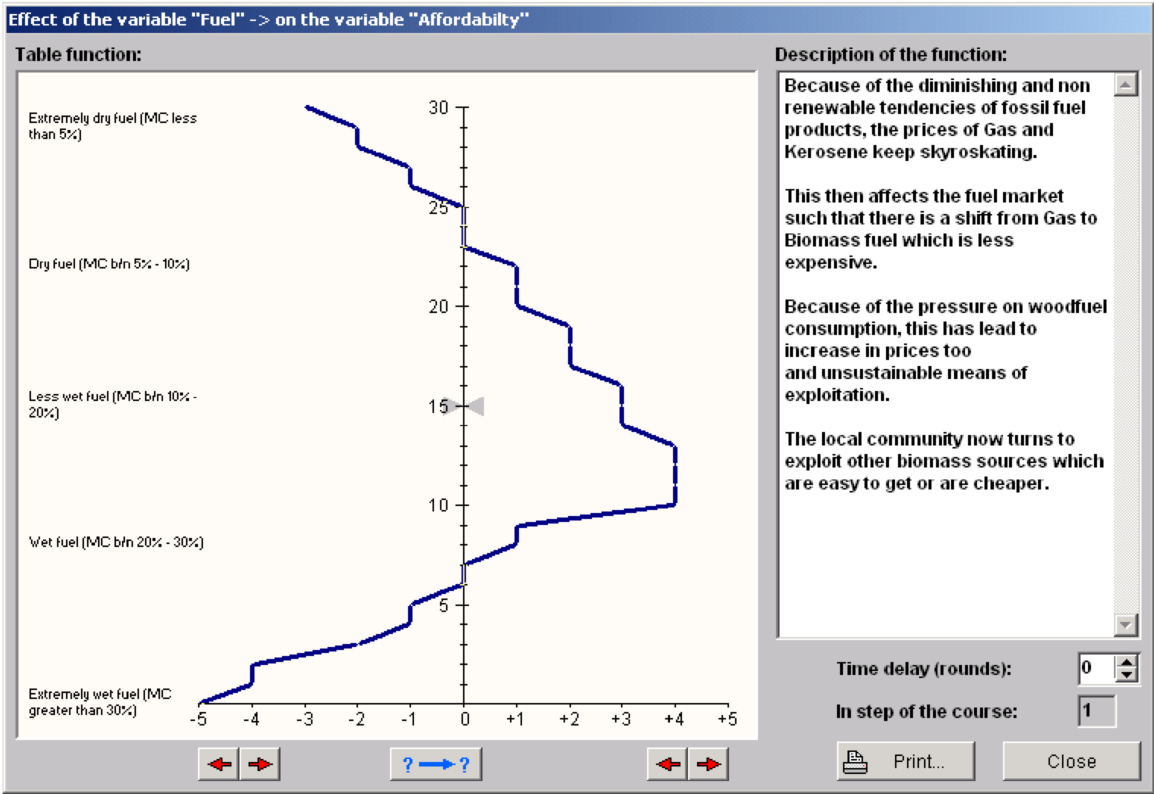


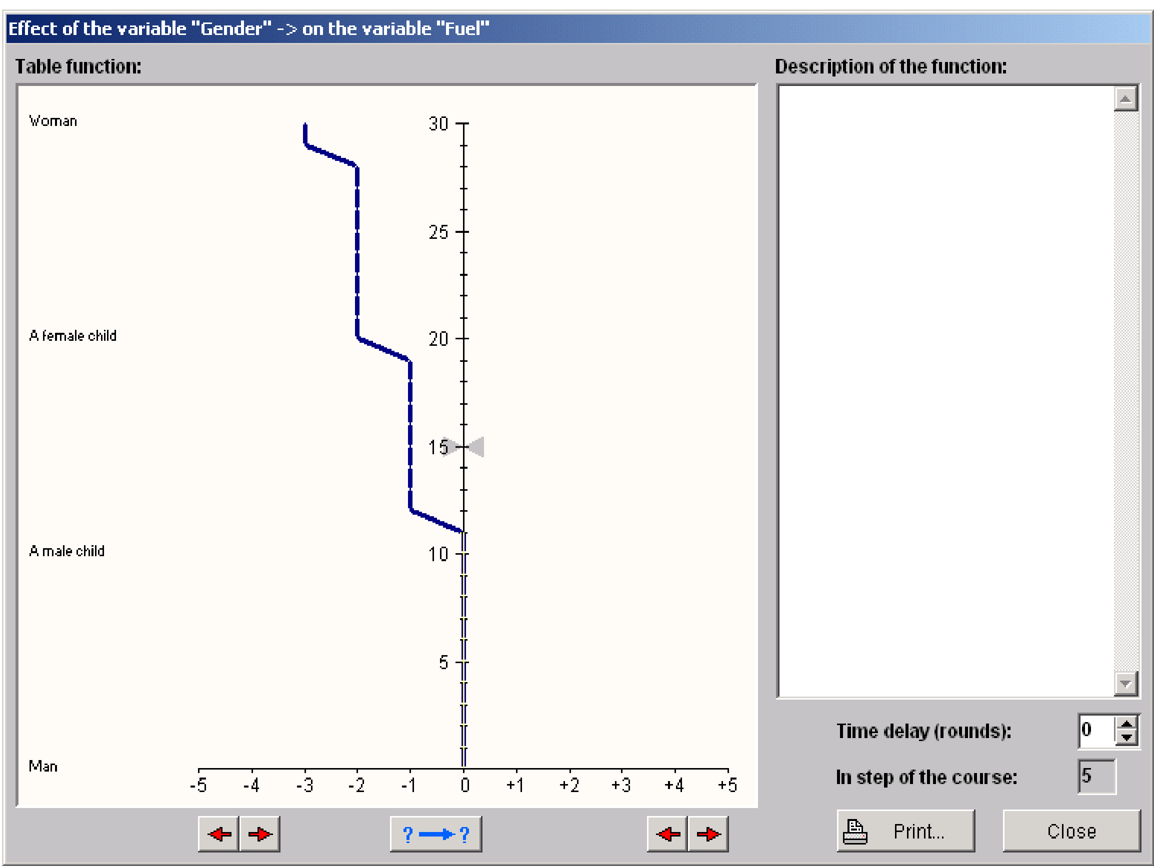

Effect of the variable "Gender" -> on the variable "Stove Design"
Table function:
Woman
A female child
A male child
Man
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
The reason for which stoves are designed are for efficient cooking and heat while causing less impact on health and the environment.
Because the woman and her kids are very much exposed to the negative impacts being caused by such poor cooking technologies, they are indirectly the reason for which stoves need to be improved upon.
Babies beacuse of their tender immune systems are most and easily affected by indoor air therefore having thesame impact on the construction of good stove designs
Time delay (rounds): 0
In step of the course: 10
Print...
Close

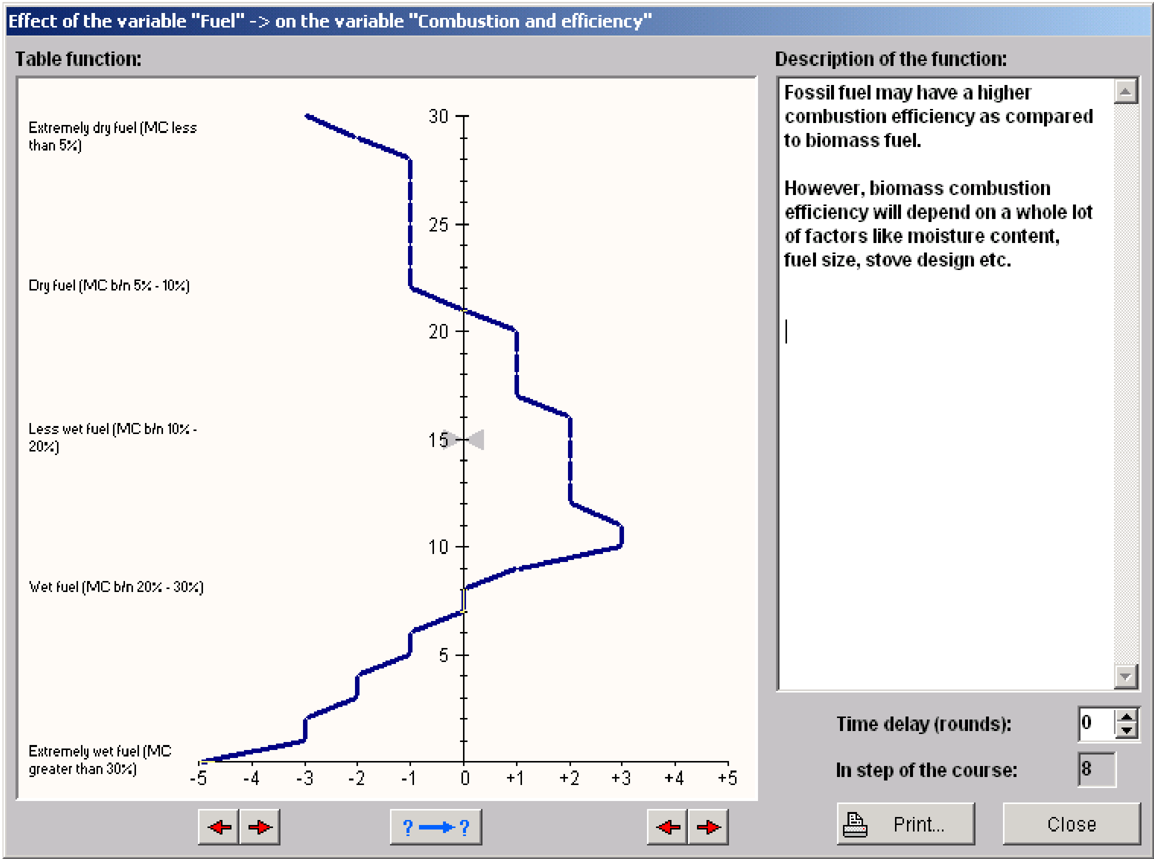

Effect of the variable "Stove Design" -> on the variable "Combustion and efficiency"
Table function:
Combustion chamber present
Presence of insulator
Vent present
Presence of a chimney
Presence of a "skirt" around the stove
Absence of a "skirt" around the stove
Absence of a chimney
Absence of vent
Absence of insulator
Combustion chamber absent
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
Stove design has a major role to play on combustion efficiency. The presence of a chimney and window will enhance aeration in the cooking chamberbut will not affect combustion and effciency.
The three stone fire side is not very good as the influx of air is not directed, so much heat is lost such that not much heat is directed to the pot cooking. This is because of the open nature of the stove.
Time delay (rounds): 0
In step of the course: 3
Print...
Close


Effect of the variable " Construction Material" -> on the variable "Stove Design"
Table function:
Metal
Clay
vermiculite
a mixture of materials for the insulating chamber
cement
Mud
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
The construction material enormously to the durability and to a smaller extent to the efficiency of the the stove.
Time delay (rounds): 0
In step of the course: 0
Print...
Close

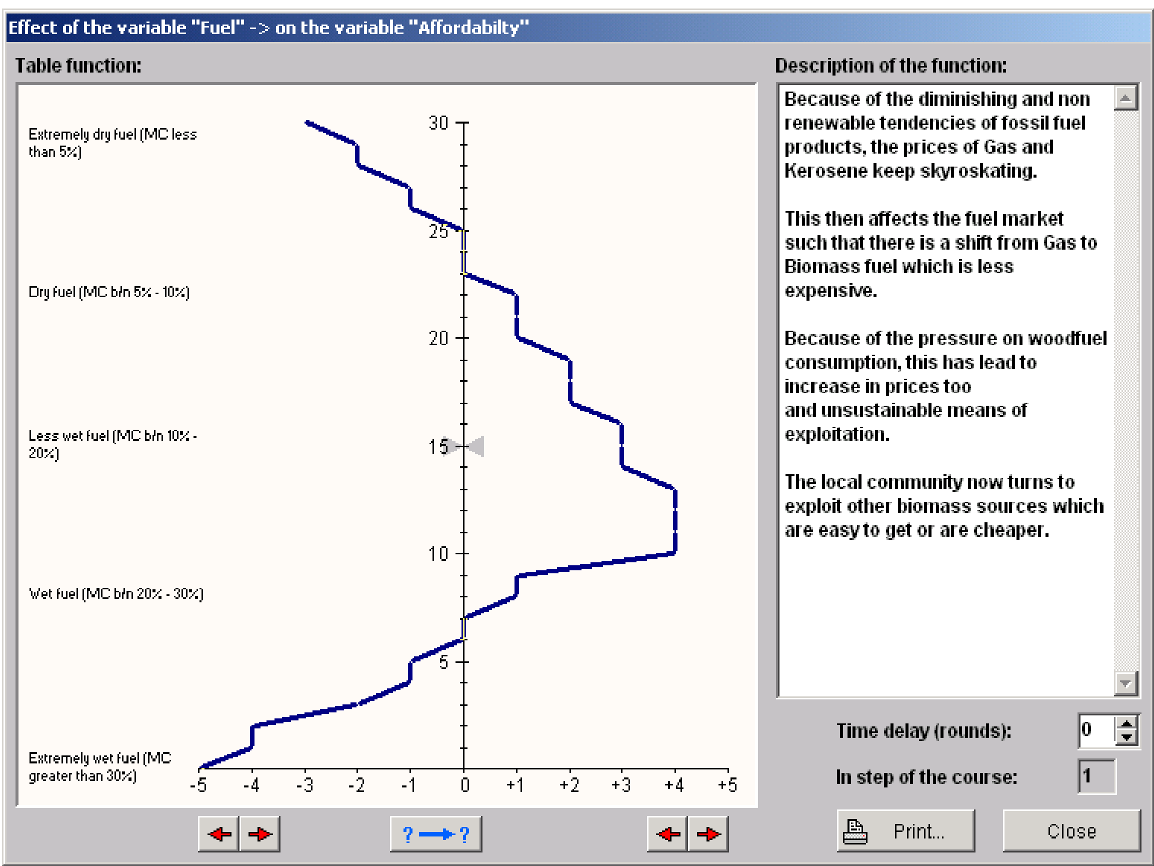

Effect of the variable "Stove Design" -> on the variable "Fuel"
Table function:
Combustion chamber present
Presence of insulator
Vent present
Presence of a chimney
Presence of a "skirt" around the stove
Absence of a "skirt" around the stove
Absence of a chimney
Absence of vent
Absence of insulator
Combustion chamber absent
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
The better the stove design, the less fuel it can need depending on the size.However, improved stoves are designed generally such that there is the minimisation of fuel.
The presence of a chimney and windows improves aertion in the cooking zone of the stove such that combustion is improved and less smoke is produced.
Though most commonly used, the three stone fire side is not a good cooking stove because of incomplete combustion of fuel thus increasing indoor air pollution levels.
Time delay (rounds): 0
In step of the course: 9
Print...
Close


Effect of the variable "Fuel" -> on the variable "Affordabilty"
Table function:
Description of the function:
Extremely dry fuel (MC less than 5%)
Dry fuel (MC b/n 5% - 10%)
Less wet fuel (MC b/n 10% - 20%)
Wet fuel (MC b/n 20% - 30%)
Extremely wet fuel (MC greater than 30%)
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Because of the diminishing and non renewable tendencies of fossil fuel products, the prices of Gas and Kerosene keep skyroskating.
This then affects the fuel market such that there is a shift from Gas to Biomass fuel which is less expensive.
Because of the pressure on woodfuel consumption, this has lead to increase in prices too and unsustainable means of exploitation.
The local community now turns to exploit other biomass sources which are easy to get or are cheaper.
Time delay (rounds):
0
In step of the course:
1
Print...
Close

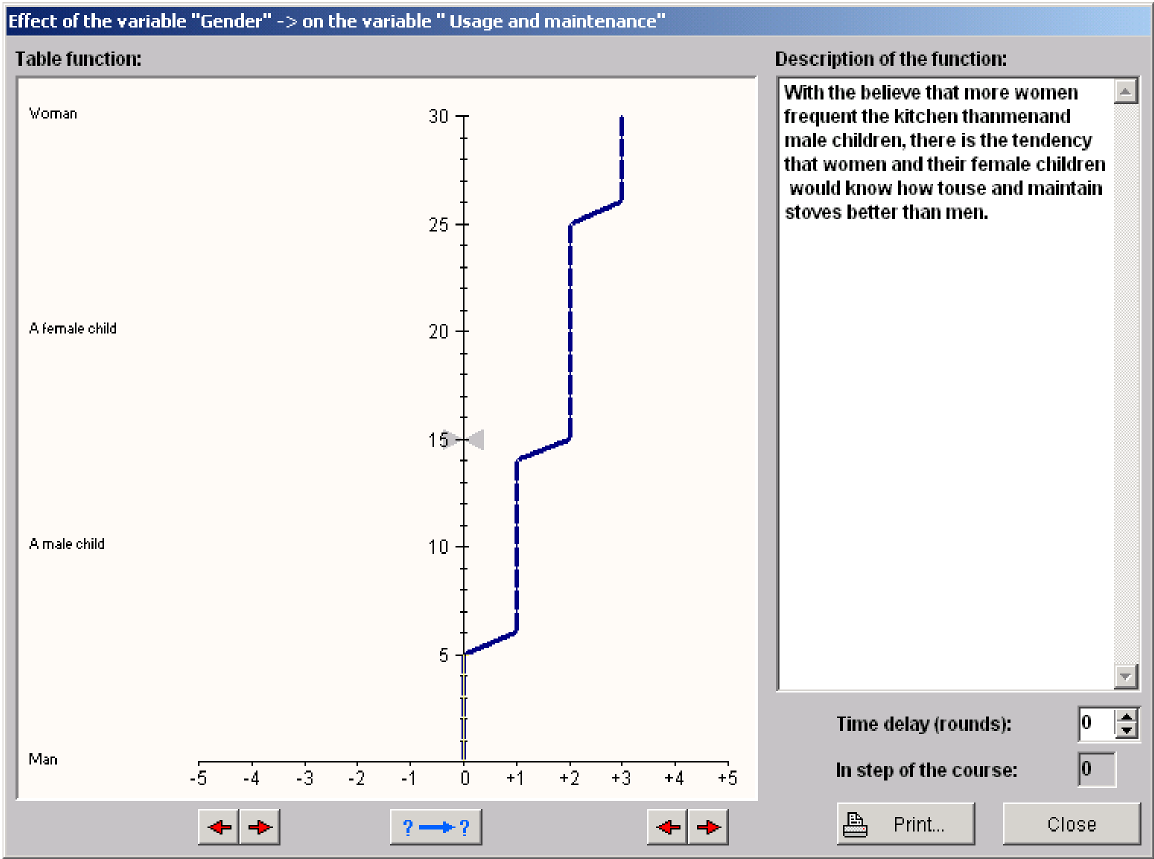

Effect of the variable "Gender" -> on the variable "Fuel"
Table function:
Description of the function:
Woman
A female child
A male child
Man
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Time delay (rounds):
0
In step of the course:
5
Print...
Close

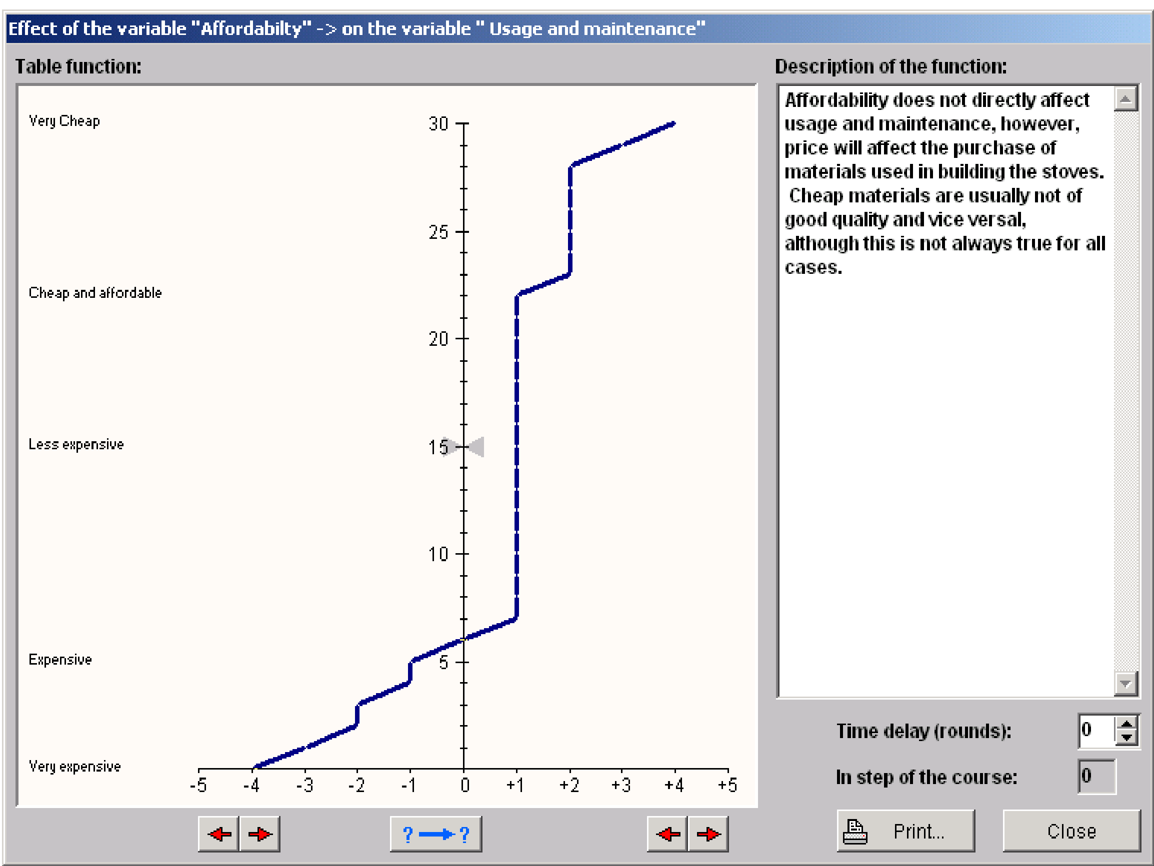


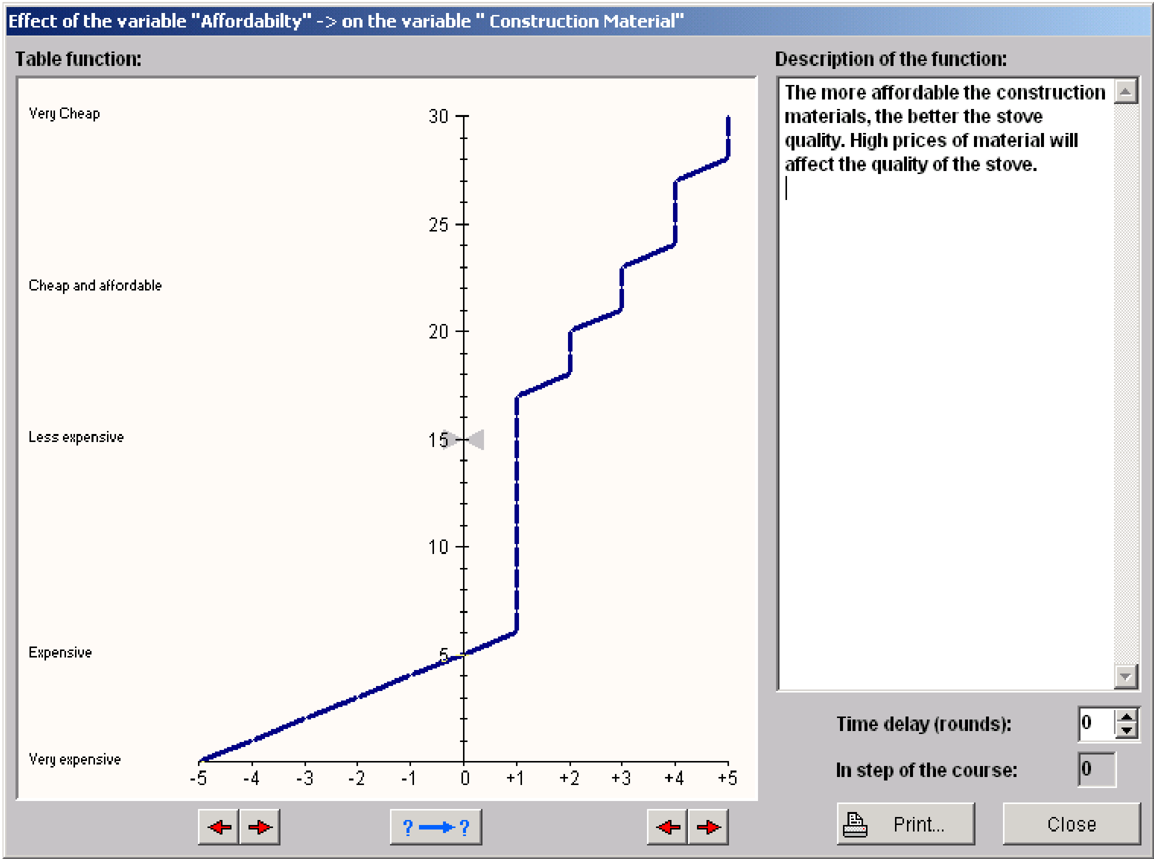
Effect of the variable "Fuel" -> on the variable "Combustion and efficiency"
Table function:
Extremely dry fuel (MC less than 5%)
Dry fuel (MC b/n 5% - 10%)
Less wet fuel (MC b/n 10% - 20%)
Wet fuel (MC b/n 20% - 30%)
Extremely wet fuel (MC greater than 30%)
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
Fossil fuel may have a higher combustion efficiency as compared to biomass fuel.
However, biomass combustion efficiency will depend on a whole lot of factors like moisture content, fuel size, stove design etc.
Time delay (rounds): 0
In step of the course: 8
Print...
Close

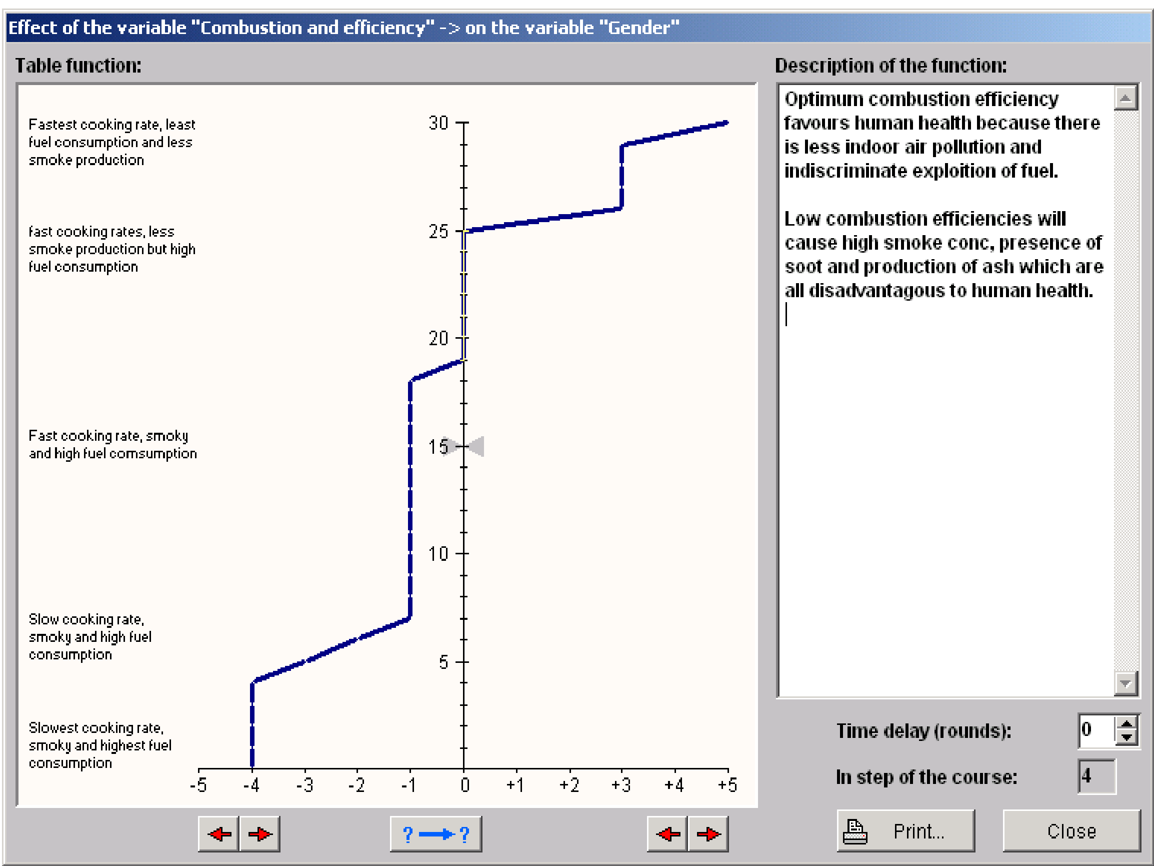


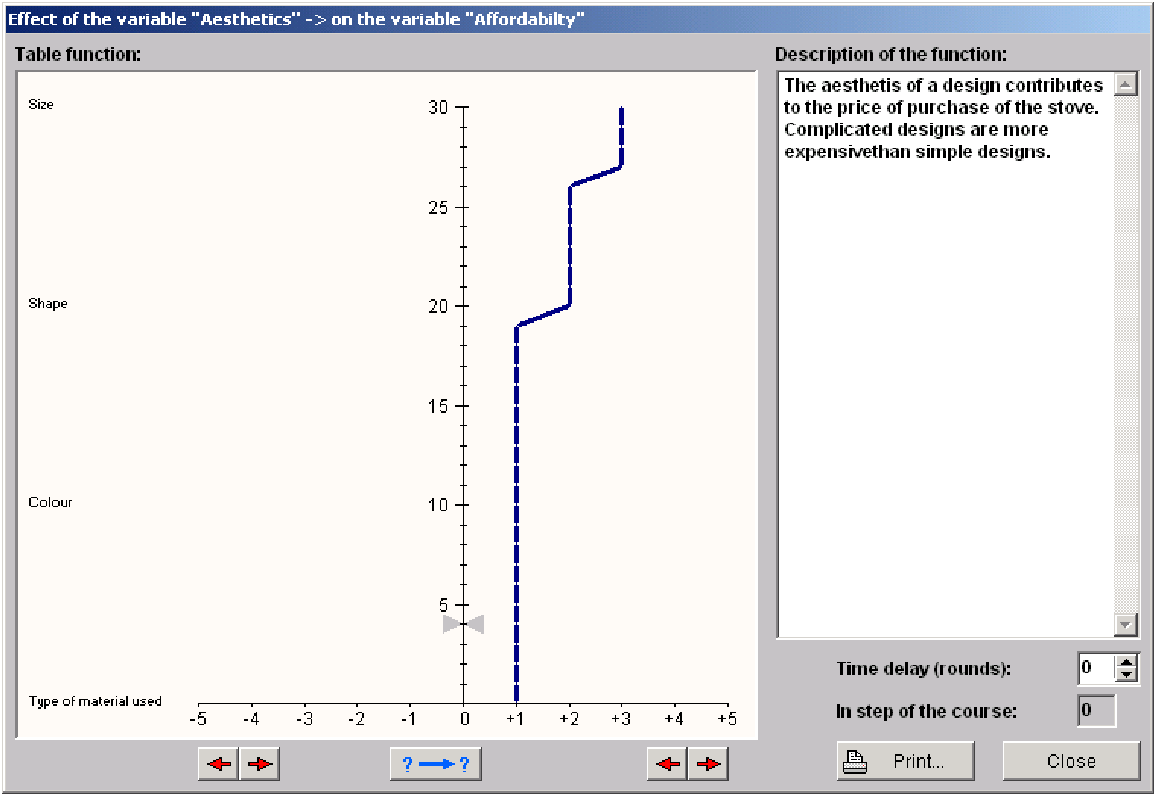
Effect of the variable "Fuel" -> on the variable "Affordabilty"
Table function:
Extremely dry fuel (MC less than 5%)
Dry fuel (MC b/n 5% - 10%)
Less wet fuel (MC b/n 10% - 20%)
Wet fuel (MC b/n 20% - 30%)
Extremely wet fuel (MC greater than 30%)
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
Because of the diminishing and non renewable tendencies of fossil fuel products, the prices of Gas and Kerosene keep skyroskating.
This then affects the fuel market such that there is a shift from Gas to Biomass fuel which is less expensive.
Because of the pressure on woodfuel consumption, this has lead to increase in prices too and unsustainable means of exploitation.
The local community now turns to exploit other biomass sources which are easy to get or are cheaper.
Time delay (rounds): 0
In step of the course: 1
Print...
Close


Effect of the variable "Gender" -> on the variable " Usage and maintenance"
Table function:
Description of the function:
Woman
A female child
A male child
Man
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
With the believe that more women frequent the kitchen thanmenand male children, there is the tendency that women and their female children would know how touse and maintain stoves better than men.
Time delay (rounds):
0
In step of the course:
0
? ?
Print...
Close

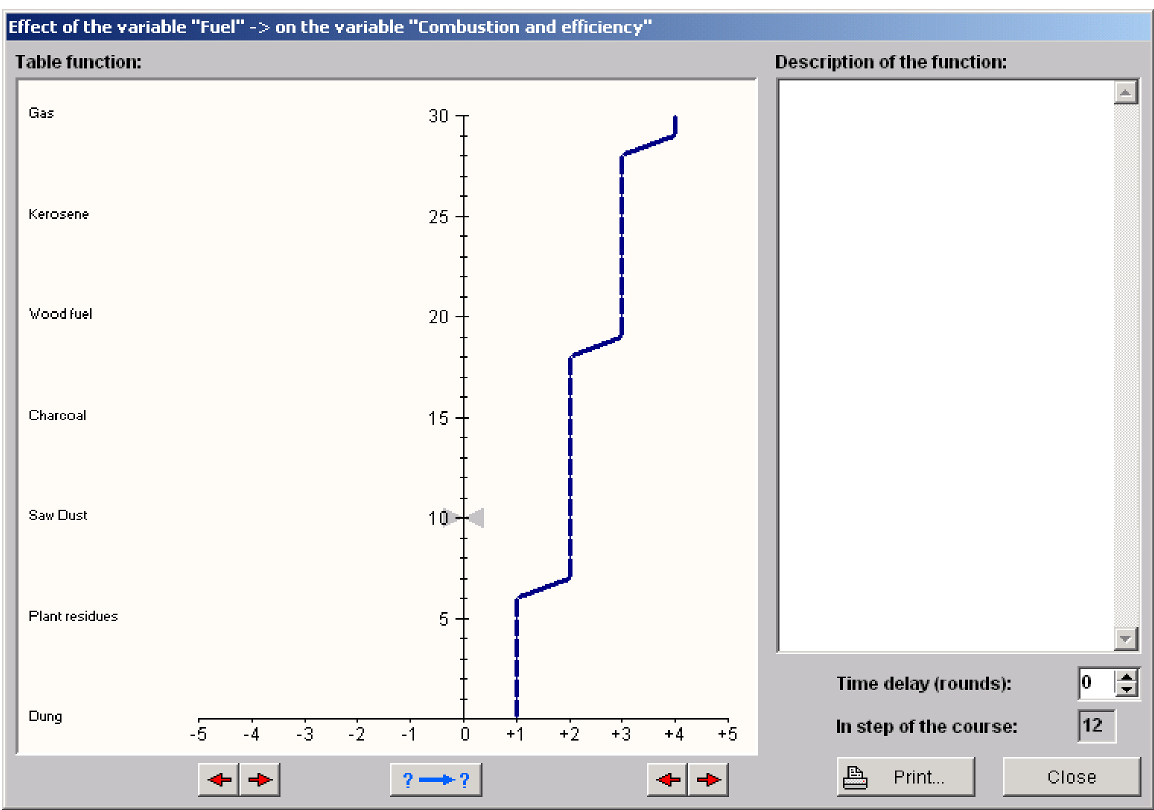

Effect of the variable "Affordabilty" -> on the variable " Usage and maintenance"
Table function:
Description of the function:
Very Cheap
Cheap and affordable
Less expensive
Expensive
Very expensive
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Affordability does not directly affect usage and maintenance, however, price will affect the purchase of materials used in building the stoves. Cheap materials are usually not of good quality and vice versal, although this is not always true for all cases.
Time delay (rounds):
0
In step of the course:
0
? ?
Print...
Close

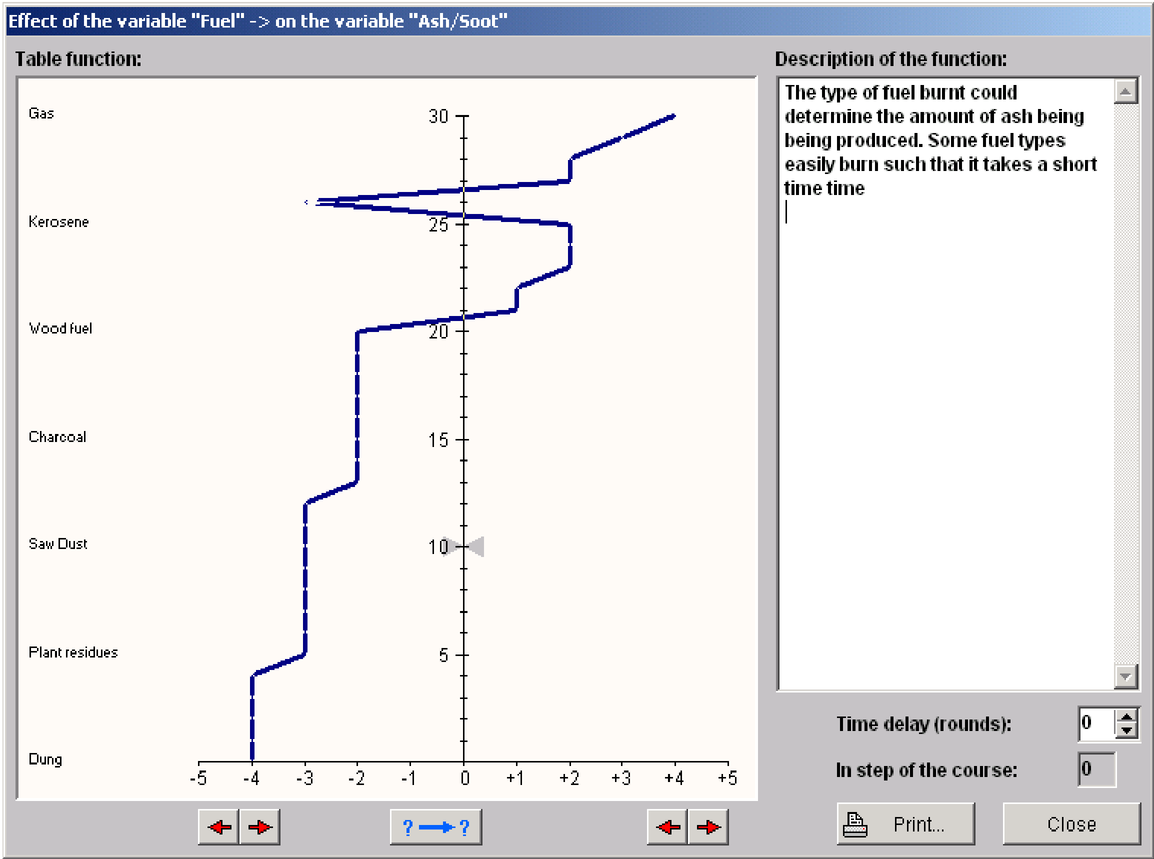

Effect of the variable "Affordabilty" -> on the variable " Construction Material"
Table function:
Description of the function:
Very Cheap
Cheap and affordable
Less expensive
Expensive
Very expensive
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
The more affordable the construction materials, the better the stove quality. High prices of material will affect the quality of the stove.
Time delay (rounds): 0
In step of the course: 0
Print...
Close

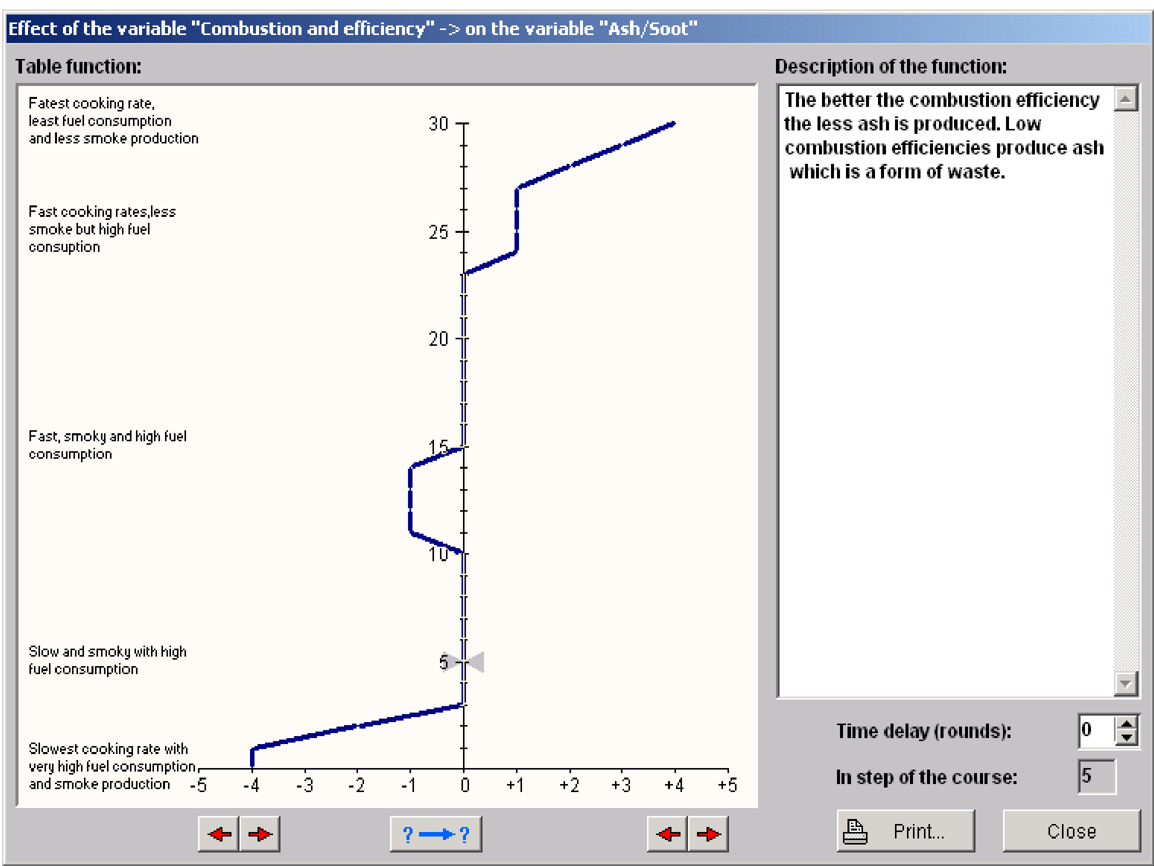

Effect of the variable "Combustion and efficiency" -> on the variable "Gender"
Table function:
Description of the function:
Fastest cooking rate, least fuel consumption and less smoke production
fast cooking rates, less smoke production but high fuel consumption
Fast cooking rate, smoky and high fuel comsumption
Slow cooking rate, smoky and high fuel consumption
Slowest cooking rate, smoky and highest fuel consumption
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Optimum combustion efficiency favours human health because there is less indoor air pollution and indiscriminate exploition of fuel.
Low combustion efficiencies will cause high smoke conc, presence of soot and production of ash which are all disadvantagous to human health.
Time delay (rounds): 0
In step of the course: 4
Print...
Close

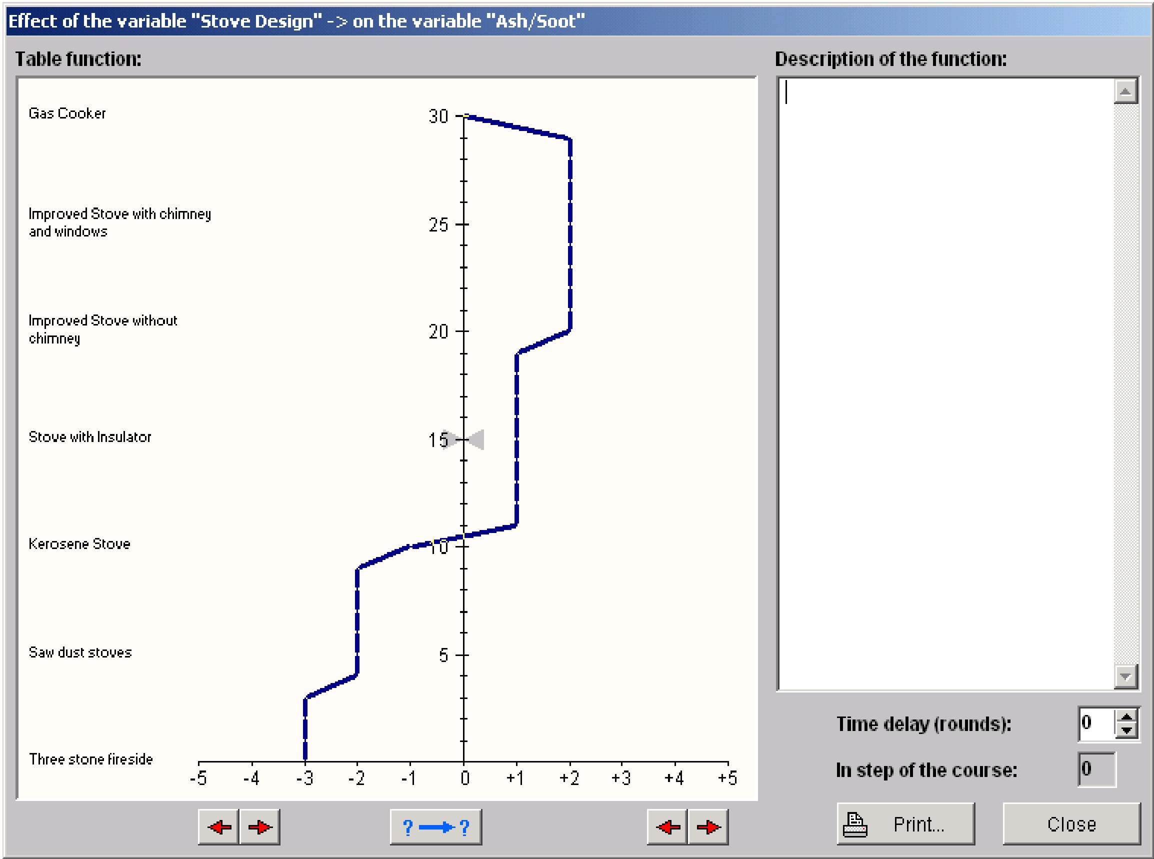


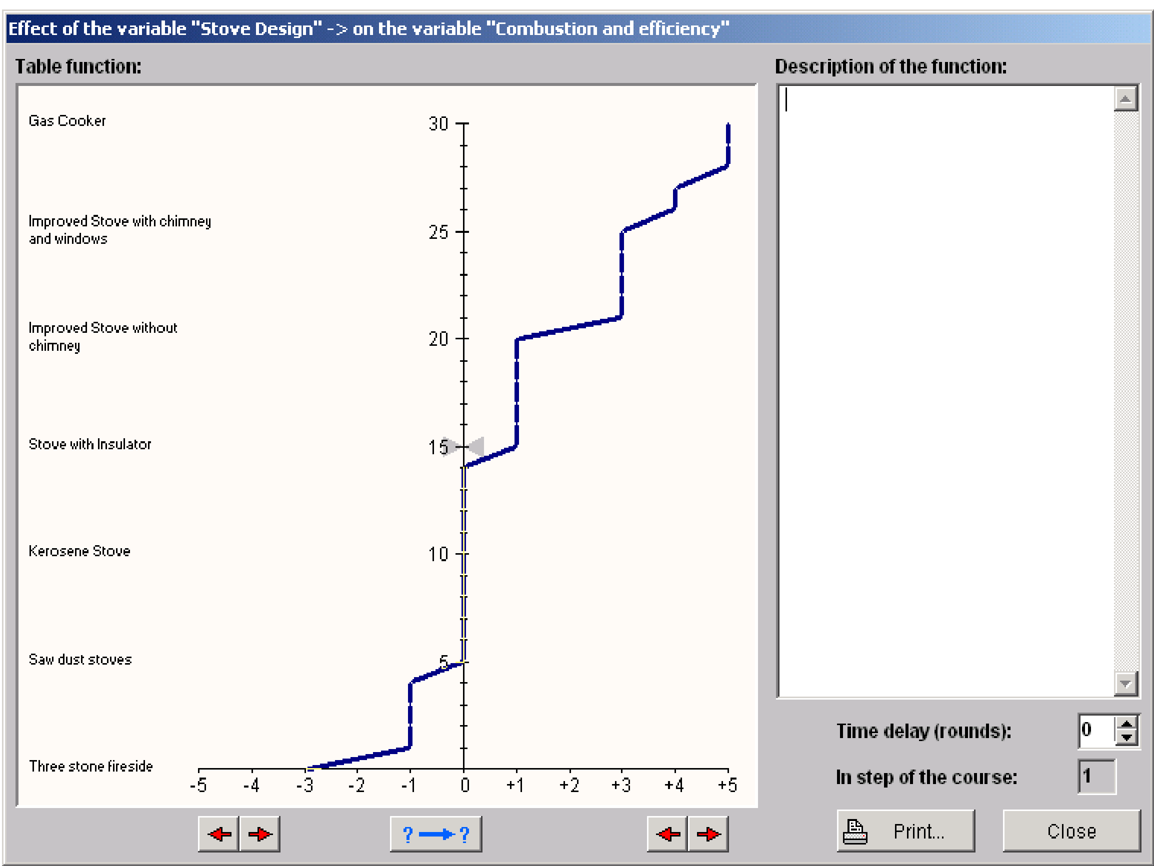
Partial Scenario 2: Combustion Efficiency

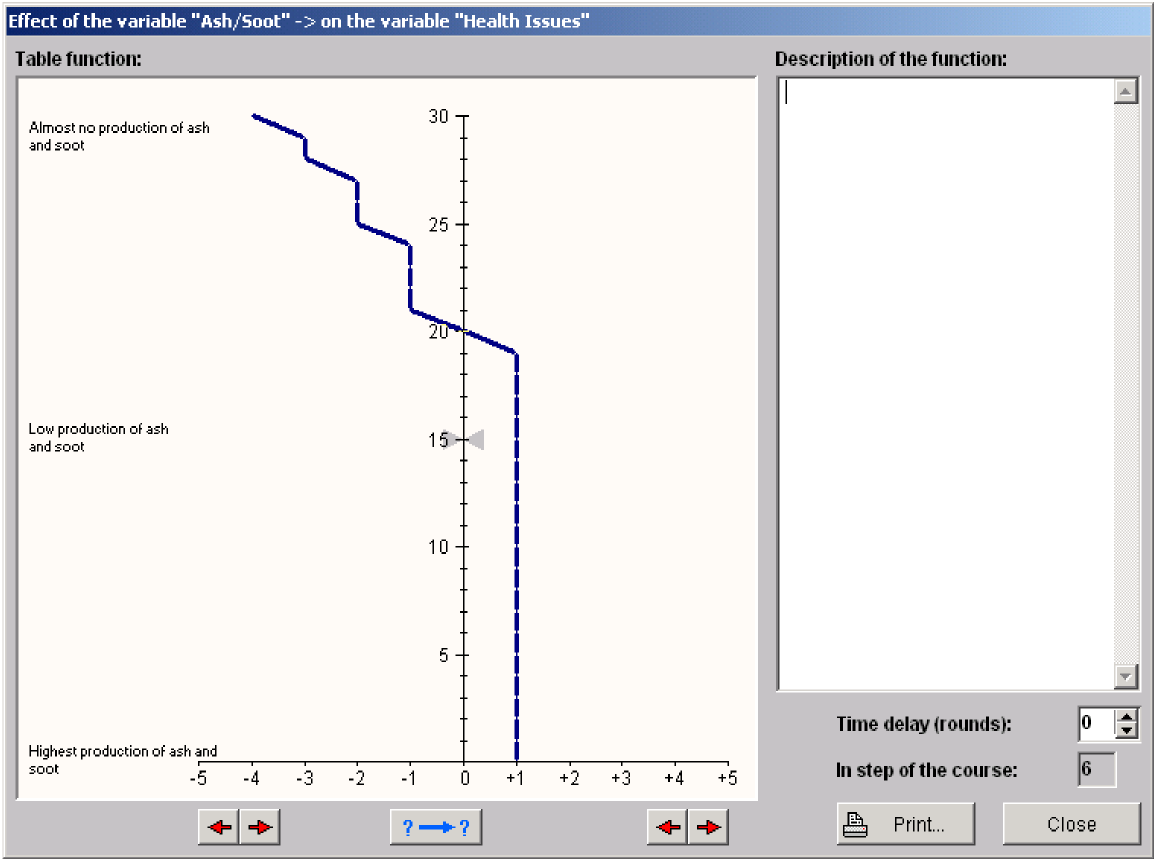


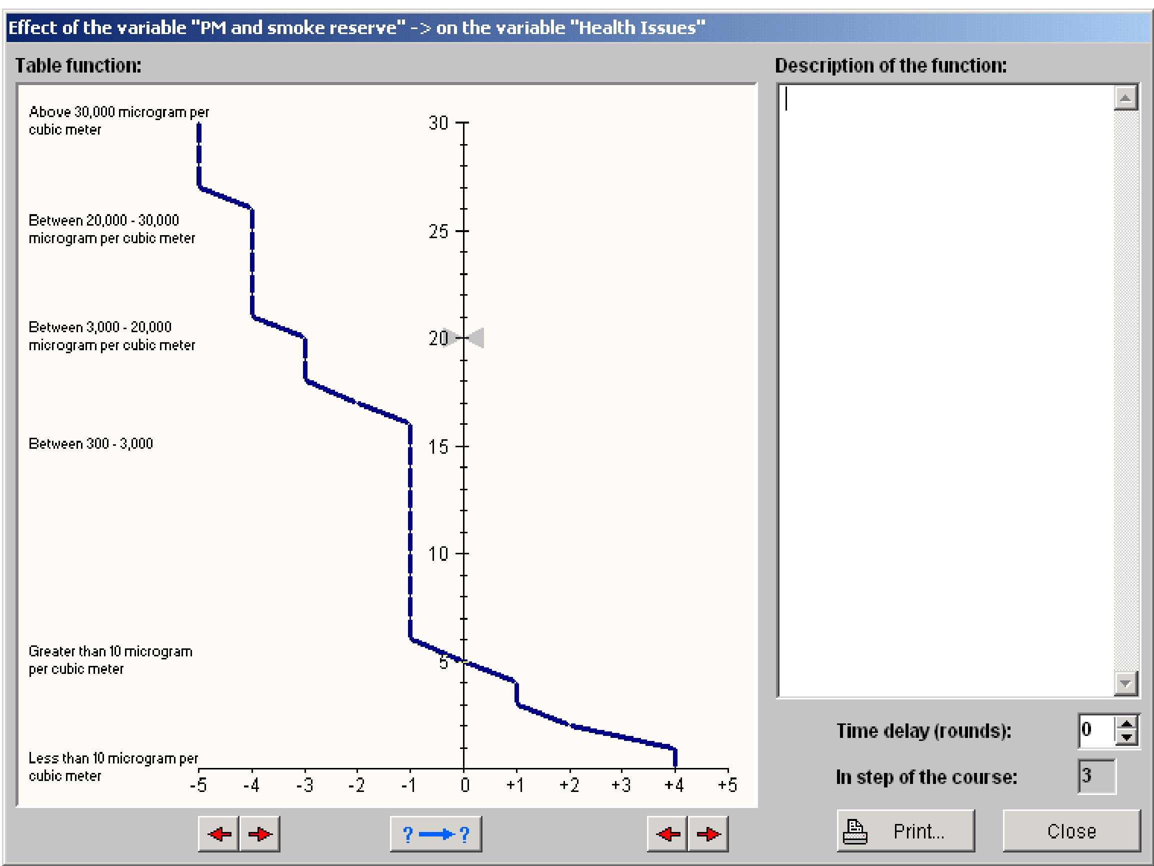

Effect of the variable "Fuel" -> on the variable "Ash/Soot"
Table function:
Gas
Kerosene
Wood fuel
Charcoal
Saw Dust
Plant residues
Dung
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
The type of fuel burnt could determine the amount of ash being being produced. Some fuel types easily burn such that it takes a short time time
Time delay (rounds): 0
In step of the course: 0
Print...
Close

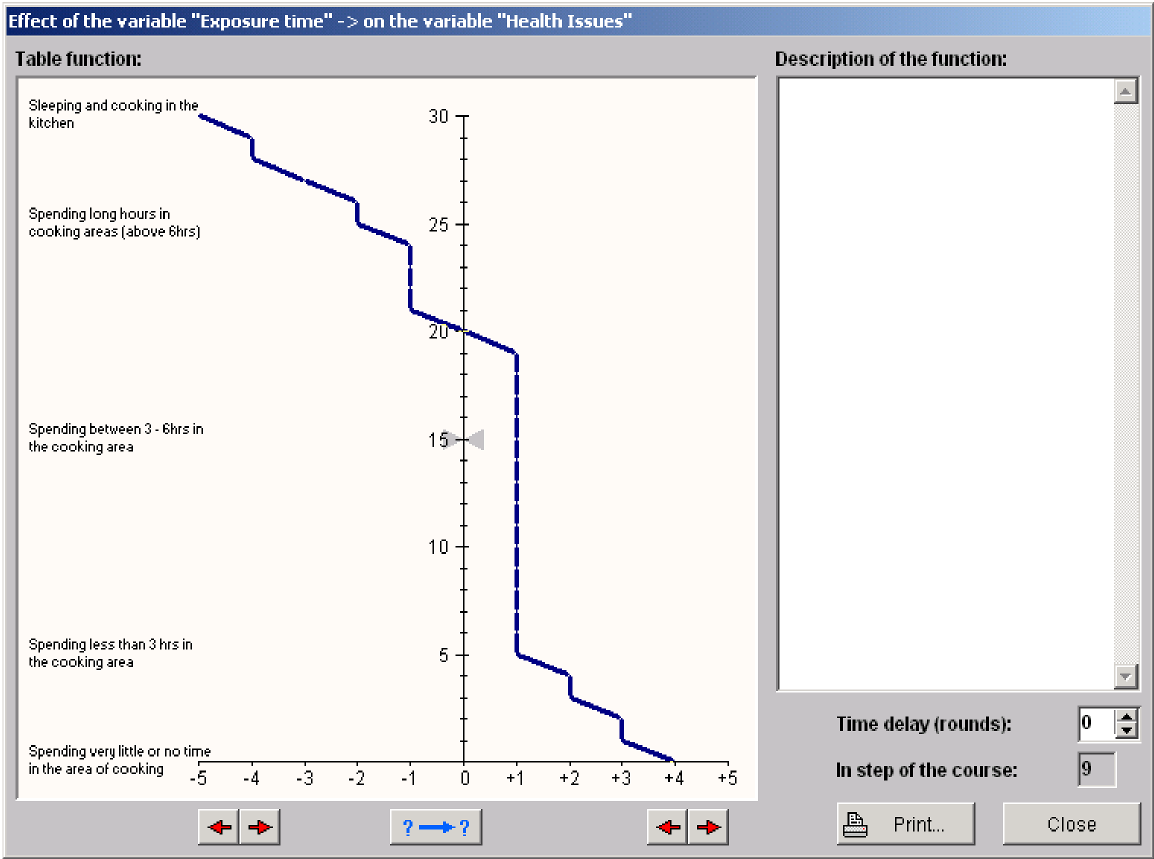

Effect of the variable "Combustion and efficiency" -> on the variable "Ash/Soot"
Table function:
Fatest cooking rate, least fuel consumption and less smoke production
Fast cooking rates,less smoke but high fuel consuption
Fast, smoky and high fuel consumption
Slow and smoky with high fuel consumption
Slowest cooking rate with very high fuel consumption and smoke production
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
The better the combustion efficiency the less ash is produced. Low combustion efficiencies produce ash which is a form of waste.
Time delay (rounds): 0
In step of the course: 5
Print...
Close

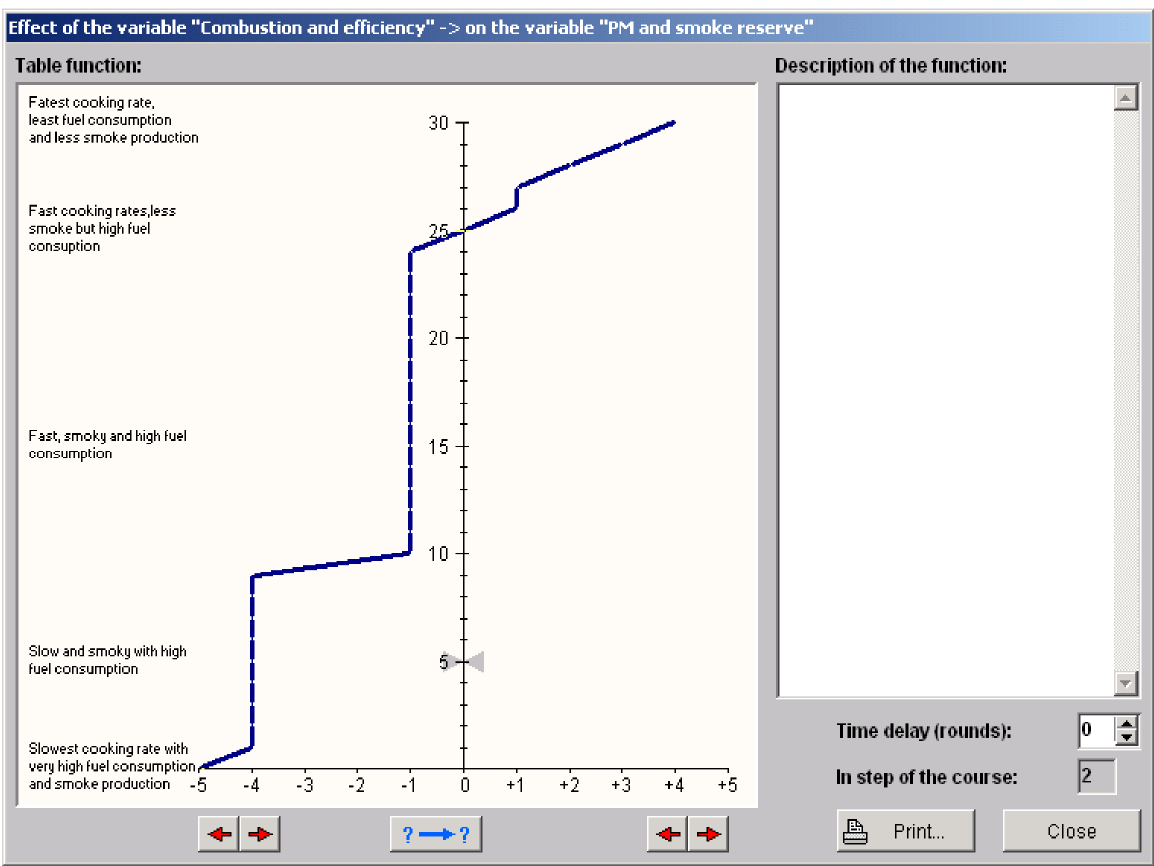

Effect of the variable "Stove Design" -> on the variable "Ash/Soot"
Table function:
Description of the function:
Gas Cooker
Improved Stove with chimney and windows
Improved Stove without chimney
Stove with Insulator
Kerosene Stove
Saw dust stoves
Three stone fireside
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Time delay (rounds):
0
In step of the course:
0
Print...
Close

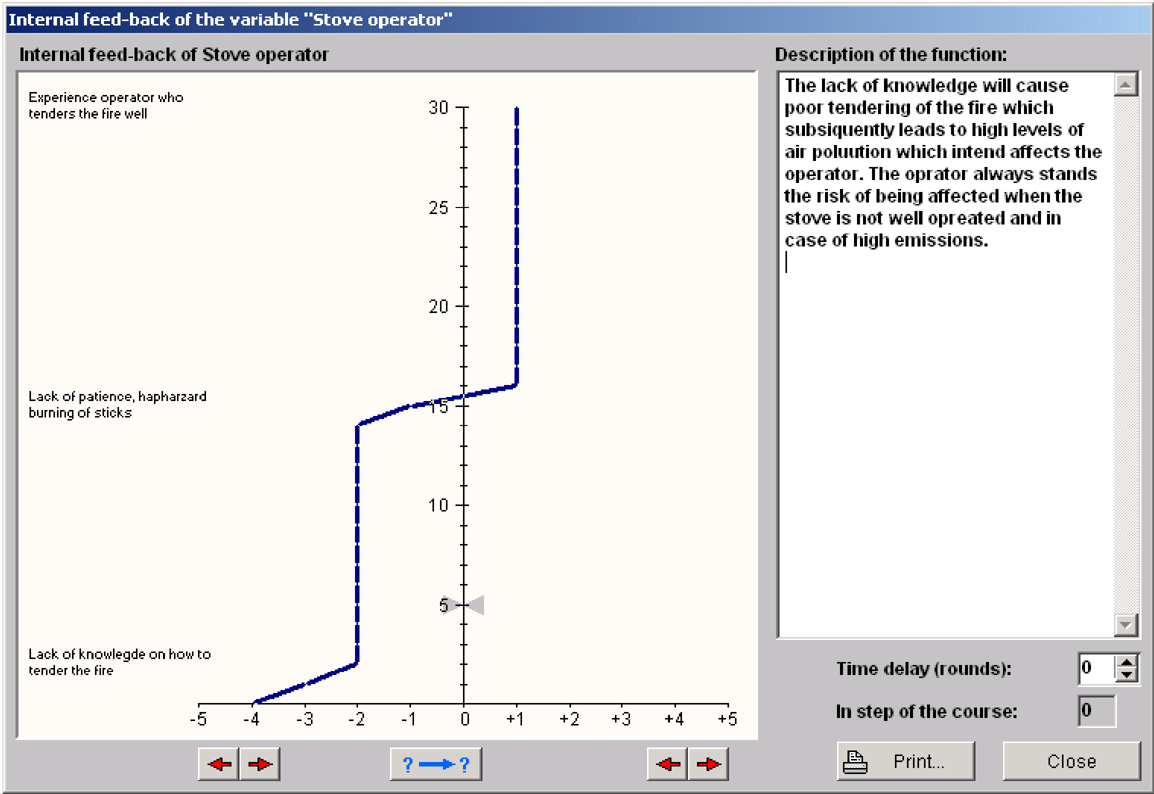

Effect of the variable "Stove Design" -> on the variable "Combustion and efficiency"
Table function:
Description of the function:
Gas Cooker
Improved Stove with chimney and windows
Improved Stove without chimney
Stove with Insulator
Kerosene Stove
Saw dust stoves
Three stone fireside
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Time delay (rounds):
0
In step of the course:
1
Print...
Close


Effect of the variable "Ash/Soot" -> on the variable "Health Issues"
Table function:
Description of the function:
Almost no production of ash and soot
Low production of ash and soot
Highest production of ash and soot
30
25
20
15
10
5
-5
-4
-3
-2
-1
0
+1
+2
+3
+4
+5
Time delay (rounds):
0
In step of the course:
6
Print...
Close

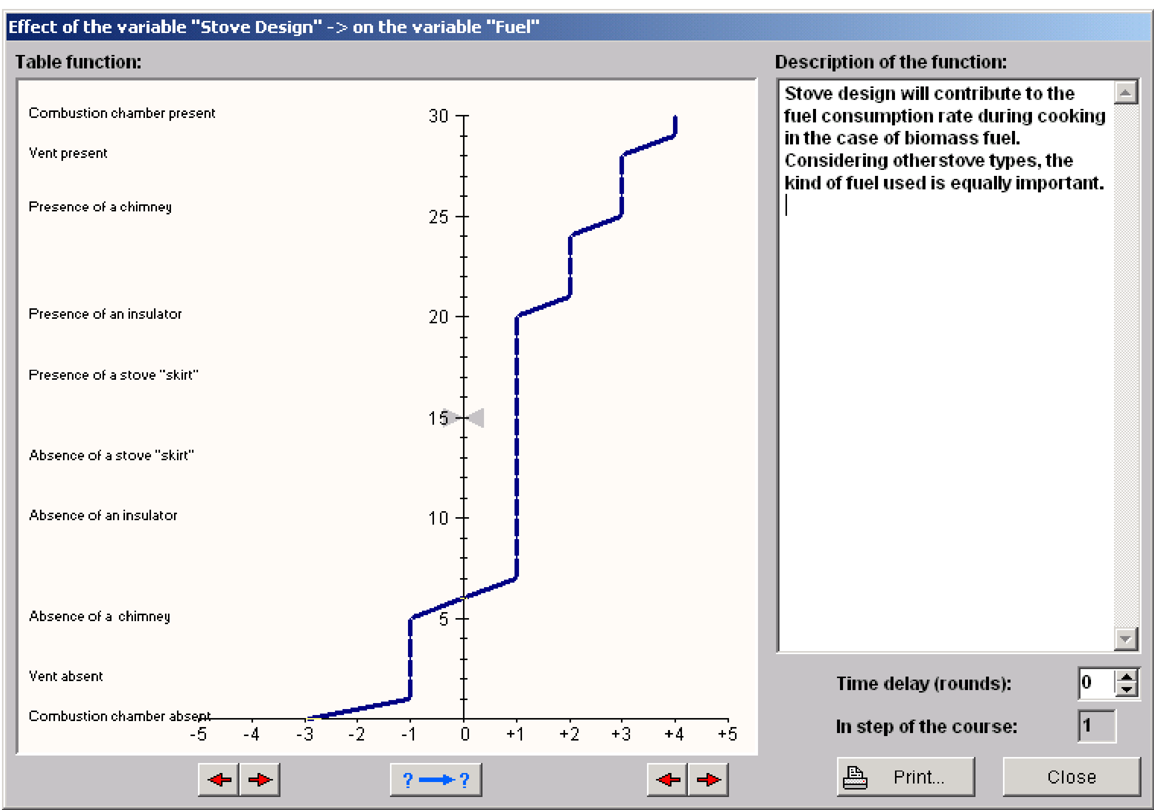

Effect of the variable "PM and smoke reserve" -> on the variable "Health Issues"
Table function:
Description of the function:
Above 30,000 microgram per cubic meter
Between 20,000 - 30,000 microgram per cubic meter
Between 3,000 - 20,000 microgram per cubic meter
Between 300 - 3,000
Greater than 10 microgram per cubic meter
Less than 10 microgram per cubic meter
30
25
20
15
10
5
-5
-4
-3
-2
-1
0
+1
+2
+3
+4
+5
Time delay (rounds):
0
In step of the course:
3
Print...
Close

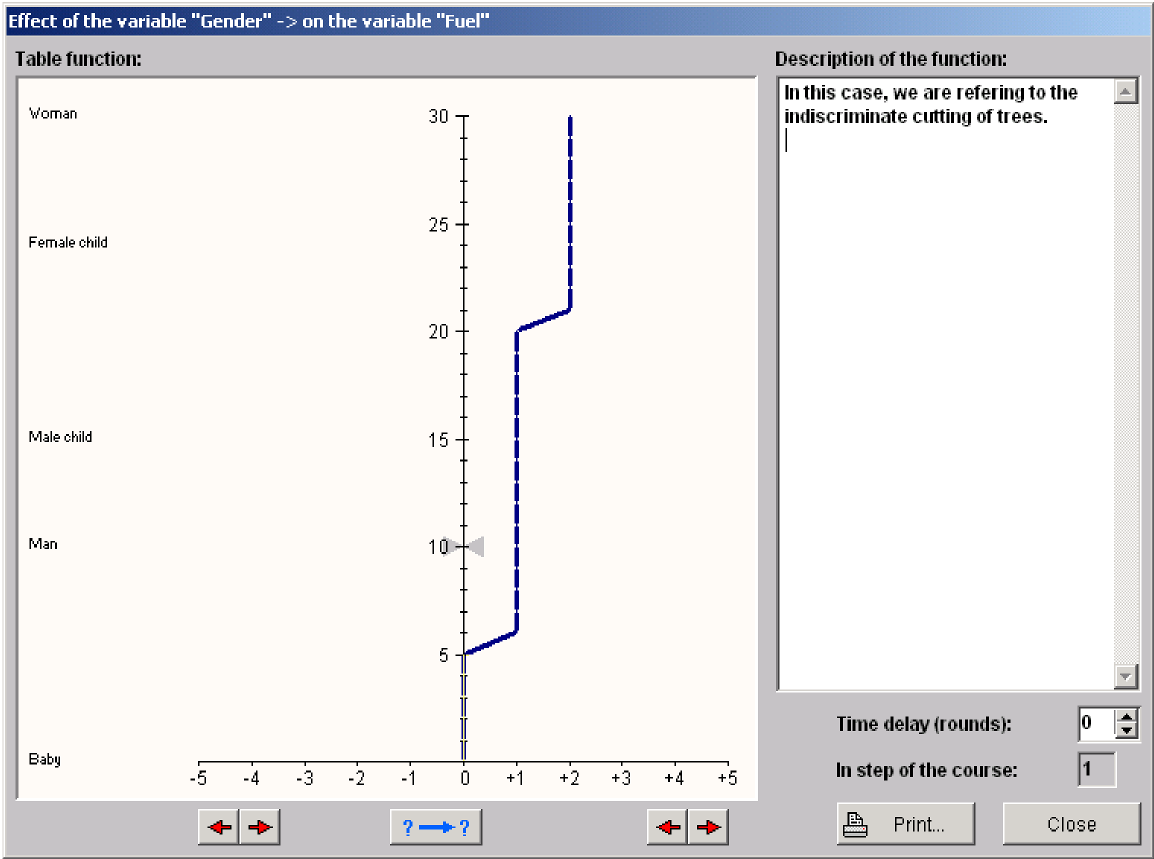

Effect of the variable "Exposure time" -> on the variable "Health Issues"
Table function:
Description of the function:
Sleeping and cooking in the kitchen
Spending long hours in cooking areas (above 6hrs)
Spending between 3 - 6hrs in the cooking area
Spending less than 3 hrs in the cooking area
Spending very little or no time in the area of cooking
30
25
20
15
10
5
-5
-4
-3
-2
-1
0
+1
+2
+3
+4
+5
Time delay (rounds):
0
In step of the course:
9
Print...
Close

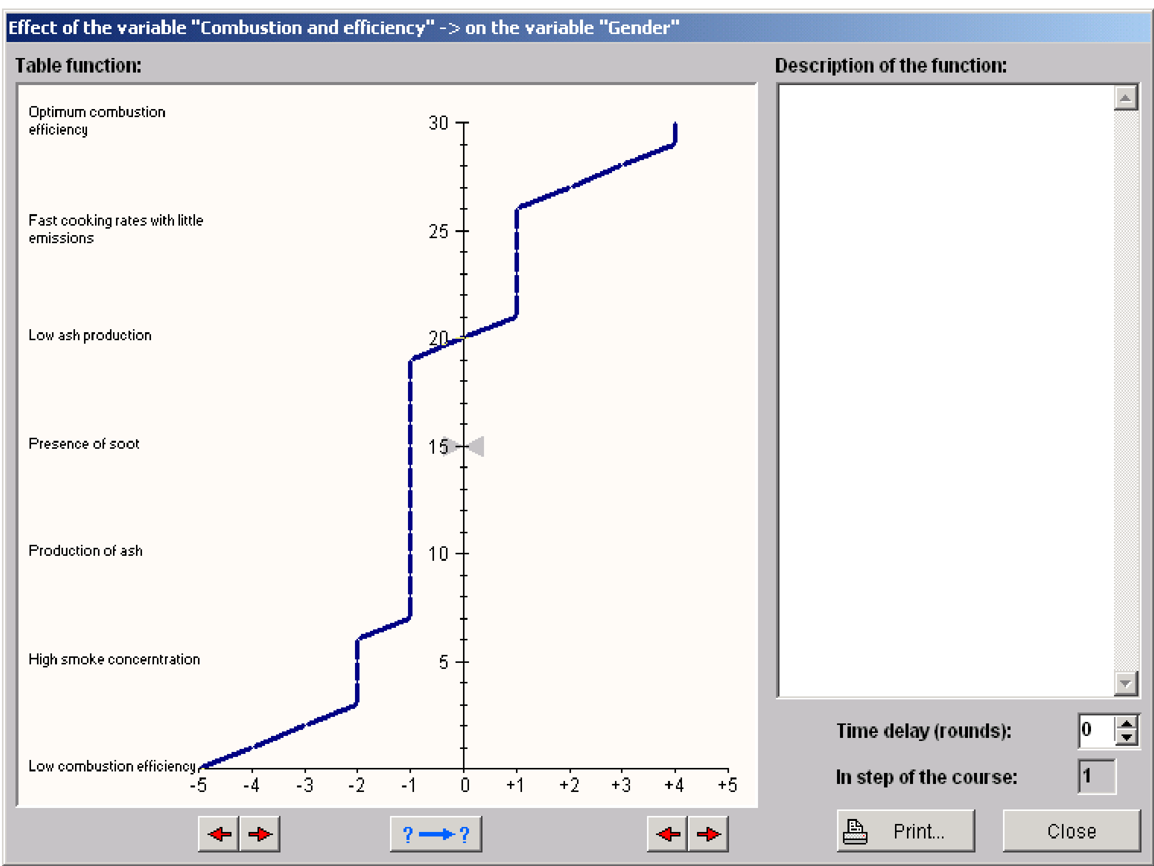

Effect of the variable "Combustion and efficiency" -> on the variable "PM and smoke reserve"
Table function:
Description of the function:
Fatest cooking rate, least fuel consumption and less smoke production
Fast cooking rates,less smoke but high fuel consuption
Fast, smoky and high fuel consumption
Slow and smoky with high fuel consumption
Slowest cooking rate with very high fuel consumption and smoke production
30
25
20
15
10
5
-5
-4
-3
-2
-1
0
+1
+2
+3
+4
+5
Time delay (rounds):
0
In step of the course:
2
Print...
Close

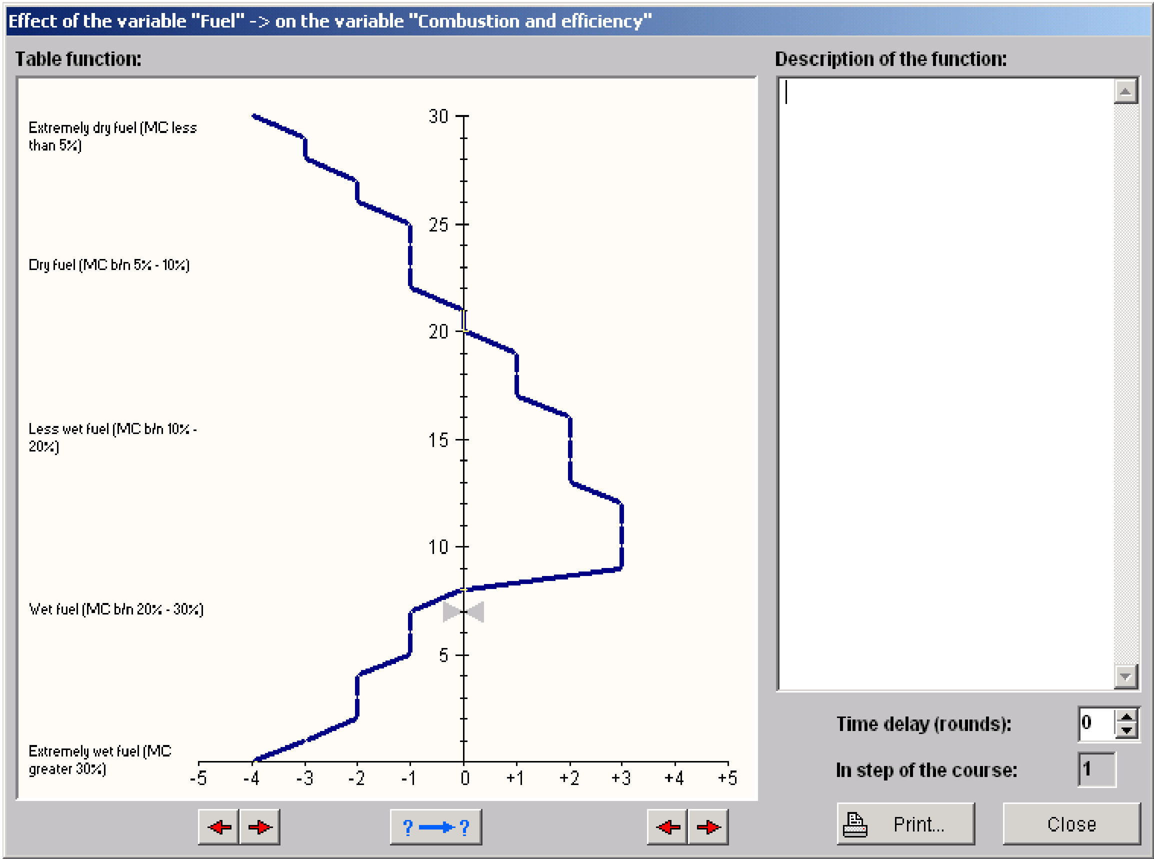


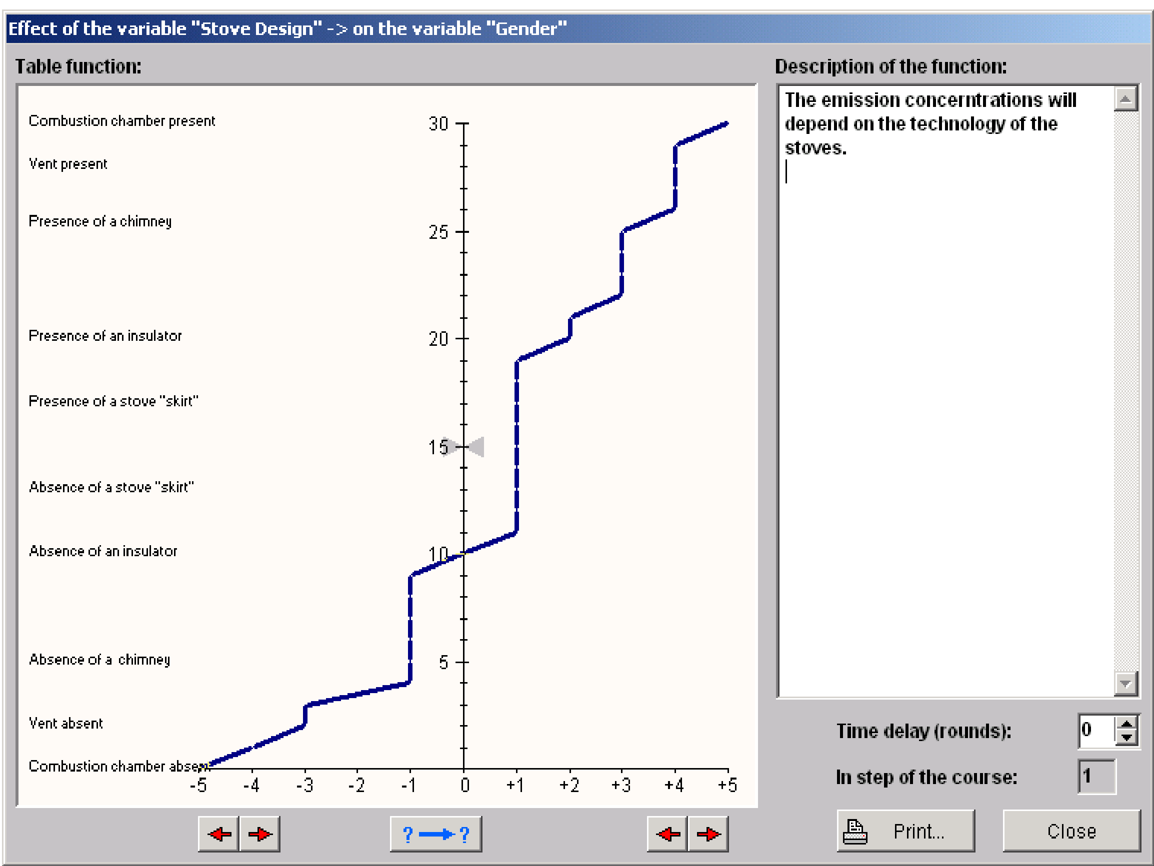
Partial Scenario 3: Health Issues

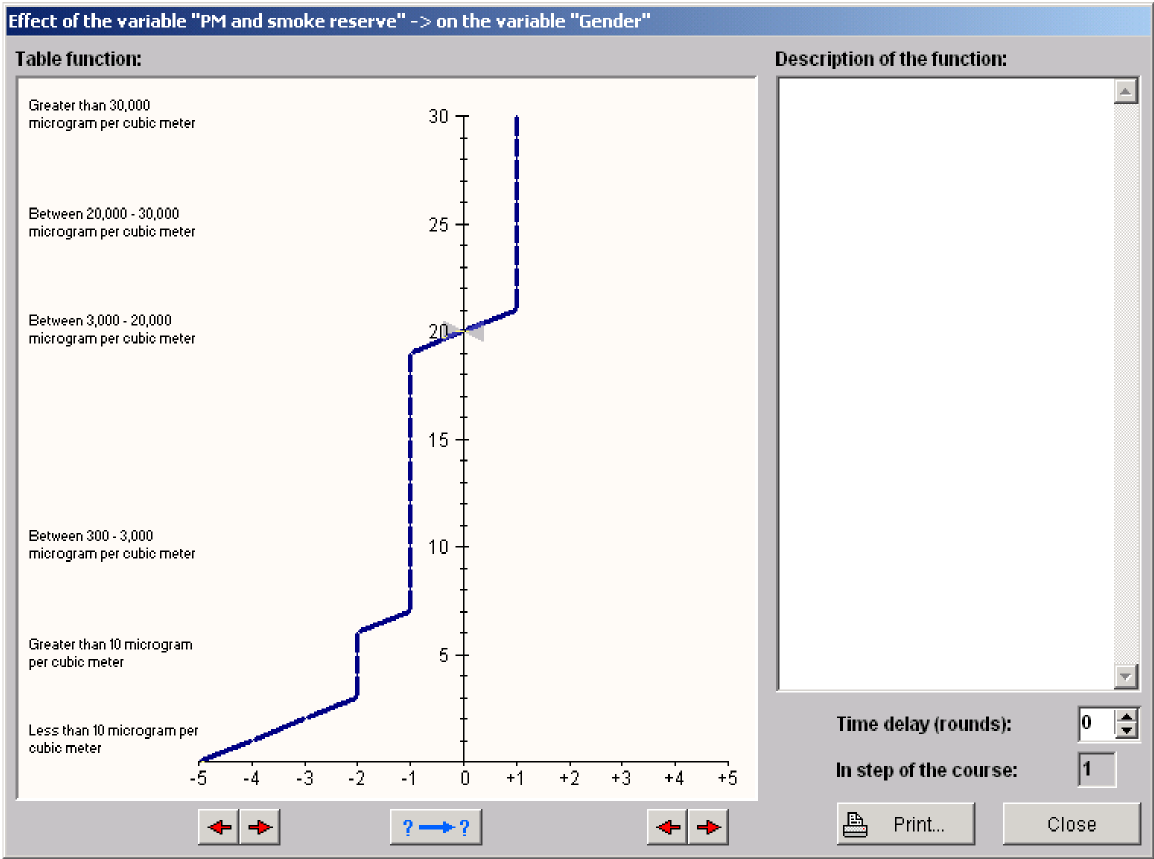


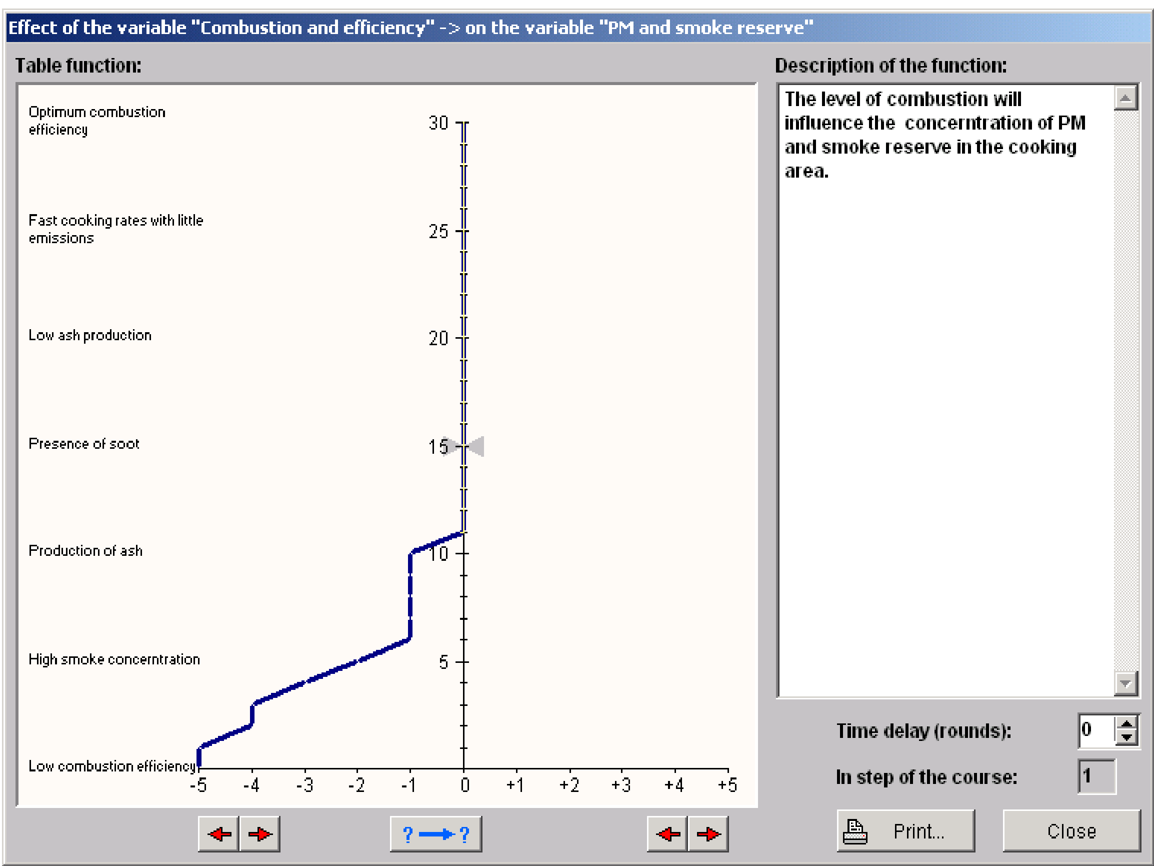

Effect of the variable "Gender" -> on the variable "Fuel"
Table function:
Woman
Female child
Male child
Man
Baby
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
In this case, we are refering to the indiscriminate cutting of trees.
Time delay (rounds):
0
In step of the course:
1
Print...
Close

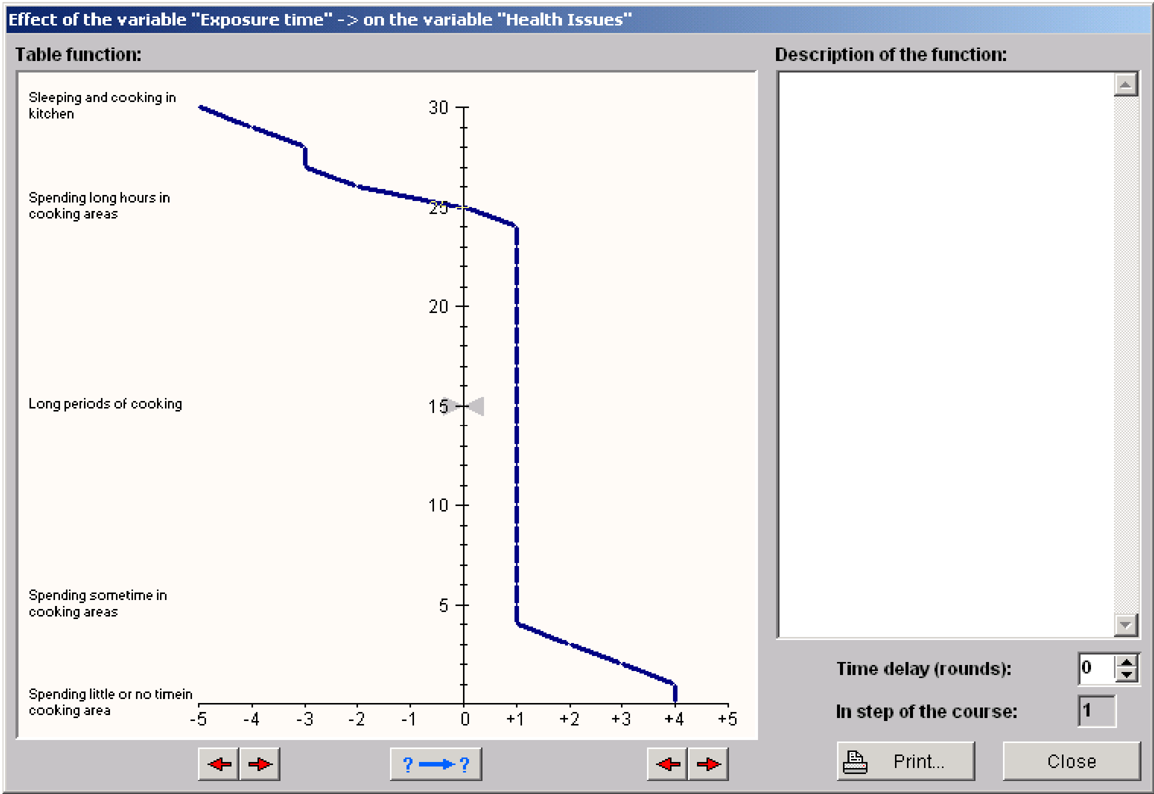

Effect of the variable "Combustion and efficiency" -> on the variable "Gender"
Table function:
Optimum combustion efficiency
Fast cooking rates with little emissions
Low ash production
Presence of soot
Production of ash
High smoke concerntration
Low combustion efficiency
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
Time delay (rounds):
0
In step of the course:
1
Print...
Close


Effect of the variable "Fuel" -> on the variable "Combustion and efficiency"
Table function:
Description of the function:
Extremely dry fuel (MC less than 5%)
Dry fuel (MC b/n 5% - 10%)
Less wet fuel (MC b/n 10% - 20%)
Wet fuel (MC b/n 20% - 30%)
Extremely wet fuel (MC greater 30%)
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Time delay (rounds):
0
In step of the course:
1
Print...
Close

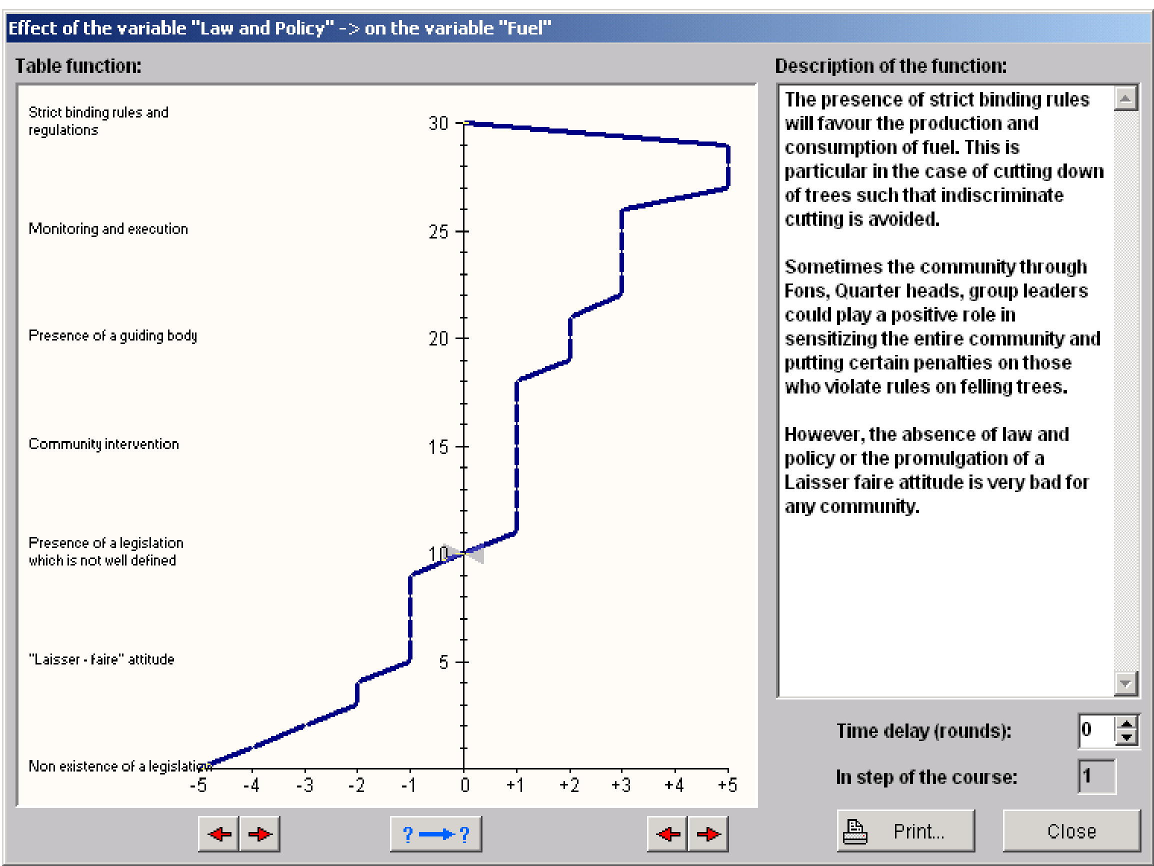

Effect of the variable "Stove Design" -> on the variable "Gender"
Table function:
Description of the function:
The emission concerntrations will depend on the technology of the stoves.
Combustion chamber present
Vent present
Presence of a chimney
Presence of an insulator
Presence of a stove "skirt"
Absence of a stove "skirt"
Absence of an insulator
Absence of a chimney
Vent absent
Combustion chamber absent
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Time delay (rounds):
0
In step of the course:
1
Print...
Close

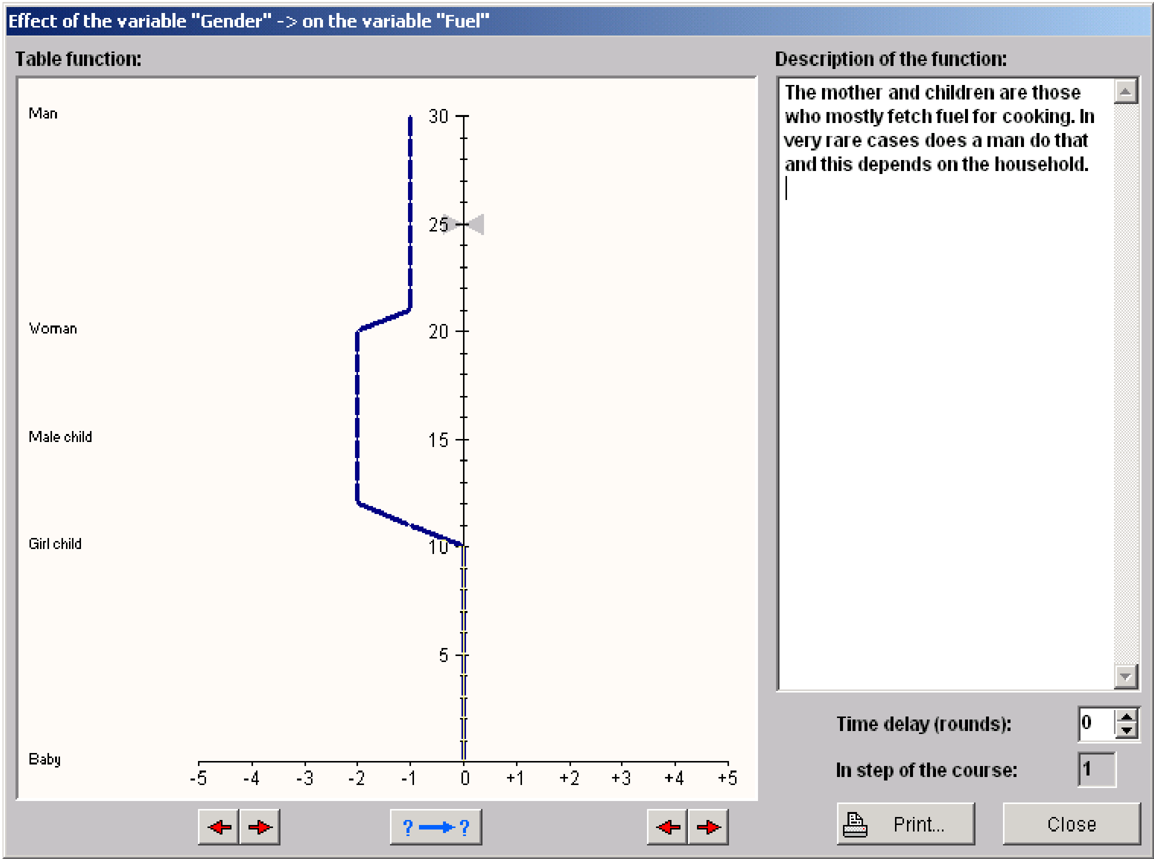

Effect of the variable "PM and smoke reserve" -> on the variable "Gender"
Table function:
Greater than 30,000 microgram per cubic meter
Between 20,000 - 30,000 microgram per cubic meter
Between 3,000 - 20,000 microgram per cubic meter
Between 300 - 3,000 microgram per cubic meter
Greater than 10 microgram per cubic meter
Less than 10 microgram per cubic meter
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
Time delay (rounds): 0
In step of the course: 1
Print...
Close

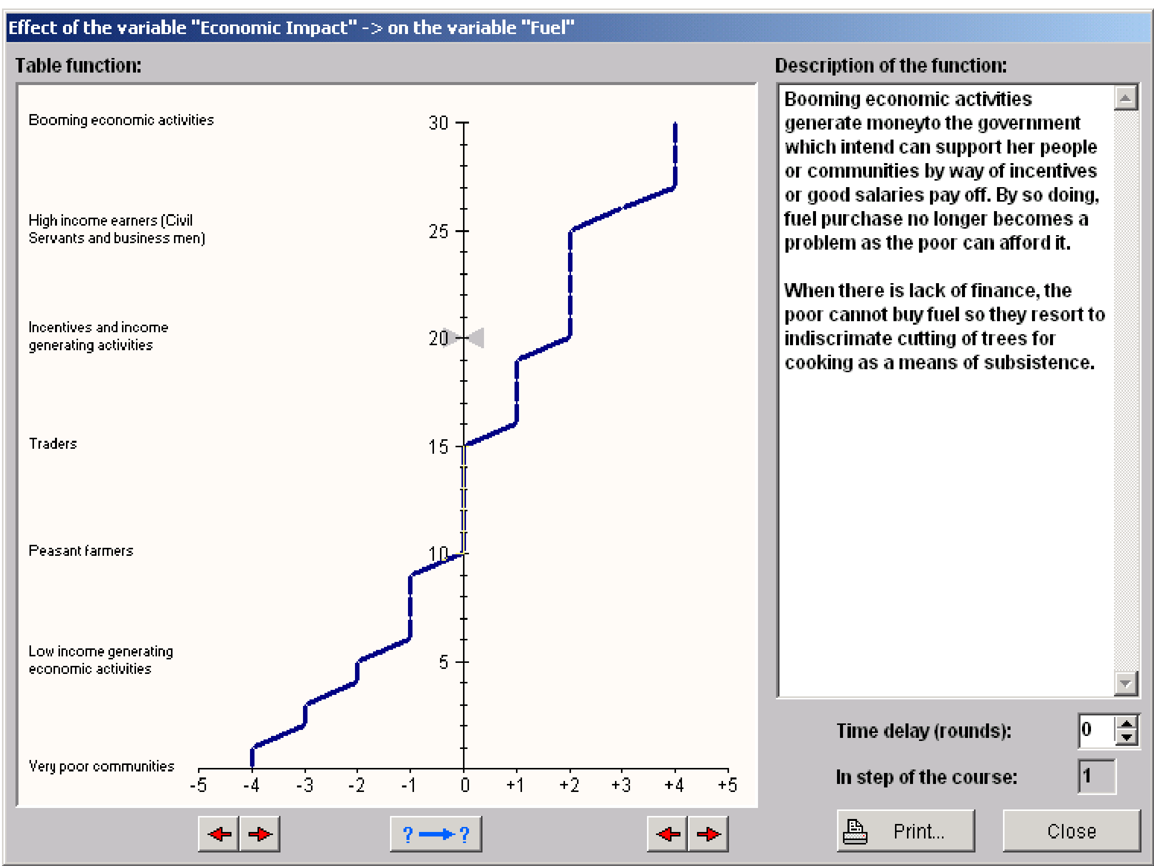

Effect of the variable "Combustion and efficiency" -> on the variable "PM and smoke reserve"
Table function:
Optimum combustion efficiency
Fast cooking rates with little emissions
Low ash production
Presence of soot
Production of ash
High smoke concerntration
Low combustion efficiency
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
The level of combustion will influence the concerntration of PM and smoke reserve in the cooking area.
Time delay (rounds): 0
In step of the course: 1
Print...
Close

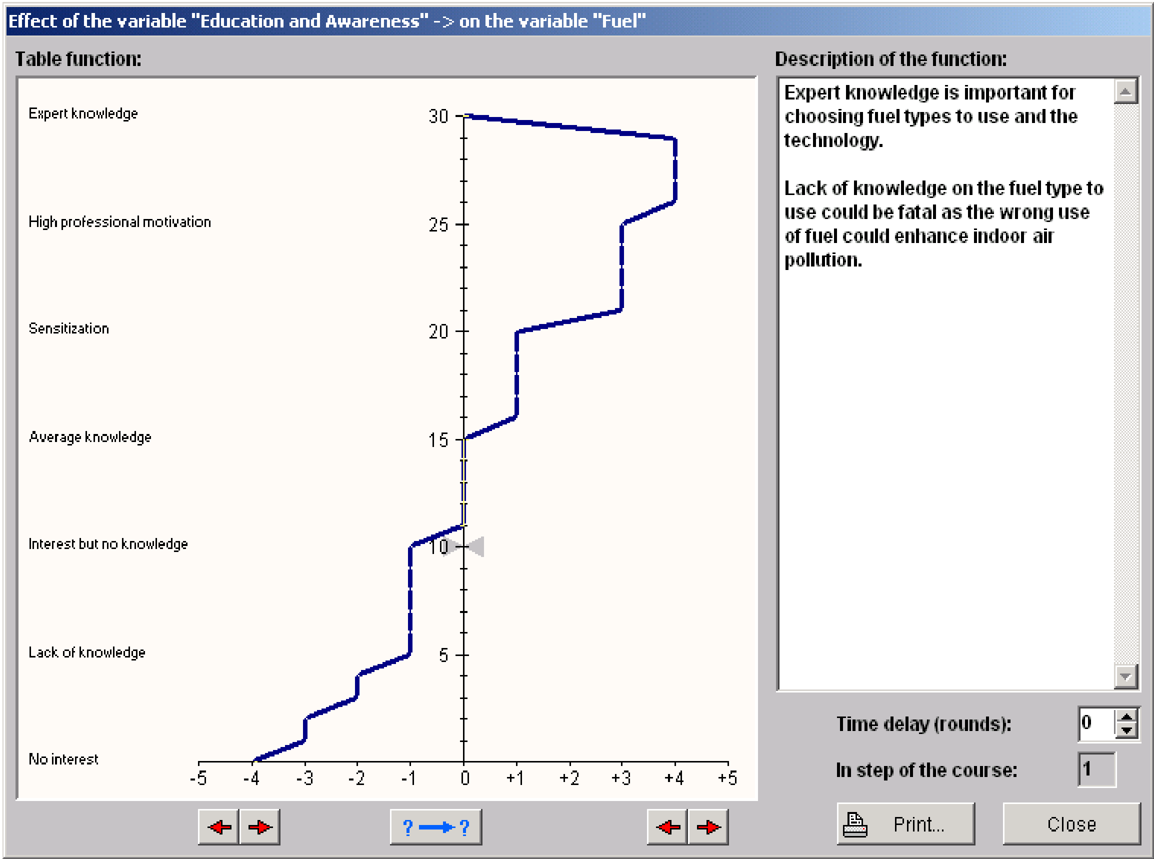


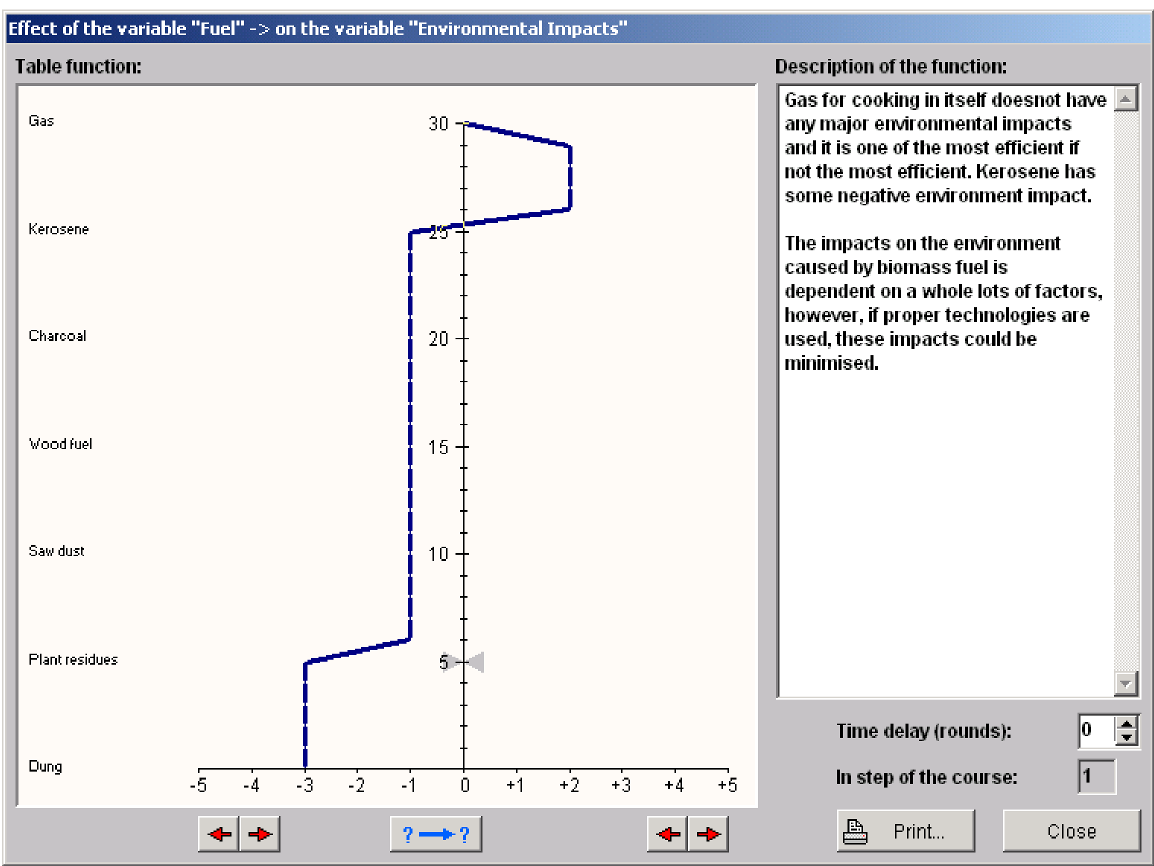
Partial Scenario 4: Economic Aspects

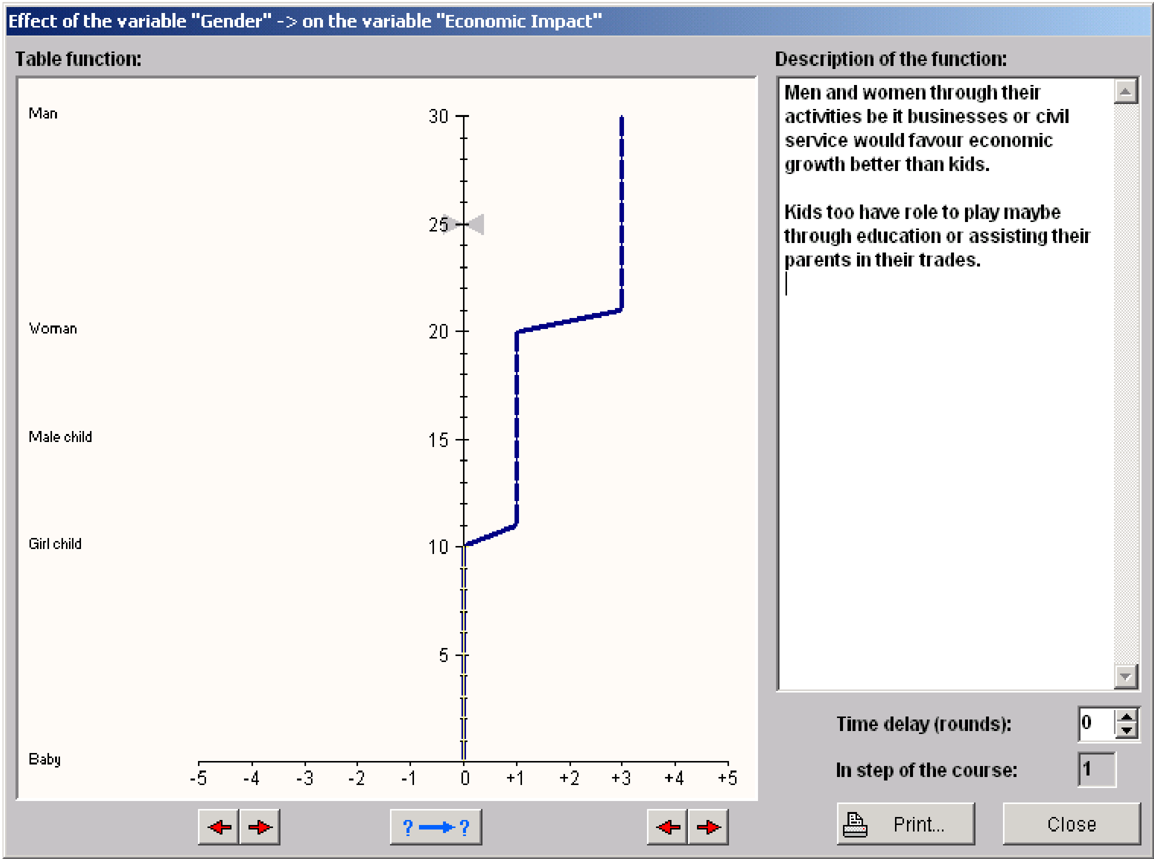


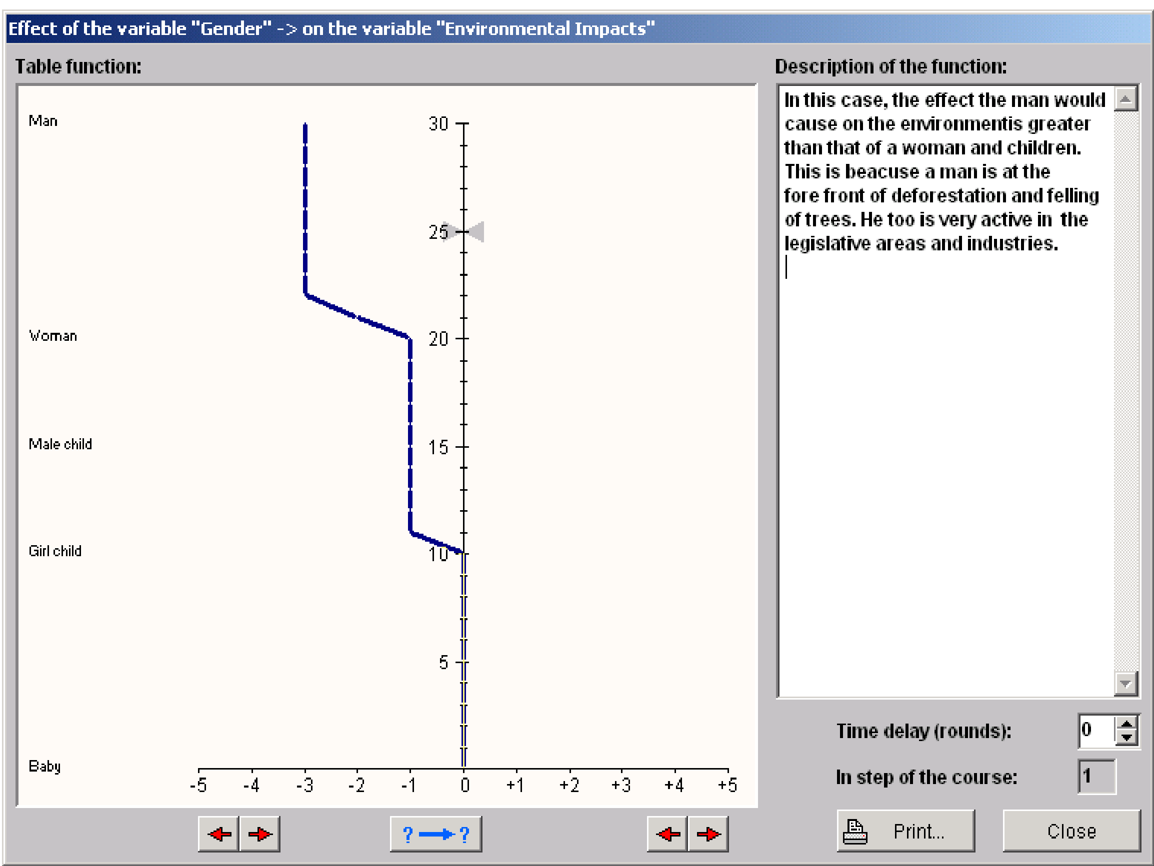

Effect of the variable "Gender" -> on the variable "Fuel"
Table function:
Man
Woman
Male child
Girl child
Baby
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
The mother and children are those who mostly fetch fuel for cooking. In very rare cases does a man do that and this depends on the household.
Time delay (rounds): 0
In step of the course: 1
Print...
Close

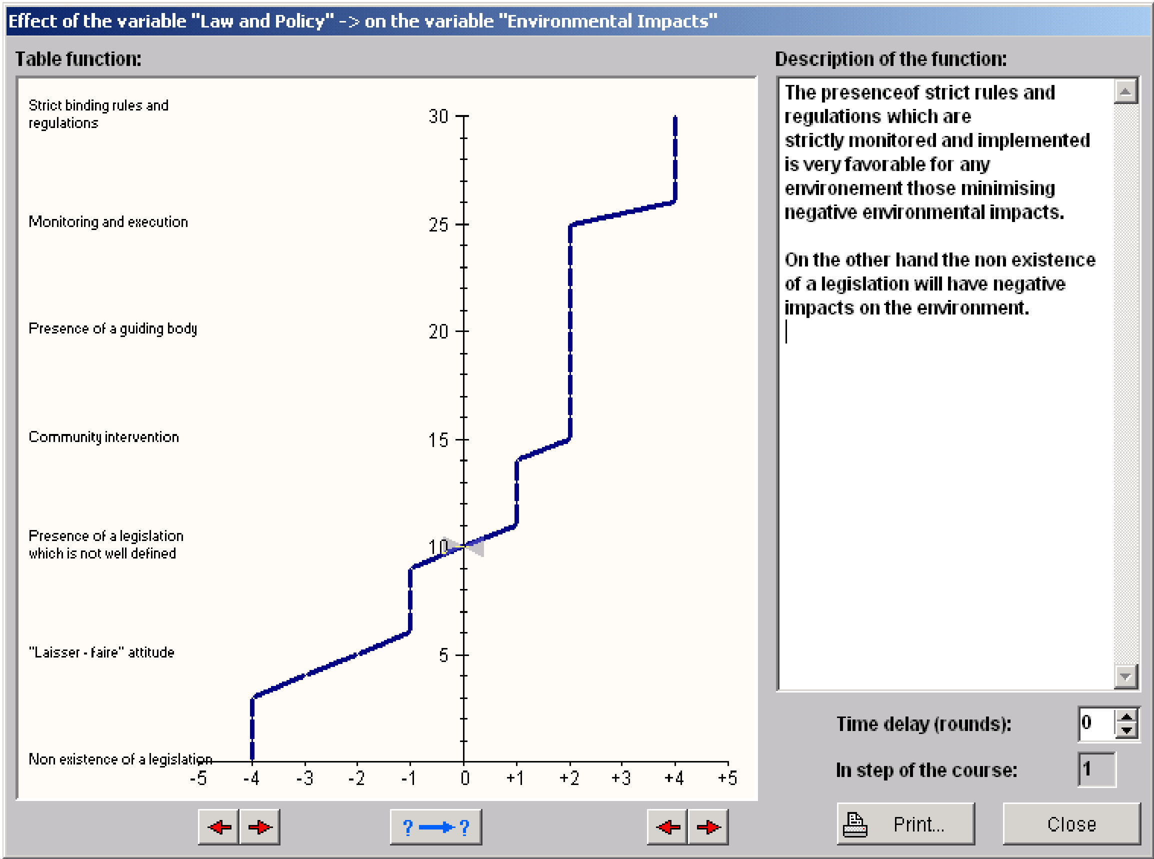

Effect of the variable "Economic Impact" -> on the variable "Fuel"
Table function:
Booming economic activities
High income earners (Civil Servants and business men)
Incentives and income generating activities
Traders
Peasant farmers
Low income generating economic activities
Very poor communities
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
Booming economic activities generate moneyto the government which intend can support her people or communities by way of incentives or good salaries pay off. By so doing, fuel purchase no longer becomes a problem as the poor can afford it.
When there is lack of finance, the poor cannot buy fuel so they resort to indiscrimate cutting of trees for cooking as a means of subsistence.
Time delay (rounds): 0
In step of the course: 1
Print...
Close

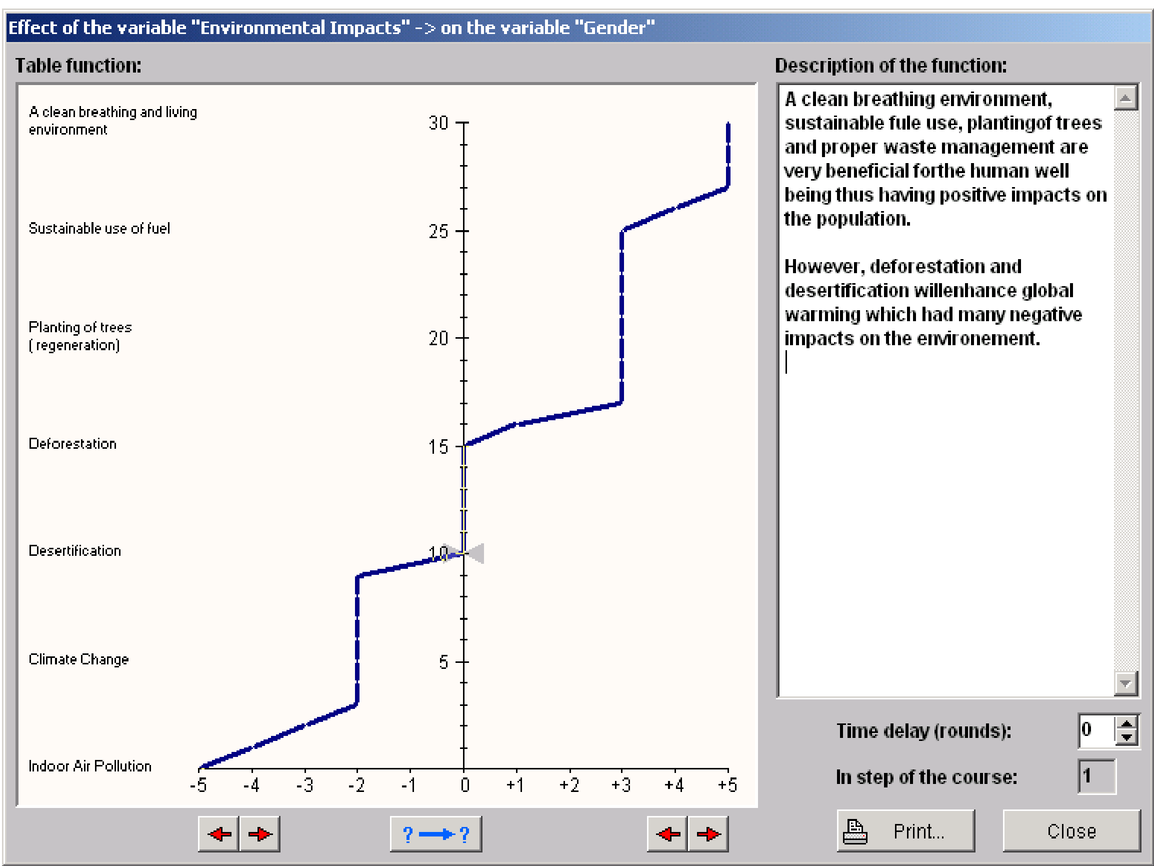

Effect of the variable "Education and Awareness" -> on the variable "Fuel"
Table function:
Expert knowledge
High professional motivation
Sensitization
Average knowledge
Interest but no knowledge
Lack of knowledge
No interest
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
Expert knowledge is important for choosing fuel types to use and the technology.
Lack of knowledge on the fuel type to use could be fatal as the wrong use of fuel could enhance indoor air pollution.
Time delay (rounds):
0
In step of the course:
1
Print...
Close

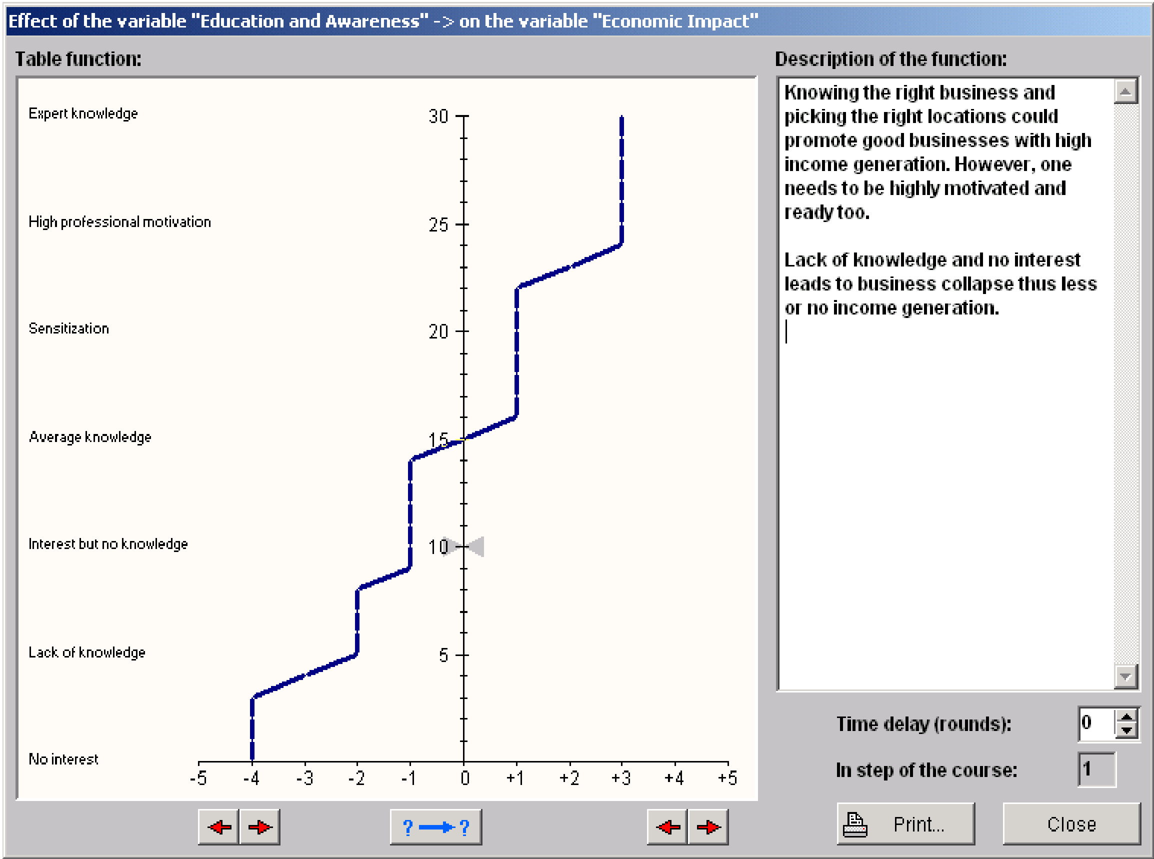

Effect of the variable "Fuel" -> on the variable "Environmental Impacts"
Table function:
Gas
Kerosene
Charcoal
Wood fuel
Saw dust
Plant residues
Dung
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
Gas for cooking in itself doesnot have any major environmental impacts and it is one of the most efficient if not the most efficient. Kerosene has some negative environment impact.
The impacts on the environment caused by biomass fuel is dependent on a whole lots of factors, however, if proper technologies are used, these impacts could be minimised.
Time delay (rounds):
0
In step of the course:
1
Print...
Close

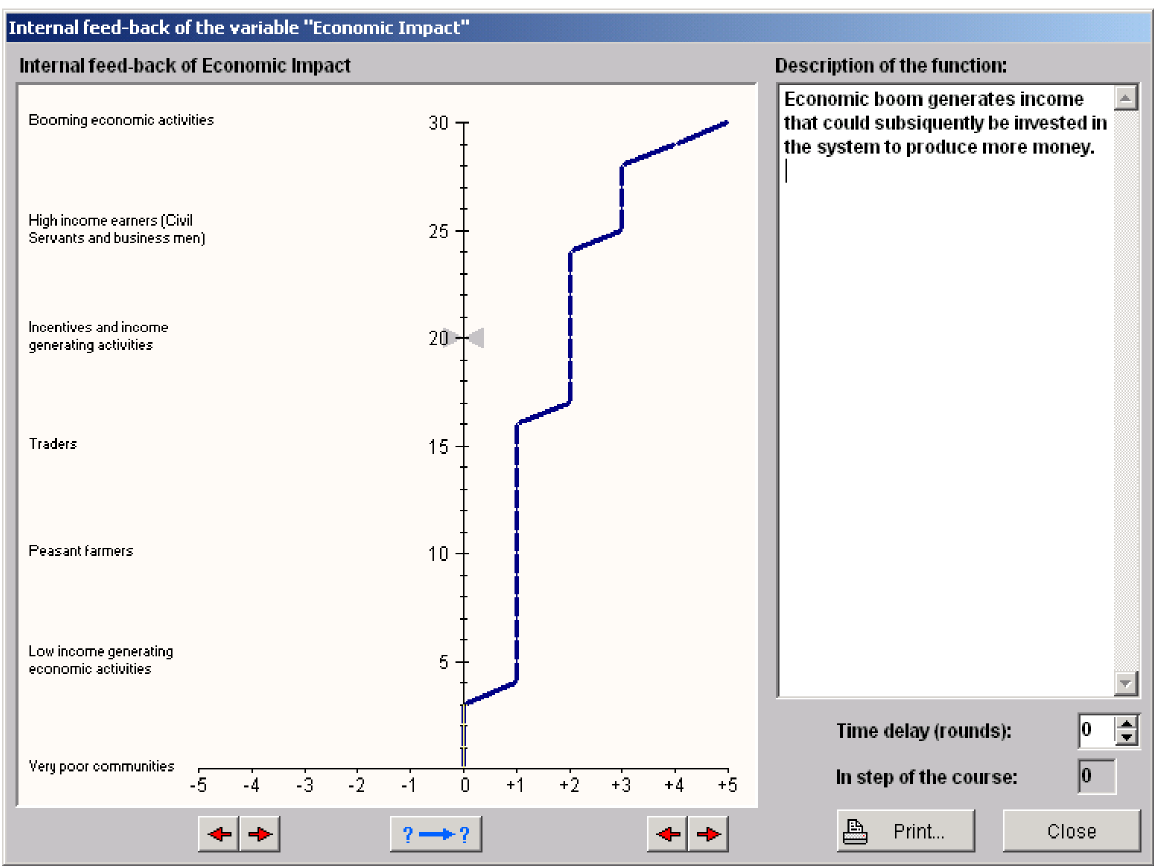

Effect of the variable "Gender" -> on the variable "Economic Impact"
Table function:
Description of the function:
Man
Woman
Male child
Girl child
Baby
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Men and women through their activities be it businesses or civil service would favour economic growth better than kids.
Kids too have role to play maybe through education or assisting their parents in their trades.
Time delay (rounds): 0
In step of the course: 1
Print...
Close

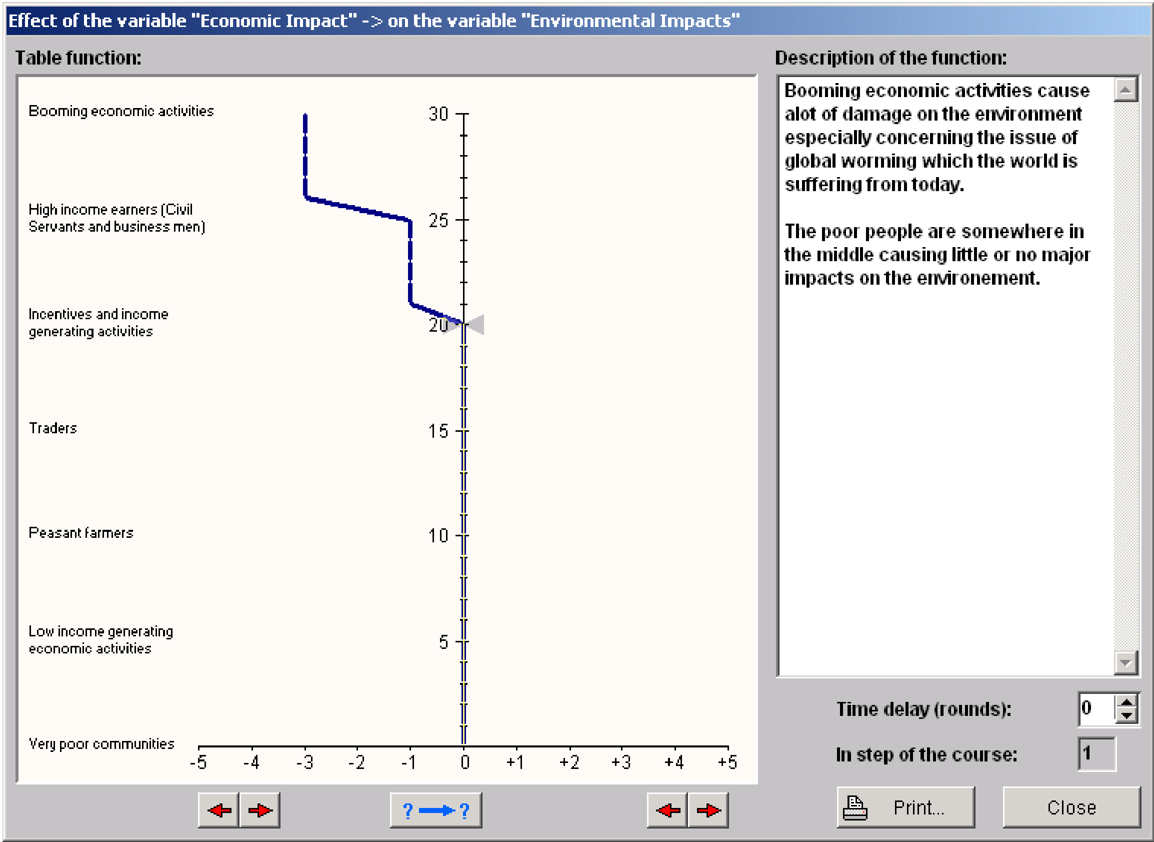

Effect of the variable "Gender" -> on the variable "Environmental Impacts"
Table function:
Description of the function:
Man
Woman
Male child
Girl child
Baby
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
In this case, the effect the man would cause on the environmentis greater than that of a woman and children. This is beacuse a man is at the fore front of deforestation and felling of trees. He too is very active in the legislative areas and industries.
Time delay (rounds): 0
In step of the course: 1
Print...
Close

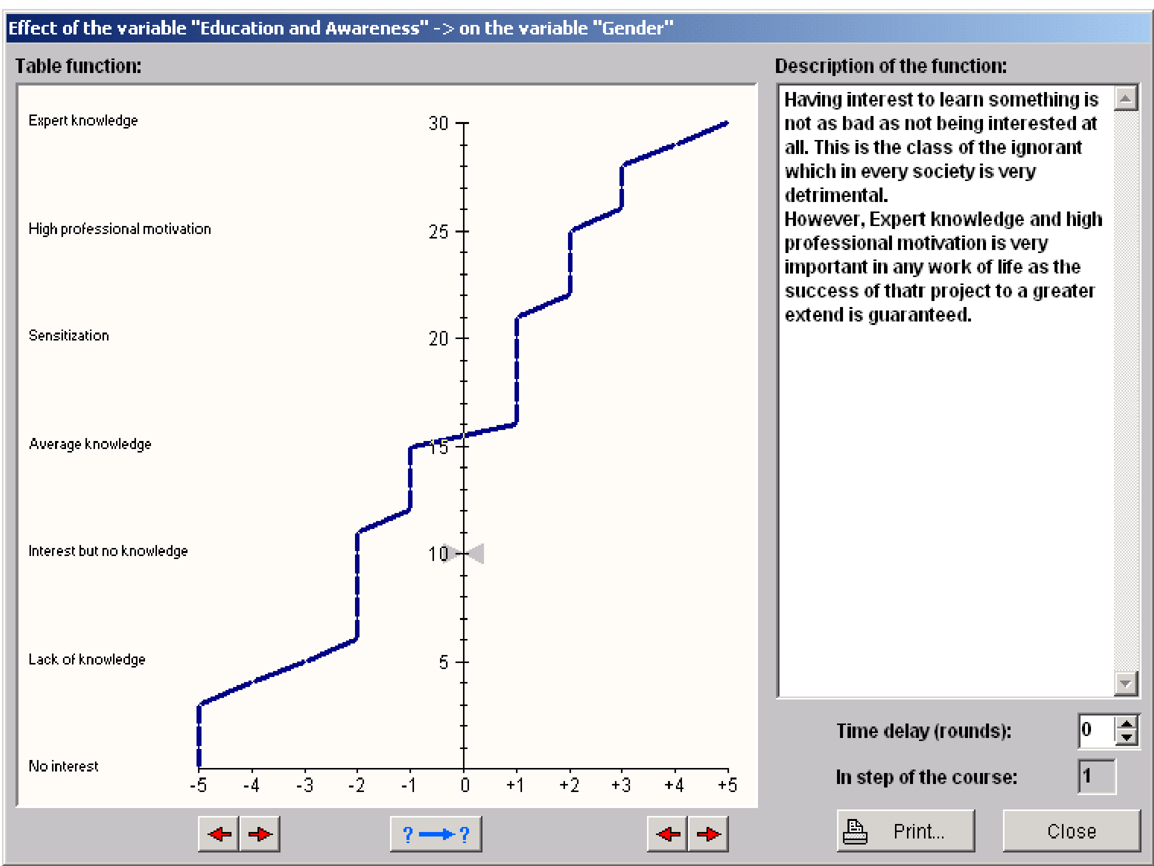

Effect of the variable "Law and Policy" -> on the variable "Environmental Impacts"
Table function:
Strict binding rules and regulations
Monitoring and execution
Presence of a guiding body
Community intervention
Presence of a legislation which is not well defined
"Laisser - faire" attitude
Non existence of a legislation
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
The presenceof strict rules and regulations which are strictly monitored and implemented is very favorable for any environement those minimising negative environmental impacts.
On the other hand the non existence of a legislation will have negative impacts on the environment.
Time delay (rounds): 0
In step of the course: 1
Print...
Close


Effect of the variable "Environmental Impacts" -> on the variable "Gender"
Table function:
A clean breathing and living environment
Sustainable use of fuel
Planting of trees (regeneration)
Deforestation
Desertification
Climate Change
Indoor Air Pollution
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
A clean breathing environment, sustainable fule use, plantingof trees and proper waste management are very beneficial forthe human well being thus having positive impacts on the population.
However, deforestation and desertification willenhance global warming which had many negative impacts on the environement.
Time delay (rounds): 0
In step of the course: 1
Print...
Close


Effect of the variable "Education and Awareness" -> on the variable "Economic Impact"
Table function:
Expert knowledge
High professional motivation
Sensitization
Average knowledge
Interest but no knowledge
Lack of knowledge
No interest
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
Knowing the right business and picking the right locations could promote good businesses with high income generation. However, one needs to be highly motivated and ready too.
Lack of knowledge and no interest leads to business collapse thus less or no income generation.
Time delay (rounds): 0
In step of the course: 1
Print...
Close


Internal feed-back of the variable "Economic Impact"
Internal feed-back of Economic Impact
Booming economic activities
High income earners (Civil Servants and business men)
Incentives and income generating activities
Traders
Peasant farmers
Low income generating economic activities
Very poor communities
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Description of the function:
Economic boom generates income that could subsiquently be invested in the system to produce more money.
Time delay (rounds): 0
In step of the course: 0
Print...
Close


Effect of the variable "Economic Impact" -> on the variable "Environmental Impacts"
Table function:
Description of the function:
Booming economic activities
High income earners (Civil Servants and business men)
Incentives and income generating activities
Traders
Peasant farmers
Low income generating economic activities
Very poor communities
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Booming economic activities cause alot of damage on the environment especially concerning the issue of global worming which the world is suffering from today.
The poor people are somewhere in the middle causing little or no major impacts on the environement.
Time delay (rounds): 0
In step of the course: 1
Print...
Close


Effect of the variable "Education and Awareness" -> on the variable "Gender"
Table function:
Description of the function:
Expert knowledge
High professional motivation
Sensitization
Average knowledge
Interest but no knowledge
Lack of knowledge
No interest
30
25
20
15
10
5
-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Having interest to learn something is not as bad as not being interested at all. This is the class of the ignorant which in every society is very detrimental.
However, Expert knowledge and high professional motivation is very important in any work of life as the success of thatr project to a greater extend is guaranteed.
Time delay (rounds): 0
In step of the course: 1
Print...
Close