Improved Cooking Stoves in South Asia

Engr. Md. Lutfar Rahman
Research Fellow
Technology Transfer
SAARC Energy Centre
2010
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South Asian countries are characterised by high percentage of rural population. Rural and semi-urban population in this region are dependent on the biomass fuels for cooking, heating and other household purposes. Given the economic condition of the people vis-à-vis high cost of commercial fuel, it is anticipated that the trend of biomass consumption as fuel in this region will continue for decades to come. Use of biomass fuels by the growing population has been exerting pressure on the natural sources of biomass causing deforestation, degradation of soil, environmental and ecological problems. Different health hazards due to incomplete combustion are associated with cooking with biomass using with traditional cooking stoves. Improved Cooking Stoves (ICS) with higher thermal efficiencies have been regarded by scientists, academics and policy makers in the region as effective tools to minimise the severity of multifarious problems arising out of the use of biomass. However, success in this field so far has been very limited, remained elusive for a considerable time in most cases.

This study Improved Cooking Stoves in South Asia undertaken by the SAARC Energy Centre as an in-house study under its thematic programme area of technology transfer and sharing best practices, reviewed different programmes implemented by various organisations across the region, investigated the reasons for failures or limited success of these programmes as well as the factors contributing to success of handful of projects, and identified barriers to wide-spread acceptance of Improved Cooking Stoves in the region. This study also highlighted the adverse effects of biomass and importance of Improved Cooking Stoves in different SAARC Member States. Furthermore, the author has put forward some important recommendations in view of the present status of ICS programmes and use of biomass fuels in South Asia.

This report is a comprehensive document on the Improved Cooking Stoves in South Asia. I hope it will be an important reference document for the researchers, academics and project planners working in this field. I appreciate the efforts of the author Engr. Md. Lutfar Rahman who painstakingly collected and compiled information from different sources, validated and presented in this report. I also thank the reviewers from India, Pakistan and SAARC Energy Centre for their valuable contributions towards improving quality of the report.

11 October, 2010

Hilal A. Raza
Director
SAARC Energy Centre
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<td>ADP</td>
<td>Annual Development Programme</td>
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<td>AEPC</td>
<td>Alternative Energy Promotion Centre</td>
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<td>AKPBSP</td>
<td>Aga Khan Planning and Building Services, Pakistan</td>
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<td>ARECOP</td>
<td>Asia Region Cookstove Programme</td>
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<td>ARTI</td>
<td>Appropriate Rural Technology Institute</td>
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<td>ATDO</td>
<td>Alternative Technology Development Organisation</td>
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<td>BACIP</td>
<td>Building and Construction Improvement Programme</td>
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<td>BCSIR</td>
<td>Bangladesh Council of Scientific and Industrial Research</td>
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<td>BRDB</td>
<td>Bangladesh Rural Development Board</td>
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<td>BYDA</td>
<td>Bhutan Youth Development Association</td>
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<td>CBO</td>
<td>Community Based Organisations</td>
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<td>CCT</td>
<td>Controlled Cooking Test</td>
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<td>CDM</td>
<td>Clean Development Mechanism</td>
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<td>DANIDA</td>
<td>Danish International Development Agency</td>
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<td>ESAP</td>
<td>Energy Sector Assistance Programme</td>
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<td>GHG</td>
<td>Greenhouse Gas</td>
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<td>GO</td>
<td>Government Organisation</td>
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<td>GS</td>
<td>Grameen Shakti</td>
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<td>GTZ</td>
<td>Gesellschaft für Technische Zusammenarbeit (German Technical Cooperation)</td>
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<td>IAP</td>
<td>Indoor Air Pollution</td>
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<td>ICS</td>
<td>Improved Cooking Stove(s)</td>
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<td>IFRD</td>
<td>Institute of Fuel Research and Development</td>
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<td>ITDG</td>
<td>Intermediate Technology Development Group</td>
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<td>IDEA</td>
<td>Integrated Development Association</td>
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<td>JICA</td>
<td>Japan International Cooperation Agency</td>
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<td>KPT</td>
<td>Kitchen Performance Test</td>
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<td>LPG</td>
<td>Liquefied Petroleum Gas</td>
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<td>MNES</td>
<td>Ministry of Non-conventional Energy Sources</td>
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<tr>
<td>MTOE</td>
<td>Million Tones of Oil Equivalent</td>
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<td>NGO</td>
<td>Non-Government Organisation</td>
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<td>NWAB</td>
<td>National Women’s Association of Bhutan</td>
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<td>NPCIC</td>
<td>National Programme on Improved Chulhas</td>
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<td>PCAT</td>
<td>Pakistan Council for Appropriate Technologies</td>
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<td>PCRET</td>
<td>Pakistan Council of Renewable Energy Technologies</td>
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<td>PM</td>
<td>Particulate Matter</td>
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<td>PEFR</td>
<td>Peak Expiratory Flow Rate</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<td>RECAST</td>
<td>Research Centre for Applied Science and Technology</td>
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<td>South Asian Association for Regional Cooperation</td>
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<td>SEC</td>
<td>SAARC Energy Centre</td>
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<td>SEW</td>
<td>Self Employed Worker</td>
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<td>SGP</td>
<td>Small Grants Programme</td>
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<td>TBU</td>
<td>Technical Back-up Unit</td>
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<tr>
<td>TIDE</td>
<td>Technology Informatics Design Endeavour</td>
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<tr>
<td>TOE</td>
<td>Tonne of Oil Equivalent</td>
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<td>UT</td>
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<td>United Nations Development Programme</td>
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<td>VITA</td>
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<td>WBT</td>
<td>Water Boiling Test</td>
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<td>World Health Organisation</td>
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Executive Summary

The study titled “Improved Cooking Stoves in South Asia” was undertaken as an in-house study by the SAARC Energy centre. This study endeavoured to cover the necessity of improved cooking stoves (ICS) in view of biomass dependence in the region and consequences of cooking with biomass fuels with traditional stoves, overview of ICS programmes in the South Asia, obstacles in dissemination, methods of construction and properties of ICS developed in the region. A section-wise summary of the study report is presented below.

Section I: South Asia, comprising eight countries, viz. Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka, has a population about 1.6 billion that accounts for more than one-fifth of the total population on the earth. Overwhelmingly high percentages of the population are living in the rural areas. People in this region especially in the rural areas and a section in the urban areas are mostly at the lower rung of the energy ladder who are dependent on the biomass fuels like wood, crop residues and cattle dung for cooking, heating, food processing and other household necessities. They have very limited access to modern form of commercial energy sources e.g. electricity, piped natural gas, LPG and kerosene etc. With the persistent rise in the size of population coupled with high prices of commercial fuels, the traditional sources of biomass are increasingly being subjected to pressure. Most of the countries in the region have been trying to reduce dependence on the biomass fuels. But the ground reality is that biomass fuel will continue to be used as main source of cooking fuel in this region for years ahead. Most countries in the region are trying to popularise improved cooking stoves for cooking with biomass to offset adverse effects of biomass use by improving efficiency of combustion and reducing emissions. SEC has carried out this study with following objectives:

- To highlight the importance of improved cooking stoves considering the extent of biomass use as fuel in the South Asian region;
- To get updated information about the dissemination programmes in SAARC countries and analyse factors behind successes and failures of these programmes;
- To compare the properties of ICS models developed by various institutions in the region; and
- To share technology and best practices in development and dissemination of ICS in the region.

Section II: Biomass represents approximately 13% of the world’s final energy consumption and about 75% of biomass fuels are used in developing countries. Over the last several decades, economic development and modernisation has allowed households in wealthier parts of the world to switch over to cleaner fuels such as petroleum products (e.g. kerosene, LPG) and electricity. However, more than 2 billion people of the world, mostly in poor and developing countries of Asia, Africa and Latin America, still rely on solid unprocessed biomass fuels as the primary source of domestic energy. Of these, 800 million people depend solely on crop residues and dung. It has been observed that people cook with biomass at least once a day in half of the world’s households. Although the proportion of global energy derived from biomass fuel has fallen from 50% in 1900 to around 13% currently, biomass use is increasing among the poor due to high price of commercial fuels.

According to the International Energy Agency (IEA), biomass accounted for about 80 percent of residential energy consumption in 2000 in South Asia and will account for 70 percent of total residential energy consumption by 2020. Because the primary end uses of biomass are cooking and heating, the expansion of electricity access, used primarily for lighting, is not expected to have a significant effect on biomass use in the near future. Over last half a century the use of commercial energy has been increasing, however, the total amount of biomass fuel used in this region has not decreased, rather it has significantly increased.

Section III: In simple devices like the household stoves commonly used in South Asia, biomass fuel does not combust cleanly. Due to poor combustion efficiency, biomass fuel emits a very high quantity of health-damaging particulates during burning. These include respirable particulate matter with diameter less than 10 (PM$_{10}$) and 2.5 microns (PM$_{2.5}$) or even less (ultra fine), carbon monoxide (CO), oxides of nitrogen and sulfur. Besides, biomass smoke contains at least five chemical groups recognized by the International Agency for Research on Cancer as known or potential human carcinogens. Biomass smoke exposure increases the risk of common and serious diseases of both children and adults. It has been causally linked to acute respiratory infections (ARI), chronic obstructive pulmonary diseases (COPD), otitis media, tuberculosis, asthma, low birth weight, cataract and blindness, lung cancer, cancer of nasopharynx and larynx etc. Factors influencing emissions include fuel type, kitchen, age of the people and type of stoves used.
Improved cooking stove is seen as a tool in combating Indoor Air Pollution (IAP) thus improving public health particularly rural women and children, in improving rural economy by saving time and money in collection of cooking fuel, in preventing deforestation and reduction of greenhouse gas emission.

Section IV: The Bangladesh Council of Scientific and Industrial Research (BCSIR), under the Ministry of Science and Technology, began conducting research and development in this technology in 1982 and expanded to wide-scale dissemination by 1987. BCSIR developed more than 18 different ICS models with laboratory testing and field trials, focusing their dissemination work primarily with six different models. BCSIR’s ICS programme had a significant impact, disseminating over 300,000 stoves from the mid 1980s until 2001. To popularise the improved stoves Scientists of IFRD under BCSIR conducted over 215 training courses on improved stove technology and trained up more than 10,000 men and women from different government, semi-government and non-government organisations. Primary weakness of this programme was the lack of a strong monitoring and follow up programme. The absence of adequate post installation support services resulted in eventual disuse of many of the stoves. Presently NGOs partially supported by donor agencies and CDM are engaged in the dissemination of ICS in Bangladesh with Grameen Shakti and GTZ in the leading role.

The National Women’s Association of Bhutan (NWAB) took up the installation of improved cooking stoves in the villages of Thimphu Dzongkhag on a pilot basis in order to create awareness on smoke-related diseases. In 1983 NWAB provided 22 such stoves in Wang Simu and Dalu villages, and in 1984 they provided 118 improved cooking stoves covering all the gewogs of Thimphu Dzongkhag (district) with technical assistance from the erstwhile Public Works Department. Subsequently, Government decided to take the project a step further and in 1985 government mandated NWAB to take up the nation-wide programme known as the National Stove Project with the financial assistance from UNICEF. The project was taken over by the Public Works Department in 1988 when the Association had installed over 14,000 improved cooking stoves across the country. In 1999 GEF/UNDP Bhutan Youth Development Association (BYDA), an NGO, installed 10 Improved Community Cooking Stoves in North Trashiogang and installed improved stoves in 2000 households. The project, which involved the Tsirang District Administration from the start, achieved these results by training women from villages to construct, maintain and repair the stoves; these women have in turn trained others. Presently, there is no ongoing programme on ICS in Bhutan.

The Indian National Programme on Improved Chulhas (NPIC) was launched in 1983 in all states and union territories aimed to disseminate improved clay and mud stoves in order to increase the fuel efficiency of traditional stoves and reduce indoor air pollution. It was managed by the central government bureaucracy, along with six regional officers and numerous other state and district officers. More than 30 models of chulhas were developed during 17 years and around 34 million chulhas were installed by 2001-2002. However, the primary drawback in this world’s second largest programme of ICS after China National Programme of ICS gradually became evident as multiple levels of government bureaucracy complicated the initiative. Programme administration was truly cumbersome and fragmented. In addition, the budget was insufficient for the level of supervision and assessment the programme required. In 2002 the NPIC was deemed a failure and funding was discontinued; responsibility for continued ICS dissemination was passed to the states. Since that time, a handful of state governments and NGOs have continued ICS related projects; however, the lack of central government support and funding has thus far precluded initiatives in all.

In Nepal, improved cooking stoves were first introduced during 1950s. In the 1960s, an agro-engineering workshop in the Department of Agriculture developed a mould-based stove model, which was disseminated through the mid-1970s. A number of NGOs and GOs (Peace Corps, Women Training Centre, RECAST, and UNICEF) were involved in ICS research and dissemination of the Lorena stove model. Unfortunately, lack of funding led to stagnation in stove dissemination. In the 1980s, the National Planning Commission addressed the fuel wood consumption issues in its sixth 5 year Plan. HMG initiated dissemination of ceramic pre-fabricated stoves, supported by FAO and UNDP. The ceramic inserts proved inappropriate to most areas of Nepal, since they were often breaking during long and complicated transportation in hill areas. Until 1998, about 95,000 ICS were distributed or installed at various districts in the country by the Community Forest Development Projects (CFDP) and other organisations involved in the promotion of ICS.

To complement these efforts, National ICS Programme has been initiated with the support of Energy Sector Assistance Programme (ESAP) of DANIDA. The first phase originally planned to be 2000-2004 continued until March 2007. During this period the programme covered 35 districts and a total 2,130,059 numbers of ICS were installed in the mid hill districts to demonstrate that a sustainable strategy for mass ICS dissemination has been developed and that it is possible to implement success-
fully on a reasonably larger scale. It is envisioned that by end of Phase II (2007-2011) 4,34,000 ICS will be installed in Mid Hills and Terai. The national programme has been selective of areas on providing subsidies. No subsidy has been provided to households mud improved cooking stoves in Hills and Mid Hills of Nepal. A subsidy of 50% but not exceeding NPR 2,500 per unit is provided to improved metal cook stoves in High Mountains for cooking and space heating, as they are costly and unaffordable. According to AEPC as of middle of 2009 about 300,000 (mud-bricks) ICS have been disseminated throughout the mid hill districts of Nepal.

Pakistan Council of Renewable Energy Technologies (PCRET) is the pioneering organisation in designing and disseminating ICS in Pakistan. Its predecessor, Alternative Technology Development Organisation (ATDO) designed improved mud stoves in cooperation with NWFP University of Engineering and Technology, Peshawar in early eighties and launched programme on training NGO workers on construction of these stoves in in plain areas. Pakistan Council for Appropriate Technologies (PCAT) formed in 1986 renaming the ATDO, continued the programme of improved mud stoves. PCAT under government funded Fuel Saving Technology (FST) programme (FSP) disseminated about 70,000 improved mud stoves during 1994-95 to 1998-99. PCRET from 2002-2004 designed three types efficient metal stoves and two baked clay stoves, suitable for rural areas of Pakistan. PCRET and its predecessor organisations arranged 200 training programmes and conducted 4,000 demonstration programmes. Private entrepreneurs are now involved in manufacturing and selling ICS designed by PCRET especially metal stoves in the northern areas of the country.

The Aga Khan Planning and Building Services, Pakistan (AKPBS), introduced fuel-efficient cooking stoves in 1985 in the villages of Ghizer and Hunza in the northern Pakistan. From 1985-99 the people replicated about 10,000 stoves in the area. From 1999 to 2009 under Building and Construction Improvement Project (BACIP) it has installed about 10,500 ICS of more improved models for cooking and heating. Its programme is mainly non-subsidised. However, they provide of upto 70% of subsidy for metal stoves in some selected households for demonstration purpose. The Escorts Foundation, an NGO founded by a private company in Lahore focusing its efforts specifically upon the development of the Changa Manga region, installed 11,728 improved mud cookstoves without providing any subsidy. UNDP contributed US$ 7,500 in 1995 and $32,698 in 1999 to the programme under Small Grants Programme (SGP).

World Wide Fund for Nature-Pakistan (WWF-P) has been promoting improved cooking stoves with 50-70% subsidy in selected areas in the northern areas of the country as one of the components of their greater programmes of conserving nature and wildlife since 90s. Under different projects funded by donor agencies, WWF-P imparts training to local artisans in stove making and organise demonstrations, visits by community representatives and educational programme to increase awareness about benefits of ICS to the local people. They organise such programmes jointly with communities. Besides, GTZ implemented a programme titled Fuel Efficient Cooking Technology (FECT)’ programme during 1988-92, when they distributed three-pot metal stoves without chimney and horizontal tonodor through NGOs in the northern areas.

Since its inception in early 1970s improved cook stove (ICS) programme in Sri Lanka has gone through several stages of development, which can be broadly divided into three phases i.e. (1) Design and testing phase: 1970-1985 (2) Promotion & dissemination: 1985-1991 (3) Commercialisation phase: 1991-2005. During this period of development, several stakeholders from government and non-government and non-government organisations participated, and the objectives changed from a narrow focus on firewood conservation to a more integrated-development approach.

About 300,000 stoves were disseminated during the subsidised phase from 1985 – 1990 with the support of the government and several donor agencies mainly the DGIS (Royal Netherlands Government). Integrated Development Association (IDEA) is a non profit organisation established in 1991 to promote commercialisation of improved stoves and capacity building of grassroot level organisations to implement stove programmes at the household level. The mission of IDEA is to facilitate commercialisation of ICS for the benefit of the 80% of the population using firewood. Holistic strategies are adopted to cover development aspects related to energy, health, environment, poverty alleviation and gender issues etc. IDEA since 1991 has been commercialising, a two-pot single piece clay stove called “Anagi”. It can be estimated that over two million “Anagi” stoves have been commercially produced and marketed since 1991. Now, about 300,000 stoves are annually produced by 120 rural potters trained by IDEA scattered in 14 districts of the country.

Section - V & VI: Brief history, classification, design criteria and model selection principle have been described in Section V. Classification of ICS is based on function, construction material, portability and fuel type. Users particularly women should be given preference in selecting ICS model for use.
in the households. Construction procedure, drawings and images of some selected models of ICS in this region have been presented in Section VI. These include domestic mud stoves and metal stoves as well as semi-industrial stoves.

Section-VII: Thermal efficiency, reduction of toxic gasses and particulate matters are the main parameters indicating performance of stoves. Thermal efficiencies of ICS introduced in this region vary from 14 to 31% while the efficiencies of three-stone and other traditional stoves vary from 5 to 13%. This indicates that improved stoves in the region are able to save biomass fuels up to 60% compared to traditional stoves. From the available data it is known that some of ICS models improve the air quality in the kitchen by reducing average concentration of CO and particulate matters by up to around 60%. In South Asia, the unit price of domestic mud ICS varies from 1.25 to 15 USD and for metallic ones it varies from 16 to 125 USD.

Section VIII: Lack of awareness about health due to illiteracy, lifelong habits, variation of efficiency from the lab to the field, needs for maintenance, need of expert for constructions and poverty are regarded as main barriers to wider acceptance of ICS in the region.

Section – IX: From this study following conclusions can be drawn:

- Despite efforts by governments, NGOs and donor agencies response from the general people to the ICS dissemination programmes has not been very encouraging.
- Considering economic, environmental and heath aspects, pursuance of ICS programmes should be continued.
- Programmes should be demand driven and should be planned for commercial success.
- Continuous monitoring, follow-up and technical supervision on ICS performance and use are crucial for the success of any ICS programme.
- More awareness creation is necessary to make ICS programmes successful.

For wider dissemination of ICS and sustainability of the programmes, this study makes following recommendations:

- **Awareness building and education**: It is very difficult to make a social programme successful unless people are aware of the benefits of the programme activities. Workshops, road shows and village fairs can be arranged to educate people about the health, environmental and financials benefits of improved cooking stoves. Special attention should be given to the women and school children for to awareness building. Training workshop may be arranged for school teachers and students in the rural areas by the technicians and educationists.

- **Promote commercialisation of ICS**: Evidences from region and international experience strongly support the goal of full commercialisation of stove buying and selling. Countries need to promote commercialisation in order to make the use of improved cooking stoves sustainable in the long run. The government institutions may play important role in improving designs; setting technical standards; and providing credit facilities for stove makers.

- **Supervisory body for ensuring quality**: A government body under the renewable energy department of each country may be entrusted with the responsibility of testing different models before the introduction of a model and after installation in the fields. They can make regular evaluation of different dissemination programmes and advice project authorities accordingly.

- **Facilitate collaboration between designers, manufacturers and consumers**: The technical backup units need to be more involved with the manufacturers and consumers of the stoves particularly women, who are the main users. This might lead to the design of models that are more durable and better adapted to consumer preferences.

- **Holistic approach to reach the poor**: It will be difficult to convince the people to buy and use ICS as a separate activity especially who live in poverty. ICS dissemination programmes may be undertaken as integral part of other social development and income generating activities. If women are involved in income-generating activities that will value their time and make it more profitable to purchase firewood than collect it, improved stoves will have higher chances of success. Micro-financing organisations may be more involved in this activity.

- **Sharing knowledge and best practices at regional level**: Periodical workshops or seminars may be arranged at regional level to share knowledge and best practices on dissemination, awareness creation and technical upgradation issues to adopt appropriate strategies by individual countries.
1.1 Introduction

The South Asian Association for Regional Coopera-
tion (SAARC), a contiguous block of eight coun-
tries, started with seven countries — Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan and Sri Lanka — when it was established in 1985, and was extended to include Afghanistan as the eighth member in 2007. In this report the term South Asia will imply these eight countries under the SAARC.

This region, having around 1.6 people in approximately 5.1 million square kilometers geographic area, is the home of over one fifth of the world's population, making it both the most populous and the most densely populated geographical region in the world. Indicative geographical positions of SAARC countries are shown in the Figure 1.

About 70% of the South Asian population live in rural areas and mostly rely on agriculture for their livelihood. Agriculture sector employs about 60% of the labour force and contributes 22% of the regional GDP [World Bank 2010]. Overall growth in South Asia has been accelerating since the early 1990s, and its economic performance during the last decade and a half has been impressive. Economic growth has contributed to significant reduction in poverty in the region. Despite being home of nearly half of the world’s poor population, today, South Asia stands at a point where the potential for sustained high growth and poverty reduction is excellent. The region has a unique opportunity to drastically reduce poverty over the next decade, provided the right policy choices are made.

Adult literacy rate in South Asia is 63% with Maldives having the highest of 97% and Afghanistan with the lowest literacy rate of 28.1% [ACCU 2009]. This leaves 37% people illiterate which turns out to be 390 million in the 8 SAARC countries. Although illiteracy is widespread throughout much of South Asia, in consequence of traditional patterns of gender discrimination in the region, it is most highly concentrated among women. Overall female literacy rate in the region is slightly above half of that recorded for males.

South Asian nations are faced with rapidly rising energy demand coupled with increasingly insufficient energy supplies, although the per capita energy consumption in this region is the lowest of all the regions of the world. Most of South Asia is grappling with energy shortfalls, typically in the form of recurrent, costly and widespread electricity outages. Because of the economic and political ramifications arising from such shortfalls, improving the supply of energy, particularly the supply of electricity, is an important priority of national and local governments. Total 614 million people in South Asia, 40% of total population in the region, do not have access to electricity [WEO 2009]. The countries of South Asia are looking to diversify their traditional energy supplies, promote additional foreign investment for energy infrastructure development, improve energy efficiency, reform and privatise energy sectors, and promote and expand regional energy trade and investment.

People in this region especially in the rural areas and a section of people in the urban areas are generally at the lower rung of the energy ladder i.e. dependent on the biomass – fuelwood, crop residues, and cattle dung etc – for cooking, heating, food processing and other household necessities. They have very limited access or affordability to modern forms of commercial energy like electricity, piped natural gas and LPG. With the persistent rise in the size of population coupled with high prices of commercial fuels, the traditional sources of biomass are being increasingly subjected to pressure.

The three stones (open) fire (TSF) and ‘U’ shaped cooking stoves (chulhas) persist as the most prevalent biomass fuel-using technology to cook foods in...
the villages and semi-urban areas of the South Asia. Traditional stoves have been around for thousands of years and have evolved to meet the local needs in a way that is affordable for the users. The thermal efficiencies of these traditional stoves are found to be in the range of only five to thirteen percent. Inefficient and incomplete burning of biomass has significant direct and indirect adverse effects on rural economy, public health, soil fertility and environment.

Improved cooking stove having higher thermal efficiency and providing better kitchen environment is regarded as an effective means in holding back the pace biomass demand and offsetting associated problems in cooking with biomass. Like other developing regions South Asian countries have been engaged in campaign for widespread dissemination of Improve Cooking Stoves (ICS) for over three decades. Research institutions as well as the organisations involved in dissemination in the field level are continuously trying for upgrading of efficiency, lowering cost and decreasing the emission level etc for wider acceptance in the community level. This study aims at comprehensive review of the past and the ongoing important programmes or projects undertaken in the SAARC Member States so far for popularising the use of ICS with attention on design, efficiency, emission reduction, cost and level of acceptance of different models.

1.2 Objectives

The study has been carried out with following objectives:

- To highlight the importance of improved cooking stoves considering the extent of biomass use as fuel in the South Asian region;
- To get updated information about the dissemination programmes in SAARC countries and identify factors behind successes and failures of these programmes;
- To compare the properties of ICS models developed by various institutions in the region; and
- To share technology and best practices in development and dissemination of ICS in the region.

1.3 Methodology

Attempts were made to collate necessary information for the study as much as possible from the published documents both printed and on websites. Author also collected information directly communicating with concerned officials of different organisations. Besides, the author discussed various issues with experts working on ICS to exchange views and ideas for assimilating in-depth knowledge of dissemination programmes and models introduced.
2.1 Global Scenario

Biomass is the oldest source energy used by people around the world for cooking, heating and other purposes. This vital source of fuel, which holds important place in present days world energy scenario despite tremendous increase in modern commercial fuels, accounted for approximately 13 % of the world’s final energy consumption in 2006 [IEA 2008]. The amount of biomass fuel use varies considerably among regions, mainly owing to differences in the stages of development. About 75 % of world consumption of biomass fuels takes place in developing countries [Parikka 2004]. Biomass is one such renewable, which accounts for nearly 33% of a developing country’s energy needs [Ramachandra et al., 2004].

Over the last several decades economic development and modernisation has allowed households in wealthier parts of the world to switch over to cleaner sources of energy such as natural gas, kerosene, LPG and electricity. However, more than 2 billion people of the world, mostly in poor, developing countries of Asia, Africa and Latin America, still rely on solid unprocessed biomass fuels as the primary source of domestic energy. Modern energy sources such as electricity and petroleum-based fuels generally provide a small part (2-10%) of the energy consumed by rural people, mainly because of supply and affordability constraints. It has been observed that people cook with biomass at least once a day in half of the world’s households. Although the proportion of global energy derived from biomass fuel has fallen from 50% in 1900 to around 13% currently, biomass use is increasing among the poor [WHO 2007]. Figure 2.1 illustrates the trend of biomass use in percentage of total energy. In the developed countries like USA the percentage of biomass fell quicker than the world, which manifest in the inability of many developing countries with high rural population and lower income to switch over to commercial fuels. The World Energy Outlook 2000, prepared by the International Energy Agency, projected an increase in the consumption of combustible renewables and waste (CRW; including fuelwood, charcoal, crop residues and animal wastes) between 1997 and 2020 in absolute terms in every region of the world. In developing countries, the primary energy supply through CRW will grow from 886 MTOE in 1997 to 1,103 MTOE in 2020, at an annual growth rate of 1% [WEC 2001].

![Figure 2.1: Share of Biomass Energy in USA and the World](source: EIA 2002)
2.2 South Asia

As is the case in other developing regions, South Asia continues to rely heavily on biomass i.e. crop residues, animal waste and wood etc. for residential energy consumption, particularly in rural areas. According to the International Energy Agency (IEA), biomass accounted for about 80 percent of residential energy consumption in 2000 and will account for 70 percent of total residential energy consumption by 2020 [EIA 2004]. Because the primary end uses of biomass are cooking and heating, the expansion of electricity access, used primarily for lighting, is not expected to have a significant effect on biomass use in the near future. Figure 2.1 shows the total primary energy supply in the region. Over nearly four decades the use of commercial energy has been increasing but the use of biomass (Comb.renewable and waste) has not decreased, in fact, it has significantly increased.

![Figure 2.2 Total Primary Energy Supply in South Asia](source: EIA Energy Statistics)

2.2.1 Afghanistan

The Afghan economy continues to be overwhelmingly agricultural, despite the fact that only 12% of its total land area is arable and less than 6% currently is cultivated. Agricultural production is constrained by an almost total dependence on erratic winter snows and spring rains for water; irrigation is primitive. Relatively little use is made of machines, chemical fertilizer, or pesticides. Afghanistan is endowed with a wealth of natural resources, including extensive deposits of natural gas, petroleum, coal, marble, gold, copper, chromite, talc, barites, sulfur, lead, zinc, iron ore, salt, precious and semi-precious stones. In 2006, the US Geological Survey and the Afghan Ministry of Mines and Industry reported that Afghanistan’s resource base was much greater than previously believed. According to their findings, undiscovered petroleum resources in northern Afghanistan range from 3.6 to 36.5 trillion cubic feet (TCF) of natural gas, with a mean of 15.7 TCF. Estimates of oil range from 0.4 to 3.6 billion barrels (BBO), with a mean of 1.6 BBO. Estimates for natural gas liquids range from 126 to 1,325 million barrels (MMB) with a mean of 562 MMB. Besides Afghanistan has significant potential for hydro electricity generation [USGS 2006].

For nearly three decades, the availability of secured energy supplies in Afghanistan was significantly disrupted by conflict. Much of the country’s power generation, transmission and distribution infrastructure was destroyed, and what remained was stretched far beyond capacity. More than 90% of the population had no access to electricity [ADB 2009]. The rural population, which comprises of a little less than 90% of the total population, has minimal access to electricity. Historically, Afghanistan’s rural population has been meeting their energy needs from traditional sources like fuel wood, and other biomass resources. Use of modern forms of energy- electricity, fossil fuel etc. are comparatively
new and making them accessible to rural areas is a great challenge because of rugged topography viz. a viz. resource constraints to build up infrastructure. Use of biomass in this country is very high which accounts for 85-95% of the total energy supply.

2.2.2 Bangladesh

Bangladesh is a densely populated country with a population of about 150 million, around 72% of which live in the rural areas. The rural population in Bangladesh consumes a large amount of traditional biomass fuels for cooking and other purposes. The commonly used biomass fuels in Bangladesh are fuelwood including tree wastes, agricultural residues and animal dung. Biomass fuels account for 54% of the total energy consumption of the country, the remaining 46% of the need being met by commercial fuels i.e., natural gas, oil, hydro-electricity and coal. About 70% of house hold energy demand is met by biomass. On a national basis, 98% of the total biomass energy are supplied by the agricultural croplands (68%), homesteads (14%), animal dung (16%) and the remaining 2% from the reserved forest of the country [Akhter 2002].

Bangladesh is one of the environmentally threatened countries suffering from scarcity of fuels including biomass fuels. The country has rather small coverage of forest (15% of the total area of the country; actual tree cover may not however be more that 7-8%) [Attiqullah & Yusuf 2002]. There are indications that consumption of biomass energy has already exceeded the regenerative limit and there prevails energy crisis in rural areas in Bangladesh. This is one of the causes of deforestation that is going on in an alarming rate [Rouf & Haque 2008].

Although share of biomass in percentage of national energy consumption is decreasing due to increase in consumption of commercial energy, the total amount of biomass exploitation is increasing. Over 20 years from 1980 to 2000 use of biomass increased by 25% in Bangladesh [Akhter 2002]. Total biomass consumed per year is about 39 million tonnes of which major portion comes from agricultural residues. Increasing use of agricultural residues is depriving soil of organic matter and essential micro nutrients like zinc, molybdenum, boron etc. If this trend is not changed, fertility will go down tremendously making the land barren in the next 50 – 100 years [Attiqullah & Yusuf 2002]. This is a matter of great concern. Population is increasing at the rate about 1.4 percent per year. Because of the increase in population, increasing amounts of fuels are needed for cooking. Since, in the rural areas, no fuels other than biomass fuels are affordable or available and since there is scarcity of wood fuels, people are increasingly exploiting agriculture residues for energy.

2.2.3 Bhutan

With over 70 percent forest coverage and wide range of altitude and climate, Bhutan has rich and diverse flora and fauna. The southern foothills, which is situated in Subtropical Zone (150m to 2000m) has tropical or subtropical vegetation. The Temperate Zone (2000 to 4000m) with conifer or broadleaf forests covers most parts of the country; and the Alpine Zone (4000m and above) with no forest cover is at the northern Himalayan regions. Forest type in Bhutan is diverse. Over 60 percent of the common plant species of the Eastern Himalayas are found in Bhutan. The forest type consists of mixed conifer forest, fir forest chirpine forest, blue-pine forest, broadleaf mixed with conifers, tropical lowland forests, lowland hardwood forest and upland hardwood forest [Bhutan Tour 2009].

Both biomass and hydro energy resources hold important positions in the country’s economy. Bhutan is rich in hydro energy resources with about 23,000MW presently economically viable. Currently, hydropower is the main resource for electricity generation to cater domestic energy needs as well as to earn revenues by way of export of electricity, whereas biomass in the form of fuel-wood is the main resource for meeting residential energy demands, such as cooking and space heating. According to JICA Integrated Rural Energy Master Plan Study, in rural areas per capita consumption of fire wood is 3.95 kg per day, corresponding 1.27 tons per year. Fuelwood constitutes 57.7% of total energy consumption in the country. The effective use of firewood and charcoal is thus recommended by Master Plan Study since the reduction of fire wood consumption directly affects to the preservation of forest resources [Adhikari 2008].

2.2.4 India

Traditional fuels constitute about 30% of India’s primary energy consumption. Over 72 percent of all households in India and 90 percent of households in the country’s poorer rural areas use traditional solid fuels, such as crop residue, cow-dung and firewood, to meet their cooking needs. About 15% of urban households in India use biomass [Edugreen]. About 80% of the energy consumptions in rural household accounts for cooking. About 75% of the biomass energy is used for cooking while other uses include food processing, and preparation, textile, ayurvedic medicine, brick making where wood and other biomass is the source of process heat. According to IEA estimate in India solid biomass energy use in the year 2006 was 6,691,627 terajoule, equivalent to about 160 million tonnes of oil [IEA 2009]. The number of biomass users in the country in 2002 was 585 million and it is expected to reach 632 million by 2030 (IEA, 2002). However, one thing is en-
courting - due to different positive efforts by the government the forest and tree cover has remained unchanged over two to three decades. The forest cover of the country is 67.71 million hectares which is 20.60% of the total geographic area. Total growing stock (volume of wood) of wood in the forest and outside the forest in the country is about 6.22 billion cubic meters [Forest Report 2005].

2.2.5 Maldives

Households in the Maldives rely on diesel, kerosene, LPG and biomass for their energy needs. Specifically, outer island households still depend on biomass including fuelwood for most cooking energy requirements. The utilisation of biomass was approximately 4,626 tonnes of oil equivalent (toe) according to the Maldives energy balance in 2002 (ECN 2004), which constituted 24 percent of the accessible biomass resources (NEP 2005). However, biomass (shrub and coconut husks) use is under threat due to rapid deforestation in the outer islands. Communities are, therefore, switching over to LPG, but its cost and uncertainty of supply, which is dependent on an inefficient inter-island transport network, are hampering the switchover. In 2005, consumption of biomass reduced to 2,763 TOE [UNDP 2007].

The Maldives, with 80 percent of the homeland rising a mere one meter above sea level, is staring down the barrel of global warming that threatens to submerge this string of 1,200 atolls. But the little nation is not merely holding its collective breath, waiting for the inevitable. The government has recently announced a radical new energy plan that will make his country carbon neutral within the space of a decade. The plan eliminates the use of fossil fuels on the islands, relying instead on a network including “a new renewable electricity generation and transmission infrastructure with 155 large wind turbines, half a square km of rooftop solar panels, and a biomass plant burning coconut husks” [Guardian 2009].

2.2.6 Nepal

Amount of commercial energy consumption in Nepal is very low. In 2007 total commercial energy consumption was only 1.12 MTOE which turned out to be 40 kilogram of oil equivalent per capita [Acharyia 2009]. Nearly 85-90% of the energy requirement is still met by traditional biomass: fuel wood, agri-residue and animal dung. In the overall energy consumption, 77% energy comes from the firewood, 9% from the agriculture residues and animal dried dung and remaining 14% energy comes from imported petroleum product, coal and electricity. The rural area consumes 86% of the total energy of the country where share of the biomass energy is the highest. Renewable energy (Biomass) and imported kerosene oil are the two main sources of the energy used in the rural area [Shrestah & Thapa]. However, over the years, the contribution of traditional energy forms in the total energy mix has been decreasing. This is due to increase in the use of commercial energy. The total amount of biomass use remains unchanged. This trend is expected to continue until 2030 and beyond. According to Energy Strategy Formulation Project under Water and Energy Commission Secretariat (WECS), it is estimated that by the 2030, the share of traditional fuel will reduce to around 35% with 375. 69 MGJ compared to 87.67% with 323.050MGJ in 2005.

2.2.7 Pakistan

About 72% of population in Pakistan is dependent on the biomass for house energy needed for cooking and heating [WHO 2007]. One-third of energy consumption in Pakistan is estimated to be contributed by non-commercial traditional sources, primarily biomass. A study conducted some time back jointly by the World Bank and UNDP titled Household Energy Strategy Study (HESS) showed that Pakistan’s annual biomass consumption (including firewood, animal dung and crop residue) was about 17 million tonnes of oil equivalent in 1991. Biomass comprised: firewood 63%, animal dung 21% and crop residue 16%. Biomass has been used by most of nearly 20 million rural households in Pakistan for cooking and heating through primitive inefficient stoves [Raza 2008]. In 2007 estimated consumption of biomass 28.2 MTOE which accounted for approximately 33% of total primary energy consumption [IEA 2009]. This indicates that over 16 years biomass use in Pakistan has risen significantly.

In high altitude northern area of Pakistan (Gilgit, Ghizer, Ghanche, Skardu, Diamer districts) consumption of fuelwood for cooking and heating is very high. Average fuelwood consumption in winter is about 4,900 kg per house hold while in the summer (March to September) the average consumption is 900 to 1200 kg per house hold. Average fuelwood consumption per household per year 5.9 tons in this area. The annual per capita fuel wood consumption in the Northern Areas is 744 kg [Ahmed & Abbasi 2001].

2.2.8 Sri Lanka

According to the 2001 Census, in 16 out of surveyed 18 districts the percentage of households using biomass for cooking ranges between 80-93%. In the Colombo district it is 30% and the Gampaha district 60%. Firewood is therefore the major source used for cooking in Sri Lanka. According to the National Energy Balance nearly 8.9 million tonnes of biomass fuels are used in the household sector.
Majority in the rural areas collect their firewood from home gardens or from the vicinity while about 30% purchase their firewood. Collection of firewood and cooking are mainly done by the women. It is of importance to note that almost 77% of the supply is derived from agricultural activities. Over a period of 13 years (1990-2003) it was observed that composition of biomass in the total energy consumed has dropped from 73% to 56.8% and LPG has increased by about 361%. Yet, the actual biomass consumption has increased by 13.6%. In the country cooking is the major energy consuming activity which consumes about 43.9% followed by transport 24.4%, industries 23.2% and lighting 4%. Biomass provides 93% of the energy required for cooking, while LPG and kerosene provide 4% and 3% respectively [Amerasekera 2009].
Section – III
Effects of Biomass Fuels and ICS as an Intervention in South Asia

3.1 Emissions during Cooking with Biomass

In simple devices like the household stoves commonly used in South Asia and other developing regions, biomass fuel does not combust cleanly. Due to poor combustion efficiency, biomass fuel emits a much high quantity of particulates during burning compared to cleaner commercial fuels as shown in Table 3.1.

Table 3.1: Particulate Emission from Wood and LPG

<table>
<thead>
<tr>
<th>Type of fuel</th>
<th>Particles emitted during cooking (μg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>1200</td>
</tr>
<tr>
<td>LPG</td>
<td>200-380</td>
</tr>
</tbody>
</table>

Source: [Ellegard 1996]

Some of the highest exposure to air pollutants occurs inside homes where biomass fuels are used for daily cooking. Wood consists primarily of two polymers - cellulose and lignin. Other biomass fuels also contain these polymers, but their relative proportions differ compared to wood. Besides polymers, small amounts of low molecular weight organic compounds such as resins, waxes and sugars, and inorganic salts are present in biomass. During combustion, pyrolysis occurs and the polymers break apart producing a variety of smaller molecules. Biomass combustion is typically inefficient. As a result, a multitude of partially oxidised health-damaging pollutants are generated.

The list of air pollutants from combustion of biomass as given in Table 3.2 is long and it includes respirable particulate matter with diameter less than 10 microns (PM₁₀) and 2.5 microns (PM₂.₅) or even less (ultra fine), carbon monoxide (CO), oxides of nitrogen and sulfur. Besides, biomass smoke contains at least five chemical groups recognised by the International Agency for Research on Cancer as known or potential human carcinogens. They include polycyclic aromatic compounds such as benzo(a)pyrene and volatile organic compounds such as benzene, toluene and xylene [Sinha et al., 2006]. Other toxic compounds are 1,3-butadiene, formaldehyde, and cilia-toxic respiratory irritants such as phenols, cresols and acrolein.

Table 3.2: Pollutants in Wood Smoke

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Physical state</th>
<th>Emissions (g/kg wood)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide</td>
<td>Volatile</td>
<td>80-370</td>
</tr>
<tr>
<td>Methane</td>
<td>&quot;</td>
<td>14-25</td>
</tr>
<tr>
<td>Volatile organic compounds</td>
<td>&quot;</td>
<td>7-27</td>
</tr>
<tr>
<td>Benzene</td>
<td>&quot;</td>
<td>0.6-4.0</td>
</tr>
<tr>
<td>Toluene</td>
<td>&quot;</td>
<td>0.15-1.0</td>
</tr>
<tr>
<td>Phenol (and derivatives)</td>
<td>Volatile/Particulate</td>
<td>0.2-0.8</td>
</tr>
<tr>
<td>Nitrogen oxides (NO, NO₂)</td>
<td>Volatile</td>
<td>0.2-0.9</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>&quot;</td>
<td>0.16-0.24</td>
</tr>
<tr>
<td>Total particle mass</td>
<td>Particulate</td>
<td>7-30</td>
</tr>
<tr>
<td>Particulate organic carbon</td>
<td>&quot;</td>
<td>2-20</td>
</tr>
<tr>
<td>Particulate elemental carbon</td>
<td>&quot;</td>
<td>0.3 – 5</td>
</tr>
<tr>
<td>Oxygenated PAHs</td>
<td>Volatile/Particulate</td>
<td>0.15-1.0</td>
</tr>
<tr>
<td>Benzo(a)anthracene</td>
<td>&quot;</td>
<td>4 x 10⁻² - 2 x 10⁻³</td>
</tr>
<tr>
<td>Benzo(a)pyrene</td>
<td>&quot;</td>
<td>3 x 10⁻⁴ - 5 x 10⁻³</td>
</tr>
<tr>
<td>Dibenzo(a,h) anthracene</td>
<td>&quot;</td>
<td>2 x 10⁻³ - 2 x 10⁻³</td>
</tr>
<tr>
<td>Iron</td>
<td>Particulate</td>
<td>3 x 10⁻⁶ - 5 x 10⁻³</td>
</tr>
</tbody>
</table>

Source: [EPA 1993]

Table 3.3 shows concentrations of different pollutants due to burning of 1 kg of wood and comparisons with the standard values. The magnitude of air pollution from biomass smoke can be judged from the report that concentration of respirable suspended particulate matter in Indian kitchens is 30 times of the WHO guideline while its outdoor concentration is 2.5 times of the guideline. Approximately 5-20%
of biomass smoke particulate mass consists of elemental carbon, the composition of the organic fraction varies dramatically with the specific fuel type and with the combustion conditions. These particles are considered as the single best indicator of potential harm. Thus, tens of millions of people in developing countries routinely encounter pollution levels similar to the infamous London killer fog of 1952.

Table 3.3: Comparison of Pollutants in Wood Smoke with WHO Standard

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Typical concentrations</th>
<th>Standards/guideline set to protect health</th>
<th>Number of times in excess of standard/guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide (ppm)</td>
<td>129</td>
<td>8.6</td>
<td>15</td>
</tr>
<tr>
<td>Particles (μg/m³)</td>
<td>3,300</td>
<td>100</td>
<td>33</td>
</tr>
<tr>
<td>Benzene (μg/m³)</td>
<td>800</td>
<td>2</td>
<td>400</td>
</tr>
<tr>
<td>1-3, butadiene (μg/m³)</td>
<td>150</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>Formaldehyde (μg/m³)</td>
<td>700</td>
<td>100</td>
<td>7</td>
</tr>
</tbody>
</table>

Source: [WHO 2007]

People of the developing countries are typically exposed to very high levels of indoor air pollution for 3 to 7 hours a day. Since it is always the women who cook daily household meals, their exposure is much higher than men’s. Young children are often carried on their mother’s back or lap while she is cooking. So, from early infancy, children spend many hours breathing smoke.

3.2 Health Impacts of Biomass Fuel

3.2.1 Excess mortality

The health impact of biomass smoke containing high concentrations of particulates and other pollutants can be devastating because for every 20 μg/m³ rise of PM10 in ambient air over the standard, 1% increase in total daily mortality occurs [Samet et al., 2000]. Most people are aware that outdoor air pollution can damage their health. But fewer know indoor air pollution often causes greater harm.

Globally, indoor air pollution from biomass fuel use is responsible for 1.6 million deaths due to pneumonia, chronic respiratory disease and lung cancer. Biomass fuels accounts for 2.9% of all deaths per year worldwide, and 3.7% of the overall disease burden in developing countries. In fact, indoor smoke from biomass burning is the most important health hazard after malnutrition and lack of safe water and sanitation.

3.2.2 Excess morbidity

Biomass smoke exposure increases the risk of common and serious diseases of both children and adults. It has been causally linked to acute respiratory infections (ARI), chronic obstructive pulmonary diseases (COPD), otitis media, tuberculosis, asthma, low birth weight, cataract and blindness, lung cancer, cancer of nasopharynx, larynx and uterine cervix.

3.2.3 Increase in ARI

Acute respiratory infections (ARI) is the most common cause of illness in children and a major cause of death throughout the world. Among children under five years of age, 3-5 million deaths annually have been attributed to ARI, of which 75% are from pneumonia. ARI accounts for 6.5% of global burden of disease. Lower respiratory infections including infection of the lung with pneumonia being the most serious form alone accounts for about 1 million childhood deaths. Studies in developing countries have shown that young children living in households using biomass fuel have two to three times more risk of serious ARI than unexposed children after adjustment for potential confounders. Exposure to indoor air pollution from biomass burning doubles the risk of pneumonia and is responsible for 900,000 deaths annually [WHO 2007].

3.2.4 Tuberculosis

Tuberculosis is a major health problem in the developing countries including South Asia. Approximately 466,400 persons died from tuberculosis in 2007 in the SAARC region [WHO 2009]. An analysis of data from 260,000 Indian adults as part of the Indian National Family Health Survey 1992-93 found that persons living in biomass-using households had more instances of tuberculosis than persons living in households that use cleaner fuels. Biomass smoke exposure can explain up to 59% of rural and 23% of urban cases of tuberculosis in India [Mishra et al., 1999]. Increased risk of tuberculosis may result from reduced resistance to infection as exposure to smoke interferes with mucociliary defenses and decreases antibacterial property of lung macrophages.
3.2.5 Chronic obstructive pulmonary disease (COPD)

Chronic obstructive pulmonary disease (COPD) that includes emphysema and chronic bronchitis (CB) is a lung disease in which the lung is damaged, making it hard to breathe. It is the 4th leading cause of death in the U.S. The symptoms of COPD as described by National Heart, Lung and Blood Institute include: cough sputum production shortness of breath, especially with exercise, wheezing (a whistling or squeaky sound during breathing), and chest tightness. The Global Strategy for the Diagnosis Management and Prevention of Chronic Obstructive Lung Disease has recognised indoor air pollution as a risk factor for COPD. Indoor air pollution is responsible for approximately 700,000 out of the 2.7 million global deaths due to COPD [WHO 2005].

3.2.6 Bronchial asthma

Asthma is a chronic respiratory disease characterized by sudden attacks of labored breathing, chest tightness, and coughing. Of the limited research that does exist on this subject, some studies have found a positive association between cooking smoke and asthma. Data from India’s second National Family Health Survey, 1998-99 suggest exposure to cooking smoke is strongly associated with prevalence of asthma among elderly men and women( ≥ 60 years of age) [Mishra 2003].

3.2.7 Cardiovascular risk

Chronic inhalation of smoke in biomass users results in significant reduction in hemoglobin level and erythrocyte counts and elevation in total leukocytes, neutrophils and plateleto counts. Studies have shown that the absolute number of P-selectin-expressing platelets many times higher in biomass fuel users, suggesting excess cardiovascular risk in biomass users.

3.2.8 Change in immune defense

Particulates emitted from biomass combustion may affect specific and non-specific host defense. Air pollutants commonly found in biomass smoke have been associated with compromised pulmonary immune defense in both animals and humans. Biomass smoke particles often contain transitional metals, especially iron, which induce production of reactive oxygen species (ROS) that may catalyse redox reactions in human lung epithelial cells, leading to oxidative stress and increased production of mediators of pulmonary inflammation.

3.2.9 Hormonal changes

Biomass smoke contains steroid disruptors and the causative agents were identified as polycyclic aromatic hydrocarbons and their derivatives, substituted phenolic compounds, aromatic carbonyl compounds and higher molecular weight alcohol and ketones.

3.2.10 Eye irritation and cataract

Eye irritation from smoke is widely reported. There is also preliminary evidence that a biomass smoke exposure is associated with blindness. Animal studies have demonstrated that biomass smoke damages the lens in rats causing discoloration and opacities. The mechanism is thought to involve absorption and accumulation of toxins, which then lead to oxidative stress.

3.2.11 Otitis media

Evidence from developing countries suggests a close relationship between biomass smoke exposure and middle ear infection (Otitis media) – a condition that causes a considerable amount of morbidity. A study carried out in Nigeria on Otitis among the children showed that a higher proportion belonged to low social class, 75% lived in poorly ventilated and overcrowded houses with 97.1% exposed to indoor pollution [Olubanjo 2008].

3.2.12 Low birth weight and perinatal mortality

Cooking with biomass doubles the risk of stillbirth low birth weight (weight < 2,500g), an important risk factor for infant mortality and morbidity, which is common among biomass users. Conditions that interfere with transplacental delivery of nutrients and oxygen usually cause varying degrees and types of intra-uterine growth retardation and consequent low birth weight. Carbon monoxide emitted from combustion of wood when inhaled combines with hemoglobin to form carboxyhemoglobin (COHb), a much more stable compound that does not readily give up oxygen to peripheral tissues and organs, including fetus. Studies have shown that exposure to biomass smoke is associated with COHb levels of 2.5-13% against a critical level of 2.5%. COHb level according to WHO guidelines should be less than 2.5%. [WHO 1999].

3.2.13 Genotoxic effects

Cooking with biomass is a major contributor of mutagens in breathing air. Smoke emitted from burning biomass increases the frequency of cytogenetic alterations in blood lymphocytes of exposed populations, possibly because of exposure to mutagens present in biomass fuels. A study in India has shown greater frequency of micronucleus (MN) formation and other chromosomal abnormalities in lymphocytes of biomass users compared with users
of LPG. The relative MN frequency in relation to fuel type was in the order of cowdung > wood > kerosene ≥ LPG [Musthapa et al., 2004].

3.2.14 Increased risk of cancer

Biomass smoke contains many potentially carcinogenic compounds including polycyclic aromatic hydrocarbons (PAHs) such as benzo(a)pyrene volatile organic compounds (VOCs) such as benzene, 1,3-butadiene, styrene, xylene and aldehydes. A consistent body of evidence has shown that women exposed to smoke from coal fires in the home have an elevated risk of lung cancer. This effect has not been demonstrated among populations using biomass, but the presence of carcinogens in the smoke implies that the risk may be present [WHO2009].

3.3 Factors Influencing Emission of Pollutants

3.3.1 Fuel type

Daily average concentrations of PM10 in kitchen and living areas of rural households vary significantly for different fuel types. Studies have shown that concentrations are highest in dung-using households, followed by wood, kerosene, and LPG-using households, although the outdoor concentrations are not significantly different across fuel types.

3.3.2 Kitchen type

Cooking areas in many rural households are poorly ventilated and a large number of them do not have separate kitchen. Exposure to indoor air pollution from biomass burning vary with the kitchen type. Four common kitchen types are present in rural area:

- a separate enclosed indoor kitchen with partition,
- an enclosed indoor kitchen with no partition,
- a separate enclosed outdoor kitchen, and
- an open outdoor kitchen (i.e., open air cooking).

Among biomass using households, concentrations of air pollutants are significantly higher in enclosed indoor kitchens as compared to outdoor kitchens but not significantly different between enclosed indoor kitchen types. Since dispersion is much higher outdoors, outdoor kitchens result in lower concentrations close to the stove. Living area concentrations are also significantly higher in indoor-enclosed kitchens as compared to outdoor kitchens.

3.3.3 Age and activity of the people

Women who cook with biomass are subjected to highest 24-hr average exposure concentrations than the non-cooks. Men in the age group 16-50 years experience lowest exposures presumably because they mostly have outdoor jobs. Conversely, women within 16-50 age-group are most exposed to because it their responsibly for cooking food for the family.

3.3.4 Type of cooking stove

It is an established fact that compared with LPG and kerosene, traditional biomass-using cook stoves release several times more air pollutants in the cooking areas. Use of less smoky biomass such as charcoal significantly reduces the emission and exposure, but still it is higher than LPG and kerosene. Improved cook stove for biomass burning, on the other hand, further reduce the exposure and the high cost devices appeared to be more efficient in this regard than the low cost ones. In any case, biomass use even in most advanced high cost improved cook stoves generates more air pollution than that of LPG and kerosene using cook stoves.

3.4 Leading Causes of Biomass Fuel Use

Owing to population growth and economic development, energy consumption in this region is increasing rapidly. Energy and energy technologies have a central role in social and economic development at all scales, from household and community to regional and national. Among its welfare effects, energy is closely linked with public health both positively and negatively, the latter through environmental pollution and degradation. The three main determinants in the transition from traditional to modern energy use are:

- Affordability
- Fuel availability, and
- Cultural preferences

3.4.1 Affordability

The incremental costs of switching over to modern and superior fuels are prohibitive for many rural households. The high operating cost of LPG is not favourable to the rural poor who cannot afford to pay for refilling an LPG cylinder every month or two. The affordability of energy-using equipment is just as important as the affordability of fuels. The initial cost of acquiring kerosene and LPG stoves, and LPG bottles may discourage some people from switching away from biomass.
3.4.2 Availability

Fuel availability is another important factor. If a modern distribution system is not in place, households cannot obtain access to modern fuels, even if they can afford them. LPG penetration rates are low in many developing countries, partly because distribution infrastructure is lacking. In rural areas, biomass is often perceived as something that is “free” and readily available. This kind of thinking seriously hampers the switching over to modern energy. Even when firewood is purchased, it is likely to be cheaper than the cheapest alternative fuel.

3.4.3 Cultural preferences

In some cases, traditions determine the fuel choice regardless of fuel availability and income. For instance, many rich Indian households keep a biomass stove to prepare their traditional roti (bread).

3.5 Reasons for Promoting Improved Cooking Stoves

3.5.1 Health

For people who cook indoors with wood in unventilated or partially ventilated kitchens, the introduction of improved cooking stoves with chimneys or other means to reduce exposure to the health-threatening pollutants found in biomass smoke is of significant benefit. As described before in this section numerous studies in recent years have associated a number of health problems with smoke exposure. The World Development Report has classified indoor air pollution as one of the four most critical global environmental problems. Use of ICS will contribute in reducing the severity of the adverse effects of indoor burning of biomass fuel in the kitchen. A healthier and safer environment, particularly for women and children, may be one of the most important potential contributions of improved cooking stoves to ameliorating the cramped living conditions of many poor people.

3.5.2 Economics

Efficient burning of fuel will reduce the amount of fuel needed per family which will in turn reduce the time for collection of fuel. Further efficient burning will generate more heat during the time for cooking thus shorten the time for cooking. These will enable the women to be engaged in other income generating activities. ICS will also reduce the expenditure of families who have to buy biomass fuel for cooking because of the reduction of amount of fuel. Improved biomass stoves, with their higher fuel efficiency and better design, can potentially diminish the drudgery of collecting fuels and expenditure on cooking energy for millions of rural families who cannot afford modern fuels.

3.5.3 Demand-side management

Demand-side approach refers to introduction of improved cooking stove technology as a new step in the energy ladder between traditional biomass stoves, and the modern fuels and appliances. This approach is appropriate in the many parts of the developing world where modern fuels are not affordable or will not be affordable in the near future. So, the people will have to continue to rely on traditional fuels. If improved biomass stoves were adopted on a large enough scale in such settings, they would reduce the pressure on biomass resources.

In addition, a deliberate slowing of the transition to modern fuels may sometimes be warranted. In China, for example, many rural households had been moving up the energy ladder to coal, which, because opening up of the rural economy, was widely available in many areas that do not have official supplies. This in turn contributed to severe problems in coal supply, so the Chinese government wanted to slow or even reverse the movement of households to coal [Smith et. al 1993]. The government included improved biomass stoves as a part of the strategy.

3.5.4 Prevent deforestation

Traditional forests are under constant threats of extinction due to diversified use of forest resources including demand for fuelwood by the ever-increasing population particularly in developing countries. Some of the adverse effects of deforestation are climatic change, ecological imbalance and soil erosion etc. Improved cooking stoves, by enhancing thermal efficiency and consequent reduction in volume of fuel, may contribute in preserving the forest and save many species of flora and fauna from extinction; and prevent environmental degradation.

3.5.5 GHG reduction tool

Improved cooking stoves can contribute positively in reduction of greenhouse gas (GHG) emissions. The Asian Institute of Technology (AIT) conducted a study on GHG reduction by different stoves in seven countries. The total emission reduction potentials of substitution of all traditional stoves by each of the selected cooking options are given in the Table 3.4. GHG emission amounting to about 38, 58, and 60 million tons of CO2 equivalent can be reduced annually in the selected countries by substitution of traditional stoves by improved cooking stoves, biogas stoves and producer gas stoves, re-
spective. These values are equivalent to about 1.1%, 1.7%, and 1.8% of the total CO2 emitted from fossil fuel use in the selected countries, respectively. It is also estimated that GHG emission will be increased by 50, 70 and 173 million tons of CO$_2$ equivalent per year if all traditional stoves are replaced by natural gas, LPG and kerosene fired stoves respectively [SERD 2009].

Table 3.4: Total GHG Emission Reduction Potential of Different Cooking Options

<table>
<thead>
<tr>
<th>Country</th>
<th>Emission reduction potential (million tons CO2 equivalent per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Improved stove</td>
</tr>
<tr>
<td>China</td>
<td>8.3</td>
</tr>
<tr>
<td>India</td>
<td>18.1</td>
</tr>
<tr>
<td>Nepal</td>
<td>1.6</td>
</tr>
<tr>
<td>Pakistan</td>
<td>4.7</td>
</tr>
<tr>
<td>Philippines</td>
<td>1.7</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>0.6</td>
</tr>
<tr>
<td>Vietnam</td>
<td>3.1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>38.1</td>
</tr>
</tbody>
</table>

Source: [SERD 2009]
Section - IV
Overview of ICS Programmes in South Asia

4.0 Introduction

This section gives an overview of programmes or projects on improved cooking stoves in the different countries in South Asia. There has been no activity on improved cooking stoves in the war-trodden Afghanistan. It has been learnt that in Maldives one NGO tried to disseminate ICS in the nineties but the organisation is now non-existent. Therefore, discussion in this section is limited to important programmes in other six countries.

4.1 ICS Programmes in Bangladesh

Early initiatives in research and development of ICS in Bangladesh were spearheaded by a state-owned organisation, Bangladesh Council for Scientific and Industrial Research (BCSIR). BCSIR led dissemination programmes involved both government organisations and NGOs. Presently, NGOs partially supported by donor agencies and are engaged in the dissemination of ICS in the country with Grameen Shakti and GTZ in the leading role.

4.1.1 ICS Programme of BCSIR

The Bangladesh Council of Scientific and Industrial Research, under the Ministry of Science and Technology, was the pioneer in the research, development and dissemination of ICS technology in Bangladesh. BSCIR began conducting research and development in this technology in 1982 and embarked on wide-scale dissemination of ICS by 1987. Development and dissemination of ICS models suitable for Bangladesh was the primary objective for the BCSIR programme. The Institute of Fuel Research & Development (IFRD) of BCSIR has been pursuing R&D activities on “Stove Technology” to suit the need in respect of biomass fuel, shape of the cooking pot and cooking habit of the users. BCSIR developed more than 18 different ICS models with laboratory testing and field trials, focusing their dissemination work primarily with six different models. BCSIR’s ICS programme had a great impact in familiarising ICS in the country, disseminating over 300,000 stoves from the mid 1980s until 2001. Stoves developed and disseminated by them may be grouped into 3 categories: (i) Improved stoves without chimney, (ii) Improved stoves with chimney, and (iii) Improved stoves with waste heat utilisation.

The dissemination programme of BSCIR was implemented in three stages. Costs of ICS were fully subsidised by the government of Bangladesh and the house owners had to provide soil only.

Stage 1 (1988–1991) Fuel Saving Project: Total 133,841 ICS were installed in 33 upzillas (subdistricts) in collaboration with NGO partners Swanirvar Bangladesh, Aid Bangladesh, Village Education Resource Center (VERC), Bangladesh Association of Community Education (BACE) and Bandhujan Parishad [Winrock 2008].

Stage 2 (1994-1997) and Stage 3 (1998-2001): IFRD of BCSIR completed 2 (two) ADP projects on dissemination of improved cook stoves in the country. Some of the main objectives of the projects are given below [Rouf and Haque]:

- To save traditional fuels by popularising the improved stoves and keep pollution free environment in rural areas of Bangladesh.
- To develop skilled manpower for dissemination of improved stoves through training courses.
- To create awareness about the effectiveness and usefulness of improved stoves through massive advertisement through various media.
- To reduce deforestation and maintain ecological balance of the country through massive use of improved stoves.
- To involve different Government, Semi-Government and Non-Government Organisations in dissemination programme of improved stoves.
- To improve the hygienic condition of the kitchen.

Both the projects were implemented jointly by BCSIR with Ansar-VDP and BRDB as shown in Table 4.1.
Training Programme of BCSIR

To popularise the improved cooking stoves IFRD developed 2 (two) training course manuals on “Improved Stoves” one for one week and the other for four days duration. Scientists of IFRD conducted over 215 training courses on improved stove technology and trained up more than 11,000 men and women from different government, semi-government and non-government organisations of the country. Most of the trained personnel are now engaged in dissemination of improved stoves in different parts of the country.

Shortcomings of the BCSIR Programmes

The programme’s primary weakness was the lack of a strong monitoring and follow-up programme. The absence of adequate post installation support services resulted in eventual disuse of many of the stoves [Winrock 2008].

4.1.2 IAP Project by USAID/Winrock

From 2005 to 2007 Winrock International, Village Education Resource Center (VERC) and Concern Worldwide Bangladesh jointly implemented a USAID funded project titled “Reduction of Exposure to IAP through Household Energy and Behavioral Improvements” in selected wards of Sadipur and Parbatipur municipalities in Nilphamari and Dinajpur districts respectively in the northwest region of Bangladesh. The project’s main objectives were to increase awareness and behavior change about IAP, and to promote and develop a commercial market for ICS, including training for entrepreneurs. By the end of the project more than 580 improved stoves were disseminated in two districts by 20 entrepreneurs who used seed funds to launch and grow stove businesses [Winrock 2008].

The project promoted three stove models, tested for efficiency and emissions and validated by the target households. The project had a strong focus on community mobilisation and awareness raising. Activities included local demonstrations of ICS in communities and schools, folk song performances and film shows. Local community groups were formed to raise awareness and monitor stove construction activities. The project team developed and disseminated IAP behavior change messages through a network of local health volunteers.

The project established a seed fund to assist interested stove entrepreneurs with their businesses. These entrepreneurs, mostly women, were trained in basic business development skills and improved stove construction, use and maintenance.

4.1.3 ICS Programme of Grameen Shakti

Grameen Shakti (GS), a subsidiary of Grameen Bank, has launched a programme to promote improved cooking stoves in Bangladesh to address the high demand for biomass fuels and indoor air pollution caused by cooking on traditional stoves. GS has become interested in ICS because it helps women and makes their lives easier. GS sees a potential market of at least 2 million ICSs in the first three years of the programme. GS plans to depend on two types of local players for expanding Improved Cook Stoves – local technicians and local manufacturers. GS has already trained more than 600 local youth especially women to make, sale and repair ICSs. GS plans to train more technicians in the next phase. These trained technicians will train others as well as produce and commercialise improved cooking stoves on behalf of Grammen Shakti. Many of them will soon start their own business in arrangement with GS and will lay the basis of developing ICS entrepreneurs at the rural level. GS has developed and pilot tested its own model of three mouthed stoves which is more efficient than previous models.

### Table 4.1: Dissemination of Improved Cooking Stoves under GOB Project

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Name of projects</th>
<th>Duration</th>
<th>Budget (Million TK.)</th>
<th>Project Areas</th>
<th>No of Persons Trained</th>
<th>No. ICS Installed</th>
<th>No of ICS Installed by 3 organisations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Dissemination of Improved Stoves (1st Phase)</td>
<td>1994-1997</td>
<td>1,510</td>
<td>105 Upazillas* of 35 Districts</td>
<td>1,000</td>
<td>62,509</td>
<td>BCSIR:12,577 ANSAR-VDP:32,932 BRDB:17,000</td>
</tr>
</tbody>
</table>

Source: [Rouf & Haque, 2008]

* Upazilla means sub-district
in Bangladesh. GS has also set up 10 manufacturing units in rural settings for constructing ICS accessories such as metal grates and chimneys. These manufacturing units are run by entrepreneurs with the financial and technical assistance from GS. This strategy has proved to be successful. More than 2,000 ICSs were constructed within first six months of the programme. Women and commercial organisations such as food industries, restaurant hostels, soap manufacturers have shown great interest in ICS. Till March 2009 GS installed 35,000 ICS in the country. It has targeted to install 10 million ICS in the country by 2012. There is no subsidy by the government. However, GS receives Taka 500 (US$7) per stove from the JP Morgan, USA under Carbon Credit Fund which is partially spent on institutional cost and partially in reducing the stove sales cost.

4.1.4 Sustainable Energy Development Project by GTZ

The Sustainable Energy Development (SED) project is being implemented by GTZ until 2010 with support from the Ministry of Power, Energy and Mineral Resources (MPEMR), and the German Federal Ministry for Economic Cooperation and Development. The project is actively supporting the dissemination of biogas digesters, ICS and solar home systems in rural areas of Bangladesh. The objective of the project is to promote these technologies with a commercial and sustainable approach. The project has focused efforts on identifying locally acceptable, reliable technology design and developing systems for marketing and maintenance. The main strengths of the project are its focus on capacity building, entrepreneur development and involvement of local communities and private sector. As of June 2009 the project installed over 150,000 ICS, including 3,000 stoves for institutional applications, and over 1,200 biogas plants [REIN 2010].

The SED’s ICS work promotes three models of ICS with chimneys with the help of 80 partner organizations (PO) across Bangladesh. The project initially focused on one stove model, which made quality control and monitoring easier. These stoves require 50% less fuel for cooking than traditional stoves, and cost between BDT 200-800 each. In remote areas the three-pot stove cost can be higher, at around BDT 1100. GTZ allows its POs to formulate financing mechanisms for selling the improved cook stoves. The POs use existing micro-credit mechanisms to channel funds. GTZ provides re-financing for these loans, thus enabling households to have a longer pay-back period. GTZ does not provide any direct subsidy on stoves. It provides incentives of Taka 350 (US$5) per stoves sold to the POs as organisational development grant and market development grant. GTZ project is also expected to receive financial support from JP Morgan, USA. Training is an important component of the programme and programme partners. NGOs and private companies are trained in stove construction and marketing. As of June 2009, GTZ trained approximately 8,000 people, including stove technicians, NGO workers and private entrepreneurs. The project provides hands-on training for constructing the ICS, and courses on entrepreneur development and marketing. GTZ has developed detailed training manuals for training of stove manufacturers and training of trainers. GTZ also helps identify supply chains for stove parts such as chimneys and grates by providing technical assistance to village industries. There is some focus on user awareness and a simple user manual has been developed. Monitoring of partner activities is a key component and GTZ is developing a monitoring format. GTZ also supports promotional activities by organising local exhibitions and fairs for renewable energy technologies including ICS.

GTZ programme has been extended until 2014. It has been learnt that this programme has been able to attract users. When they started the programme in 2006 it was very difficult to persuade people to buy an ICS, but now people are spontaneously buying the ICS. This signals long-term sustainability of ICS projects in the country.

4.2 ICS Programmes in Bhutan

4.2.1 ICS Programme by NWAB

Firewood was and remains the exclusive source of fuel wood for cooking in the rural areas of Bhutan. Cooking in smoke-filled kitchens is a common sight resulting in respiratory and eye infections. Therefore, the National Women’s Association of Bhutan took up the installation of improved cooking stoves in the villages of Thimphu Dzongkhag on a pilot basis in order to create awareness on smoke-related diseases. In 1983 total 22 houses were provided with such stoves in Wang Simu and Dalu villages. One year later 118 improved cooking stoves were installed covering all the gewogs of Thimphu Dzongkhag (district) with technical assistance from the erstwhile Public Works Department.

In view of the advantages of the improved cooking stoves as outlined above, there was also an upsurge in the demand for these stoves from all over the country that the issue came into focus in the National Assembly of Bhutan. Subsequently, the Royal Government decided to take the project a step further and the project was launched on a national scale in 1985 with the National Women’s Association being mandated to take up the nationwide programme known as the National Stove Project. It was taken up with financial assistance from
UNICEF and technical backstopping from the erstwhile Public Works Department. A Project Coordinator, with adequate number of supervisors and technicians, was appointed to implement the project. The target for the installation of 4,000 units of improved stoves was achieved by December of the same year. In fact, an additional 331 stoves were installed in the Dzongkhangs (districts) of Thimphu, Haa, Paro, Punakha, Wangdue, Trongsa, Bumthang, Mongar, Lhuntse, Trashigang, Pemagatshel, Samdrup Jongkhar, Tsirang, Sarang, Zhemgang and Samtsi. In order to achieve the target, training on the technical aspects of stove installation was conducted in the beginning of the year in Thimphu for the technicians. Another such training was organized during March-April, 1986, with financial assistance from UNICEF. The training included both mud and stone stove installation, rectifications, evaluation of efficiency and maintenance. A total of 80 technicians were trained in two batches for duration of one month each. During the installation of these stoves, women in the villages were also provided on-the job training in the maintenance and rectification of the stoves.

In addition to the regular visits undertaken by the president and members of the Association to assess the impact of the project on the lives of the rural women, a country-wide assessment of the efficacy of the project was undertaken through the deployment of national graduates in 1987 and the result confirmed high efficiency of the improved cooking stoves.

With requisition for more improved stoves pouring in from all the Dzongkhangs (districts), it became difficult for the Association to manage the project in the absence of regional offices and storage facilities outside Thimphu. Therefore, it was taken over by the Public Works Department in 1988. By then the Association had installed over 14,000 improved cooking stoves across the country.

4.2.2 Programme by BYDA and Tsirang Women’s Group

In 1999 UNDP under small grant programme (SGP) launched a capacity building and demonstration programme titled Improved Community Cooking Stove – an alternative to mitigate fuelwood pressure in North Trashigang, and Biomass Fuel Efficiency Project in Tsirang. This project was implemented by Bhutan Youth Development Association (NGO) and Tsirang Women’s Group (CBO). UNDP provided US$25,670 for North Trashigang component and US$44,440 for the Tsirang component. The project in Trashigang installed community cook stoves in 10 religious institutions, including two nunneries. The project reduced the use of firewood at these sites by 50%, and stimulated the interest of the Trashigang District Administration in distributing the stoves in other community kitchens such as schools, monasteries and army camps. The project in Tsirang resulted in the installation of individual, improved stoves in 2,000 households. The project, which involved the Tsirang District Administration from the start, achieved these results by training women from villages to construct, maintain and repair the stoves; these women had in turn trained others. The BYDA as an association did not have the replication of project activities, as currently the association has been dissolved. However, because of the good demonstration project the technology has proved to be an alternative [SGP/UNDP, 1999].

4.2.3 Present Status

At present there is no programme on ICS in Bhutan. However, it has been known from Renewable Energy Division, Department of Energy Ministry of Economic Affairs that government is planning to launch a large-scale ICS programme under GEF project.

4.3 ICS Programmes in India

India has an extensive firewood shortage problem. A rapid increase in the price of commercial fuels (kerosene, coal and charcoal) compelled poorer groups depending on firewood/biomass as the means of household energy. Again, the firewood shortage in various rural areas has caused many families to turn to burning dung and straw for fuel – thus steering them down the energy ladder. Women in rural India, especially the poor, have to trudge long distances to forage for scraps of firewood. Under these circumstances, widespread rural dissemination of improved cooking stoves is seen as a promising way to reduce the overall firewood requirement.

4.3.1 National Programme on Improved Chulhas (NPIC)

Hoping to reduce the need for firewood, the Indian National Programme on Improved Chulhas (NPIC) was launched in 1983, to be implemented in all states and union territories. The programme aimed to disseminate improved clay and mud stoves (equipped with chimneys) in order to increase the fuel efficiency of traditional stoves and reduce indoor air pollution. Installation of improved chulhas in rural and semi-urban households started in 1986-87 with the following objectives:

i. Conservation of fuel wood and other biomass;

ii. Removal of smoke from kitchen;

iii. Check on deforestation and environmental
iv. Reduction in the drudgery of women and girl children from cooking in smoky kitchen;
v. Reduction of health hazards and in cooking time; and
vi. Providing employment opportunities to rural people.
The administrative structure of NPIC is shown in Figure 4.1. There were two components of the programme – the R&D component and the target fulfillment component.

The R&D component was handled by technical backup units (TBU). This was an independent non-government or academic body comprising of R&D professionals. The tasks assigned to TBU were: i) Development, through laboratory and field trial, of improved stove models to the eating habit and cooking habit prevalent to in the region of operation, ii) Adoption of villages for field testing of the developed models; iii) Training stoves-makers, trainers, users, officers of the programme implementing agencies; iv) Preparation of publicity materials in the local language, v) Entrepreneurship training for commercialisation of improved stoves through potter-entrepreneurs; vi) Feedback surveys in randomly selected villages to assess the quality of installed stoves and to collect user feedback for further improvements in stove designs as well as target fulfillment strategies; and vii) Testing of models of portable improved stoves for approval of manufactures for participating in the target fulfillment component in the state.

Figure 4.1: Administrative Structure of NPIC
Source: [Hanbar et al 2002]
The target fulfillment component was handled by the state government machinery through various implementing agencies at different levels. This was run primarily as welfare activity of the government. In most cases the state government’s department or ministry that dealt with the rural development was the “nodal department” for the programme. However, in some states the programme was attached to the Forest Department or Social Welfare Department. The secretary of the nodal department was the overall in charge of the programme. Every year the nodal department received a certain target of improved stoves to be installed in the state. The target was apportioned among all districts in the state. At the district level, the Chief Executive Officer (CEO) of the district headquarters was in charge of the programme. The CEO apportioned the target among all the blocks in his district. In each Block Development Officer (VDO) was the in charge of the programme who in turn selected villages for installation of improved stoves. In the latter stage of the programme, the responsibility was shifted to the Child Development Project Officer (CDPO), keeping with the growing emphasis on reducing the health effects of using wood and biomass as fuel in the households. The village panchayat handled the programme at the village level, with the help of the self-employed workers or SEW (improved chulha makers trained by TBU) and improved stove manufacturers.

Nodal department was helped by several nodal agencies that received independent funding from the MNES. These were energy development agencies in different states, and national level organisation such as Khadi and Village Industries Commission, National Dairy Development Board and All India Women’s Conference. These agencies also took up targets for installation of improved stoves and fulfilled them with the help of programme implementation structure present in the state.

The Indian Government invested a lot in promotion to disseminate the improved stoves in rural India through NPIC. A key element of the dissemination policy was the provision of a government subsidy to all households purchasing an improved stove. A minimum of 50% subsidy was available, reducing the cost of new stoves from US$10 to US$4.30 [Barnes et al., 1994]. Financial incentives provided in the year 2001-2002 are presented in Table 4.2.

### Table 4.2: Financial Incentives in 2001-2002 under NPIC

<table>
<thead>
<tr>
<th>Type of Chulha</th>
<th>Amount of Central subsidy per chulha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durable fixed type chulhas with chimneys</td>
<td>Rs. 270/-</td>
</tr>
<tr>
<td>(i) N.E. Region States &amp; Sikkim</td>
<td>Rs. 80/-</td>
</tr>
<tr>
<td>(ii) Other</td>
<td></td>
</tr>
<tr>
<td>Portable Chulha</td>
<td>Rs. 135/-</td>
</tr>
<tr>
<td>(i) N.E. Region States &amp; Sikkim</td>
<td>Rs. 75/-</td>
</tr>
<tr>
<td>(ii) Islands and notified hilly and desert areas</td>
<td>Rs. 50/-</td>
</tr>
<tr>
<td>(iii) SC/ST beneficiary in other States / UTs</td>
<td></td>
</tr>
<tr>
<td>High Altitude Chulha</td>
<td>Rs. 450/-</td>
</tr>
<tr>
<td>(i) N.E. States and Sikkim</td>
<td>Maximum up to Rs. 250/-</td>
</tr>
<tr>
<td>(ii) Jammu &amp; Kashmir, Uttarakhand, Himachal Pradesh and hilly districts of West Bengal</td>
<td></td>
</tr>
</tbody>
</table>

While institutional supports included:

i. **Self Employed Workers** charges for construction & maintenance of improved chulhas:
   - Single pot fixed chulha with chimney: Rs. 30 per chulha
   - Two/three pot fixed chulha with Chimney and community chulha: Rs. 40 per chulha

ii. **Dealership support for fair price shops**: Rs. 5 per chulha and co operative stores and private retailers.

iii. **Support for organisations and infrastructure**: Rs. 4 per chulha to State Government, Nodal Departments and Agencies.

iv. **Support for State level publicity awareness**: A minimum support of Rs. 30,000/- was given to the States and agencies having an annual target of upto 15,000 improved chulhas. The other States and agencies which had an annual target of more than 15,000 chulhas were entitled to receive funds @ Rs. 2/- per chulha, with an upper ceiling of Rs. 2.50 lakh.

v. **Training support**: at the rate of Rs. 16,000 per SEW course, Rs. 10,000 per Trainers Training Course, Rs. 27,000 per Entrepreneurship Development Course and Rs. 1,000 per Users Course.

vi. **Support for Technical Backup Units**: @ Rs 8
lakh to Rs 10 lakh per year.

vii. Support for Fixed Chulha Moulds: at the rate of Rs. 1,500 per village panchayat.

More than 30 models of chulhas were developed during the 17 years of NPIC and around 34 million chulhas were installed by 2001-2002 [Mahapatra 2003]. However, the primary drawback in the world’s second largest programme of ICS after China National Programme of ICS gradually became evident as multiple levels of government bureaucracy complicated the initiative. Programme administration was truly cumbersome and fragmented. In addition, the budget was insufficient for the level of supervision and assessment which the programme required. Problems were not noticed and rectified in good times [Sinha 2002]. In 2002 the NPIC was deemed a failure and funding was discontinued; responsibility for continued ICS dissemination was passed to the states. Since this time, a handful of state governments and NGOs have continued ICS and related projects. However, the lack of central government support and funding has thus far precluded initiatives in all.

Some shortcomings of NPIC

Effect of subsidy

The presence of a large government subsidy was a big discouragement for the success of the NPIC. As the government automatically paid builders for half the cost of stoves, producers’ motivation for building improved stoves was directed more towards the government than towards the consumers [Barnes et al., 1994]. Stove producers were only concerned about government specifications and did not respond to the need for consumers’ preferences or an aggressive marketing strategy. As a result, local stove construction was often hasty and technically faulty. Many stoves did not accommodate the household cooking pot, or could not withstand the heat required for cooking. Many of the stoves plainly did not offer the assured savings in household firewood consumption. The heavy government subsidy for cook stoves also suppressed efforts by private entrepreneurs to disseminate their own improved stoves, as they could not possibly compete with the highly subsidised government price.

Failure to target resource-poor regions

Another limitation was that NPIC failed to target regions where fuel scarcity were especially severe, or where firewood was a very expensive. Many rural households could not afford, or were not willing to pay for, the highly subsidised improved cook stove as they were collecting the firewood/biomass for free. The purchase of a new improved stove is never seen an interesting option to those who are very poor in India.

Need for maintenance

Another reason was the lack of interest of women towards maintenance, as they did not perceive the usefulness of the stove. A national survey in 1992–93 noted that some households opted for the stove only for the subsidy in the form of pipes, metallic sheets, etc. In a number of cases, chimney pipes were re-used as links for the sanitary latrine, irrigation channel or even sold in open market, after being removed from the stove.

Indoor air pollution as a factor

Indoor air pollution (IAP) was never a key driving factor of NPIC up until the last 3-4 years. When MNES finally decided to incorporate IAP concerns in the programme, it went for a ‘short cut’ solution. Instead of giving time to the TBUs to come with user-friendly easy-to-install nonpolluting stoves, and to make systematic efforts to make the chulhas-users aware of the hazard of IAP. It simply sent a directive that every fixed stove installed under NPIC henceforth must have a chimney. The consequence in Maharashtra state was as follows: The choice that was offered under NPIC was between fixed stoves with a chimney and metallic portable stoves. Due to various practical problems associated with installing a fixed stove with a chimney, the state government’s implementing agencies went in a big way for metallic portable stoves. Consequently, most of the users ended up with having to accept the portable stove due to ‘non-availability’ of the fixed one. Traditionally in this region the portable stoves are not used as the main day-to-day cooking stoves. The result is that the government ‘target’ for stoves has been fulfilled, but the ‘beneficiaries’ continue to use their traditional stoves for daily cooking [Sinha 2002].

Some positive aspects of the NPIC

Despite all the problems, overall, there are three good visible signs in favour of the NPIC programme.

(1) Women are raising their voices in various forums to demand improved cooking stoves.

(2) Some states have promoted improved cook stoves through people’s programmes. For example, Andhra Pradesh is popularising cook stoves under Janambhoomi and Karnataka under Panch Sutry Yojana.

(3) Several non-governmental organisations and local bodies, such as Gram Panchayats, are actively participating with the government.
in raising awareness among women to use improved cooking stoves.

4.3.2 Commercial Approach in India

a. ARTI in Maharashtra

Appropriate Rural Technology Institute (ARTI) worked as the Technical Back-up Unit (TBU) for NPIIC for Maharashtra and Goa states from 1996-2002. Since 2003, ARTI has been trying to commercialise a range of biomass fuelled cooking devices in Maharashtra state on the west coast of India. Only those devices that satisfy basic criteria of reduction in indoor air pollution are included in the project. The commercialisation project is currently supported by the Shell Foundation, UK under its Breathing Space programme.

The Pilot Project was operated by ARTI, with the help of ten grassroot level NGOs spread over Maharashtra state, from January 2003 to December 2005. In the initial stages, the project concentrated on market testing of the products, and technical and entrepreneurial training of potential entrepreneurs. At the end of the project period, there were 120 active rural enterprises spread over the state, and during August 2004 to December 2005, these enterprises had collectively sold clean biomass energy cooking products to about 75,000 rural families in Maharashtra. In this process, the NGOs involved in the project, including ARTI, learnt important lessons in the commercial approach (as against the welfare approach) to rural upliftment. Through the pilot project, it was established that there is a growing demand for improved biomass fuels and cooking devices.

The Scale-up Project from 2006 to 2010 takes off from the success of the pilot project and is also being supported by Shell Foundation. The project aims to reach out to about 15,00,000 rural households in Maharashtra and around 50,000 rural households in Gujarat. It is envisaged that this project will successfully establish sustainable business chains for supplying the clean biomass energy cooking products the rural population in Maharashtra and Gujarat states. This will be achieved through active participation of rural entrepreneurs, Self Help Groups (SHGs) and Non-Government Organisations (NGOs). ARTI, with its long standing experience in development and dissemination of rural technologies, will drive the synergetic working between various NGOs and entrepreneurs. Considering the rural population of Maharashtra and Gujarat states (about 20 million households) the market potential is very attractive. It is learnt that currently 30-40 thousand improved cooking stoves every year are being disseminated in the state.

b. TIDE in Kerala and Karnataka

Technology Informatics Design Endeavour (TIDE), established in 1993, is a non-profit organisation which seeks to apply appropriate technology to rural situations. It works through a network of extension agents who learn about a new technology from TIDE and then move to another area to manufacture and market this technology. TIDE employs 24 staff and about nine volunteers. It is funded through grants from government departments, funding agencies and private clients, and had an income of £105,000 in 2007 [Wheldon 2008].

In South India alone, it is estimated that eight million people work in small and tiny businesses (including food processing and preparation, textiles, ayurvedic medicine and brick making) where wood and other biomass is the source of process heat. Most of these businesses operate with low overheads, so fuel efficiency has not been a priority. This use of fuelwood by industry has contributed to de-forestation, a serious problem in the ecologically sensitive Western Ghats. It also has serious impacts on the health and safety of workers, who may work long hours over open fires or inefficient stoves.

TIDE has, therefore, developed a programme specifically to improve the efficiency of wood use in small and tiny businesses, initially in Karnataka and Kerala, but now expanding to Tamil Nadu and Andhra Pradesh as well. Improved efficiency is achieved through better heat transfer and combustion of the fuel and improved insulation to prevent heat losses. Each stove which TIDE develops and promotes is designed around a specific current sector of use, and with user participation, so that the existing process requires minimal modification. In addition, TIDE will develop and commercialise a system only if it will be affordable without subsidy in the industry which it is designed for. This need to balance cost, functional design and efficiency inevitably leads to compromises, but means that the stoves are viable commercial products. The stoves save at least 30% of biomass use, and more in some sectors. TIDE estimates that the 1,050 stoves installed up to the end of 2007 are saving 43,000 tonnes/year of biomass, and that a cumulative 150,000 tonnes of biomass has been saved since the scheme started in 2000 [Wheldon 2008].

Payment

TIDE provides initial support for awareness-raising and marketing, and usually subsidises initial demonstration units, but customers must pay a price which covers the cost of the stove and provides the entrepreneur with a reasonable profit. Normally a deposit is required when a stove is ordered, with a further payment when the construction starts and the balance on completion, although some entrepre-
neurs will wait a month for the final payment. Industries using several heating units will often replace one at a time, and thus spread the capital cost over a period.

Nearly all users pay the full economic cost of the stove, which ranges from about IRs 2,000 (£25) for a simple silk-reeling stove to over IRs. 65,000 (£820) for a large drier. The cost of the stove is usually paid back within one year from savings on buying fuelwood or biomass. For some industries the payback time is less than two months. An assessment carried out by TIDE at the end of 2006 suggested that the stoves then in use were saving IRs. 39 million (about £0.5 million) per year in fuel costs, and since then the price of wood has increased.

TIDE has arranged loans through financial and industry associations for the areca stove purchasers. However, there has not been a wide uptake on loans, because the stoves are affordable without them and many people are cautious about using credit. Occasionally a subsidy may be available for a particular industry. For instance, the Department of Sericulture in the Government of Karnataka provide a 40% subsidy for silk-reeling stoves, which is paid to the entrepreneur when the user has paid their 60% contribution [Wheldon 2008].

The size of the devices, and thus the price, varies greatly. Some examples are:

- Silk-reeling stove IRs 2,000 (about £25). [£1 = 79 Indian Rupees, April 2008]
- Ayurvedic medicine stoves IRs 4,000 (£50).
- Areca stove IRs 5,500 (£70) for one-pan model, IRs 10,000 (£130) for two-pan model.
- Small heated dyeing vat IRs 15,000 (£190). 100 litre water-boiler, IRs 15,000 to 17,000 (£200).
- Improved tava cookstove (for dhosa, rotis, omelettes) IRs 17,000 (£220).
- Large bleaching vat IRs 25,000 (£320).
- Fixed brick kiln IRs 40,000 (£510).
- Portable metal drier IRs 65,000 (£820).

**Training, support and quality control**

The extension model used by TIDE has been very effective, supporting the development of independent entrepreneurs while maintaining good control of quality. TIDE trains extension workers, who are sometimes university graduates, to take technology into new areas. Initially this training lasted for two years, but shorter programmes are now used. Trainees are prepared to become a private entrepreneurs, to develop their own marketing approaches, and to work in a specific geographical area with a controlled degree of competition. If competition becomes a problem, they are encouraged to work with different clients. Some entrepreneurs leave the TIDE network to set up other businesses, such as promoting solar-PV technology.

The small industries with which TIDE works are understandably cautious about taking on new technology, and changing their working patterns. It is for this reason that the TIDE stoves are designed to directly replace existing equipment, with minimum disruption to users and their routines. New customers usually help the entrepreneurs to construct their stoves, and the entrepreneur helps them to understand how to use the stove properly. TIDE arranges courses which are attended by stove users from a wide area, allowing them to learn from each other.

Entrepreneurs offer a one-year warranty for the equipment they have installed. Following this, they carry out servicing and repairs on a chargeable basis, and also follow-up customers informally to check that equipment is working well. The stoves are expected to last for four to five years. On-going support can be arranged via a contract.

Quality control is an important factor for TIDE. The Central Power Research Institute (CPRI) of the Government of India tests the efficiency of all the products. The Centre for Sustainable Technologies at the Indian Institute of Science (CSTIISc) sometimes collaborates in the development process, carrying out field testing and data collection. The entrepreneurs are required to keep detailed records of where stoves are installed and provide this data to TIDE, and must also keep a complaints register. TIDE makes random spot checks on its own systems and those installed by entrepreneurs, and finds that they are generally working well.

**Benefits**

By the end of 2007, total 1,050 stoves or other heating appliances, all fired by biomass had been supplied by TIDE, mainly in the South Indian states of Kerala and Karnataka and to a small extent in Tamil Nadu and Andhra Pradesh. This number includes equipment supplied directly by TIDE and or through their network of entrepreneurs.

**c. Gram Vikas in Orissa**

Gram Vikas, which literally means ‘village development’, is an organisation that has been working since 1979, to bring about sustainable improvement in the quality of life of poor and marginalised rural communities, mostly in Orissa. The core group of Gram Vikas had come to Orissa as student volunteers of Young Students’ Movement for Develop-
ment (YSMD) to serve victims of a devastating cy-
clone in 1971. Registered as a society on 22 January
1979, Gram Vikas today serves more than 252,000
people in 704 habitations of 21 districts of Orissa, in
Eastern India. 5072 smokeless mud chulhas (stoves)
designed by Gram Vikas were installed in year 2007-
08, now totaling 10321 in GV villages. Annual
Report 2007-08 mentioned that 232 local youth and
women Self Help Groups (SHGs) have been trained
in chulha-making and they in turn, guide users in
maintenance.

4.4 ICS Programmes in Nepal

Nepal relies heavily on fuel wood for its energy
requirement. Initiatives to improve the efficiency of
stoves are fairly old in Nepal. These initiatives may
be divided in two broad categories - Early Initiatives
and New Initiatives.

4.4.1 Early Initiatives in Nepal

The Indian stove models, the Hyderabad and Magan
Chullah, were the first Improved Cooking Stoves,
introduced in Nepal, during the 1950s. In the 1960s,
an agro-engineering workshop in the Department of
Agriculture developed a mould-based stove model,
which was disseminated through the mid-1970s, a
number of NGOs and GOs (Peace Corps, Women
Training Centre, RECAST, and UNICEF) were
involved in ICS research and dissemination of the
Lorena stove model. Unfortunately, lack of funding
led to stagnation in stove dissemination. In the
1980s, the National Planning Commission ad-
dressed the fuel wood consumption issues in its
Sixth Five-year Plan, together with the introduction
of Community Forestry. Government initiated dis-
semination of ceramic pre-fabricated stoves, sup-
ported by FAO and UNDP. About 57,000 ICS of
this model were disseminated in different parts of
the country. The ceramic inserts proved inappropriate
to most areas of Nepal, since they were often
breaking during long and complicated transportation
in hill areas [Shersta & Thapa].

4.4.2 New Initiatives in Nepal

a. ICS Development in 1990s

New initiatives have been underway since 1990s
with new stoves design that can be built from cheap
readily available local materials and changed ap-
proaches from top down, target oriented, subsidised
approach to bottom up demand driven, self con-
struction approach. With combined efforts of gov-
ernment organizations, donor agencies and NGOs
about 40,000 ICS of various types (mud, metallic)
were disseminated until 1998. In 1995, ICS network
supported by ARECOP and managed by Centre for
Rural Technology (CRT/N) was established.

b. National ICS Programme

National ICS Programme has been initiated from
early 1999 with the support of Energy Sector Assis-
tance Programme (ESAP) of DANIDA. Similarly,
networking of ICS promoting organisations have also
been undertaken with the support of ARECOP.
In this initiative, Centre for Rural Technology
(CRT/N) in cooperation with various GOs and
NGOs is coordinating network strengthening activi-
ties. Alternative Energy Promotion Centre (AEPC),
a government agency, is supporting to further
strengthen the Network activities.

The general objective of this programme is to estab-
lish a sustainable framework and strategy for mak-
ing available needed technically and socially appro-
priate ICS in rural communities based on local ca-
pacity building and income generation. The imme-
diate objective is to create and build up the capacity
on community, district and national level regarding
the promotion and dissemination of ICS and to
achieve broad coverage of ICS primarily in mid-
hills.

This national programme has to an extent attempted
to address the strategic challenges based on the les-
sions learnt from the past ICS disseminating pro-
grames. This programme thus has developed sus-
tainable approaches characterised by the following
features:

- Participatory,
- Demand driven,
- No direct end users subsidies, and
- Effective and appropriate Technology.

Programme Implementation Process

The programme is primarily focused to the rural
women with the appropriate strategies to build ca-
pacity at local level. The promoters are paid by the
end-user in cash or kind. The approaches taken to
disseminate are also flexible so that the programme
could be collaborated with more NGOs, GOs and
NGOs at national, district and local level. The fol-
lowing steps describe the general implementation
procedure followed by the National ICS Pro-
gramme:

1) Establishment of ICS Promotion Unit in the
district,
2) Identification of Suitable Local Partners for
collaboration,
3) Programme Initiation Workshop,
4) Baseline and Need Assessment,
5) Training of Partner Staffs,
6) Identification, Selection and Training of Lo-
cal Promoters,
7) Village wise Orientation and Demonstration, local Information Campaign for Demand Creation,
8) ICS installation, Monitoring, Follow-up and Technical Testing and Promoters Regular Meeting,
9) Participatory Monitoring,
10) Annual Review and Planning,
11) Certification and Award to Best Promoters,
12) Formation of Promoters Association, and
13) Phase out and Extension of Programme to New Areas.

Vision for the Future and Programme Outputs

The vision of the future is to contribute to a national strategy for ICS promotion and dissemination, which would be sustainable in the sense, that ICS promotion and dissemination could continue to take place in rural (and semi rural) areas, primarily in the Middle Hills, by the local people themselves without external inputs. The coverage of ICS at this time is already very broad so that an ICS is now more common than a traditional stove.

Local institutions and individual households will have stoves that they are capable of using and maintaining, and replacing when needed and which give more benefits than they costs with regard to biomass consumption, health issues, women’s and girls’ work load, indoor environment and social aspects.

Phases of Nepal’s National ICS Programme

Phase 1 (2000-2006): The first phase was originally planned to be 2000-2004 but it continued until March 2007. During this period the programme covered 15 districts and a total of 2,13,059 numbers of ICS were installed in the mid hill districts to demonstrate that a sustainable strategy for mass ICS dissemination has been developed and that it is possible to implement successfully on a reasonably larger scale. The programme was aimed at developing and strengthening local capability, and promoting ICS through close collaboration of Women Development Programme, CBOs, NGOs and other informal groups such as Community Forest Users Groups, Mother’s Group and Women’s Groups/ Cooperatives etc.

Phase 2 (2007-2011) and Future Vision: In ESAP II, support to Improved Cooking Stoves (ICS), it has been perceived that a more comprehensive approach towards overall biomass energy development would help in achieving the long-term objectives of socio-economic, gender, poverty reduction, and empowerment of rural people. Contrary to the historical approach to disseminate ICS, which was limited to improving fuelwood efficiency and addressing gender education and health issues through ICS Programme in the mid-hills, the revised approach would address more general social and economic, environment issues including ICS. The component mainly relates its activities to decentralisation, institutional capacity and policy, and socio-economic uplifting of rural people.

Unlike in Phase-I, which focused on dissemination of ICS, especially for households in the middle hills, this Component in Phase-II is designed to include all major biomass energy technologies as solutions to rural energy problems, e.g. stoves for institutions like hotels, restaurants, schools, army barracks, religious centers and piloting of stoves for High Mountain and Terai. Besides, the Component is also addressing introducing biomass briquetting, biofuel and gasification technologies. The component will also focus on providing appropriate information materials to fill the gap of information for a wider range of stoves and other biomass energy technologies.

It is envisioned that by end of Phase II 4,34,000 ICS will be installed in Mid Hills and Terai, 10,000 household gasifiers disseminated through commercial market, 1,000 Institutional gasifiers disseminated on economic basis, 5,000 Institutional ICS installed as demonstration, 50,000 metal stoves installed in high hill [AEPC].

Phase 2 is envisaged as scale-up ICS dissemination spread to all the mid-hills of Nepal and some mountain and terai districts using the strategy developed during Phase 1. During this phase, quite a large number of NGOs and substantial number of community-based organisations would be mobilised to develop purely market based ICS dissemination through out the country.

Apart from the National ICS Programme, other NGOs/NGOs will also take maximum advantages from this programme to implement ICS activities in the rural areas, which is not covered from this programme. All the valuable experiences and the training manuals and awareness campaign materials developed for these initiatives will serve as supplementary efforts to contribute in meeting the national plan target of ICS dissemination. The programme has been partnering with 153 local districts based organisations (NGOs, CBOs and GOs), nine national level NGOs as service providers and has an understanding on promotion of institutional improved cooking stove promotion with UN World Food Programme in four districts.
**ICS Networking and Lobbying**

In the above context of the implementation of Phase 1 and 2 as well as other ICS related programmes to be implemented, strengthening of ICS Networks at the central level as well as the decentral level will play a vital role in terms of information dissemination, inter-linking programme experiences and collaboration and development on ICS. Thus the present network capacity building efforts with ARE-COP support will serve as “fill in the gap” to the current programme and contribute more as complementary support for effective ICS programme implementation in the future. The Government would be active in lobbying with the GOs, INGOs and Donors in developing consensus regarding basic concepts for sustainable ICS dissemination and promotion.

**Subsidy Policy**

The national programme has been selective of areas on providing subsidies:

- No subsidy has been provided to households mud improved cook stoves in Hills and Mid Hills of Nepal.
- 50% subsidy will be provided to improved cook stoves in High Mountains for cooking and space heating, as they are costly and unaffordable but which is not more than NPR. 2,500.

4.5 **ICS Programmes in Pakistan**

4.5.1 **Programmes in Public Sector**

Appropriate Technology Organisation (ATDO) and NWFP University of Engineering and Technology, Peshawar in 1984 developed three-mouthed mud stove for cooking in the plain areas of Pakistan and named it Economic Cook Stove. Soon after, they went for dissemination of this stove mainly through NGOs. Subsequently they developed two-pot stove on the realisation that in most cases the third pot remains idle. ATDO was responsible for training the NGO workers in the field. Installation of stoves in the households was the responsibility of the NGOs who were supported by donor agencies. In 1986, ATDO was renamed as Pakistan Council for Appropriate Technology (PCAT), which continued the mud stove programme launched by the ATDO. It is learnt that in many cases the specifications were not followed during installation of stoves which resulted in worse performance.

PACAT undertook a programme called Fuel Saving Technology (FST) Programme with financial support from the government of Pakistan to train NGOs and private entrepreneurs who were already in this business with thrust on the mud stoves with chimney. PCAT provided training and chimney component as subsidy during this four-year programme from 1994-95 to 1998-99. About 70,000 improved mud stoves were disseminated under this project.

Pakistan Council of Renewable Energy Technologies (PCRET), established in 2001 merging PCAT and National Institute of Silicon Technology (NIST), during 2002-2004 designed three metal stoves with assistance from Empower New Zealand, a non-government organisation under their Coal Cake Manufacturing project. Under this project PCRET trained metal stove manufactures of the northern region of the country. Although these stoves were initially designed for coal cake, they were later adopted for other fuels. These stoves have been widely accepted among the people in the northern region. Most of the household in Muree Tasil district are now using these stoves especially MA-I and MA-II metal stoves. These stoves are also found in Aftabad, Mardan, Swat, Dheer and Chittral districts of the northern Pakistan. PCRET during this period also developed two baked mud stoves but they remained limited as R & D products only, which could not be disseminated.

From mid 80s to 2004 first ATDO, then PACAT and finally PICRET conducted 200 training programmes and 4,000 demonstration programmes throughout the country on ICS. Presently PCRET is no more involved in ICS dissemination activity. But it has been able to give a commercial shape to the programme. Private entrepreneurs are now involved in manufacturing and selling ICS designed by PCRET especially metal stoves in the northern areas of the country.

4.5.2 **FECT Programme by GTZ**

GTZ implemented a programme titled ‘Fuel Efficient Cooking Technology (FECT)’ programme during 1988-92 when they disseminated three-pot metal stoves without chimney and horizontal *ton-door* through NGOs in the northern areas. This was a subsidised programme.

4.5.3 **Programme by BACIP of AKPBSP**

Aga Khan Planning and Building Services, Pakistan introduced a fuel-efficient stove design in 1985 in the villages of Ghizer and Hunza districts. The project was successful as people replicated more than 10,000 units of stoves for their use up to 1999. In 1997 AKPBSP launched a project titled Building and Construction Improvement Programme (BACIP) operating in the Northern Areas of Pakistan and financed by PAKSID, a collaboration between the Canadian International Development Agency (CIDA) and the Aga Khan Development
Network. The BACIP Programme Director was contracted through the Netherlands International Development Co-operation Programme (DGIS). BACIP works in co-operation with other Aga Khan Development Network Institutions (AKDNI) and engaged in programming and developing solutions to the housing issues of the communities the Northern Areas and Chitral living in the ranges of Karakoram, Himalayas and Hindukush. During 1999 and 2000 some 40 staff members, consisting of architects, engineers and social workers, were involved in the BACIP programme activities. In addition, more than 200 village-based male and female resource persons assisted on a voluntary basis in the implementation of the programme [Nienhuys 2000].

BACIP’s approach is not only to develop products that are relevant, acceptable for the community but also to overcome hurdles inhibiting the mass adoption of those products in a sustainable manner. BACIP undertakes action-research and has also so far developed, tested and based on community feedback refined more than 60 different types of housing and living conditions. BACIP also undertakes awareness raising, training of crafts persons, entrepreneurs and marketing of making products. Awareness building activities include organising road shows in remote villages and workshop etc. The BACIP has developed different models of ICS and has disseminated about 10,500 ICS during 1999 to 2009. Its programme is mainly non-subsidised. However, they provide up to 70% of subsidy for metal stoves in some houses for demonstration purpose.

4.5.4 Programme by Escorts Foundation

The Escorts Foundation, founded by a private company in Lahore, focuses its efforts specifically upon the development of the Changa Manga region. The Changa Manga region, about 80 km from Lahore, includes about 55 villages surrounding one of the largest man-made forest reserves in Pakistan, the Changa Manga Forest Reserve. There are also six villages located within the forest, and additional squatter settlements in the general area. The reserve is a protected area, but is subject to pressure from local inhabitants who depend upon firewood for cooking. These communities are very poor with very low literacy rates. There is a high rate of theft of wood from the protected area, with some villagers selling firewood from the forest to generate income. Escorts Foundation launched a programme for dissemination of improved cooking stoves among the villagers in this region. The programme was financed by UNDP under Small Grants Programme (SGP). UNDP contributed US$ 7,500 in 1995 and $7,500 and $32,698 in 1999. The programme served 11,728 households (70% adoption rate) in 54 villages.

The Escorts Foundation made use of a stove construction and dissemination model successfully implemented by the Family Planning Association of Pakistan, which in turn was adapted from work on improved stoves in India. The Escorts Foundation did not subsidise the stoves at all, believing that users must invest in the stoves if they were to continue using them and promote their use to other villagers. In any village, the implementation process used to begin through conversations with the village leader which lead to discussions with various stakeholders and planning for the training. The next step involved canvassing the village, collecting population, fuel use and other data while distributing advertising for the training. Originally, the project began by training two women from each of six villages, and then encouraging those women to go back to spread the stoves around their villages. However, this approach was unsuccessful. Although the women were paid a small amount – about $1 – per stove they constructed, adoption rates were low because traditionally the rural women make their stoves themselves and were not willing to pay anybody for constructing their stoves. They soon started to conduct public demonstrations, boiling water with the old and the new stoves, and measuring the differences in the time needed to boil the water and the amount of fuel used. This proved helpful, but the Escorts Foundation also decided to change its approach and train more women per village. At the end of each training session, two particularly motivated women were chosen from each village to take home construction kits. These women would be responsible for motivating other women to use the stoves, and for evaluating and monitoring post-construction use of the stoves. Project staff also made three follow-up visits to each village to help ensure proper maintenance and encourage expanded use. Using this refined approach raised adoption rates at 70%. At present the ICS programme of the organisation has been scaled down.

4.5.5 Programme by WWF

Under the concept ‘Partnership in Change’ World Wide Fund for Nature - Pakistan (WWF-P) implemented a project in the Bar Valley in Nagar subdivision of Gilgit district in 90s. The project titled Conservation of Wildlife in Selected Areas of Northern Area had a component of reduction of fuelwood consumption. Under this programme WWF-P introduced fuel efficient stoves, trained local artisan in fuel efficient stove (FES) making and conducted awareness programme in the area for conservation of forest by reducing fuelwood consumption.

During 1999-2004, WWF-P implemented a project funded by Department for International Develop-
ment (DFID), UK when they provided 15 fuel efficient stoves in Gulkin of Gojal, 25 stoves in Shianki of Hunza and 25 stoves in Balashar of Astore in northern area of the country. This project was implemented jointly with the community conservation committees. WWF-P bore 56% while communities bore 44% of the project cost. WWF organised training for the local craftsmen and arranged demonstration of the stoves in the communities. BA-CIP of AKPBSP provided technical support in designing and training on fuel efficient stoves.

WWF-P implemented a EU funded project ‘Environmental Education Programme’ in support of Mountain Areas Conservancy Project (MACP) in four conservancies in Northern Area and NWFP from January 2000 to December 2004. The emphasis of the project was to support the larger GEF/UNDP funded Mountain Areas Conservancy Project (MACP). The MAC project intends to conserve biological diversity in Pakistan’s Karakorum, Hindu Kush and Western Himalayan mountain ranges through a community based conservation approach. The project area included Gojal and Nangaparabat conservancies in Northern Areas and Tirchmir and Qashqar conservancies in NWFP. A demo project titled “Fuel Efficient Stoves” as alternate to fuel wood was implemented in Ghaziabad village of Nangaparbat conservancy in 2002. A Term of Partnership (ToP) was signed with Bismillah Village Welfare Organisation (BVWO), the representative CBO in August 2002. As per agreement, 60% of the total demo project cost Rs. 55,200 was contributed by the project and the remaining 40% cost (Rs. 36,800) was shared by the community. On recommendations of the community, 40 FE stoves were prepared with little modifications in the design and size of the stove, and were distributed among forty households. Another demo project was implemented in Shahoo valley of Kalam during 2004 adopting a participatory adaptive management approach. Following considerations were kept in mind while selecting the site for FES demonstration project:

- Pressure on forests due to fuel wood collection and green felling;
- Presence of an active Valley Conservation Committee (VCC); and
- Community’s willingness to contribute at least 30% of the total project cost.

The project distributed forty fuel efficient stoves among 40 households of Shahoo valley in December 2004 and trained local artisans for replication of stoves in neighboring villages. The project organised two road shows on fuel-efficient stoves in Kalam valley to introduce the fuel-wood saving technology. The communities, mostly passersby were briefed about effectiveness and efficiency of the fuel efficient stoves during the show. The project arranged a visit of 15 member group comprising village conservation committee and stove makers from Tinjus Valley to the demo project in Ghaziabad in 2003. Under this project a local artisan (blacksmith) from Kacha-Shagatang conservation committee and two artisan from Shahoo valley in Qashqar conservancy were trained on making fuel efficient stoves on 2002 and 2004 respectively [Babar 2004]. Post implementation surveys have shown that some private entrepreneurs are making fuel efficient stoves and selling in the communities. It is also reported that due this intervention and educational programmes fuelwood consumption in these areas has reduced. Presently WWF-P is implementing similar type of programmes under different names in Nathiagali, Nilam Valley and Gilgit funded by Coca Cola Foundation of USA, World Bank and DFID, UK respectively.

### 4.6 ICS Programmes in Sri Lanka


During this period of development, several stakeholders from government and non-government organisations participated, and the objectives changed from a narrow focus on firewood conservation to a more integrated development approach. About 300,000 stoves were disseminated during the subsidised phase from 1985-1990 with the support of the government and several donor agencies mainly the DGIS (Royal Netherlands Government). The main implementing agency of the dissemination stage was the Ceylon Electricity Board under the auspices of the Ministry of Power and Energy. Over 200 potters and nearly 2,000 stove installers were trained under the project and officials of the government administrative structure were used in the promotion and extension activities who were provided a financial incentive depending on the number of stoves installed in their respective areas. The stove promoted during this phase, which was a two-pot mud insulated with a pottery liner required a skilled stove installer. It was developed by the “Sarvodaya”, a leading NGO. It turned out, however, that it was difficult to promote a heavy mass stove as a marketable product.

Integrated Development Association (IDEA) is a non-profit organisation established in 1991 to promote commercialisation of improved stoves and capacity building of grassroots level organisations.
IDEA since 1991 has been commercialising, a two-pot single piece clay stove, which is the present stove called “Anagi”. The stove is designed to cater for the cooking needs of an average family of 6 people. It can be estimated that over two million “Anagi” stoves have been commercially produced and marketed since 1991. Now, about 300,000 stoves are annually produced by 120 rural potters trained by IDEA scattered in 14 districts of the country. Today “Anagi” ICS is one of the most widespread pottery items in village grocery stores. If the Anagi stove is used without insulation, its life-time may be of about 1 year and if insulated, 3 years or more. Several district surveys revealed that over 20% of households use Anagi stoves [Amerasekara 2009].

Sri Lanka’s ICS promotion is now fully commercialised. The basic factors of demand, supply and profit making concepts determine the continuation of the commercialisation of ICS. Training in stove production is provided by IDEA and a set of templates and moulds are given to the trained potters to maintain the correct dimensions and quality. A training manual has been prepared to cover all aspects of the stove construction from clay mixing, to throwing, assembling, drying and firing of stoves.
Section – V
History, Classification and Selection of ICS

5.1 Historical Background

Some very interesting cases of improved stoves technology from the 1800 and early 1900 are found in various literature resources. Their relevance is not just historical, rather these documents bring to new life the experience and inventiveness of people from the recent past; their solutions are indeed suitable for our present and even more for our future. A book titled "Essays, Political, Economical, and Philosophical" written by Count Rumford was published in London in 1802. The book contains descriptions of Count Rumford’s research on Kitchen Fire-places (stoves), Roasting Meat, Small Iron Ovens, Boilers and Stew-pots, Cooking in Steam, Portable Fire-places, Chimney Fire-place, etc. It is surprising to see many of the techniques used today included in his ideas about stoves and the way they should operate [HEDON 2009].

As an effort to improve the living conditions of rural women, experiment on improving the efficiency of Indian cooking stoves started in 1940s by All India Village Industries Association and Gandhinetan Ashram, Kallupatti near Madurai, separately. According to Food and Agriculture Organisation (FAO), in the early 1950’s in India the first phase of Improved Cooking Stove development started with technological attempts to improve the design of biomass-fired stoves. However, the scientific research and development of the Improved Cooking Stoves began to proliferate in the 1970s and early 1980s. According to Kammen, the first Improved Cooking Stoves were designed by aid groups such as United Nations Children’s Fund (UNICEF) and the humanitarian organisation fighting global poverty, CARE, in Kenya [Kammen 1995]. Due to lack of field-testing, the designers of those first Improved Cooking Stoves, mainly natives of the U.S. and Europe, obtained weak results. At early stages of ICS development, designers acted as if it would be an elementary exercise to improve the efficiency of the common metal stove, a deceptively simple can like enclosure into which charcoal or wood is fed and ignited. In fact, after much trial and error, it turned out that an extensive investigation of stove physics and engineering design was needed.

Since the late 1970’s, attention has been focused on the design and dissemination of simple, low-cost improved cooking stoves. Better stove designs gradually came about during the mid-1980s. At that time, a number of academics began to publish serious analyses of optimal stove combustion temperatures and of the insulating properties of the ceramic liner materials. In such way that the newest designs took into consideration the complex interaction between the different processes that take place in a cooking stove, such as combustion, heat transfer fluid flow and material science. A large number of Improved Cooking Stove models, based on different construction materials, fuel and end use applications, have been developed during the last 30-40 years across the world.

5.2 Classification of ICS

According to FAO the Improved Cooking Stoves can be classified into various categories [FAO 1993]:

a. **Function** – Depending upon number of functions performed ICS may classified as mono-function and multifunction stoves. Mono-function stoves: An Improved Cooking Stove which performs primarily one function, such as cooking or any other single special function such as fish smoking, baking, roasting, milk simmering, etc. Multi-function stoves: In many areas, apart from cooking, an Improved Cooking Stove can also be used for other purposes or in combination, such as for water heating, room heating, fish/meat smoking, grain/flour roasting, simmering of milk, even to electricity generation.

b. **Construction material** – Improved Cooking Stoves are mainly made of single materials: metal, clay, fired-clay or ceramics and bricks or are hybrids in which more than one material is used for different important components. Classification based on the material helps in selecting an appropriate design on the basis of locally available raw materials, skills for fabrication and necessary production facilities (e.g. centralised/decentralised) in the target area. The cost of an Improved Cooking Stove and its expected service life can also be reflected in this classification, including its portability.
c. **Portability** – On this basis, an Improved Cooking Stove can be classified as fixed or portable. Metal and ceramic Improved Cooking Stoves are normally portable in nature and can be moved indoors or outdoors while clay/brick, clay/stone Improved Cooking Stoves are generally high mass and thus are fixed. Stoves in this category can be further sub-divided into different categories depending on the number of pot holes, e.g., single, double and triple.

d. **Fuel type** – The performance of different Improved Cooking Stoves, having the same function and constructed with the same materials, will ultimately depend on the type of fuel used. In some cases, an Improved Cooking Stove may be rendered practically inoperable when switching over to fuel types for which it was not constructed. For example, an Improved Cooking Stove primarily designed for fuelwood would not perform at all with rice husks or sawdust. Similarly, an efficient charcoal Improved Cooking Stove may perform very poorly with fuelwood or agri-residues. Major types of Improved Cooking Stoves, based on fuel classification, normally encountered are: charcoal Improved Cooking Stoves, fuelwood Improved Cooking Stoves, granular/loose agri-residue Improved Cooking Stoves, stick-form agri-residue Improved Cooking Stoves, cow dung cake Improved Cooking Stoves, and briquetted biomass-fuel Improved Cooking Stoves.

### 5.3 Design Criteria

A cooking stove is best considered as a consumer-specific device. Both engineering and non-engineering parameters need to be taken into consideration in designing an appropriate ICS. This makes the exercise much more complex when compared with the design of other types of engineering equipment or of a kerosene burning stove. ICS design considerations can be classified into three major criteria, namely: social, engineering, and developmental & ecological. Inter-linkages between these parameters are shown in Figure 5.1.

![Figure 5.1: Design Considerations for Improved Cooking Stoves](Source: [FAO 1993])

### 5.4 Site and Model Selection

User should be given priority in selection site and model an ICS. The users will select the models according to their needs. The proper selection of place inside the kitchen for installation of the stove is also very important. Therefore, the womenfolk who spend most of their time in the kitchen should be fully consulted for selection of the most suitable ICS model and the right place inside the kitchen for installation of stove. Both tasks depend upon the arrangements inside the kitchen, type of fuel used, way of cooking etc. Before finalising the selection of ICS model and place for its installation, follow-
ing this have to be made sure:

a. To determine the type of traditional fuel the particular beneficiary uses.

b. That the user’s sitting position will be easy and comfortable for cooking. Some users sit in front of the stove when cooking, while others do so by sitting on a side.

c. That the cook will be able to reach for all required cooking utensils and other necessary things while cooking.

d. During winter, other family members may prefer to sit around the stove. So, there should be some space around the stove.

e. After selecting the place for stove installation, it will be easily possible to install the chimney either by making a hole through the roof or alternatively, by putting it up outside and connecting it to the stove through a hole in the wall.

f. Before an ICS construction and installation begins, the overall dimensions, utensil shapes and sizes and other design features must be laid out. A plan of the ICS model can be drawn out on the floor where installation will take place.
Section – VI
Design and Construction of ICS Models in South Asia

6.0 Introduction

Description and construction procedures of some ICS models of Bangladesh, India, Nepal, Pakistan and Sri Lanka are presented in this section. No new model of ICS was designed locally in Bhutan or Maldives. As mentioned in the Section 3, no work on dissemination or design of ICS has been done so far in Afghanistan.

6.1 ICS Models of Bangladesh

Bangladesh Council of Scientific Research has been the pioneer institution in developing different models of household and semi-industrial improved cooking stoves in the country. Design and construction of some of selected models have been presented in this section.

6.1.1 Improved Single Mouth Cooking Stove (Portable)

This model, also called Model 1, was developed by BCSIR in 1982. The model and the actual stove in use are shown in the Figure 6.1. This is suitable for wood, branches, cow dung cake, briquettes etc; and can be used for cooking throughout the year. Main parts of this model are a structure, grate and lid for covering the ash outlet.

**Figure 6.1: Single Mouth ICS (Portable)**

<table>
<thead>
<tr>
<th>a. Model</th>
<th>b. Stove in use</th>
</tr>
</thead>
</table>

**Dimensions**

a) Mouth diameter: 9 inches
b) Feed hole : U type, 4.6x4.0 inches
c) Distance between grate and raised points : 6 inches
d) Height of the raised points : 0.5 inches
e) Ash outlet : 3x3 inches
f) Entry of primary air hole diameter: 0.5 inches (7-8 nos. holes)
g) Height of the stove : 12 inches

**Procedure for construction**

a) A circular mud plate having 13 inches diameter and one inch height is made on the floor of a suitable corner of the cookhouse or cooking place. A dice rinsed with water has to be placed next on the circular mud plate (Figure 6.2).

b) Now, a structure having 13 inches height and 0.75 inch thickness is to be made by packing and molding mud around the dice. It has to be made sure that the thickness of the mud wall is about 0.75 inch around the dice.

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1 Section 6.1, containing dimensions, construction procedure and figures of ICS models of Bangladesh, has been adopted from A Technical Manual of Improved Cooking Stoves published by Bangladesh: Addressing Air Pollution, sponsored by World Bank, 2008
c) After a while, the dice is to be removed by slightly twisting it free out of the circular mud plate. The structure is left for 1-2 days to allow it to drying up to an extent.

d) After drying, a hedge is to be made at 6.5 inches below from the top of the mouth to hold the grate. The hedge is made by inserting broken pieces of earthen pot in the inner wall of the mouth and it is then covered with mud.

e) On the top of the structure on one side, a fuel feed hole for fuel having (4.5 x 4.0) inches has now to be made by cutting the mud wall, as required. The feed hole is extended about two inches towards outside by inserting pieces of pottery and then cover it with mud for holding the fuel.

f) Now, the three raised points are made each measuring 1.75 inches in length and 0.5 inch in height at the top of the structure for supporting the cooking utensil.

g) An ash outlet measuring 3x3 inches and 7-8 nos. holes of half inch diameter have to be made in the wall of the stove just below the grate for entry of primary air for better burning of the fuel. After smoothening the stove with wet mud, leave it for 5-6 days for drying. When the stove dries up completely, it will be then be ready for use. A schematic diagram is given in the Figure 6.3.

Modification of Model

This model has been slightly modified by Practical Action and ICS Technicians. Instead of one ash outlet and 7-8 holes for entry of primary air, they added two ash outlets on both sides of the stoves having same dimensions. But the efficiency is the same. Reason for modification are:

- It is easy to carry the stove from one place to another by holding it by its two ash outlets.
- During maintenance by smoothening with mud, the size of holes became smaller, which reduced the entry of primary air in the chamber under the grate.

6.1.2 Improved Single Mouth Cooking Stove (Half underground)

This model, designed by BCSIR in 1983, is the fixed version of the Model 1. If installed inside the kitchen it can be used round the year. If installed outside it is suitable for use in the dry season only. Main parts of this model are: structure, grate and two perforated lids for covering the ash outlets.
**Dimensions of the model**

a) Mouth diameter: 9 inches  
b) Feed hole: 5x5 inches  
c) Distance between grate and raised points: 9.5 inches  
d) Height of the raised points: 0.5 inch  
e) Ash outlet and primary air entry way: 5 inches  
f) Height of the stove from the G.L: 9 inches  

**Construction Procedure**

a) A hole measuring 11 inches diameter and 9 inches depth is to be made by digging the ground at a suitable place where the stove will be installed. Wet the hole with water. A dice rinsed in water is then placed in the hole. The side of the lower portion of the dice is then packed with wet mud. Now the dice will have to be lifted up to 5 inches by slowly and carefully twisting it upwards.

b) A structure measuring 9 inches in height is then made by putting mud around the dice. The thickness of the mud wall will have to be about 0.75 inch around the dice. Now the structure is left for 1-2 days for drying up partially.

c) After partial drying of the structure, a hedge is made at 10 inches down from the top of the mouth, which will hold the grate. The hedge is made by inserting pieces of pottery in the inner wall of the mouth and then it has to be covered with mud.

d) On the bottom of the structure, a 5 inches x 5 inches feed hole has to be made for fuel charging by cutting the mud wall on one side (Figure 6.6).

e) Three raised points each measuring 0.75 inch in length and 0.5 inch in height have to be made at the top of the structure, which will support the cooking pot or utensil.

**6.1.3 Double Mouth ICS with Chimney (on the floor)**

This model was developed by BCSIR in 1984 (Figure 6.7). It is suitable for burning fuelwood, branches, cow dung cake and briquettes etc. Its lifetime is 2-3 years. Name of different parts, dimensions and construction procedure of Improved Double Mouth Cooking Stove are given below.

**Main Parts**

Main parts of this model are: a) Structure, b) Grate, c) Chimney, d) Cap, and e) Lid for covering the ash outlet.
Dimensions

a) Mouths diameter: First: 9 inches and second: 8 inches.
b) Distance between two mouths: 3 inches
c) Feed hole: Length 5 inches x width 5 inches
d) Distance between grate and the top of the mouth: 8.5 inches
e) Ash outlets/primary air entry passage: Length 5 inches x width 5 inches
f) Entry way from first mouth to second mouth: 7.0x4.5 inches
g) Open space left after placing the utensil on the second mouth: 2.5 inches
h) Diameter of the flue gases exit in the second mouth: 2 inches
i) Tunnel from second mouth to chimney holder: Length 6 inches x width 3 inches x height 3 inches
j) Chimney holder: Length 5 inches x width 5 inches x height 10 inches
k) Height and diameter of the chimney: 6-9 feet and 3 inches
l) The distance between the chimney and cap: 4 inches
m) Soot removal outlet at the bottom of the chimney: Length 3 inches x width 3 inches
n) Height of the stove: 15 inches

Construction Procedure

a) Two dices of 9 and 8 inches diameter are placed one after another, where the ICS will be installed as shown in the Figure 6.8. The distance between the two dices should be 3 inches. Before placing the dices, they should be rinsed in water.
b) A rectangular mud platform measuring 36 inches long x 17 inches wide x 15 inches high is made by putting mud around the two dice as shown in the Figure 6.9.

c) After a while, both dices are removed from the mud platform by slowly and carefully twisting them from right to left as shown in Figure 6.10.
d) It is then allowed to dry for 1-2 days. After partial drying, a hedge is made down into the first mouth at 9.0 inches below from the top, which will hold the grate. The hedge is made by inserting pieces of pottery in the inner wall of the first mouth and then covered the same with mud.

e) A feed hole for fuel charging measuring 5x5 inches is made 1.5 inches below from top of the first mouth. Then just below the grate on the both sides of the first mouth, two ash outlets/primary air entry passages measuring 5x5 inches are made.

f) Then an entry way for flame and hot gases from the first mouth to the second measuring 7.0x4.5 inches is made just above the grate on the common or partition wall of the two mouths. After that, the second mouth is partially filled up with mud and a slant is made from the grate to the second mouth. A flue gases exit of 2.0 inches diameter is made at a point just one inch below from the top of the second mouth.

g) A flue gases tunnel measuring 6 inches in length x 3 inches in width x 3 inches in height is made to reach from the second mouth up to the chimney holder.

h) For placement of the chimney at the end of the second mouth, a space measuring 5 inches long x 5 inches wide x 10 inches high is made. At the top of the space, two equal sized bricks are so placed that there is a gap of 3 inches left between the bricks. On top of the two bricks, a chimney of 6-9 feet in length and 3 inches diameter is placed. The bottom of the chimney is then covered with mud.

i) A cap of appropriate size is then placed on the top of the chimney. The space between the cap and the chimney should be 3-4 inches for releasing the smoke and all.

j) After completion of the installation of an ICS, it is plastered and smoothened with mud and left for 5-7 days to dry. After drying it up perfectly, the stove can be used for cooking or other heating purposes.

k) For durability and good looks, the entire structure of the stove can be covered with a layer of brickwork, plastered and finally paint covered (red oxide).

6.1.4 Double Mouth ICS with Chimney (Half underground)

This model was developed by BCSIR in 1984 (Figure 6.11). Dimension and construction procedure are given below.

Main Parts

This stove consist of a) Structure, b) Grate, c) Chimney, d) Cap, and e) Lid for covering the ash outlet.

Demissions

a) Mouths diameters: First-9 inches and Second-8 inches.
b) Distance between two mouths: 3 inches  

c) Feed hole: Length 5 inches x width 5 inches  

d) Distance between the grate and the top of the mouth: 9.5 inches  

e) Ash outlets/primary air entry passage: Length 5 inches x width 5 inches  

f) Entry way from first mouth to 2nd: (7.0 x 4.5) inches  

g) Open space left after placing the utensil in the second mouth: 2 inches  

h) Diameter of the flue gases exit in the second mouth: 2.0 inches  

i) Tunnel from second mouth to the chimney holder: (L x W x H): 6 inches x 3 inches x 3 inches  

j) Chimney holder: 5 inches x 5 inches x 10 inches  

k) Height and dia of chimney: 6-9 feet and 3 inches  

l) Distance between the chimney and its cap: 4 inches  

m) Soot removal outlet at the bottom of the chimney: Length 3 inches x width 3 inches  

n) Height of the stove from G.L: 9 inches

Dimensions of different parts of the stove is shown in Figure 6.12.
**Construction Procedure**

a) At a suitable place where the stove will be installed, a hole measuring 11 inches diameter and 9 inches deep is made by digging the ground. The hole is then wet with water. A dice rinsed in water is then placed into the hole. The surroundings of the lower portion of the dice is then filled with wet mud. After that another dice rinsed in water is placed just 3 inches away from the first dice as shown in Figure 6.13.

b) A rectangular mud platform measuring 36 inches long x 17 inches wide x 9 inches high is made by putting mud around the two dice.

c) After a while, both the dices are removed by carefully twisting them out of the mud platform.

d) It is then allowed to dry for 1-2 days. After partial drying, a hedge is made in the first mouth at a point 10 inches below from the top, which will hold the grate. The hedge is made by inserting pieces of pottery into the inner wall of the first mouth and it is then covered with mud.

e) A 5 inches x 5 inches feed hole for fuel charging is made at a point 1.5 inches below from top of the first mouth as in Figure 6.12. Then two ash outlets/primary air entry passages measuring 5 inches x 5 inches are made just below the grate on both sides of the first mouth.

f) Next, an entry way for flame and hot gases from the first mouth to second mouth measuring 7.0 inches x 4.5 inches diameter is made just above the grate on the common wall of the two mouths. After that, the second mouth is partially filled up with mud and a slant is made from the grate reaching up to the second mouth. A flue gases exit of 2 inches diameter is made at a point just one inch below from the top of the second mouth.

g) A flue gases tunnel measuring 6 inches in length x 3 inches in width x 3 inches in height is made from the second mouth, reaching up to the chimney holder.

h) For placement of chimney at the end of the second mouth, a 5 inches long x 5 inches wide x 10 inches high space is readied. At the top of the space, two equal sized bricks are so placed that there is a gap of 3 inches left between the bricks. Then on top of the two bricks, a chimney of 6-9 feet length and 3 inches diameter is placed. The bottom of the chimney is then covered with mud.

i) A cap of appropriate size is then placed on the top of the chimney. The space available between the cap and the chimney should be 3-4 inches to let out the smoke and excess heat, if any.

j) After completion of installation of the ICS, the stove surface is smoothened with mud and left for 5-7 days for drying. After proper drying, the stove can be used for cooking or other heating purposes.

k) For longer life and better looks and finish, the entire structure of the stove can be laid with bricks, plastered and given a coat of paint finally.

**6.1.5 Single Mouth ICS with Chimney (Portable)**

This model was developed by BCSIR in 1984 (Figure 6.14), which is suitable for burning fuel wood branches, cow dung cake, briquettes etc. and can be used round the year. It consists of a structure, grate, chimney, cap and lid for covering the ash outlet. Dimensions and procedure for construction of the stove is given below.
Improved Cooking Stoves in South Asia

Dimensions

a) Mouth diameter: 9 inches  
b) Feed hole: 4.5 inches x 4.5 inches  
c) Distance between the grate and the top of the mouth: 8.0 inches  
d) Exit for flue gases: 1.5 inches (diameter)  
e) Chimney height and its diameter: 3 feet and 2 inches respectively  
f) Distance between the top of the chimney and the cap: 4 inches  
g) Ash outlet and entry of primary air: 3 inches x 3 inches  
h) Chimney holder: 2.5 inches diameter x 2.5 inches height  
i) Height of the stove: 13 inches  

Dimensions are shown in Figure 6.15 below.

Figure 6.15: Dimensions of Single Mouth ICS with Chimney (Portable)

Construction Procedure

a) A circular mud plate of 13 inches diameter and one inch height is made on the floor of the selected suitable place. A dice rinsed in water, is then placed on the circular mud plate.  
b) A structure of 9 inches diameter and 14 inches height is made by packing mud around the dice.  
c) After a while, the dice is removed by carefully loosening and twisting it out of the structure.  
d) It is then allowed to dry for 1-2 days. After partial drying, a hedge is made at a point 8.5 inches below from the top of the mouth, which will hold the grate. The hedge is made by inserting pieces of pottery into the inner wall of the stove and it is then covered with mud.  
e) A feed hole for fuel charging measuring 4.5 inches x 4.5 inches is made by cutting the mud wall at a point just an inch below the top of the structure on one side. Extend the feed hole through about two inches towards the outside by inserting pieces of pottery and then cover the same with mud. It will hold the fuel.  
f) On the opposite side of the feed hole, a chimney holder of 2.5 inches diameter and 2.5 inches height has to be made. This is made by inserting pieces of pottery into the wall of the stove and then covering the same with mud.  
g) A flue gases exit having a 1.5 inches diameter is made just 0.5 inch below the top of the mouth, which leads to the chimney holder.  
h) Then a grate is placed on the hedge, keeping two-thirds of the grate free and the remainder one-third is made to be slanting upwards up to the flue gases exit covered with mud.  
i) Two ash outlets and entry way of primary air measuring 5 inches x 5 inches are made on both sides of the stove and just below the grate.  
j) Next, a chimney of 3 feet height & 2.0 inches diameter with a cap on top of it is placed on the chimney holder.  
k) After completion of the construction, the stove is smoothened with mud and left for 5-7 days for drying. After drying, the stove can be used for cooking or other heating purposes.
**Conversion to half-underground model**

This stove can easily be made half underground as follows:

a) At a suitable place selected for installation of the ICS, a hole measuring 11 inches in diameter and 9 inches deep is made by digging into the ground. The hole is then moistened with water. A dice rinsed in water is then placed in the hole. The surroundings of the lower portion of the dice is then filled with mud. Now the dice has to be lifted upwards up to 5 inches by carefully twisting and turning it.

b) A structure of 9 inches height is then made by packing mud around the dice. Make the mud wall about 0.75 inch thick around the dice. After a while, the dice is to be removed by twisting it free by moving it carefully in the right to left movements. Then leave the structure alone for 1-2 days, allowing it to dry up partially.

c) Then the same procedure is followed for construction of improved single mouth cooking stove with chimney (Portable) discussed already.

### 6.1.6 Double Mouth ICS Coupled with Single Mouth ICS

This model was developed by supervisor of the ICS dissemination project Phase-ii in 1998 by BCSIR. It is made by coupling single mouth stoves with double mouth stoves having a common chimney. Figure 6.16 shows different parts as well as the stove in use.
**Dimensions of Double Mouth Stove**

- a) Mouths diameters: First – 9 inches and second – 8 inches.
- b) Distance between two mouths: 3 inches
- c) Feed hole: Length 5 inches x width 5 inches
- d) Distance between the grate and the top of the mouth: 8.5 inches
- e) Ash outlets/primary air entry passage: Length 5 inches x width 5 inches
- f) Entry passage from the first mouth to the second: 7.0 inches x 4.5 inches
- g) Open space left after placing the utensil on the second mouth: 2.5 inches
- h) Diameter of the flue gases exit on the second mouth: 2 inches
- i) Tunnel from the second mouth to the chimney holder (LxWxH): 6 inches x 3 inches x 3 inches
- j) Damper: 4 inches x 4 inches
- k) Height of the stove: 15 inches

**Dimensions of Single Mouth Stove**

- a) Mouth diameter: 9 inches
- b) Feed hole: 4.5 inches x 4.5 inches
- c) Distance between the grate and the top of the mouth: 8.5 inches
- d) Flue gases exit diameter: 1.5 inches
- e) Ash outlets/primary air entry passage: Length 3 x width 3 inches

Dimensions of different parts of the stove are shown in Figure 6.17.

**Construction Procedure**

Select a suitable place for installation of an improved double mouth cooking stove on the floor. Construction procedure is the same as described in Section 6.1.3. After that, an improved single mouth cooking stove (on the floor) is made on one side of the chimney holder of the double mouth stove:

- a) A moistened dice of 9 inches diameter is placed on the floor.

---

**Figure 6.17: Dimensions of Double Mouth ICS Coupled with Single Mouth ICS**
b) A rectangular mud platform measuring 19 inches in length x 17 inches wide x 15 inches high has to be made by packing mud around the dice.

c) After a while, the dice is removed from the mud platform by twisting it from right to left.

d) It is then allowed to dry for 1-2 days. After it is partially dried, a hedge is made at a point 9.0 inches down from the top, which will hold the grate. The hedge is made by inserting pieces of pottery into the inner wall of the mouth and it is then covered with mud.

e) A feed hole for fuel charging measuring 4.5 inches x 4.5 inches is made 1.5 inches below the top of the first mouth. Then two ash outlet/primary air entry passages measuring 3 inches x 3 inches are made just below the grate on the both sides of the first mouth.

f) A flue gases exit of 1.5 inches diameter is made just an inch below the tip of the cooking mouth placed opposite to the feed hole.

g) A tunnel measuring 6 inches in length x 3 inches in width x 3 inches in height is next made reaching from the flue gases exit up to the chimney holder.

h) For longer life and better finish, the entire structure of the stove can be covered with brickwork, wall plastered and finally painted with red oxide.

Both stoves have dampers just near the chimney. When both stoves are in use, the two dampers will be lifted up. But when one stove is used, the damper of the functioning stove will be lifted up and the damper of the other stove will be lowered down to prevent back suction of the flue gases through the feed hole. A damper can be made of M. S. sheet measuring 4 inches x 4 inches.

### 6.1.7 Double Mouth ICS with Chimney for Large Scale Cooking and Semi-industrial Purposes

This model shown in Figure 6.18 was developed by BCSIR in 1985. This stove is suitable for burning fuelwood, branches, cow dung cake, briquettes and fluffy fuels like straw, leaves, bagasse.

#### Materials for construction

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mud/clay (adhesive)</td>
<td>200Kg</td>
</tr>
<tr>
<td>2. Bricks</td>
<td>210</td>
</tr>
<tr>
<td>3. 0.7 inch thick ring of 18 inches diameter</td>
<td>2</td>
</tr>
<tr>
<td>4. Rods 14 inches long, 0.7 inch thick</td>
<td>26</td>
</tr>
<tr>
<td>5. Rods 8 inches long, 0.7 inch thick</td>
<td>14</td>
</tr>
<tr>
<td>6. “U” shaped iron rods 4 inches long, 0.7 inch thick</td>
<td>4</td>
</tr>
<tr>
<td>7. Cement</td>
<td>1bag</td>
</tr>
<tr>
<td>8. Sand</td>
<td>5bag</td>
</tr>
<tr>
<td>9. Red Oxide</td>
<td>250gm</td>
</tr>
<tr>
<td>10. Cast iron grate: 17 inches diameter, hole diameter 0.5 inch</td>
<td>1</td>
</tr>
<tr>
<td>11. Chimney, 4 inches diameter, 9-10 feet high</td>
<td>1</td>
</tr>
<tr>
<td>12. Cap</td>
<td>1</td>
</tr>
</tbody>
</table>

![a. Model](image1)

![b. Stove in use](image2)

Figure 6.18: Double Mouth ICS with Chimney for Large Scale Cooking and Semi-industrial Purposes
Improved Cooking Stoves in South Asia

Parts of the model

Main components of this model are: a) Structure, b) Grate, c) Chimney, d) Cap, and e) Lid for covering the ash outlet.

Dimensions

- a) Mouths diameters: First 18 inches and Second 17 inches
- b) Distance between two mouths: 6 inches
- c) Feed hole: Length 10 inches x width 10 inches
- d) Distance between the grate and the top of the mouth: 12 inches
- e) Ash outlets/primary air entry passage: Length 10 inches x width 10 inches
- f) Entry passage from first mouth to the second mouth: 10 inches
- g) Open space left after placing the utensil on the second mouth: 3 inches
- h) Diameter of the flue gases exit in the second mouth: 4 inches
- i) Flue gases tunnel reaching from the second mouth up to the chimney holder (LxWxH): 6 inches x 5 inches x 5 inches
- j) Chimney holder (LxWxH): 10 inches x 10 inches x 15 inches
- k) Height and diameter of the chimney: 8-9 feet and 4-5 inches
- l) The distance between the chimney and cap: 4 inches
- m) Soot removal outlet at the bottom of the chimney: Length 4 inches x width 4 inches
- n) Height of the stove: 22 inches.

Construction Procedure

- a) A suitable place measuring 74 inches x 30 inches is selected for installation of the stove and mark the required area using chalk.
- b) Now 16 pieces of uniform sized bricks are bundled into 8 pairs (2 pieces of bricks together) using lengths of rope.
- c) An 18 inches diameter ring is placed leaving 8 inches of open space in front and 6 inches space on the both sides of the ring. They are marked with chalk. Now the ring is removed.
- d) On the each side of the marked circle, (where there are six inches spaces) two pairs of bricks are placed in such a way that they are 10 inches apart. This space measuring 10 inches x 10 inches acts an ash outlet and entry passage for primary air into the stove. On both sides, two hedges are made on the top of the two pairs of bricks by placing pieces of iron rods and cover them with mud. Both front and back sides of these hedges will make a platform measuring 71 inches in length x 28 inches in width x 10 inches in height as shown in Figure 6.19a.
- e) Now on the first mouth (18 inches dia) of the platform, a feed hole is made by placing 4 pairs of bricks, measuring 10 inches x 10 inches and first exit measuring 10 inches in diameter for passage of flame and hot gases from the first mouth to the second mouth.

Figure 6.19: Construction of Double Mouth ICS with Chimney for Large Scale Cooking and Semi-industrial Purposes
f. The second mouth (17 inches diameter) of the stove is made, which should be six inches away from the first mouth. At the end of the second mouth, on the opposite side of the feed hole, a flue gases exit measuring 4 inches diameter is made by placing two bricks on the back side of the second mouth as shown in Figure 6.19b.

g. A flue gases tunnel is made from the exit of the second mouth to the chimney holder measuring 6 inches in length x 5 inches in width x 5 inches in height.

h. A chimney holder is made at a point 6 inches away from the second mouth which should be 10 inches in length x 10 inches in width x 15 inches in height as shown in Fig No 6.20. On one side of this chimney holder, make an outlet measuring 4 inches x 4 inches for removal of chimney soot.

i. The entire structure of the stove is then covered with mud.

j) Four “U” shaped iron rods measuring 4 inches in length are embedded in the inner wall of the first mouth at a distance of 12 inches from the top, where the grate will be held.

k) In the chimney holder, a chimney made of cement is placed, which should be of 6-9 feet height (as necessary) and 4 inches diameter. The bottom part of the chimney is now to be covered with mud.

l) A cap of appropriate size is put on the top of the chimney. The distance between the cap and the chimney should be 4 inches.

m) For longer life and better looks, the entire structure of the stove can be layered with bricks, plastered and finally given a coat of red oxide. The inner side of the stove is to be smoothened with mud.

n) After drying, the stove is made ready for use.
6.2 ICS Models of India

6.2.1 Improved Laxmi Stove

This two pot-hole fixed stove with chimney (Figure 6.21) is an improved version of the Laxmi stove that was being promoted by Appropriate Rural Technology Institute (ARTI) and several other Technical Back up Units during National Programme on Improved Chulha [Karve 2007]. The stove has a metallic grate at the bottom of the firebox, with an air tunnel below the grate. This ensures adequate air supply to the fuel and better combustion. The inner dimensions are properly matched with the chimney to ensure good air flow through the stove body. The shape and size of the pot holes has been optimised to ensure minimum leakage of air and smoke around the cooking vessels. The chimney consists of three interlocking pieces, which can be easily dismantled, cleaned, and reassembled from within the house itself. The stove can be operated using wood sticks or woody biomass as fuel.

Dimensions

Main pot hole: top dia. 220 mm, inner dia. 160 mm
Second pot hole: top as well as inner dia. 160 mm
Chimney hole: dia. 130 mm
Mouth of the firebox: height 120 mm, width 160 mm
Underground tunnel: depth 100 mm, width 100 mm.

6.2.2 Bhagyalaxmi Stove

Bhagyalaxmi (wealth of good fortune) stove is shown in Figure 6.22. This is essentially of the same design as the Laxmi Stove, however there is no chimney. In this case, pot raisers are provided on the second pot hole so that a draft can be set up by the hot air coming out from this pot hole. The pot raiser dimensions are 25 mm x 25 mm x 25 mm. There are three pot raisers.
6.2.3 Grihalaxmi Stove

Some users preferred to two single pot hole stoves rather than a single two pot hole stove. This was because both the pot holes of a two pot hole stove must be used simultaneously in order to get an efficient stove performance. This was inconvenient when only one dish had to be cooked. Therefore ATRI developed the single pot hole chimneyless stove shown in Figure 6.23. They named it Grihalaxmi (wealth of the home) Stove. In this stove they have used the concept of a top grate to direct the flames towards the center of the bottom of the cooking pot. The design of the top grate is shown in the figure below. The top grate design must be such that while changing the flame direction, it should not affect the rate of air flow through the stove. The slotted design was found to be optimal in this context.

![Figure 6.23: Grihalaxmi Stove](http://www.bioenergylists.org/laxmi)

Sources: [Hanbar 2006], [HEH Final Report 2006]

6.2.4 Sukhad Stove

The traditional stove in the region, Uttatar Pradesh, serviced by Development Alternatives (DA) is a single pot U-shaped stove made of mud without a chimney. It can be portable or fixed. The Sukhad stove is a two-pot mud stove with chimney. Figure 6.24 shows a Sukhad stove. It can be used with either wood or agricultural residues and is suitable for a medium-size family of 5-8 members using flat or spherical bottom vessels 19-30 cm in diameter. It also provides strong heat to the second pot hole. The Sukhad is designed such that the second pot hole is raised by about 6 cm above the level of the first pot hole to avoid interference between pot rims when cooking with two large pots. It can be constructed by using fabricated mould of mild steel sheet with locally available clay materials. The chimney pipe and cowl are made of asbestos cement. Optional items like pottery liners and cast iron grate can also be provided.

![Figure 5.24: Sukhad Stove](http://www.bioenergylists.org/sukhad)

Source: [HEH Final Report 2006]

6.2.4 Astra Stove

Astra Stove was designed by Astra Centre, currently named as the Centre for Sustainable Technologies, which was formed in the Indian Institute of Science, Bangalore in 1974. The initial design was a three-pan version, which was similar to the traditional stove type and also provided large surface area for heat transfer. Facilitation of proper combustion was achieved by having an enclosed burning, with controlled entry of primary and secondary air to optimise the excess air factor. A grate was introduced to define the zone of combustion. A chimney of suitable height and diameter was provided to create draught and to transport the smoke outside the kitchen. The influence of other design factors, like the space below the pots in the three pans was evaluated through water-boiling tests. For instance, when the gaps below the three pots were changed from (15, 15 and 15 cm) respectively, to (12.5, 4.5 and 2.5 cm), the overall water-boiling efficiency increased from 23.6 to 44.2%. These studies showed the importance of the internal geometry of the stove in maximising heat transfer to the pots. These vari-
ables influence the efficiency of the stove through modification of the following factors:

a. View factor for radiative heat transfer.
b. Heat transfer by convective mechanism.
c. Provision of proper combustion volume.
d. Excess air factor.

Further improvements were made by enclosing the firewood in a closed box to prevent excess air from entering. The inner lining of the stove was made using a simple insulating material like clay mixed with paddy husk. In the final configuration, the ASTRA stove (also known as ASTRA ole in Kannada) had the following spaces below the three pots: first pot, 11.00 cm; second pot, 4.0 cm and third pot 2.5 cm.

Often some households preferred two-pan stoves. In such cases, the space below the first pot was again 11.0 cm, while the space below second pot was 2.5 cm. Generally, a chimney of 7.5 cm diameter and height 2.5-3.0 m is used. Figure 6.25a shows an ASTRA stove in use in Ungra village. Figure 5.25b shows a typical section of the ASTRA stove. The ASTRA stove also has another advantage. It permits the use of a modified cooking practice for better efficiency due to the heat stored in the body of the mud stove. Once the third pan boils for about 5 min, the firewood may be withdrawn and the primary air inlet may be closed. This will lead to the cooking of wood through utilisation of heat stored in the stove. In one of the cooking experiments it was found that the specific fuel consumption (per kilogram of food cooked) in the ASTRA stove was one-fourth of the value obtained in a traditional stove. The ASTRA stove is proved to have high potential of achieving high operational efficiency along with smoke removal.

6.2.5 Sampada Gasifier Stove

This is a portable metallic stove (Figure 6.26). The fuel should be in the form of dry woody twigs or small blocks/chips of wood. The fuel is burned under a limited supply of air in a special fuel chamber, where it pyrolyses. The pyrolysis gas produced in this chamber is combusted by providing additional secondary air to it. For longer duration use, there is a provision for adding fuel through a side opening. The special feature of the stove is that charcoal is left behind in the fuel holder after the stove operation. Thus, the stove not only delivers clean cooking but also produces a valuable by-product in the form of charcoal.

6.2.6 Vivek Sawdust Stove

This is a portable metallic stove specially designed for using sawdust and other powdery biomass as fuel (Figure 6.27). The fuel needs to be packed in the stove around a metallic cylinder. The cylinder is then removed leaving an L shaped cavity in the
packed biomass. A small burning stick of wood is inserted through the inlet near the bottom. The exposed layer of biomass in the vertical tunnel ignites, and the heat is utilised for gasification of the inner layers. The pyrolysis gas comes into the tunnel and rises up, igniting just under the cooking pot placed on the pot holders. Due to its optimal design, the stove produces a clean blue flame. One full charge of fuel (about 2-3 kg sawdust) keeps the stove burning for about 2 hours.

Figure 6.27: Vivek Saw Dust Stove  
Source: ARTI

6.2.7 Sarai Cooking System

This is a portable stainless steel device operating on the combination of principles of steam cooking and retained heat cooking (Figure 6.28). This has been hailed as one of the cleanest ways of using charcoal for household cooking. In the medium sized system, just about 100-125 gm of charcoal is sufficient for cooking dal, rice, and a vegetable or meat for a family of 5 persons. The charcoal to be used can either be ordinary wood charcoal, or charcoal left over in a wood burning stove, or char briquettes made from agricultural waste. The Sarai system comes in two sizes – the medium size is for a family of 4-5 persons, whereas there is a large size for a family of 8-10 persons. In case, rice is the prime food, it is recommended to go for the large size version even for smaller family sizes.

Figure 6.28: Sarai Cooking System  
Source: ARTI

6.3 ICS Models of Nepal

6.3.1 Improved Mud Stove

The type of ICS promoted is made up of 3-part mud/earth, 2 parts straw/husk and 1 part animal dung. The whole structure is plastered smooth with the same mud mortar. It has two fire openings for cooking pots, one behind the other (Figure 6.29).
There is no need to blow the fire. It utilises the heat, generated by burning fuelwood, more by the deflection of the flames and heated air inside it which travel to the second opening with the help of an in-built baffle located just below the second opening, before the hot air exits out of the chimney, which is made of un-burnt clay bricks that can be made in the village. Presence of grate enhances proper combustion. The iron plates are fitted on the pot-holes for pots. The pot-holes are round in shape; the pot bottom fits tight on them. It can be made in different sizes and capacities to suit the family size and pot size. It can have one or more openings for pots/ pans. About 85% of total disseminated mud-brick ICS are 2nd pot hole raised (Figure 6.30).

6.3.2 Domestic Metal Stove (Jumla)

Domestic metal stoves are suitable for high altitude areas (Figure 6.31). Walls are made of 1.5 mm steel sheets and cooking surface with 4 mm plate. The stove weighs about 40 kg. There are three pot-holes along with a slot for baking roti (traditional bread) and a 9 liter stainless steel tank for water heating. Bottom of the stove is double mud filled to prevent heat loss. Adjustable air vent in the main door and damper in the flue pipe allows the regulation of draught for combustion. The average cooking efficiency is 14 to 22%. The life expectancy is about 15 years and is suitable above 2,000 m altitude.
6.6.3 Institutional Stoves–ESAP Model Two Pot Hole ICS

Figure 5.32 shows the institutional stove made of special mud-brick. Iron pot rings on both pot-holes are used to fit the cauldron tightly. The diameter of first and second pot-hole is 56 and 33 cm respectively. About 80% heat is produced in the first hole while remaining 20% is produced in second one. The height of the chimney is 2.4 to 2.7 m. There is a grate on the fuel bed and an iron gate. The gate/door is used to regulate the draught.

![Figure 5.32: ESAP Model Two Pot-hole Institutional ICS](image)

6.4. ICS Models of Pakistan

6.4.1 Three-pot Economic Cook Stove by ATDO

Three-pot economic cook stove (improved mud stove) was designed by Appropriate Technology Development Organisation (ATDO) in 1984. The construction of the economical cook stove is simple. A housewife or a mason can easily build it after a little training.

Construction Material

Clay: 1 part, Sand: 1 to 2 parts, Dung: 1/5 part and Straw: 1/3 part. This is the best ratio. However, the mixture can be made in other ratios if any element is in short supply, for economy. The aforesaid ingredients are taken to prepare a homogenous mud mixture by adding suitable quantity of water. The mixture is left lying for 24-48 hours for acquiring proper adherence and plasticity.

Lay out

After selecting a suitable place in the kitchen, layout is marked with chalk or knife (in case of katcha floor). Then first layer of mud-mixture of 3 inches thick is laid on the marked place. The second layer is applied, when the first layer is dries enough to withstand the load to be on due to upper layers to be laid and in the same manner subsequent layers are laid until it gains a height upto 13 inches (Figure 6.33). This height above the ground or kitchen floor is minimum depending upon habits (standing or sitting) while cooking. The height of platform, made of other materials, may be fixed according to the desire of the user.

![Figure 6.33: Base of Three–pot Economic Cook Stove](image)

Source: Economic Cook Stove Guidebook by ATDO
Improved Cooking Stoves in South Asia

Chimney

A chimney of 10-12 ft height and 4 inches dia well serves the purpose. It can be made earthen pot, tins, cement pipe, or wire mesh thickly lined with mud or mud molasses mixture etc. The chimney is placed inside the chimney hole about 1 inch above the exhaust hole so that it may not close the exit.

Two-Pot Cook Stove by ATDO

During the survey on the three-pot stove ATDO experts found that most of the people were not using the third carving of the stove due limited needs. Considering the reality ATDO then designed the cook stove with two carvings i.e. stove for two pots. The construction procedure is almost same except some minor changes. Cooking utensil had been modified which had added to the efficiency of the stove. A the two-pot stove is shown in the Figure 6.36.
6.4.2 Stoves Developed by PCRET

Pakistan Council of Renewable Energy Technologies (PCRET) has designed five types of efficient Cooking Stoves (MA-I to MA-V) suitable for rural areas of Pakistan. Backed clay stoves and metallic stoves for application in plain areas as well as cold hilly areas of the country. The metallic stoves particularly MA-I and MA-II have become popular in the northern area. Backed clay stoves MA-IV & MA-V remained as a products of R & D activity only.

a. Cook Stove MA-I

It is a round shape smoke free metallic stove (Figure 6.38). It has been provided with a chimney and a baffle to control the fuel-burning rate. It is suitable for room heating as well as cooking/baking simultaneously. A mettle baffle, which slows down the hot gases, surrounds the firebox of the stove and thus the hot flue gases transfer maximum their heat to the stove body before leaving through chimney. The improve design consumes less fuels, yet radiates as much heat as any traditional stove of same volume in a given time. Operating traditional stove at low power is very difficult, thus, it is operated at high power. The improved stove, however, performs well at low as well as high power. The improved model needs care and regular cleaning than the traditional stove because due to reduced speed of combustion gases, more soot particles settle around the baffle, in elbow and pipes. It has primarily been developed for the cold hilly areas of the country. Body is made of 1/22 inch G.I. sheet and 12ft high 3 inches dia chimney is made of 1/28 inch G.I. sheet. A baffle has been provided in the chimney to control air draft. Besides, the sliding doors at the combustion chamber automatically adjust the volume of air to the volume of fuel load, which contributes to a well regulated air circulation.
b. **Cook Stove MA-II**

It is an improved version of MA-I (Figure 6.39). The principal design parameters are the same except that a water container of 12 litre capacity has been added. The chimney passes through the water container so that the heat of exhaust gases is utilised for heating water. It thus performs three functions i.e. cooking/baking, water heating and room heating simultaneously. In the water container the temperature rises from 10°C to 50°C during a single operation while cooking meals.

![Figure 6.39: MA-II Cook Stove](Source: PCRET)

c. **Cook Stove MA-III**

It is also metallic smoke free stove (Figure 6.40). It contains two pot-holes to facilitate baking and cooking simultaneously. Besides, it has been provided with an oven to keep the meal warm. The flue gases are used to operate this oven. As such this unique cook stove performs four functions at a time i.e. cooking, baking, meal/bread warming and room heating.

![Figure 5.40: MA-III Cook Stove](Source: PCRET)

d. **Cook Stove MA-IV**

It is an improved version of mud stove (Figure 6.41). It was noted that the critical parameters of the mud stove contributing to its efficiency were not being strictly observed by the villagers as a result the required efficiency was not achieved which affected adversely its acceptance / propagation. In order to observe, the critical design parameters and also to reduce construction time, the prefabricated baked stove has been designed. It comprises of four prefabricated components, three of clay and one of metal (top). Chimney has also been provided with baffle to control the burning rate. It is easy to assemble in the field. One person can assemble about 50 stoves in a day. This improved stove has been designed for plain areas of the country where metallic stove are not popularised.

![Figure 6.41: MA-IV Cook Stove](Source: PCRET)

e. **Cook Stove MA-V**

It is prefabricated baked clay stove with two pot-holes (Figure 6.42). The first pot-hole works directly on heat of combustion, the heat of flue gases are utilised in the second pot-hole. Like MA-IV, it is easy to assemble. It comprises three components; two of baked clay and one metallic top. Chimney has been provided with baffle to control the burning rate. It has also been designed for the plain area of the country.

![Figure 6.42: MA-V Cook Stove](Source: PCRET)
6.4.3 ICS developed by BACIP of AKPBSP

a. Bukhari Stove

This round metal *bukhari* cooking stove was introduced by AKPBSP in 1990s. This was a great improvement in comparison with an open fire in the middle of the traditional room. As time went on, these stoves began to be manufactured using thinner recycled sheet metal to reduce the cost, resulting in less durability. The fire produced in these stoves was of high heat intensity, but extinguished rapidly. As a room heater, the thin metal sheet *bukhari* proved advantageous for it quickly heated up the interior. No separate room heating device was therefore required in the living area; the one *bukhari* functioned as both a cooking and heating device (Figure 6.43).

Most of the villagers use a round, sheet-steel cooking stove (*bukhari*) placed directly on the soil floor of the house. These *bukhari’s* are considered low-cost with prices ranging between Rs. 1,200 (20Euro) and Rs. 2,000 (35 Euro), equivalent to one month unskilled labour.

b. Top-Plate Stove

The BACIP top-plate stove is the cheapest of the line, consisting of an 18-gauge (1.2 mm) thick steel top cooking plate (Figure 6.44). The cooking plate, which may last for 8-10 years, is placed on top of a line of interlocking burned clay bricks. The stove has a reduced side heat radiation due to the insulating effect of the burned bricks and thus saves on firewood. This makes the stove particularly interesting for summer use. Thus the advantages of this model are its low cost (only the top plate), low wood consumption, ease of transport and durability. The top plate can also be made from 16-gauge (1.5 mm) steel plate. The top plate can be easily transferred between an outside summer cooking stove and the inside winter cooking/heating stove, or stored for winter.

c. Metal Sides Stove

This slimmer type of stove has the advantage of producing rapid heat radiation once the fire is lit, a characteristic which appeals to most of the clients. The metal sides stove is more expensive than the top plate stove as it requires more steel. Being made of thick 18-gauge steel plate, this stove is also durable. It is easy to manufacture and comes in four different designs (Figure 6.45a).

d. Metal Sides Stove (Insulated)

One of the design options is a wider stove, allowing room for a line of burned clay tiles of one inch thickness. These tiles are placed inside the stove between the water pipe and exterior metal sides. These clay tiles block the heat from wood fire from radiating through the sides of the stove. The advantage is that in the summer, when no heat radiation is required, the insulated stove consumes less firewood (Figure 6.45b).
Improved Cooking Stoves in South Asia

a) Metal Side Stove Construction

b) Metal Side Insulated Stove Construction

c) Dimensions of Metal Side Stoves

Figure 6.45: BACIP Metal Side Stove and Metal Side Insulated Stove Details
Source: BACIP

e. All Metal Stove on Legs

This stove is more expensive than the type with only metal sides and is preferred by people who wish to move the stove occasionally, or have wood or cement floors (Figure 6.46).

Fery - Fery: Fery-fery means “crazy” in Urdu. This free turning chimney cover is placed vertically in the top of an existing (3") chimney pipe to avoid back-draught. It twirls around like crazy when the wind comes from different directions. The fan allows the smoke to exhaust in any wind direction and improves the draught (Figure 6.47).

Chimney Roof Passage: The square chimney roof passage is designed for traditional soil roofs and is always applied with the installation of the roof hatch window as the chimney must be repositioned. It creates a waterproof chimney passage and reduces the risk of the roof catching fire in case of a burning chimney. It also helps to ventilate the room.
f. Sawdust or Chaff Stove

The sawdust stove first burns on gas from the biomass. After the sawdust is de-gasified, the remaining charcoal dust is then mixed with 10% wet clay and compacted into perforated briquettes. After the briquettes are sun-dried, they can be burned as charcoal in the same oven. A compactor is part of the equipment set. In addition to the new line of stove designs, a number of additional fittings and attachments can be obtained to improve the performance:

6.4.4 Mud Stove by Escorts Foundation

The Lahore-based Escorts Foundation, a small charity run by Pakistani women, has developed and introduced a fuel-efficient cooking stove, to relieve pressure for fuelwood in the Changa Manga forest and improve the health and economic prospects of village women. The stoves are made out of mud and straw by the women who will use them (Figure 6.48). They consume much less than half the fuelwood of a traditional stove. While traditional fires need branch-sized pieces to generate enough heat, the new stove with its small, enclosed firebox can cook simple meals with a few handfuls of twigs. It emits very little soot or smoke, leading to dramatic improvements in the health of the women who use it. This fuel efficient cook stove won the Ashden Award for Sustainable Energy in 2004.

6.5 ICS Model of Sri Lanka

6.5.1 Anagi Stove

The most popular ICS in Sri Lanka is marketed under the trade name “Anagi”. The word “Anagi” in Sinhala language means precious or excellent. Anagi (Figure 6.49a&b) was first introduced in 1986 by the Ceylon Electricity Board in collaboration with the ITDG under the Urban Stoves Programme. Its success prompted the stove to be selected for commercialisation in the rural areas with the participation of the Integrated Development Association (IDEA) and the ITDG. Later the Asian Cookstove Programme (ARECOP) supported the programme to be extended to remote areas where access to commercial networks is absent. “Anagi” is two pot single-piece clay stove designed to meet the cooking needs of a 6 people family. It can accommodate medium-size hard or soft wood and other loose biomass residues such as coconut shells, fronds and leaves. The stove design has been carefully developed to suit the cooking habits and the types of food cooked in Sri Lanka. The stove can be used directly, which is preferable for short cooking as done in urban houses. For cooking over a long period of time as in many rural houses, insulating the stove with a mud mixture improves the firewood
saving capacity. The life-time of the stove is about 3 years if it is used with insulation (normally insulation consist of clay/mud cover).

Figure 6.49: Anagi Stove

Source: http://www.inforse.dk/asia/pdf/Anagi_Constr.pdf

c. Construction of Anagi Stove

Remove excess clay from the inside bottom

Check the height with the measuring stick – it should be 7 inches

Wrap the tunnel template around the tunnel. Cut along the edges

With fingertips press the joint of the tunnel and the firebox together

Figure 6.49: Anagi Stove

Source: http://www.inforse.dk/asia/pdf/Anagi_Constr.pdf
Section – VII
Properties and Cost of ICS in South Asia

7.1 Thermal Efficiency

Thermal efficiency reflects the rate at which heat exchange surfaces transfer heat to the transfer medium. Thermal efficiency of a stove is defined as the ratio of the net amount of heat absorbed by the water in the utensil and the amount of sensible heat supplied by the fuel. The efficiency of a stove depends on the ability ofcombusting the fuel completely and reducing conducting/convection and radiation losses. Thermal efficiency is the most important property of the ICS which indicates the fuel saving potential of the stove.

Improved cooking stoves, being enclosed types, hold out the possibility of greater efficiency. In free air solid fuels burn at a temperature of only about 270°C, too low a temperature for perfect combustion reactions to occur, heat produced is largely lost through convection, smoke particles are evolved without being fully burned and the supply of combustion air cannot be readily controlled. By enclosing the fire in a chamber and connecting it to a chimney, draught is generated pulling fresh air through the burning fuel. This causes the temperature of combustion to rise to a point (600°C) where efficient combustion is achieved, the enclosure allows the ingress of air to be regulated and losses by convection are almost eliminated. It also becomes possible, with ingenious design, to direct the flow of burned gasses inside the stove such that smoke particles are heated and destroyed. Enclosing a fire also prevents air from being sucked from the room into the chimney. This can represent a significant loss of heat as an open fireplace can pull away many cubic metres of heated air per hour.

7.1.1 Methods of Measuring Efficiency

There are many ways to assess the efficiency of cooking stoves. Direct accurate thermodynamic efficiency measurements of stoves are difficult to perform because they require strictly controlled conditions and consequently do not usually give very much useful information about how the stove will work in practice – in the field.

Through the 1980s, while the two largest ICS programmes of the world i.e. Chinese and Indian programmes were being developed, many smaller efforts were also developed throughout the developing world. These were led by a mix of non-governmental organisations and donor agencies. Recognising some organisational oversight would be helpful to assess the numerous stove designs and interventions that were proliferating, the United States Agency for International Development (USAID) convened a series of workshops to promote standardisation both in the language and in the methods used to evaluate stove performance. Through this effort, led largely by Volunteers in Technical Assistance (VITA), a US-based NGO, three stove performance tests were developed. They are: (a) Water Boiling Test (WBT), (b) Controlled Cooking Test (CCT) and (c) Kitchen Performance Test (KPT). Soon after the VITA-85 standards were released, a second VITA publication describing technical aspects of stove design was released. This second publication containing slight variations of the VITA stove tests has been the most widely-cited reference for stove developers since then. The popularity of both publications led to the widespread adoption of VITA’s tests and close variations. In particular, variations of the VITA WBT have become a popular standard. The CCT and KPT have seen more limited application.

a. The Water Boiling Test

This is a laboratory test, most commonly used during the design phase of a stove development programme to investigate the effect of design changes on stove performance while it is used to boil and simmer a pot of water. It is important to understand both the strengths and weaknesses of the WBT.

Strengths include the WBT’s simplicity and replicability. In addition, it provides a preliminary understanding of stove performance, which is very helpful during the design process. Data obtained from a just few days of testing will help in the development of better stoves, which can then be tested by cooks in their intended environment. By determining thermal efficiency at high and low power, as done in case of the WBT, fuel use can be roughly predicted for various cooking tasks. However, the WBT also has weaknesses. In order to be applicable to many different types of stoves, the WBT is only a rough approximation of actual cooking. It is done in controlled conditions by trained technicians. Therefore, it cannot provide much information about how the stove performs when cooking real foods. Detailed procedure and method of calculation of the test is given in the Appendix-I.
b. The Controlled Cooking Test

In the controlled cooking test the stove is used by a rural cook to prepare a simple meal (appropriate for where the stoves will be used), and the quantity of fuel used is measured. Since fuel consumption is measured while the stove is used to prepare a real meal, this test gives a better indication of fuel consumption when used in the household. Detailed procedure and method of calculation of CCT is given in the Appendix-II.

c. Kitchen Performance Test (The Field Trial)

Field trials are used to measure the impact of an improved stove in use. It depends on measuring the impact on household fuels over an extended period in a number of households.

The Kitchen Performance Test (KPT) is the principal field-based procedure to demonstrate the effect of stove interventions on household fuel consumption. There are two main goals of the KPT: (1) to assess qualitative aspects of stove performance through household surveys and (2) to compare the impact of improved stove(s) on fuel consumption in the kitchens of real households. To meet these aims, the KPT includes quantitative surveys of fuel consumption, and qualitative surveys of stove performance and acceptability. This type of testing, when conducted carefully, is the best way to understand the stove’s impact on fuel use and on general household characteristics and behaviors because it occurs in the homes of stove users. However, it is also the most difficult way to test stoves because it intrudes on people’s daily activities. In addition, the measurements taken during the KPT are more uncertain because potential sources of error harder to control in comparison to laboratory-based tests. For this reason, the protocol for the KPT is quite different from the protocols for the Water Boiling Test (WBT) and the Controlled Cooking Test. Detailed testing procedure is long and is not presented in this report.

7.1.2 Some Important Points about Testing

For large-scale ICS dissemination programmes following points deserve attention particularly for testing:

a) The WBT should be utilised during the design stage of the ICS and potentially to check that building of stoves in place is done as intended. When using the WBT, consideration should be given to the relative importance of high-power and low-power cooking among the target population. In areas where low-power cooking dominates, testers should want to emphasise the result of the simmer test.

b) The CCT should be promoted as a more appropriate and locally relevant measure of lab-based stove performance. CCTs can be performed by NGOs with minimal training, although short-term assistance in data analysis and interpretation may be needed from universities, research institutes, or environmental consulting firms. The results from the WBT should be interpreted in the light of the CCT and an assessment of the relative importance of high-power and low-power cooking in local practices.

c) Quantification of fuel consumption in the field using the KPT is necessary if the agency implementing or funding the stove intervention wants specific data about the impact of the ICS on household, community, regional or national-scale energy consumption. Available lab-based tests are not yet reliable predictors of fuel consumption in the field.

d) Given their difficulty, field assessments should only be planned if appropriate resources are available. Thus, stove organisations need sufficient support to enable reliable field monitoring. Donors must understand this need and budgets for stove projects should reflect it by including funds for group training, hiring outside consultants, and/or subcontracting monitoring and evaluation (M&E) tasks to a third party.

7.1.3 Outcome of Three Testing Methods

From the above discussion following comparisons among the three tests have been given in the Table 7.1:
Table 7.1  Potential Outcomes from Three Stove Performance Tests

<table>
<thead>
<tr>
<th>Theoretical issues</th>
<th>Applied issues</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lab</td>
</tr>
<tr>
<td></td>
<td>Basic principles of stove operation</td>
</tr>
<tr>
<td>WBT</td>
<td>+</td>
</tr>
<tr>
<td>CCT</td>
<td>±</td>
</tr>
<tr>
<td>KPT</td>
<td>-</td>
</tr>
</tbody>
</table>

Notes
1. Key to symbols: – unsuitable; ± potentially suitable; + suitable
2. The KPT is suitable to assess adoption by end-users if it includes a qualitative survey in addition to the quantitative measure of fuel consumption.

Source: [Balis et. al. 2007]

7.1.4  Efficiency  ICS on South Asia

Table 7.2 shows the efficiencies of some of the ICS developed by different organisations across South Asia. Figures vary over a wide range from 13 to 41 percent. However gasifier stoves have higher efficiency. For convenience of comparison of cost and technology gasifier stoves are not included in conventional concept of ICS. From the table it may be seen some ICS have efficiencies very close to traditional one pot cooking stoves. Studies have shown that many of ICS which showed good efficiency in labs failed to transmit that in the real kitchen environment.

Table 7.2  Thermal Efficiency  ICS on South Asia

<table>
<thead>
<tr>
<th>Country</th>
<th>Model Name</th>
<th>Thermal Efficiency (%)</th>
<th>Fuel Savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>Single Mouth ICS (Portable)</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Single Mouth ICS (Half underground)</td>
<td>22</td>
<td>45-50</td>
</tr>
<tr>
<td></td>
<td>Double Mouth ICS with Chimney (On the floor)</td>
<td>28-30</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Double Mouth ICS with Chimney (Half underground)</td>
<td>22-25</td>
<td>45-50</td>
</tr>
<tr>
<td></td>
<td>Single Mouth ICS with Chimney (Portable)</td>
<td>28-30</td>
<td>50-55</td>
</tr>
<tr>
<td></td>
<td>Double Mouth ICS Coupled with Single Mouth ICS with Common Chimney</td>
<td>NA</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Double Mouth ICS with Chimney Large Scale Cooking and Semi-industrial Purposes</td>
<td>29-31</td>
<td>60</td>
</tr>
<tr>
<td>India</td>
<td>Laxmi</td>
<td>23</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Bhagyalaxmi</td>
<td>22</td>
<td>45-50</td>
</tr>
<tr>
<td></td>
<td>Grihalaxmi</td>
<td>23</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Saral</td>
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<td>NA</td>
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<td></td>
<td>Sampoorna</td>
<td>18</td>
<td>28</td>
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<td>Sampada</td>
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<tr>
<td></td>
<td>Bharat Laxmi</td>
<td>19</td>
<td>32</td>
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<td></td>
<td>CPRI – Cast Iron Stove</td>
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<td></td>
<td>Sukkhad</td>
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<tr>
<td>Nepal</td>
<td>One pot hole ICS</td>
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<td>NA</td>
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<tr>
<td></td>
<td>Two Pot hole ICS</td>
<td>25 Average</td>
<td>50</td>
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<tr>
<td></td>
<td>Multipurpose ICS</td>
<td>30 Average</td>
<td>60</td>
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<td>Institutional ICS Model I</td>
<td>23</td>
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<td>Institutional ICS model II</td>
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<td>42</td>
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<tr>
<td></td>
<td>Institutional ICS Model III</td>
<td>15</td>
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Table 7.2 Cont’d

<table>
<thead>
<tr>
<th>Country</th>
<th>Model Name</th>
<th>Thermal Efficiency (%)</th>
<th>Fuel Savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nepal</td>
<td>Metallic Stove for High Hills</td>
<td>22</td>
<td>45</td>
</tr>
<tr>
<td>Pakistan</td>
<td>Cook Stove MA-I</td>
<td>NA</td>
<td>25</td>
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<tr>
<td></td>
<td>Cook Stove MA-II</td>
<td>NA</td>
<td>35</td>
</tr>
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<td></td>
<td>Cook Stove MA-III</td>
<td>NA</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Cook Stove MA-IV</td>
<td>NA</td>
<td>30-40</td>
</tr>
<tr>
<td></td>
<td>Cook Stove MA V</td>
<td>NA</td>
<td>30-45</td>
</tr>
<tr>
<td></td>
<td>Bukhary</td>
<td>15-22</td>
<td>NA</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>Anagi</td>
<td>41.2</td>
<td>NA</td>
</tr>
</tbody>
</table>

Source: Complied by the author from different sources

Note: NA means not available

7.2 Indoor Air Quality

Fine particulate matter (PM) and carbon monoxide (CO), the two most important and most studied pollutants associated with biomass combustion smoke. Testing programmes are designed to measure concentrations of PM and CO study households both before and after the introduction of the improved stove (a “Before-After” study design, without controls). Normally paired PM and CO data are collected in each household, before and after dissemination of the ICS. Sample sizes are chosen to reflect the type of statistical analysis appropriate with this design, with suitable allowance for drop outs, data loss etc.

Detectors for PM2.5 and CO are placed on the wall of the kitchen for 48 hours (± 2hrs) according to the following criteria:

1. Approximately 100 cm from the edge of the combustion zone (this distance away from the stove approximates the edge of the active cooking area)
2. At a height of 145 cm above the floor (this height relates to the approximate breathing height of a standing woman)
3. At least 150 cm away (horizontally) from doors and windows, where possible both devices were co-located (placed next to each other) and placed in a relatively safe location to minimise the risk of interrupting normal household activities or being disturbed or damaged.

The detectors are capable of continuity recording the concentrations of CO and PM2.5. Devices which record data every minute interval require precise calibration in standard labs. Concentrations of both PM2.5 and CO are very high during the cooking time and drops sharply after cooking. Figure 7.1 shows typical 48 hours variation of emission in a kitchen before and after installation Sukhad improved stove in India using HOBO CO monitor, and the UCB particle monitor. The measurements were taken during monsoon season.
Very limited work has been done in assessing the indoor air quality after installation of ICS in the kitchens in the region. Table 7.3 shows concentrations of CO and particulate matters PM2.5 for some models of India Nepal, Pakistan and Sri Lanka. Data for one model from Nepal and another from Sri Lanka are shown in % reduction compared to traditional stoves. Data show that some of the ICS re-

Figure 7.1: Graphs representing typical 48-hour concentrations of CO and PM$_{2.5}$ in kitchen before and after installation of ICS

Source: [Chenagapa et.al. 2007]
duce the CO concentration level below the standard set by World Health Organisation. It may be noticed from the Table 7.3 that although the ICS by and large reduces the emission of particulate matters, it still remains way above the standard set by WHO.

Table 7.3: Indoor Air Quality Improvement by ICS

<table>
<thead>
<tr>
<th>Country</th>
<th>Stove</th>
<th>Average CO Emission (ppm)</th>
<th>WHO Standard of CO</th>
<th>PM$_{2.5}$ (mg/m$^3$)</th>
<th>WHO Standard of PM$_{2.5}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>Double Mouth (fixed) of BCSIR</td>
<td>0.205</td>
<td></td>
<td>0.237</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Single Mouth (portable) of BCSIR</td>
<td>0.367</td>
<td></td>
<td>0.127</td>
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<td>India</td>
<td>Laxmi</td>
<td>8.37</td>
<td></td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bhagyalaxmi</td>
<td>6.91</td>
<td></td>
<td>0.48</td>
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<td>Grihalaxmi</td>
<td>0.53</td>
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<td>1.7</td>
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<tr>
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<td>Saral</td>
<td>0.528</td>
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<td>1.672</td>
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<td>Sampoorna</td>
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<td>3.001</td>
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<tr>
<td></td>
<td>Sampada</td>
<td>28.63</td>
<td></td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oorja</td>
<td>21.5</td>
<td></td>
<td>18.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bharat Laxmi</td>
<td>6.012</td>
<td></td>
<td>1.58</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sarai</td>
<td>negligible</td>
<td></td>
<td>negligible</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CPRI Cast Iron Stove</td>
<td>37.3</td>
<td></td>
<td>12.17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sukkhad*</td>
<td>7.8</td>
<td></td>
<td>0.33</td>
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<tr>
<td></td>
<td>Traditional 2 Pot Stove</td>
<td>10.1</td>
<td></td>
<td>0.814</td>
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<tr>
<td></td>
<td>Traditional 1 Pot Stove</td>
<td>24.63</td>
<td></td>
<td>1.022</td>
<td></td>
</tr>
<tr>
<td>Nepal</td>
<td>Two Pot hole ICS</td>
<td>60% reduction</td>
<td></td>
<td>63% reduction</td>
<td></td>
</tr>
<tr>
<td>Pakistan</td>
<td>Bukhary</td>
<td>NA</td>
<td></td>
<td>1.19</td>
<td></td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>Anagi</td>
<td>1% reduction</td>
<td></td>
<td>NA</td>
<td></td>
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</table>


7.3 Unit Price of ICS

Unit prices of different types of ICS in different countries across South Asia are given in the Table 7.4. It appears that cost of mud-clay ICS for domestic purpose varies from 1.25 to 14US dollars with Sri Lankan Anagi model being the cheapest and some Bangladeshi models being the highest. Variations in the cost depend on the materials used, cost of labour and operational margin. Sri Lankan Anagi stove has become a pottery item made of earth only, does not need any metal component which has given it an edge in cost over other models in the region. Nepalese domestic ICS models are relatively cheap too. Nepalese model of domestic metal stoves used for cooking and space heating is in the range of 88-125US$ equivalent. Due to high cost of this model government subsidises it upto 50% for mid hill areas. Cost of ICS in most cases are significantly high in comparison with the traditional stoves, which cost 1-2 US$ if labour cost is at all considered. In rural areas women themselves can make the traditional stoves and they do not count any labour cost for that.
<table>
<thead>
<tr>
<th>Country</th>
<th>ICS Model</th>
<th>Unit Price (Local Currency)</th>
<th>Unit Price (US$)</th>
<th>Exchange Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>Domestic Mud Clay ICS</td>
<td>Tk.700 -1,000</td>
<td>10-14.5</td>
<td>1US$ = 69Tk.</td>
</tr>
<tr>
<td></td>
<td>Commercial and Institutional</td>
<td>Tk.3,000-6,000</td>
<td>43.5-87</td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>Laxmi</td>
<td>INR.700</td>
<td>15</td>
<td>1US$=47INR</td>
</tr>
<tr>
<td></td>
<td>Bhagyalaxmi</td>
<td>INR.500</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grihalaxmi</td>
<td>INR.400</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sarala</td>
<td>INR.750</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sampoorna</td>
<td>INR.600</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vivek- Gasifier</td>
<td>INR.600</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sampada</td>
<td>INR.600</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bharat Laxmi</td>
<td>INR.500</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sarai</td>
<td>INR.950</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CPRI - Cast Iron Stove</td>
<td>INR.400</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Nepal</td>
<td>One pot hole ICS</td>
<td>NRs.150 -250</td>
<td>2.2-3.7</td>
<td>1US$=68NRs</td>
</tr>
<tr>
<td></td>
<td>Two Pot-hole ICS</td>
<td>NRs.250 -1,000</td>
<td>3.7-15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Multipurpose ICS</td>
<td>NRs.350 - 1,000</td>
<td>5-15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Institutional ICS Model I</td>
<td>NRs.7,500</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Institutional ICS model II</td>
<td>NRs.7,500</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Institutional ICS Model III</td>
<td>NRs.7,500</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Metallic Stove for High Hills</td>
<td>NRs.6,000-8,500</td>
<td>88-125</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Including subsidy)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pakistan</td>
<td>Cook Stove MA-I</td>
<td>PKR.1312</td>
<td>16</td>
<td>1US$=82PKR</td>
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<tr>
<td></td>
<td>Cook Stove MA-II</td>
<td>PKR.2624</td>
<td>32</td>
<td></td>
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<tr>
<td></td>
<td>Cook Stove MA-III</td>
<td>PKR.2132</td>
<td>26</td>
<td></td>
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<tr>
<td></td>
<td>Cook Stove MA-IV</td>
<td>PKR.492</td>
<td>6</td>
<td></td>
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<tr>
<td></td>
<td>Cook Stove MA V</td>
<td>PKR.492</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BACIP Ghizer/Gojal Model</td>
<td>PKR2,000</td>
<td>25</td>
<td></td>
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<tr>
<td>Sri Lanka</td>
<td>Anagi</td>
<td>SLR 125-200</td>
<td>1.25-2</td>
<td>1US$= 100SLR</td>
</tr>
</tbody>
</table>

Source: Collected by the author.
Efforts to popularise the ICS among the people in the South Asia are spanned over time period of three to four decades. However, the widespread acceptance of improved cooking stoves has not been possible yet. Following reasons are responsible for timid response of target communities towards the ICS dissemination programmes.

a. Lifelong habit

It is natural tendency of human being that once they are used to something they remain inclined in favour of continuing it and often hesitant to accept a new concept or technology. Women in the rural areas are cooking with three-stone or other traditional stoves for thousands of years. They are used to and feel comfortable with those. There has been hesitation in using improved cooking stoves which are new in shape and method of use.

b. Effect of subsidy

Initial programmes on improved cooking stoves failed to yield expected results due to indiscriminate subsidy by government and donor agencies. And these programmes were target driven not demand driven which sometimes caused indifference to the quality of products. There were lack of efforts in improving quality of stoves and lack of sincerity in giving the programmes sustainable footing. As a consequence when subsidies were withdrawn activities stopped due to non-availability of fund.

c. Stove choice

Sometimes ICS were introduced in areas which did not match food and cooking habits, types of biomass fuel available in those areas. These reasons led to disuse of ICS even they were initially accepted to be installed under subsidised programmes.

d. Fuel consumption

Specific fuel consumptions by different models were measured in the laboratories and technicians under strict control and supervision. Some studies have shown that the some of the stoves performed worse than traditional stoves in terms of fuel consumption. These happened due to fact that the stove specifications were not strictly maintained during construction.

e. Not worried of about the cost of fuel

In rural areas biomass fuel is mostly collected from household forest trees and crop residues. In agri-based societies in the rural areas there is hardly any purchase and sales of biomass fuel in many areas. Due to fact that people are not very worried about the amount of consumption and cost, they are less interested in buying ICS.

f. Cooking outside the kitchen

In the rural area in the plain land women like to cook outside the kitchen during the dry season. This gives them a chance to have chat with others at the same time an opportunity to keep an eye on other activities around them in the house during cooking in progress. For this reasons the fixed type ICS installed in the kitchen remains idle, this reduces the importance of ICS to them.

g. Kitchen space

People who are extremely poor living in the slums in the urban areas or semi-urban areas sometimes do not have a fixed kitchen. It is difficult to reach to them with improved cooking stoves. It is also reported that some people having thatched kitchen are hesitant to install ICS with chimneys in the fear that the roof will catch fire by heat from the chimney or from accidental leakage of hot gas through the chimney.

h. Needs expert to build and needs maintenance

Women by themselves learn how to make traditional stoves so easily that no external expertise is required for this purpose. On the other hand, for better performance ICS manufacturing needs care, experience and accurate measurements has to be followed. Repair and maintenance for ICS are more difficult than traditional ones. Cleaning chimneys regularly is seen as an additional problem.

i. Cost of ICS

Some people are living in abject poverty. It is often difficult for them to arrange two ends meal. They are not ready to use ICS spending money, no matter what benefit it may otherwise bring to them.
j. Illiteracy and lack of awareness

Needless to say, mitigation of health hazards caused by indoor pollution is one of the major objectives of introduction of ICS in developing countries. Overall literacy in the rural area in the region is low; it is even lower among women. Lack knowledge about the heath hazard caused by the indoor air pollution (IAP) by biomass has been seen as a major impediment in dissemination of improved cooking stoves.
Section - IX
Conclusions and Recommendations

9.1 Conclusions

Systematic scientific research and dissemination of ICS started in the South Asia in 1980’s with various objectives. Some of the programmes were aimed at improving the efficiency of fuelwood to reduce pressure on biomass which in turn would prevent deforestation. While some programmes aiming at the indoor air pollution (IAP) took ICS as a tool for alleviating health hazards caused by toxic gases and particulate matters present biomass smoke. Yet, others launched ICS programmes with both of these objectives including empowerment of rural women.

Over the last three decades varieties of ICS models have been developed in the South Asia. For the people of plains efforts are going on to popularise low cost clay/mud stoves for cooking purpose only. While for the areas at high altitude and cold weather, metal stoves are being disseminated for use of both cooking and space heating.

Early programmes were subsidised either from the government fund or international donor agencies. Currently, there are some programmes that provide subsidies but these are limited in nature and based on some conditions. It is done from the realisation that indiscriminate subsidy undermines the objective of sustenance in many ways. Efforts are underway to attract private entrepreneurs and run the programmes as commercial ventures.

Like many other good initiatives, progress in propagating the ICS programmes among the mass population in larger scale has been difficult due to ignorance of the people health impact of burning biomass in closed kitchen with traditional stoves. Furthermore, many of the programmes could not transmit the efficiency of the stoves obtained in labs to the real kitchens. The economic benefit thus remained unrecognisable to the people.

Given the fact that due to low per capita income huge number of people cannot afford to cook with cleaner commercials fuel, biomass will continue to be the cooking and heating source for large section of population especially in rural areas of the South Asia in the foreseeable future.

From this study following conclusions can be drawn:

- Despite efforts by governments, NGOs and donor agencies response from the general people to the ICS dissemination programmes has not been very encouraging.
- Considering economic, environmental and health aspects endeavour for wider dissemination of ICS should be continued.
- Programmes should be demand driven and should be planned for commercial success.
- Continuous monitoring, follow up and technical supervision on ICS performance in practical use are crucial for the success of any ICS programme.
- More awareness creation is necessary to make ICS programmes successful.

9.2 Recommendations

For wider dissemination of ICS and sustainability of the programmes this study makes following recommendations:

- **Awareness building and education:** It is very difficult to make of social programme success unless people are aware of the benefits of the programme activities. Workshops, road shows and village fairs can be arranged to educate people about the health, environmental and financials benefits of improved cooking stoves. Special attention should be given to the women and school children with respect to awareness building. Training workshops may be arranged for school teachers and students by the technicians and educationists.

- **Promote commercialisation of ICS:** Evidences from regional and international experience strongly support that the ultimate goal of ICS dissemination programmes should be full commercialisation of stove business. Countries need to promote commercialisation in order to make the use of improved stoves sustainable in the long run. The government institutions may play important role in improving designs; setting technical standards; and providing credit facilities for stove makers.
• **Supervisory body for ensuring quality:** A government body under the renewable energy departments of each country may be entrusted with the responsibility of testing different models before the model is introduction in the field and after installation in the fields. They can make regular evaluation of different dissemination programmes and advise project authorities accordingly.

• **Facilitate collaboration between designers, manufacturers and consumers:** The technical backup units need to be more involved with the manufacturers and consumers of the stoves particularly women, who are the main users. This might lead to the design of models that are more durable and better adapted to consumer preferences.

• **Holistic approach to reach the poor:** ICS dissemination programmes may be undertaken as integral part of other social development and income generating activities. If women are involved in income-generating activities that will value their time and make it more profitable to purchase firewood than collect it, improved stoves will have higher chances of success. Micro-financing organisations may be more involved in this activity.

• **Sharing knowledge and best practices at regional level:** Periodical workshops or seminars may be arranged at regional level to share knowledge and best practices on dissemination, awareness creation and technical upgradation issues to adopt appropriate strategies by individual countries.
Acknowledgement

Most difficult part of the study was to collect information and data from different countries in the region. But I found some people who turned to be very cooperative. I acknowledge with gratitude contributions of the following officials and experts who have benefited the study by providing information and identifying sources of information from different countries of the SAARC region. Without their generous support it would very difficult on my part to conduct the study.

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Md. Lutfar Rahman
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Improved Cooking Stoves in South Asia

appeared in Health Effects of Chronic Exposure to Smoke from Biomass Fuel Burning in Rural Areas’ published by WHO, 2007


Appendix-I

The Water Boiling Test (WBT)
(Source: Household Energy and Health Programme, Shell Foundation)

The WBT developed for the Shell Household Energy and Health (HEH) programme consists of three phases that immediately follow each other.

1) In the first phase, the cold-start high-power test, the tester begins with the stove at room temperature and uses a pre-weighed bundle of wood or other fuel\(^1\) to boil a measured quantity of water in a standard pot. The tester then replaces the boiled water with a fresh pot of cold water to perform the second phase of the test.

2) The second phase, the hot-start high-power test, follows immediately after the first test while stove is still hot. Again, the tester uses a pre-weighed bundle of fuel to boil a measured quantity of water in a standard pot. Repeating the test with a hot stove helps to identify differences in performance between a stove when it is cold and when it is hot.

3) The third phase follows immediately from the second. Here, the tester determines the amount of fuel required to simmer a measured amount of water at just below boiling for 45 minutes. This step simulates the long cooking of legumes or pulses common throughout much of the world.

This combination of tests measures some aspects of the stove’s performance at both high and low power outputs, which are associated with the stove’s ability to conserve fuel. However, rather than report a single number indicating the thermal efficiency of the stove, which is not necessarily a good predictor of stove performance\(^2\), this test is designed to yield several quantitative outputs. Different stove designers may find different outputs more or less useful depending on the context of their stove programmes. The outputs are:

- time to boil (adjusted for starting temperature);
- burning rate (adjusted for starting temperature);
- specific fuel consumption (adjusted for starting temperature);
- firepower;
- turn-down ratio (ratio of the stove’s high power output to its low power output); and
- thermal efficiency.

Before starting the tests:

The following five steps should be completed before beginning the actual tests.

1) Be sure that there is sufficient water and fuel. If possible, try to obtain all of the wood from the same source. It should be well-dried and uniform in size. If kindling is to be used to start the fire, it should also be prepared ahead of time and included in the pre-weighed bundles of fuel.

2) Perform at least one practice test on each type of stove in order to become familiar with the testing procedure and with the characteristics of the stove. As a rough guide, procure at least 15 kg of air-dried fuel for each stove in order to ensure that there is enough fuel to test each stove three times. Large multi-pot stoves may require even more than 15 kg.

3) The practice tests should also be used to determine the local boiling point of water. This should be determined by the following procedure:

- Choose whether you will use the large or small standard pot. Measure 5 liters of water

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\(^1\) This test was originally designed for woodstoves, but has been adapted to accommodate other types of stoves and fuels.

\(^2\) A direct calculation of thermal efficiency derived from the Water Boiling Test is not a good indicator of the stove’s performance because it rewards the excess production of steam. Under normal cooking conditions, excess steam production wastes energy because it represents energy that is not transferred to the food. Temperatures within the cooking pot do not rise above the boiling point of water regardless of how much steam is produced. Thus, unless steam is required for the cooking process – for example in the steaming of vegetables, excess steam production should not be used to increase indicators of stove performance.
for the large standard pot (or 2.5 liters for the small standard pot). Bring it to a rolling boil. Make sure that the stove’s power output is high, and the water is fully boiling.

- Using the same thermometer that will be used for testing, measure the boiling temperature when the thermometer is positioned in the centre, 5 cm above the pot bottom. Tester may find that even at full boil, when the temperature no longer increases, it will still oscillate several tenths of a degree above and below the actual boiling point.

- The tester should record the temperature over a five minute period at full boil and note the maximum and minimum temperatures observed during this period. The maximum and minimum temperatures should then be averaged and this result recorded as the “local boiling temperature” on the data and calculation form. This need only be done once for your test location.

4) One full WBT requires at least 10 liters of cool water for each pot being used. If water is scarce in the area, water used one day may be cooled and reused in the next day’s testing. But, do not start any tests with water that is significantly above room temperature.

5) Make sure that there is adequate space and sufficient time to conduct the test without being disturbed. Testing should be done indoors in a room that is protected from wind, but with sufficient ventilation to vent harmful stove emissions. It will take 1½ - 2 hours to do the high and low power test for each stove. It will save time if the tester prepares enough bundles of fuel to conduct several tests before starting the first test.

**Equipment used for the Water Boiling Test:**

- Scale with a capacity of at least 6 kg an accuracy of ±1 gram
- Digital Thermometer, accurate to 1/10 of a degree, with thermocouple probe suitable for immersion in liquids
- Wood moisture meter (optional)
- Timer
- Standard pot(s) (see note 1)
- Wood fixture for holding thermocouple
- At least 10 liters of clean water for each WBT (in locations where water is scarce, this may be cooled and reused for later tests) probe in water
- Heat resistant pad to protect scale
- Small shovel/spatula to remove charcoal from stove
- Tongs for handling charcoal
- Dust pan for transferring charcoal
- Metal tray to hold charcoal for weighing
- Heat resistant gloves
- 2 bundles of air-dried fuelwood each weighing between 1 and 2 kg for each test (each stove is tested three times). More fuel may be needed for high-mass stoves

**Initial steps:** to be done once for each tests

1) Fill out the first page of the Data and Calculations form. This includes information about the stove, fuel and test conditions. Number each series of tests for future reference.

2) Measure each of the following parameters. These should be recorded once for each series of tests. Record the measurements on page 1 of the Data and Calculation form.

   a. Air temperature
   b. Average dimensions of wood (length x width x height). This is to give a rough idea of the size of fuel used for the test. Similarly sized wood should be used for every test to reduce variation in test conditions. If the stove design requires a specific size of fuel then you should use the optimal size for the stove. Otherwise, use sticks 2-5 cm in diameter.
   c. Wood moisture content (% wet basis): to be determined 1) By weighing a sample of fuel, drying the sample completely in a controlled manner, and weighing it again or 2) By using the wood moisture meter included in the testing kit. The Data and Calculation form contains a special worksheet to record and process your measurements.
   d. Dry weight of standard supplied pot without lid. If more than one pot is used, record the dry weight of each pot. If the weights differ, be sure not to confuse the pots as the test proceeds. Do not use pot lids for this, or any other phase of the WBT. The standard pot (supplied with the test equipment) should be used wherever possible (see notes). If it is not compatible with the stove, use a pot that is typically used and note its dimensions in the “comments” section of the Data and Calculations worksheet.
   e. Weight of container to be used for charcoal.
   f. Local boiling point of water determined by using the same digital thermometer and sensor that will be used in the testing.
g. If the tester have access to a camera (not included in standard kit), photograph the stove. If tester does not have access to a camera, a tape is used to measure for recording the dimensions of the stove and describe it in the space provided.

3. Prepare 2 bundles of fuel wood. These should be pre-weighed: one for each of the two measurement phases of the test. The fuel should be relatively uniform in size and shape: split big pieces of wood and avoid using very small pieces (except for kindling, which should also be prepared in advance if necessary).

4. Once these parameters have been measured and recorded and the fuel is prepared, proceed with the test.

**Phase 1: High Power (Cold Start)**

Data recorded in the remaining phases of the test should be recorded on page two of the Data and Calculation form.

1. Prepare the timer, but do not start it until fire has started.

2. Fill each pot with 5 kg (5 liters) of clean room temperature water (if using the smaller standard pot, fill the pot with 2.5 kg or 2.5 liters of water). The amount of water should be determined by placing the pot on the scale and adding water until the total weight of pot and water together is 5 kg (or 2.5 kg) more than the weight of the pot alone. Record the weight of pot and water in the Data and Calculations Sheet. (If the stove can not accommodate the standard pot and the pot that is used can not accommodate 5 (or 2.5) kg of water, OR if a multi-pot stove is used with nonstandard pots that can not accommodate 5 (or 2.5) kg of water, fill each pot ~2/3 full and record the change in procedure in the comment space. Record the weight of the pot(s) with the water on the Data and Calculation Form. Use the same amount of water for each test iteration.)

3. Using the wooden fixtures, place a thermometer in each pot so that water temperature may be measured in the center, 5 cm from the bottom. If there are additional pots, use the additional thermometers if possible. Record the initial water temperature in each pot and confirm that it does not vary substantially from the ambient temperature.

4. The stove should be at room temperature. Start the fire in a reproducible manner according to local practices. Record any starting materials that are used other than the wood from the first bundle of pre-measured wood (e.g. paper or kerosene).

5. Once the fire has caught, record the starting time. Throughout the following “high power” phase of the test, control the fire with the means commonly used locally to bring the first pot rapidly to a boil without being excessively wasteful of fuel.

6. When the water in the first pot reaches the predetermined local boiling temperature as shown by the digital thermometer, rapidly do the following:

a. Record the time at which the water in the primary pot (Pot # 1) first reaches the local boiling temperature. Record this temperature also.

b. Remove all wood from the stove and extinguish the flames (flames can be extinguished by blowing on the ends of the sticks or placing them in a bucket of ash or sand; do not use water – it will affect the weight of the wood). Knock all loose charcoal from the ends of the wood into the container for weighing charcoal.

c. Weigh the unburned wood removed from the stove together with the remaining wood from the pre-weighed bundle. Record result on the Data and Calculation form.

d. For multi-pot stoves, measure the water temperature from each pot (the primary pot should be at the boiling point). Record the temperatures on the Data and Calculation Form.

e. Weigh each pot, with its water. Record these weights on the Data and Calculation form.

f. Extract all remaining charcoal from the stove, place it with the charcoal that was knocked off the sticks and weigh it all. Record the weight of the charcoal + container on the Data and Calculation Form.

**Summary**

- Make sure that time and temperature of the boiling water in the first pot, the amount of wood remaining, the weight of Pot # 1 with the remaining water, and amount of charcoal remaining have been recorded on the Data and Calculation Form. For multi-pot stoves, be sure that the temperature that each additional pot reached when Pot # 1 first came to its full boiling temperature has been recorded.

- This completes the high power phase. Now,
begin the high power-hot start test, immediately while the stove is still hot.

**Phase 2: High Power (Hot Start)**

1. Reset the timer, but do not start it until fire has started.
2. Refill the pot with 5 (or 2.5) kg of fresh cold water. Weigh the pot (with water) and measure the initial water temperature; record both measurements on the Data and Calculations sheet. For multi-pot stoves, fill the additional pots, weigh them and record their weights.
3. Light the fire using kindling and wood from the second pre-weighed bundle designated for this phase of the test.
4. Record the starting time, and bring the first pot rapidly to a boil without being excessively wasteful of fuel using wood from the second pre-weighed bundle.
5. Record the time at which the first pot reaches the local boiling point as indicated on the Data and Calculation form. Record this temperature for the first pot.
6. After reaching the boiling temperature, quickly do the following (speed is important at this stage because we want to keep the water temperature as close as possible to boiling in order to allow us to proceed directly to the simmer test):
   a. Remove the unburned wood from the stove. Knock off any loose charcoal, but try to keep it in the combustion area (do not weigh the charcoal at this stage). Weigh the wood removed from the stove, together with the unused wood from the previously weighed supply. Record result on Data and Calculation form.
   b. Record the water temperature from other pots if more than one pot is used.
   c. Weigh each pot, with it’s water and record the weights. After weighing, immediately replace each pot on the stove (remember, we want to keep the water temperature as close as possible to boiling in order to proceed directly to the simmer test).
7. Replace and relight the wood removed from the fire proceed immediately with the low power test.

**Phase 3: Low Power (Simmering)**

This portion of the test is designed to test the ability of the stove to shift into a low power phase following a high-power phase in order to simmer water for 45 minutes using a minimal amount of fuel. For multi-pot stoves, only the primary pot will be assessed for simmering performance.

Start of Low Power test:

1. Reset the timer.
2. Place the thermometer in the pot. Adjust the fire to keep the water as close to 3 degrees below the established boiling point as possible.
3. For 45 minutes maintain the fire at a level that keeps the water temperature as close as possible to 3 degrees below the boiling point.
4. After 45 minutes rapidly do the following:
   a. Record the finish time of the test (this should be 45 minutes). Record this and all remaining measurements on the Data and Calculation Form under the heading “Finish: 45 minutes after Pot # 1 boils”.
   b. Remove all wood from the stove and knock any loose charcoal into the charcoal container. Weigh the remaining wood, including the unused wood from the pre-weighed bundle.
   c. Record the final water temperature on Data and Calculation Form – it should still be roughly 3 °C below the established boiling point.
   d. Weigh the pot with the remaining water. Record the weight on the Data and Calculation Form.
   e. Extract all remaining charcoal from the stove and weigh it (including charcoal which was knocked off the sticks). Record the weight of pan plus charcoal.

This completes the WBT. The test should be conducted a total of three times for each stove.

**Notes on the WBT**

1. **Pots**: The capacity, dimensions and material of the pot have a significant influence on stove performance. In order to maximize the comparability of the WBT across different types of stove we recommend that testers use one of two standard pots depending on the design and
power output of the stove being tested. The recommended pots are 1) a large pot (with a 7 liter capacity) and 2) a small pot (with a 3.4 liter capacity. Depending on the power output of the stove and cooking practices in the area where the stove is used, testers should use either the large or small standard pot unless the stove requires a specific pot in order to function properly. If testers use a non-standard pot, they should record the capacity, dimensions, weight, and material. Use of a non-standard pot may bias the results and make them difficult to compare to other WBTs.

2. **Boiling point:** The local boiling point of water is the point at which the temperature no longer rises, no matter how much heat is applied. This should be determined empirically by the following procedure: Put 5 liters of water in the standard pot and bring it to a boil. Using the same thermometer that will be used for testing, measure the boiling temperature when the thermocouple is positioned in the center, roughly 5 cm above the pot bottom. The tester will find that even at full boil (when new higher temperatures are no longer observed), the temperature will oscillate several tenths of a degree above and below the actual boiling point. The tester should record the temperature over a five-minute period at full boil and note the maximum and minimum temperatures observed during this period. The maximum and minimum temperatures should then be averaged and this result recorded as the “local boiling temperature” on the data and calculation form. (This need only be done once for your test location). The local boiling temperature is influenced by several factors including altitude, minor inaccuracies in the thermometer, and weather conditions. For these reasons, the local boiling temperature cannot be assumed to be 100° C. For a given altitude h (in meters), the boiling point of water may be estimated by the following formula.

\[ T_b = \left( 100 - \frac{h}{300} \right) \]°C

3. **Fuels:** The type and size of fuel can affect the outcome of the stove performance tests. In order to minimize the variation that is potentially introduced by variations in fuel characteristics VITA (1985) recommends taking the following precautions:

- Try to use only wood (or other fuel) that has been thoroughly air-dried. Wooden stocks 3-4 cm in diameter may take from 3-8 months to dry fully. Dung or crop resis-

dues take somewhat less time in dry conditions. For woodfuel, drying can be accelerated by ensuring that the wood is stored in a way that allows air to circulate through it.

- Different sizes of solid fuels fuel have different burning characteristics. While stove users may not have the ability to optimize fuel size, testers should try to use only similar sizes of wood to minimize this source of variation.

4. **Moisture content of wood:** well-dried fuel contains 10-20% water while fresh cut wood may contain more than 50% water by mass (wet basis). Ideally, fuel used for both testing stoves and for cooking by project beneficiaries should be dried as much as local environmental conditions allow. However, dried fuel is not always available and both stove testers and household cooks must use what they can get. In order to control for variations in fuel moisture content, stove testers should measure it and account for it in their stove performance calculations. Thus, there is a space for moisture content to be input in the Data and Calculation form and software.

There are two ways of defining fuel moisture content: on a wet basis and on a dry basis. In the former, the mass of water in the fuel is reported as a percentage of the mass of wet fuel and in the latter case, it is reported as a percentage of the mass of the dry fuel. The calculations for each are shown below followed by a plot showing how both wood moisture on a wet basis and wood mass vary with wood moisture defined on a dry basis for one kg of oven-dry wood. Unless otherwise specified, we will report wood moisture on a wet basis. The testers should always take care to specify which basis they are using.

\[ \text{MC}_{\text{wet}}(\%) = \frac{(\text{Mass of fuel}_{\text{wet}}) - (\text{Mass of fuel}_{\text{dry}})}{(\text{Mass of fuel}_{\text{wet}})} \times 100 \] and

\[ \text{MC}_{\text{dry}}(\%) = \frac{(\text{Mass of fuel}_{\text{wet}}) - (\text{Mass of fuel}_{\text{dry}})}{(\text{Mass of fuel}_{\text{dry}})} \times 100 \]

The two moisture contents are related in this way: \( \frac{\text{MC}_{\text{wet}}}{\text{MC}_{\text{dry}}} + 1 \)

5. Measuring moisture content can be done in two ways. The most precise way is to use the equations listed above by weighing a sample of the air-dry fuel (Mass of fuel) wet and weighing it again after it has been completely dried (Mass of fuel) dry. Take a small sample (200-300 g) of the fuel randomly from the stock of fuel to be used for the tests. Weigh the sample and record the mass. Dry the sample an oven at a few de-
degrees over 100 °C and weigh it again. This may be done at the testing site if an oven is available, or the wet sample may be weighed on-site and then stored carefully and dried later, when an oven is available.

To dry the sample, put it in an oven and then remove it and weigh the sample every two hours on a sensitive scale (±1 g accuracy) until the mass no longer decreases. The oven temperature should be carefully controlled so that it doesn’t exceed 110°C (230°F). If the wood is exposed to temperatures near 200°C (390°F), it will thermally break down and lose matter that is not water, causing an inaccurate measurement of moisture content.

5. **Lids**: The WBT should be conducted without lids. This may seem counterintuitive, because lids generally improve the performance of the stove. However, the main purpose of the WBT is to quantify the way that heat is transferred from the stove to the cooking pot. While a lid helps to retain heat in the pot, and should therefore be used for any actual cooking task, it does not effect the transfer of heat from the stove to the pot. Hence, a lid is not needed for the WBT even if lids are commonly used among communities for which the improved stove is intended. In fact, lids can complicate the WBT by increasing the variability of the outcome and making it harder to compare results from different tests. As Baldwin writes, “If a lid is used then the amount of water evaporated and escaping is somewhat dependent on the tightness of the lid’s fit to the pot, and very dependent on the firepower. If the firepower is so low that the temperature is maintained a few degrees below boiling, effectively no water vapor will escape. If the firepower is high enough so that the water boils, the escaping steam will push the lid open and escape.”

6. The water lost has different effects on each indicator of stove performance. However, since it is difficult to standardise the lid’s “tightness of fit”, even for a standardised pot, it is recommended that testers not use the lid for the WBT. This should have little impact on the high power testing phase – indicators like specific consumption and thermal efficiency are both relatively insensitive to evaporated water.

7. However, the indicators derived from the low power test are more sensitive to the amount of water evaporated. Again, from Baldwin, “By not using a lid, evaporation rates are higher and the stove must be run at a somewhat higher power to maintain the temperature than is the case with a lid”.

8. **Power control**: Many stoves lack adequate turn-down ability. The tester may find that it is impossible to maintain the desired temperature without the fire going out (especially after the initial load of charcoal in the stove has been consumed). If this is the case, the tester should use the minimum amount of wood necessary to keep the fire from dying completely. Water temperatures in this case will be higher than 3° below boiling, but the test is still valid. The tester should not attempt to reduce power by further splitting the wood into smaller diameter pieces.

### An explanation of the calculations used in the WBT

The WBT consists of three phases: a high-power phase with a cold start, a high power phase with a hot start, and a low power (simmer) phase. Each phase involves a series of measurements and calculations. The calculations for the one-pot test are described below. For stoves that accommodate more than one pot, the calculations will be adjusted to account for each pot. These adjustments are explained below.

Variables that are constant throughout each phase of the test:

- **HHV** Gross calorific value (dry wood) (MJ/kg)
- **LHV** Net calorific value (dry wood) (MJ/kg)
- **m** Wood moisture content (% - wet basis)
- **Ceff** Effective calorific value (accounting for moisture content of wood)
- **P** Dry weight of empty Pot (grams)
- **k** Weight of empty container for char (grams)
- **Tb** Local boiling point of water (deg C)

**HHV** – Higher heating value (also called gross calorific value). This is the theoretical maximum amount of energy that can be extracted from the combustion of the moisture-free fuel if it is completely combusted and the combustion products are cooled to room temperature such that the water produced by the reaction of the fuel bound hydrogen is condensed to the liquid phase.

**LHV** – Lower heating value (also called net heating value). This is the theoretical maximum amount of energy that can be extracted from the combustion of the moisture-free fuel if it is completely combusted and the combustion products are cooled to room temperature but the water produced by the reaction of the fuelbound hydrogen remains in the gas phase. For woodfuels, LHV typically differs from HHV by 1.32 MJ/kg.5

**m** – This is the % wood moisture content on a wet...
basis, defined by the following formula:

\[ m = \frac{(\text{mass of wet fuel}) - (\text{mass of dry fuel})}{\text{mass of wet fuel}} \times 100 \]

This can be determined gravimetrically (by weighing a sample of wet fuel, drying the sample, and weighing it again) or through the use of a wood moisture meter.

If the Delmhorst J-2000 moisture meter is used in this test to measure wood moisture content, be aware that it provides moisture content on a dry basis. In order to use ‘m’ in the following analysis, the output of the instrument must be converted to moisture content on a wet basis. Dry basis must be converted to wet basis using the following equation:

\[ MC_{\text{wet}} = \frac{MC_{\text{dry}}}{1 + MC_{\text{dry}}} \]

\( c_{\text{eff}} \) – This is the effective calorific value of the fuel, with takes account of the energy required to heat and evaporate the moisture present. This is calculated in the following way:

\[ c_{\text{eff}} = \frac{LHV \times (\text{mass of dry fuel}) - (\text{mass of water in fuel}) \times (80 + 4.186 + 2260)}{\text{mass of wet fuel}} \]

where 80°C represents the typical change from ambient temperatures to the boiling point of water, 4.186 kJ/(kg°C) is the specific heat capacity of water, and 2260 kJ/kg is the energy required to evaporate one kilogram of water. The graph below shows ceff as a function of wood moisture content (wet basis) assuming an HHV of 20,000 kJ/kg (LHV of 18,680 kJ/kg), which is a typical value for hardwoods. Note that at 50% moisture, which is not uncommon for freshly cut (green) wood in moist climates, the effective energy content of the fuel is reduced by more than half.

\[ \text{Variables that are directly measured} \]

- \( f_{\text{ci}} \) Weight of fuel before test (grams)
- \( P_{\text{ci}} \) Weight of Pot with water before test (grams)
- \( T_{\text{ci}} \) Water temperature before test (°C)
- \( t_{\text{ci}} \) Time at start of test (min)
- \( f_{\text{cf}} \) Weight of wood after test (grams)
- \( c_{\text{c}} \) Weight of charcoal and container after test (grams)
- \( P_{\text{cf}} \) Weight of Pot with water after test (grams)
- \( T_{\text{cf}} \) Water temperature after test (°C)
- \( t_{\text{cf}} \) Time at end of test (min)

\[ \text{Variables that are calculated} \]

- \( f_{\text{cm}} \) Wood consumed, moist (grams)
- \( D_{\text{cc}} \) Change in char during test phase (grams)
- \( F_{\text{ed}} \) Equivalent dry wood consumed (grams)
- \( W_{\text{cv}} \) Water vaporized (grams)
- \( w_{\text{cr}} \) Water remaining at end of test (grams)
- \( D_{\text{tc}} \) Duration of phase (min)
- \( h_{\text{c}} \) Thermal efficiency
- \( r_{\text{cb}} \) Burning rate (grams/min)
- \( SC_{\text{c}} \) Specific fuel consumption (grams wood/grams water)
- \( SC_{\text{Th}} \) Temp-corrected specific consumption (grams wood/grams water)
- \( FP_{\text{c}} \) Firepower (W)

1. **High power test (cold start)**

Explanations of Calculations

- \( f_{\text{cm}} \) – **Wood consumed (moist):** This 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:

\[ f_{\text{cm}} = f_{\text{cf}} - f_{\text{ci}} \]

- \( D_{\text{cc}} \) – **Net change in char during test phase:** This is the mass of char created during the test found by removing the char from the stove at the end of the test phase. Because it is very hot, the char will be placed in an empty pre-weighed container of mass k (to be supplied by testers) and weighing the char with the container, then subtracting the two masses.

\[ D_{\text{cc}} = c_{\text{c}} - k \]

- \( f_{\text{ed}} \) – **Equivalent dry wood consumed:** This is a calculation that adjusts the amount of wood that was burned in order to account for two factors: (1) the energy that was needed to remove the moisture in the wood and (2) the amount of char remaining un-
burned. The calculation is done in the following way:

\[ f_{cd} = f_{cm} \times (1-(1.12 \times m)) - 1.5 \times D_{cc} \]

The factor of 1-(1.12 \times m) adjusts the mass of wood burned by the amount of wood required to heat and evaporate m\times f_{cm} grams of water. It takes roughly 2260 J to evaporate a kilogram of water, which is roughly 12% of the calorific value of dry wood. Thus if wood consists of m% moisture, the mass of wood that can effectively heat the pot of water is reduced by roughly 1- (1.12 \times m) because the water must be boiled away. The factor of 1.5 \times D_{cc} accounts for the wood converted into unburned char. Char has roughly 150% the calorific content of wood, thus the amount of wood heating the pot of water should be adjusted by 1.5 \times D_{cc} to account for the remaining char. Note, in the simmer phase it is possible that there will be a net loss in the amount of char before and after the test, in which case D_{c} is negative and the equivalent dry wood increases rather than decreases.

\[ W_{cv} = \text{Water vaporized: This is a measure of the amount of water lost through evaporation during the test. It is calculated by simple subtraction of initial weight of pot and water minus final weight of pot and water.} \]

\[ w_{cv} = P_{ci} - P_{cf} \]

\[ w_{cr} = \text{Water remaining at end of test: This is a measure of the amount of water heated to boiling. It is calculated by simple subtraction of final weight of pot and water minus the weight of the pot.} \]

\[ w_{cr} = P_{cf} - P \]

\[ D_{cc} = \text{Time to boil pot #1: This is simply the time taken to perform the test. It is a simple clock difference:} \]

\[ D_{cc} = t_{cf} - t_{ci} \]

\[ DT^{T}_{c} = \text{Temperature-corrected time to boil pot #1: this is the same as above, but adjusts the result to a standard 75 °C temperature change (from 25 °C to 100 °C). This adjustment standardizes the results and facilitates a comparison between tests that may have used water with higher or lower initial temperatures.} \]

\[ DT^{T}_{c} = (t_{cf} - t_{ci}) \times 75/(T_{cf} - T_{ci}) \]

\[ h_{c} = \text{Thermal efficiency: This is a ratio of the work done by heating and evaporating water to the energy consumed by burning wood. It is calculated in the following way.} \]

\[ h_{c} = \frac{4.186 \times (P_{ci} - P) \times (T_{cf} - T_{ci}) + 2260 \times (w_{cv})}{f_{cd} \times LHV} \]

In this calculation, 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 (2260 J/g). The denominator (bottom of the ratio) is determined by taking the product of the dry-wood equivalent consumed during this phase of the test and the LHV.

\[ r_{cb} = \text{Burning rate: This is a measure of the rate of wood consumption while bringing water to a boil. It is calculated by dividing the equivalent dry wood consumed by the time of the test.} \]

\[ r_{cb} = \frac{f_{cd}}{t_{ci} - t_{cf}} \]

\[ SC_{c} = \text{Specific fuel consumption: Specific consumption can be defined for any number of cooking tasks and should be considered “the fuelwood required to produce a unit output” whether the output is boiled water, cooked beans, or loaves of bread. In the case of the cold-start high-power WBT, it is a measure of the amount of wood required to produce one liter (or kilo) of boiling water starting with cold stove. It is calculated in this way:} \]

\[ SC_{c} = \frac{f_{cd}}{P_{cf} - P} \]

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

\[ SC^{T}_{c} = \frac{f_{cd}}{P_{cf} - P} \times \frac{75}{T_{cf} - T_{ci}} \]

\[ FP_{c} = \text{Firepower: This is a ratio of the wood energy consumed by the stove per unit time. It tells the average power output of the stove (in Watts) during the high-power test.} \]

\[ FP_{c} = \frac{f_{cd} \times LHV}{60 \times (t_{cf} - t_{ci})} \]

Note, by using \( f_{cd} \) in this calculation, we have accounted for both the remaining char and the wood moisture content.

**High power test (hot start)**

In this test, measurements and calculations are identical to the cold start test except that the char remaining is not extracted and weighed. Simply substitute the subscript ‘h’ for the subscript ‘c’ in each variable as in the table below. Char remaining is assumed to be the same as the char remaining from the “cold start” phase.
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Variables that are directly measured

- $f_{hi}$: Weight of fuel before test (grams)
- $P_{hi}$: Weight of Pot with water before test (grams)
- $T_{hi}$: Water temperature before test ($^\circ$C)
- $t_{hi}$: Time at start of test (min)
- $f_{hf}$: Weight of wood after test (grams)

Variables that are calculated

- $f_{hm}$: Wood consumed, moist (grams)
- $\Delta c_h$: Net change in char during test phase (grams)
- $f_{nd}$: Equivalent dry wood consumed (grams)
- $w_{hv}$: Water vaporized (grams)
- $w_{hr}$: Water remaining at end of test (grams)
- $\Delta t_h$: Time to boil pot #1
- $\Delta T_h$: Temp-adjusted time to boil pot #1
- $h_h$: Thermal efficiency
- $r_{ab}$: Burning rate (grams/min)
- $SC_h$: Specific fuel consumption (grams wood/grams water)
- $SC^T_h$: Temp-corrected specific consumption (grams wood/grams water)

$$c_h = \text{Weight of charcoal and container after test (grams)}$$

$$P_{hf} = \text{Weight of Pot with water after test (grams)}$$

$$T_{hf} = \text{Water temperature after test ($^\circ$C)}$$

$$t_{hf} = \text{Time at end of test (min)}$$

Low power (simmering) test

In this test, the initial measurements are the same as in the high power tests, however the goal of this test is to maintain water at a high temperature with minimal power output from the stove. Since the goal differs, the interpretations of the calculations also differ from those of the high power phases. In addition, one important assumption is made using data from the hot start high power test and one additional calculation is performed that does not appear in the high power tests. These are both explained below.

The assumption made in this test is based on the amount of char present when the water first boils. The low power phase starts by repeating the high power hot start test, however when the water comes to a boil, it is quickly weighed without disturbing the char and then the fire is tended to maintain the water within a few degrees of boiling for 45 minutes. There will be char remaining in the stove from the wood that was used to bring the water to a boil. Removing that char from the stove, weighing it and relighting it disturbs the fire and may result in the water temperature dropping too far below boiling. Thus, the recommended procedure is to assume that the char present at the start of the simmer phase is the same as the char that was measured after the high power cold start test ($D_{cc}$). While this is not entirely accurate, the error introduced by this assumption should be minimal especially if the tester(s) followed an identical procedure in bringing the water to a boil. In this test, the initial measurements are the same as in the high power tests, however the goal of this test is to maintain water at a high temperature with minimal power output from the stove. Since the goal differs, the interpretations of the calculations also differ from those of the high power phases.
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In addition, one important assumption is made using data from the hot start high power test and one additional calculation is performed that does not appear in the high power tests.

### Variables that are directly measured

- **$f_{si}$**: Weight of unused fuel when the water first boils (grams)
- **$P_{si}$**: Weight of Pot with water when the water first boils (grams)
- **$T_{si}$**: Water temperature at boiling ($T_{si} = T_b$) ($^\circ$C)

### Variables that are calculated

- **$f_{em}$**: Wood consumed, moist (grams)
- **$\Delta c_s$**: Net change in char during test phase (grams)
- **$f_{sd}$**: Equivalent dry wood consumed (grams)
- **$w_{sw}$**: Water vaporized (grams)
- **$w_{sr}$**: Water remaining at end of test (grams)
- **$\Delta t$**: Duration of phase (min)
- **$h_s$**: Thermal efficiency
- **$r_{sb}$**: Burning rate (grams/min)
- **$SC_s$**: Specific fuel consumption (grams wood/grams water)
- **$FP_s$**: Firepower ($W$)
- **$TDR$**: Turn-down ratio

- **$t_{si}$**: Time at start of simmer phase test (min)
- **$f_{sf}$**: Weight of unburned wood remaining after test (grams)
- **$c_s$**: Weight of charcoal and container after test (grams)
- **$P_{sf}$**: Weight of Pot with water after test (grams)
- **$T_{sf}$**: Water temperature at end of test ($^\circ$C)
- **$t_{sf}$**: Time at end of test (min)

\[
\begin{align*}
\Delta c_s &= c_s - k - \Delta c_c \\
f_{sd} &= f_{em} + (1 - (1.12 \times m)) - 1.5 \times \Delta c_c \\
w_{sw} &= P_{si} - P_{sf} \\
w_{sr} &= P_{sf} - P \\
\Delta t_s &= t_{sf} - t_{si} \\
h_s &= \frac{4.186 \times (P_{si} - P) \times (T_{si} - T_{sf}) + 2260 \times (w_{sw})}{f_{sd} \times LHV} \\
r_{sb} &= \frac{f_{sd}}{t_{si} - t_{sf}} \\
SC_s &= \frac{f_{sd}}{P_{sf} - P} \\
FP_s &= \frac{f_{sd} \times LHV}{60 \times (t_{sf} - t_{sr})} \\
TDR &= \frac{FP_s}{FP_s}
\end{align*}
\]
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Appendix-II

Controlled Cooking Test (CCT)
(Source: Household Energy and Health Programme, Shell Foundation)

The controlled cooking test (CCT) is designed to assess the performance of the improved stove relative to the common or traditional stoves that the improved model is meant to replace. Stoves are compared as they perform a standard cooking task that is closer to the actual cooking that local people do every day. However, the tests are designed in a way that minimizes the influence of other factors and allows for the test conditions to be reproduced.

Equipment

The equipment required to conduct a series of CCTs is similar to the equipment required to perform the WBT. In addition, a sufficient quantity of food will be needed to conduct all of the tests. This is discussed in more detail below.

- **Fuel**: A homogeneous mix of air-dried fuel wood should be procured. Sufficient wood for all of the CCTs should be obtained ahead of time. Use local input to determine the quantity of fuel required to cook a “standard meal” on a traditional stove. Assume that each stove will be tested at least 3 times and allow for some margin of error. For example, if local people report that a standard meal requires ~2.5 kg of fuel wood and three stoves are to be tested, then the full range of tests will require.

\[
\frac{2.5 \text{ kg meal}}{\text{meal}} \times 3 \text{ stoves} \times \frac{3 \text{ tests}}{\text{stove}} \times 2
\]

- The final factor of two is included to allow for aborted tests and other contingencies. This is roughly 45 kg of wood. As in the WBT, the fuel may be divided into pre-weighed bundles to save time during testing.

- **Food and water**: Testers should be sure they have sufficient food and water for the entire range of tests. Like fuel, the food should be homogenous so that variability in food does not bias the results of the test.

- **Cooking pot(s)**: if possible, use the standard pots supplied with the testing kits. If the standard pots do not fit one or more of the stoves being tested, use the most appropriate pots and be sure to record the specifications in the Data and Calculation form. If possible, the same type (size, shape, and material) of pots should be used to test each stove. However, unlike the WBT, lids should be used if local cooks commonly use them.

- **Scale**: Supplied with testing kit: (at least 6 kg capacity and 1 gram accuracy): (see note in WBT section).

- **Heat resistant pad to protect scale when weighing hot charcoal**.

- **Wood moisture meter**.

- **Timer**.

- **Thermometer** (this is only for recording ambient temperature – food temperatures are not recorded in this CCT).

- **Small shovel/spatula to remove charcoal from stove for weighing**.

- **Dust pan for transferring charcoal**.

- **Metal tray to hold charcoal for weighing**.

- **Heat resistant gloves**.

CCT testing procedure

The CCT described here is meant primarily to compare the performance of an improved stove to a traditional stove in a standardised cooking task. The procedure that follows should be applied to type of stove commonly in use in the community as well as the model or models of stove being promoted. Three repetitions of the CCT for each stove that is being compared are recommended.

1. The first step in conducting the CCT is to consult with people in the location where the stove or stoves are going to be introduced in order to choose an appropriate cooking task. This should be done well ahead of time, to ensure that sufficient food can be obtained to conduct all of the necessary tests.

   - If the stove is designed for home use, then the task should be a typical meal consisting of foods that are regularly eaten in the community. It may include one or more dishes, though foods requiring complicated preparations should be avoided in the interest of...
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time. In addition to the type of food, the testers and community participants must also decide on the precise quantity of food that is best representative of a typical family’s meal. This is critical to ensure that tests are uniform. If local measures are used, the testers should convert this into standard measurements and record these on the Data and Calculations form.

- If the stove is designed for specialized applications, for example making tortillas or chapati, then the cooking task requires less input and testers must simply decide on the exact amount of food on which to base the test.

- Once a cooking task has been decided on, ensure that sufficient food is available to conduct the tests.

After deciding on a cooking task, the procedure should be described in as much detail as possible and recorded in a way that both stove users and testers can understand and follow. This is important to ensure that the cooking task is performed identically on each stove. If possible, include an objective measure of when the meal is “done”. In other words, it is preferable to define the end of the cooking task by an observable factor like “the skins come off the beans” rather than a subjective measure like “the sauce tastes right” (VITA, 1985, CCT Procedural note 2).

2. After sufficient ingredients and fuel have been obtained and the steps of the cooking task are written up and well understood by all participants, the actual testing can begin. The cooking itself should be done by a local person who is familiar with both the meal that is being cooked and the operation of the stove to be tested. If the stove is a new design that differs significantly from traditional cooking practices, some training will probably be required before conducting the actual tests. When comparing stoves with the CCT, if more than one cook is used, each cook should test each stove the same number of times, in order to remove the cook as a potential source of bias in the tests. In addition, to ensure that the testers have control over the testing environment, the tests should be conducted in a controllable setting such as a lab or workshop rather than in a private home.

3. Record local conditions as instructed on the Data and Calculation form.

4. Weigh the predetermined ingredients and do all of the preparations (washing, peeling, cutting, etc) as described by the cooking directions recorded in step 2 above. To save time, for non-perishable food, the preparation can be done in bulk, so that food for all of the tests is prepared at once.

5. Start with a pre-weighed bundle of fuel that is roughly double the amount that local people consider necessary to complete the cooking task. Record the weight in the appropriate place on the Data and Calculation form.

6. Starting with a cool stove, allow the cook(s) to light the fire in a way that reflects local practices. Start the timer and record the time on the Data and Calculation form.

7. While the cook performs the cooking task, record any relevant observations and comments that the cook makes (for example, difficulties that they encounter, excessive heat, smoke, instability of the stove or pot, etc).

8. When the task is finished, record the time in the Data and Calculation form (see the comments on determining when the task is complete in step 2 above).

9. Remove the pot(s) of food from the stove and weigh each pot with its food on the balance. Record the weight in grams on the Data and Calculation form.

10. Remove the unburned wood from the fire and extinguish it. Knock the charcoal from the ends of the unburned wood. Weigh the unburned wood from the stove with the remaining wood from the original bundle. Place all of the charcoal in the designated tray and weigh this too. Record both measurements on the Data and Calculation form.

11. The test is now complete – you may now enjoy the food that was cooked or proceed by testing the next stove – each stove should be tested at least 3 times.

Note: this procedure only requires the use of one standardised cooking task. However, stove testers are encouraged to develop a CCT for several different cooking tasks – particularly if the communities where the stove is being promoted cook meals that are equally popular, but differ significantly in their specific cooking requirements (for example, one task that involves slow boiling and another task that involves frying).
Analysis of the CCT

Variables

As in the WBT, there are a number of variables that are directly measured. These include environmental variables and physical test parameters. The environmental variables may vary slightly from one test to another, but should be nearly constant. The physical test parameters should be constant for all tests.

Environmental variables:
- Wind conditions
- Air temperature

Physical test parameters:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg dimensions of wood (centimeters)</td>
<td>--</td>
</tr>
<tr>
<td>Wood moisture content (% - wet basis)</td>
<td>m</td>
</tr>
<tr>
<td>Empty weight of Pot # 1 (grams)</td>
<td>P₁</td>
</tr>
<tr>
<td>Empty weight of Pot # 2 (grams)</td>
<td>P₂</td>
</tr>
<tr>
<td>Empty weight of Pot # 3 (grams)</td>
<td>P₃</td>
</tr>
<tr>
<td>Empty weight of Pot # 4 (grams)</td>
<td>P₄</td>
</tr>
<tr>
<td>Weight of container for char (grams)</td>
<td>k</td>
</tr>
<tr>
<td>Local boiling point of water (°C)</td>
<td>Tᵇ</td>
</tr>
</tbody>
</table>

Measurements and Calculations

Upon finishing the test, a number of measurements are taken. These include:
- Initial weight of fuelwood (wet basis) (grams) fᵢ
- Final weight of fuelwood (wet basis) (grams) fᵢᶠ
- Weight of charcoal with container (grams) cᶜ
- The weight of each pot with cooked food (grams):
  Pⱼ (j is an index for the cooking pot ranging from 1–4 depending on the number of pots used for cooking)
- Start and finish times of cooking (minutes) tᵢ and tᵢᶠ

These measurements are then used to calculate the following indicators of stove performance:

Total weight of food cooked (Wᵢ) – this is the final weight of all food cooked; it is simply calculated by subtracting the weight of the empty pots from the pots and food after the cooking task is complete:

\[ Wᵢ = \sum_{j} (Pⱼ - P) \text{ where } j \text{ is an index for each pot (up to four).} \]

Weight of char remaining (Δcᶜ) – the mass of charcoal from within the stove, including the char removed from the ends of the unburned fuel that is extinguished just at the end of the cooking task. This is found by simple subtraction:

\[ Δcᶜ = cᶜ - k \]

Equivalent dry wood consumed (fᵈ) – This is defined as for the WBT, adjusting for the amount of wood that was burned in order to account for two factors: (1) the wood that must be burned in order to vaporize moisture in the wood and (2) the amount of char remaining unburned after the cooking task is complete. The calculation is done in the following way:

\[ fᵈ = (fᵢ - fᵢᶠ) * (1 - (1.12 * m)) - 1.5 * Dₑ \]

Specific fuel consumption (Sᶜ) – This is the principal indicator of stove performance for the CCT. It tells the tester the quantity of fuel required to cook a given amount of food for the “standard cooking task”. It is calculated as a simple ratio of fuel to food:

\[ SC = \frac{fᵈ}{Wᵢ} \times 1000 \]

Notice this is reported in grams of fuel per kilogram food cooked, whereas Wᵢ is reported in grams. Thus a factor of 1000 is included in the calculation.

Total cooking time (Δt) – This is also an important indicator of stove performance in the CCT. Depending on local conditions and individual preferences, stove users may value this indicator more or less than the fuel consumption indicator. This is calculated as a simple clock difference:

\[ Δt = tᵢᶠ - tᵢ \]
ANNEX A (Clause 11.1)

TEST FOR THERMAL EFFICIENCY

A-1 THERMAL EFFICIENCY

A-1.0 Thermal efficiency of a chulha may be defined as the ratio of heat actually utilised to the heat theoretically produced by complete combustion of given quantity of fuel (which is based on the net calorific value of the fuel).

A-2 CONDITIONS FOR CARRYING OUT THERMAL EFFICIENCY TEST

A-2.1 Test Room Conditions

A-2.1.1 The air of the test room shall be free from draught likely to affect the performance of the Chullha. The room temperature shall be at 25 ± 5°C.

A-2.1.2 At the start of the test, the chulha and the wood being used shall be at room temperature.

A-3 EQUIPMENT

A-3.1 Instruments and other Accessories

a. Bomb calorimeter,
b. Mercury glass thermometer (range 0-100 °C) with solid stem/other temperature measuring device with accuracy ±0.1°C.
c. Single pan balance 1kg capacity (dial type with least count of 10g)
d. Measuring jars 1-l, 2-l, and 5-l capacity.
e. Stop watch or time measuring device.
f. Pairs of tong, metallic tray match sticks, etc.
g. Piece of clean cloth.

A-3.2 Fuel and Its Preparation

A-3.2.1 The fuel shall be Kail/Deodar/Mango/Accasia cut from the same log into pieces of 3cm x 3 cm square cross section and length of half the dia/length of combustion chamber so as to be housed inside the combustion chamber. The fuel pieces shall be dried by the following method:

a. Weigh total quantity of wood (say ‘M’ kg).
b. Pick up one piece and mark ‘X’ by engraving and take its mass (say ‘m’ g).
c. Raise the temperature of the oven up to 105°C.
d. Stack the wood pieces in a honey comb fashion inside the oven.
e. Maintain the oven temperature at 105°C.
f. After 6 hours, remove the marked ‘X’ piece, weigh it and note reduction in mass from ‘m’ g, if any. If reduction is observed put the marked piece in the oven again and repeat weighing ‘X’ marked piece after every subsequent 6 hours durations till the mass is constant and no further reduction in mass is observed.
g. At this, weigh the total quantity of wood and note loss of mass from ‘M’ kg.
h. Determine the calorific value of prepared wood with the help bomb calorimeter.

A-3.3 Determination of Burning Capacity of Rate

If the fuel burning rate per hour is not given by the manufacturer, the method below shall be used to estimate the burning capacity of the chulha.

A-3.3.1 Stack the combustion chamber with test as given in A-3.2 in honey comb fashion up to 3/4 of height or in a pattern recommended by the manufacturer.

A-3.3.2 Sprinkle 10 to 15 ml of kerosene on the fuel from the top of chulha/fire box mouth.

A-3.3.3 Weigh the chulha with fuel, let the mass be $M_1$ kg.

A-3.3.4 After half an hour of lighting weigh the chulha again let the mass be $M_2$ kg.
A-3.3.5 Then calculate the burning capacity of the chulha as heat input per hour as follows:

\[
\text{Heat input per hour} = 2(M_1-M_2) \times CV \text{ kcal/h}
\]

where,

- \(M_1\) = the initial mass of the chulha with test fuel in kg,
- \(M_2\) = the mass of the chulha, after burning the test fuel for half an hour in kg, and
- \(CV\) = Calorific value of the test fuel in kcal/kg.

A-3.4 Vessels

The size of the vessel and the quantity of water to be taken for the thermal efficiency test shall be selected Table 1 given below depending upon the burning capacity rating of the chulha as determined in A-3.3.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Heat Input Rate (kcal/h)</th>
<th>Vessel Diameter (Ext) (± 5%)</th>
<th>Vessel Height (Ext.) (±5%)</th>
<th>Total Mass with Lid (± 20%)</th>
<th>Mass of Water in Vessel (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Upto 2,000</td>
<td>180</td>
<td>100</td>
<td>356</td>
<td>2.0</td>
</tr>
<tr>
<td>2.</td>
<td>2,001-2,800</td>
<td>205</td>
<td>110</td>
<td>451</td>
<td>2.8</td>
</tr>
<tr>
<td>3.</td>
<td>2,801-3,200</td>
<td>220</td>
<td>120</td>
<td>519</td>
<td>3.7</td>
</tr>
<tr>
<td>4.</td>
<td>3,201-3,800</td>
<td>245</td>
<td>130</td>
<td>632</td>
<td>4.8</td>
</tr>
<tr>
<td>5.</td>
<td>3,801-4,200</td>
<td>260</td>
<td>140</td>
<td>750</td>
<td>6.1</td>
</tr>
<tr>
<td>6.</td>
<td>4,201-4,800</td>
<td>285</td>
<td>155</td>
<td>853</td>
<td>7.7</td>
</tr>
<tr>
<td>7.</td>
<td>4,801-5,400</td>
<td>295</td>
<td>165</td>
<td>920</td>
<td>9.4</td>
</tr>
<tr>
<td>8.</td>
<td>5,401-6,000</td>
<td>320</td>
<td>175</td>
<td>1,100</td>
<td>11.4</td>
</tr>
<tr>
<td>9.</td>
<td>6,001-6,600</td>
<td>340</td>
<td>185</td>
<td>1,200</td>
<td>12.5</td>
</tr>
<tr>
<td>10.</td>
<td>6,601-7,200</td>
<td>350</td>
<td>195</td>
<td>1,310</td>
<td>14.0</td>
</tr>
<tr>
<td>11.</td>
<td>7,201-7,800</td>
<td>370</td>
<td>200</td>
<td>1,420</td>
<td>16.0</td>
</tr>
<tr>
<td>12.</td>
<td>7,801-8,400</td>
<td>380</td>
<td>210</td>
<td>1,530</td>
<td>18.0</td>
</tr>
<tr>
<td>13.</td>
<td>8,401-9,000</td>
<td>400</td>
<td>215</td>
<td>1,640</td>
<td>20.0</td>
</tr>
<tr>
<td>14.</td>
<td>9,001-9,600</td>
<td>410</td>
<td>225</td>
<td>1,750</td>
<td>22.0</td>
</tr>
<tr>
<td>15.</td>
<td>9,601-10,200</td>
<td>420</td>
<td>230</td>
<td>1,860</td>
<td>24.0</td>
</tr>
<tr>
<td>16.</td>
<td>10,201-10,800</td>
<td>435</td>
<td>240</td>
<td>2,000</td>
<td>26.5</td>
</tr>
<tr>
<td>17.</td>
<td>10,801-11,400</td>
<td>450</td>
<td>245</td>
<td>2,130</td>
<td>29.0</td>
</tr>
<tr>
<td>18.</td>
<td>11,401-12,200</td>
<td>460</td>
<td>250</td>
<td>2,240</td>
<td>31.0</td>
</tr>
<tr>
<td>19.</td>
<td>12,201-12,800</td>
<td>470</td>
<td>255</td>
<td>2,320</td>
<td>33.0</td>
</tr>
<tr>
<td>20.</td>
<td>12,801-13,600</td>
<td>480</td>
<td>260</td>
<td>2,440</td>
<td>35.0</td>
</tr>
<tr>
<td>21.</td>
<td>13,601-14,400</td>
<td>490</td>
<td>265</td>
<td>2,520</td>
<td>38.0</td>
</tr>
<tr>
<td>22.</td>
<td>14,401-15,400</td>
<td>500</td>
<td>270</td>
<td>2,650</td>
<td>41.0</td>
</tr>
<tr>
<td>23.</td>
<td>15,401-16,400</td>
<td>510</td>
<td>275</td>
<td>2,720</td>
<td>44.0</td>
</tr>
<tr>
<td>24.</td>
<td>16,401-17,400</td>
<td>530</td>
<td>280</td>
<td>3,050</td>
<td>47.0</td>
</tr>
<tr>
<td>25.</td>
<td>17,401-18,600</td>
<td>540</td>
<td>285</td>
<td>3,190</td>
<td>50.0</td>
</tr>
<tr>
<td>26.</td>
<td>18,601-19,800</td>
<td>550</td>
<td>290</td>
<td>3,330</td>
<td>53.0</td>
</tr>
<tr>
<td>27.</td>
<td>19,801-21,000</td>
<td>560</td>
<td>300</td>
<td>3,480</td>
<td>57.0</td>
</tr>
</tbody>
</table>
A-4 PROCEDURE

A-4.1 Take the test fuel according to burning capacity rating for an hour. Divide the test fuel in 4 equal lots. Let the mass be ‘X’ kg.

A-4.2 Stack the lot of test fuel in combustion chamber in honey comb fashion or as indicated by the manufacturer.

A-4.3 Put the vessel with lid and stirrer in accordance with Table 1. Minimum two such vessels sets will be required. Put the recommended quantity of water at 23±2 °C (t) .

A-4.4 Sprinkle measured quantity of ‘x’ ml (say 10-15ml) of kerosene for easy lighting on the test fuel and light. Simultaneously start the stop watch.

A-4.5 Feeding of fresh test fuel lot shall be done after every 15 minutes.

A-4.6 The water in the vessel shall be allowed to warm steadily till it reaches a temperature of about 80°C, then stirring is commenced and continued until the temperature of water reaches 5°C below boiling point at a place. Note down time taken the heat the water up to final temperature (less than 5°C below the boiling point) t1 °C .

A-4.7 Remove the vessel of A-4.6 from the chulha and put the second vessel immediately on the chulha. Prepare first vessel for subsequent heating.

A-4.8 Repeat the experiment by alternatively putting two vessels taken in A-4.3 till there is no visible flame in the combustion chamber of the chulha. Note down the temperature of the water in the vessel. Let it be t3 °C .

A-5 CALCULATIONS

A-5.1 Thermal efficiency of the chulha shall be calculated as follows:

A-5.1.1 (In SI units)

If

\[ t_2 = \text{final temperature of water, in } ^\circ \text{C} \]
\[ t_3 = \text{final temperature of water in last vessel at the completion of test, in } ^\circ \text{C} \]
\[ n = \text{total number of vessels used. (Specific heat of } \text{aluminum} = 0.896 \text{ kJ/kg}^\circ \text{C}) \]

Heat utilized = \((n-1) (W \times 0.986 + w \times 4.1868) (t_2 - t_1) + (W \times 0.896 + w \times 4.1868)(t_3 - t_1)\) kJ

Heat produced = \(4.1868[(X \times c_1) + (x dc_2/1000)]\) kJ

Thermal efficiency = \(\frac{\text{Heat Utilized}}{\text{Heat Produced}} \times 100\) percent η

\[ \eta = \left[ (n-1) (W \times 0.986 + w \times 4.1868) (t_2 - t_1) \\
+ (W \times 0.896 + w \times 4.1868)(t_3 - t_1) \right] \times 100 \]
\[ 4.1868[(X \times c_1) + (x dc_2/1000)] \]

A-5.2 (In Metric Units)

If

\[ w = \text{mass of water in vessel, in kg} \]
\[ W = \text{mass of vessel complete with lid and stirrer, in kg} \]
\[ X = \text{mass of fuel consumed, in kg} \]
\[ c_1 = \text{calorific value of wood, in kcal/kg} \]
\[ x = \text{volume of kerosene consumed, in ml} \]
\[ c_2 = \text{calorific value of kerosene, kcal/kg} \]
\[ d = \text{density of kerosene, g/ml} \]
\[ t_1 = \text{initial temperature of water in } ^\circ \text{C} \]
\[ t_3 = \text{final temperature of water, in } ^\circ \text{C} \]
\[ n = \text{total number of vessels used. (Specific heat of } \text{aluminum} = 0.214 \text{ kcal/kg}^\circ \text{C}) \]

Heat utilized = \((n-1) (W \times 0.214 + w ) (t_2 - t_1) \\
+ (W \times 0.214 + w)(t_3 - t_1)\) kcal

Heat produced = \([ (X \times c_1) + (x/1000 \times c_2) ]\) kcal

Thermal efficiency = \(\frac{\text{Heat Utilized}}{\text{Heat Produced}} \times 100\) percent η

\[ \eta = \left[ (n-1) (W \times 0.214 + w ) (t_2 - t_1) \\
+ (W \times 0.214 + w)(t_3 - t_1) \right] \times 100 \\
\left[ (X \times c_1) + (x/1000 ) \right] \]
A-5.2 Power Output Rating
The power output rating of the chulha is a measure of total useful energy produced during one hour by fuel wood. It shall be calculated as follows:

\[
\text{Power output rating} = \frac{F \times CV \times \eta}{860 \times 100} \text{ kW}
\]

where
\[F = \text{quantity of fuel wood burnt, kg/h;}
\]
\[CV = \text{calorific value of fuel wood in kcal/kg; and}
\]
\[\eta = \text{thermal efficiency of chulha.}
\]

ANNEX B
( Clause 11.2)

TEST FOR COMBUSTION EFFICIENCY

B-1 CO/CO₂ RATIO MEASUREMENT

B-1.1 Equipment

B-1.1.1 The chulha shall be tested with its grate filled with fuelwood equivalent to 1/4 of the burning capacity of wood as determined in A-3.3. Before starting the test, a vessel of the type and size as described in A-3.4 and containing water sufficient for the test shall be placed over the chulha. In addition a collecting hood as shown in Figure A3.1 in page 95 suitable for chulha under examination shall be used.

B-1.1.2 The hood shall be so designed that, while not interfering in any way with the normal combustion of the chulha, it collects a fairly high proportion of the flue gases. Also it shall be such that the sample collected represents the whole of combustion gases and not those from one particular point. When using hood, the damper provided shall be set, or additional flue pipe added, so that spillage of the flue gases around the skirt is minimised.

B-1.2 Procedure

B-1.2.1 With the hood in position over the chulha under investigation, the wood shall be lit as given in A-4.1 to A-4.5 till a stable flame is achieved and the kerosene is completely burnt, then a sufficient number of samples shall be collected.

B-1.2.2 Any of the recognised methods may be used for gas analysis. For carbon monoxide, it is recommended that co-indicator of prescribed accuracy or the iodine pentaoxide method or catalytic method, for example Dragger method, Kartz method, or infra-red analysis may be used. Carbon dioxide may be tested with Orsat apparatus, Haldane apparatus or by infrared analysis.

B-1.2.3 Each chulha shall be tested separately. The carbon monoxide and carbon dioxide contents of the product of combustion shall be determined by the methods capable of an accuracy of 0.001 percent and 0.05 percent, respectively of the volume of the sample.

B-2 TEST FOR TOTAL SUSPENDED PARTICULATE MATTER (TSP)

B-2.1 Equipment

B-2.1.1 To determine total suspended particulate matter in ambient air, handy sampler is used as an instrument. Handy sampler consists of an impinger (transparent nozzle type), filter holder, filter paper (Gelman GN-4, 37mm and 64678 or its equivalent Whatman) and motor unit (which involves rotameter and suction pump). These accessories of the instrument have been shown flow diagram (Figure A3-2) in page 95.

B-2.2 Preparation Before Operation

Filter paper (very neat and clean) is weighed on an electronic balance having an accuracy of 0.01mg, very carefully and placed between the filter holder. The holder and the No. 1 surge tank (as shown in flow diagram) are connected too the impinger and the other arrangements of the accessories are checked out as per flow diagram.

B-2.3 Procedure

Timer can be set for desired sampling time. It is set for an hour. Sampling time can be set to various times within 60 minutes by turning the knob toward clockwise. The flow rate of suction of ambient air is set by rotameter, which can be used to up to 2.5 l/minute, Max, for the purpose of this specification. The instrument maintaining the above said condition is placed at a distance of 30 to 45 cm from the burning chulha and at a height of 30 to 37.5 cm from the ground level. After completion of one hour the filter paper is taken out and is again weighed on the same electronic balance, on which weighed initially

B-2.4 Calculation

The total suspended particulate matter is computed by measuring the mass of collected particulates and the volume of air sampled in the ambient air, in the following manner:
If
Initial mass of the filter, in g = \( X \)
Final mass of filter paper, in g = \( Y \)
Flow rate of ambient air, in l/min = \( Z \)

Note: Flow rate \( Z \) l/min is maintained for 1 hour.

Mass of collected particulate = \((Y-X)\) g
\(= (Y-X)\times 1000 \text{ mg}\)

Total volume of air = \( Z \times 60 \) litre = \( 60Z/1000 \text{ m}^3\)

Total suspended particulate

\[
\frac{\text{Mass of collected particulates}}{\text{Volume of air sampled (m}^3\text{)}}
\]

---

**Figure A3.1: Hood for Chulha**

**Figure A3.2: Flow diagram for Handy Sampler**
## Table 1: CALORIFIC VALUE OF FUELS

<table>
<thead>
<tr>
<th>Sr</th>
<th>Fuel</th>
<th>Approx heating value Kcal/Kg</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Natural State</td>
<td>Dry state</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>BIOMASS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Wood</td>
<td>1500</td>
<td>3500</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cattle dung</td>
<td>1000</td>
<td>3700</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Bagasse</td>
<td>2200</td>
<td>4400</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Wheat and rice straw</td>
<td>2400</td>
<td>2500</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Cane trash, rice husk, leaves and vegetable wastes</td>
<td>3000</td>
<td>3000</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Coconut husks, dry grass and crop residues</td>
<td>3500</td>
<td>3500</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Groundnut shells</td>
<td>4000</td>
<td>4000</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Coffee and oil palm husks</td>
<td>4200</td>
<td>4200</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Cotton husks</td>
<td>4400</td>
<td>4400</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Peat</td>
<td>6500</td>
<td>6500</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>FOSSIL FUELS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Coal</td>
<td>4000-7000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Coke</td>
<td>6500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Charcoal</td>
<td>7000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Carbon</td>
<td>8000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Fuel oil</td>
<td>9800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Kerosene and diesel</td>
<td>10000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Petrol</td>
<td>10800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Paraffin</td>
<td>10500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Natural gas</td>
<td>8600</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Coal gas</td>
<td>4000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Biogas (Kcal/M$^3$) (12 kg of dung produces 1 M$^3$ gas)</td>
<td>4700-6000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Source: www.indiasolar.com/cal-value.htm*
### Table 1: Emission of CO2 from Combustion of Fuels

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Net calorific value (MJ/kg)</th>
<th>Carbon content (%)</th>
<th>Direct carbon emission from combustion</th>
<th>Direct CO2 emission from combustion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Net calorific value (MJ/kg)</strong></td>
<td></td>
<td></td>
<td><strong>kg/GJ</strong></td>
<td><strong>kg/MWh</strong></td>
</tr>
<tr>
<td>Hard coal</td>
<td>29</td>
<td>75</td>
<td>26</td>
<td>94</td>
</tr>
<tr>
<td>Oil</td>
<td>42</td>
<td>85</td>
<td>20</td>
<td>72</td>
</tr>
<tr>
<td>Natural gas</td>
<td>38</td>
<td>73</td>
<td>19</td>
<td>69</td>
</tr>
<tr>
<td>LPG</td>
<td>46</td>
<td>82</td>
<td>18</td>
<td>64</td>
</tr>
<tr>
<td>Electricity (UK grid)</td>
<td>-</td>
<td>-</td>
<td>35</td>
<td>125</td>
</tr>
<tr>
<td>Electricity (large scale wood chip combustion)</td>
<td>-</td>
<td>-</td>
<td>160</td>
<td>576</td>
</tr>
<tr>
<td>Electricity (large scale wood chip gasification)</td>
<td>-</td>
<td>-</td>
<td>80</td>
<td>286</td>
</tr>
<tr>
<td>Wood chips (25% MC) Fuel only</td>
<td>14</td>
<td>37.5</td>
<td>27</td>
<td>96</td>
</tr>
<tr>
<td>Wood chips (25% MC) Including boiler</td>
<td>14</td>
<td>37.5</td>
<td>27</td>
<td>96</td>
</tr>
<tr>
<td>Wood pellets (10% MC starting from dry wood waste)</td>
<td>17</td>
<td>45</td>
<td>26</td>
<td>95</td>
</tr>
<tr>
<td>Wood pellets (10% MC) Including boiler</td>
<td>17</td>
<td>45</td>
<td>26</td>
<td>95</td>
</tr>
<tr>
<td>Grasses/straw (15% MC)</td>
<td>14.5</td>
<td>38</td>
<td>26</td>
<td>95</td>
</tr>
<tr>
<td>Biogas (60% CH₄, 40% CO₂)</td>
<td>30</td>
<td>56</td>
<td>19</td>
<td>67</td>
</tr>
</tbody>
</table>

**Source:** [www.biomassenergycentre.org.uk](http://www.biomassenergycentre.org.uk)
### Table 2: Emission of CO₂ from Transport Fuels

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Net calorific value (MJ/kg)</th>
<th>Carbon content (%)</th>
<th>Carbon emission on combustion</th>
<th>Direct CO₂ emission from combustion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>g/litre</td>
<td>kg/gal</td>
</tr>
<tr>
<td>Petrol</td>
<td>44</td>
<td>87</td>
<td>635</td>
<td>2.89</td>
</tr>
<tr>
<td>Diesel</td>
<td>42.8</td>
<td>86</td>
<td>713</td>
<td>3.24</td>
</tr>
<tr>
<td>LPG (mainly propane)</td>
<td>46</td>
<td>82</td>
<td>418</td>
<td>1.90</td>
</tr>
<tr>
<td>Bioethanol (from sugar beet)</td>
<td>27</td>
<td>52</td>
<td>410</td>
<td>1.87</td>
</tr>
<tr>
<td>Bioethanol (from wheat)</td>
<td>27</td>
<td>52</td>
<td>410</td>
<td>1.87</td>
</tr>
<tr>
<td>Biodiesel (from rapeseed oil)</td>
<td>37</td>
<td>77</td>
<td>678</td>
<td>3.08</td>
</tr>
<tr>
<td>Biodiesel (from waste vegetable oil)</td>
<td>37</td>
<td>77</td>
<td>678</td>
<td>3.08</td>
</tr>
</tbody>
</table>

Source: www.biomassenergycentre.org.uk
SAARC Energy Centre
Plot No. 18, Street No. 6, Sector - H9/1
Islamabad, Pakistan
Tel : + 92-51-4436710, Fax: + 92-51-4436795
E-mail : info@saarcenergy.org
Web: saarcenergy.org